

Tests of Food Choice (Periphyton vs. Macrophyte)  
by Two Freshwater Snails (*Lymnaea stagnalis* and *Physa*)

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*Abstract.* *Lymnaea stagnalis* and *Physa* were placed in Nalgene containers with *Potamogeton richardsonii* in the presence and absence of periphyton. A treatment with macrophyte only was also used to determine the change in biomass (growth or decay) which would occur in the absence of grazers. The feeding experiment, which ran for 9 days, demonstrated that snails do indeed prefer periphyton. Macrophytes were consumed to a greater extent in the absence of periphyton which is consistent with Stahl's (1989) experiment. In only one treatment did snail feeding negatively affect the growth of the macrophytes. In four of the five treatments, the macrophyte shoots were actually still gaining biomass despite the presence of the snails. In fact, these four treatments showed no significant difference between them.

*Lymnaea stagnalis* consumed the macrophyte more readily than the *Physa*, but it still showed that it will preferentially consume periphyton over macrophytes. *Lymnaea stagnalis* did show that it contains the ability to impact the distribution of macrophytes since it can and will consume macrophytes to the point of shreds if no other food source is available. But since periphyton is normally present where macrophytes are present, and other food sources such as detritus are usually available, it cannot be asserted that this potential will manifest itself in nature since the snail will choose the preferred, alternative food source. *Physa*, on the other hand, did not demonstrate an ability to readily and substantially consume macrophytes, and therefore it would be difficult to ascertain that

Physa could negatively affect macrophyte growth regardless of the setting.

*Key words* : macrophytes, periphyton, herbivory, *Lymnaea stagnalis*, *Physa*, *Potamogeton richardsonii*, grazers, biomass.

## Introduction

Shelford (1918) wrote: "One could probably remove all the larger plants and substitute glass structures of the same form and surface texture without greatly affecting food relations." Indeed, the understanding of freshwater macrophytes has come a long way since this ill-made statement. Some still maintain that there is a low degree of herbivory on living vascular plants as a result of tough cell walls, lignified structures, low nutritional value (high C/N ratio), and secondary plant substances (Porter 1977, Otto and Svensson 1981, Gregory 1983, taken from Bronmark 1990), but more recently it was suggested that the importance of low nitrogen ratios and digestion-inhibiting and toxic compounds has been overly emphasized in previous studies (Carpenter and Lodge 1986, taken from Bronmark 1990). Furthermore, Lodge states: "Evidence contradictory to the importance of grazing on macrophytes is based largely on a lack of investigation, not a critical body of evidence that establishes the rarity or unimportance of grazing" (Lodge, in press). In fact, recent studies have shown that macrophytes are a very significant element in the food chain, that a great variety of animals feed directly upon them, and that a large quantity of these plants are often consumed (Welch 1952, taken from Lodge, in press). There are several organisms which are known to graze on macrophytes such as crayfish, waterfowl, muskrats, and fish (Lodge, in press). Although it is now evident that live macrophytes are involved in aquatic food webs, sometimes to the extent that macrophyte biomass, productivity, and relative abundance is

dramatically changed, there is still some debate in regards to specific organisms involved in the macrophyte-grazer complex and their relative contribution to the complex. One specific organism in debate is the snail.

Sheldon (1987) stated that herbivorous snails can strongly influence the distribution, abundance, and diversity of freshwater macrophytes. Although some snails may graze on macrophytes, Sheldon's (1987) statement is very broad and subject to a great deal of criticism for two main reasons. First, there is the mass of information suggesting that live macrophytes form a minute proportion of the diets of snails. Reavell (1980) studied the gut contents of a large number of freshwater snail species and determined that living macrophytes constituted a minor part of their diet (<1%). Clampitt (1970) found that the gut contents of *Physa gyrina*, the same snail utilized by Sheldon (1987) in her lab experiments, were dominated by detritus and algae, while animal parts and vascular plant tissue constituted only a minor proportion. Snails are known to prefer periphyton (Lodge 1986), and the grazing of macrophytes by snails has never been observed in freshwater lakes of northern Wisconsin and upper Michigan (Lodge, from Stahl, unpublished). Second, there are some problems with Sheldon's experimental procedures. Her conclusions are based primarily on indirect evidence and she herself did not observe snails grazing on macrophytes (Lodge, *personal communication*). The macrophyte biomass she documented, may just as well have been due to another organism or combination of organisms. In manipulating snail densities in the lake she examined, she may have also manipulated

the density of other organisms, and if these organisms were grazers of macrophytes they would probably enhance biomass loss in the macrophytes. Bronmark (1990) states: "The herbivore damage on *Potamogeton amplifolius* Tuckerm. described by Sheldon (1987) may very well be ascribed to the activities of trichopteran and lepidopteran larvae, which are well known consumers of aquatic macrophytes and which, in addition, use pieces of leaves to construct larval cases and retreats." In addition, variations in crayfish densities inside and outside of cages could also contribute to the patterns observed by Sheldon (1987) (Bronmark 1990), since crayfish have been shown to affect biomass and species richness of submersed freshwater macrophytes (Lodge and Lorman 1987).

In the summer of 1989, Stahl (1989) began research at the University of Notre Dame's Environmental Research Center (UNDERC) in order to investigate the questions regarding snail herbivory. His research was aimed at discovering the amount of live macrophyte (*Potamogeton richardsonii*) a snail (*Lymnaea stagnalis*) would consume when it was presented only with macrophyte, and then when another food source (periphyton) was present. He concluded that *Lymnaea stagnalis* eat macrophytes, but to a far lower degree when another food source, such as periphyton, is present (Stahl, unpublished). He was unable to conclude that *Lymnaea stagnalis* do not eat *Potamogeton richardsonii* when periphyton is present due to a lack of control (macrophyte only) in the experiment. My research at UNDERC was designed in order to follow up Stahl's (1989) research and thus further investigate the debate regarding snail herbivory.

My research consisted of a feeding experiment similar to Stahl's (1990). This included two snail species, *Lymnaea stagnalis* and *Physa*, and one macrophyte, *Potamogeton richardsonii*, used. *Lymnaea stagnalis* was used because it was the same snail used by Stahl (1989), and it does, at least sometimes, eat macrophytes (Reavell 1980; Scheerboom and Van Elk 1978; Lodge, personal communication, taken from Stahl 1989). *Physa* was utilized because it was the same snail which Sheldon (1987) claimed to have consumed macrophytes to a great degree. *Potamogeton richardsonii* was chosen because this is the macrophyte species Sheldon (1987) stated *Physa* preferred most of all. The goal of this experiment was to determine the degree to which the snails would consume live macrophytes in the presence and absence of periphyton.

## Materials and Methods

Research was conducted in the basement of the research laboratory at the University of Notre Dame Environmental Research Center (UNDERC) which is located in northern Wisconsin and the upper peninsula of Michigan. *Lymnaea stagnalis* was collected from Mann Pond, *Physa* was collected from Little John Lake, and *Potamogeton richardsonii* from Tenderfoot Lake. *Lymnaea stagnalis* and *Physa* had to be collected at these sites which were off the property since a sufficient quantity could not be found in the UNDERC lakes. The snails were all collected on June 27. The *Physa* were taken from rocks on the shore of Little John Lake, while *Lymnaea stagnalis* was taken from various substrates in Mann Pond (wood, macrophytes, free floating). The plants were collected and weighed on June 29, which is the same day the experiment was begun.

The experiment consisted of 5 treatments with 9 replicates of each treatment. The treatments ran from June 29-July 8. The treatments were conducted in Nalgene containers (25 cm by 18 cm by 14 cm deep) and consisted of the following: A) *Lymnaea stagnalis* (6), *Potamogeton richardsonii* (3.4-4.2 g), and periphyton covered rocks B) *Lymnaea stagnalis* (6), and *Potamogeton richardsonii* (3.9-4.5 g) C) *Physa* (20), *Potamogeton richardsonii* (3.9-4.3 g), and periphyton covered rocks D) *Physa* (20), and *Potamogeton richardsonii* (3.5-4.3 g) E) *Potamogeton richardsonii* (3.5-4.3 g). The containers were filled approximately 3/4 of the way to the top with lake water. One or two macrophyte shoots were placed in the containers such that the total weight was between 3.4 and 4.5



grams. Snail shell lengths for *Physa* placed in the containers at the onset of the experiment ranged from 5.0 to 18.5 centimeters with an average of 8.32 centimeters, while *Lymnaea stagnalis* shell lengths ranged from 3.05 to 4.40 centimeters with an average of 35.3 centimeters. The *Physa* which were added throughout the experiment as a result of loss in the treatments due to escape or death ranged in size from 6.0 to 14.0 centimeters with an average length of 8.03 centimeters.

Before setting up the treatments the macrophytes were gently hand rubbed under running water in order to remove any periphyton that might be on them. This was extremely important since there were two treatments in which it was desired to have only macrophyte available to the snails. After removing the periphyton the macrophyte shoots were spun dry with a salad spinner and then weighed. The salad spinner was spun 100 revolutions for each macrophyte shoot at approximately the same speed. The shoots were then transported to the Nalgene containers. The snails within the containers were starved for more than 24 hours before the treatments began in order that they would be hungry at the onset of the experiment. In treatments requiring periphyton enough rocks were placed in the containers to cover the bottom. The rocks varied in size with all having a thin layer of periphyton on them. The rocks did not contain the same quantity of periphyton as seen on rocks earlier in the season and this was an area of concern in the experiment. It was important to ensure that there was always an alternate food source available to the snails and therefore rocks were frequently replaced. Another area of concern was the types of

algae available on these rocks. The concern was whether these contained a nutritious alternative for the snails.

During the experiment the containers were cleaned three times. The containers were cleaned as follows: the snails, macrophyte, and rocks (if present) were removed, the water was dumped out, the sides of the container were scrubbed (only in treatments with macrophyte only as a food source), and then the snails, macrophyte and fresh rocks (if needed) were added again. It is important to note that lake water was used, which was different from Stahl's (1989) experiment in which tap water was used. Lake water was used in order to achieve a treatment more closely related to a natural system. It was especially important to scrub the sides of the containers in those treatments containing macrophyte only as a food source in order to prevent growth of periphyton in the containers. Dead snails were also replaced during the experiment. A stock of snails were kept in aquaria with an aerator while the experimenting was running to ensure there would be a sufficient snails for replacement of dead snails. The extra stock of snails were fed minimal amounts of periphyton and macrophyte in order to ensure that they would be hungry when placed in the experiment. Rocks were replaced as needed, which was generally every day. It could be seen that the snails were readily moving periphyton from the rocks and thus it was crucial to change the rocks frequently. The temperature of the water in the containers was taken periodically, and the dissolved oxygen content was taken on two occasions. The temperature and dissolved oxygen of Tenderfoot Lake was taken as a comparison to my treatments.

At the end of the experiment the macrophyte shoots were collected, spun dry, and weighed in order to compare the measurements to the starting weights.

Statistical analysis was performed using the SYSTAT program on the data for macrophyte weights. The change in macrophyte biomass between the treatments was compared in order to determine if there was a significant difference between them. An analysis of variance demonstrated wher significant differences between treatments existed.

## Results

There were a few problems in the experiment. Throughout the experiment *Physa* were crawling out of the containers and subsequently died, while others were dying within the containers. In total 68 *Physa* had to be replaced. There were always at least 16 *Physa* in each container at all times, and any missing snails were replaced quickly since I checked on them daily. No *Lymnaea stagnalis* had to be replaced. The other difficulty of the experiment was the fact that the rocks were not well covered with periphyton as they had been early in the summer. Rocks therefore had to be replaced frequently to ensure that periphyton was constantly available.

Temperatures in the containers ranged from 15.8 to 24.8°C. Tenderfoot Lake by comparison ranged from 20.6 to 26.8°C. The temperature in Tenderfoot was always 2-3°C higher. Dissolved oxygen (DO) readings ranged from 3.0 to 7.6 mg/L depending on the treatment. The treatments with macrophyte only had the highest DO, while those with *Lymnaea stagnalis* had the lowest DO. Tenderfoot by comparison ranged from 6.0 to 8.1 mg/L. Appendix 3 can be consulted for more specific data on temperatures and DO values.

When assessing the change in macrophyte biomass during the experiment I considered two sets of data. One set of data included pieces or fragments of macrophyte found in the containers at the conclusion of the experiment (Figure 1). This set shows how much macrophyte was consumed by the snails. The second set of data (Figure 2) did not include the pieces, and this demonstrates theoretically the amount of macrophyte loss we would see in the

field since these small pieces would be carried away. So the second set shows not only what the snails consumed, but also what they shredded. Both sets are important to consider since the goal is to determine to what extent snails will control the distribution and abundance of macrophytes. They can do this both by eating and shredding macrophytes. Figure 1, showing macrophyte change with pieces included, demonstrates that there is no significant difference between four of the treatments, although there is almost a statistically significant difference between *Lymnaea stagnalis* with periphyton and *Physa* with periphyton ( $p < .064$ ). *Lymnaea stagnalis* with macrophyte only is statistically different from all the others ( $p < .001$ ). Figure 2 depicts the change in macrophyte biomass with pieces excluded. Statistical analysis of this data here demonstrates that there is a significant difference between *Lymnaea stagnalis* with periphyton and *Physa* with periphyton ( $p < .003$ ) and between *Lymnaea stagnalis* with periphyton and the control ( $p < .018$ ). It is important to realize that most of the macrophytes in the treatments were actually gaining biomass. Only one treatment in Figure 1 shows a decrease in biomass, while 2 treatments in Figure 2 show a decrease.

## Discussion

This experiment was designed to determine the extent to which snails would consume macrophytes in the presence and absence of an alternate food source, periphyton. The experiment was constructed such that the snails in two of the treatments would have macrophyte only as a food source. This was done for both of the snails. From this it could be determined if the snails would consume macrophytes if no other food source was available or if it would simply starve itself. The other two treatments with snails were designed to give the snails a choice for their diet between macrophytes and periphyton. Therefore it could be determined which was the preferred food source and if macrophyte would be consumed if another food source was available. It has been stated that periphyton is the preferred food source for the snails and this experiment was constructed to determine the validity of this statement. Finally, there was a control treatment which demonstrated the change in biomass which occurs in the absence of grazers.

The snails and macrophyte for this experiment were chosen for some specific reasons. *Physa* was chosen because this was the snail Sheldon (1987) used in her lab experiments and it is the snail upon which she based her conclusions. *Potamogeton richardsonii* is the macrophyte Sheldon (1987) stated that *Physa* preferred most of all, so if *Physa* was going to consume macrophytes in my experiment it would certainly consume this plant to the greatest degree since this is its favorite one. *Lymnaea stagnalis* was used because this is the one which Stahl (1989) used, and it also is large and has a big

mouth, so if any snail has the capability to consume macrophyte this one certainly did.

The results reinforce the conclusions proposed by Stahl (1989). Macrophytes were consumed to a far lower degree in the presence of periphyton. *Physa* did not eat macrophytes to a large extent regardless of whether or not an alternate food source was present. The average value of change in biomass for the treatments containing *Physa* demonstrated that macrophytes were consumed to a greater degree when periphyton was not available, but the difference was not significant. In other words, *Physa* will not eat if or will eat very little if presented with macrophyte only. Macrophytes are certainly not a preferred food source of *Physa*. *Lymnaea stagnalis* also consumes periphyton preferentially. However, when presented with macrophyte only, *Lymnaea stagnalis* will feed on the macrophyte and reduce it to mere shreds. They also attack the older leaves preferentially. Possibly this has something to do with plant defense mechanisms suggested by several researchers (Porter 1977, Otto and Svensson 1981, Gregory 1983). However, *Lymnaea stagnalis* will not eat an appreciable quantity of macrophyte if periphyton is available. In fact, *Potamogeton richardsonii* still is growing despite the presence of grazers. The snails are not consuming the macrophytes to the extent that it controls their growth rates since they are still able to grow in the presence of the snails. The fact that a large quantity of snails was used further exemplifies this point.

The purpose of this project was to determine if snails have the potential to affect the distribution, abundance, and diversity of

freshwater macrophytes. The main process by which they could affect their distribution and abundance would be by feeding on them. As one examines Figure 1 which depicts the change in biomass as a result of feeding, it is clear that this process cannot affect macrophytes distribution and abundance. Snails consume macrophytes in such small amounts such that they hardly affect macrophyte growth. Another process to consider however is shredding. Even if snails are not consuming macrophyte, they could affect their growth through shredding the macrophyte. This possibility is also taken into account, and the change in biomass as a result of feeding and shredding is depicted in Figure 2. This figure does not include pieces of macrophyte that were on the bottom of the container and were no longer part of the main stem. The amount of added biomass loss due to shredding was still small, and thus once again one cannot conclude that snails have an affect on macrophyte abundance and distribution.

This research project involved live macrophytes. There have been some research done suggesting that snails eat decaying macrophytes however. In fact, Scheerboom and Van Elk (1978) stated that *Lymnaea stagnalis* eat decaying macrophytes preferentially to all other food sources besides periphyton. Also, in an experiment set up exactly as this one except with decaying macrophytes, Stahl (1989b) concluded that *Lymnaea stagnalis* ate decaying macrophytes to the same degree whether or not periphyton was present and that *Physa* does not eat decaying macrophytes to any significant degree. So it appears as if there is some evidence suggesting that certain snails will consume macrophytes. However, the purpose of this project



was to determine whether or not snails can affect the abundance, distribution, and diversity of macrophytes. Snails consumption of decaying macrophytes will not affect the abundance of macrophytes because they are only hastening the plants process of senescence. The macrophytes have already reproduced at this point and therefore consumption of them will not change their abundance or distribution in the following year. It was for this reason that fresh, live macrophytes were used. Snails can only control plants abundance and distribution if they eat them while the macrophytes are still living and in the process of growing.

It could be asserted that some snails eat decaying macrophytes through research such as Scheerboom and VanElk's (1978) and Stahl's (1989b). It could also be asserted that certain snails (such as *Lymnaea stagnalis*) are capable of eating live macrophytes despite the existence of tough cell walls, lignified structures, and secondary plant substances. However, in the early summer when periphyton is abundant, snails will preferentially choose this food source. Snail will only choose to consume live macrophytes when no other choice is given to them. Some snails given no other choice may even starve themselves (possibly *Physa*). But snails usually will have a choice because periphyton is usually present where macrophytes are present. Even if periphyton was not available, it does not mean that they would consume live macrophytes because snails are known to eat other food sources such as detritus (Reavell 1980, Scheerboom and VanElk 1978). Thus these experimental results combined with the vast array of literature supporting these findings, seem to show that snails cannot affect the distribution and

abundance of macrophytes. This contradicts the conclusions drawn by Sheldon (1987), but the conclusions drawn here are based upon direct evidence, while Sheldon's (1987) are based largely upon indirect evidence. An analysis of the gut contents of the snails in the experiment is being conducted, as well as an analysis of the gut content of snails taken from the field (*Physa*, *Lymnaea stagnalis*, *Helisoma*, and *Amnicola*). This investigation should shed more light on the debate of the snail's interaction with freshwater macrophytes.

The main problem with this experiment was the number of deaths of *Physa*. The most plausible explanation for this based on the data I have is that the dissolved oxygen was too low. However, there were no deaths of *Lymnaea stagnalis* which also had low dissolved oxygen. Therefore, other factors such as stress could have contributed to the mortality rate. Other factors to consider are the abilities of the different species to withstand low oxygen levels. Snails however were replaced daily to ensure that 20 snails would be present and living the vast majority of the time that the experiment was running. The other problem was that the rocks did not contain a large amount of periphyton and the material may not have been as nutritious as that which covered the rocks earlier in the summer. However, the snails were still consuming the periphyton and rocks were replaced frequently in order to alleviate some of the problem. It could be maintained that snails will consume even lower quantities of macrophyte earlier in the season because more periphyton is available, but such an assertion would require further

investigation. Despite these problems, the experiment ran very well and demonstrated a definite food preference in both snails.

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## Figures

Figure 1. Histogram of mean weight change (g) of macrophytes (pieces or shreds included) with 95% Confidence Intervals.

Figure 2. Histogram of mean weight change (g) of macrophytes (pieces or shreds excluded) with 95% Confidence Intervals.

Figure 1

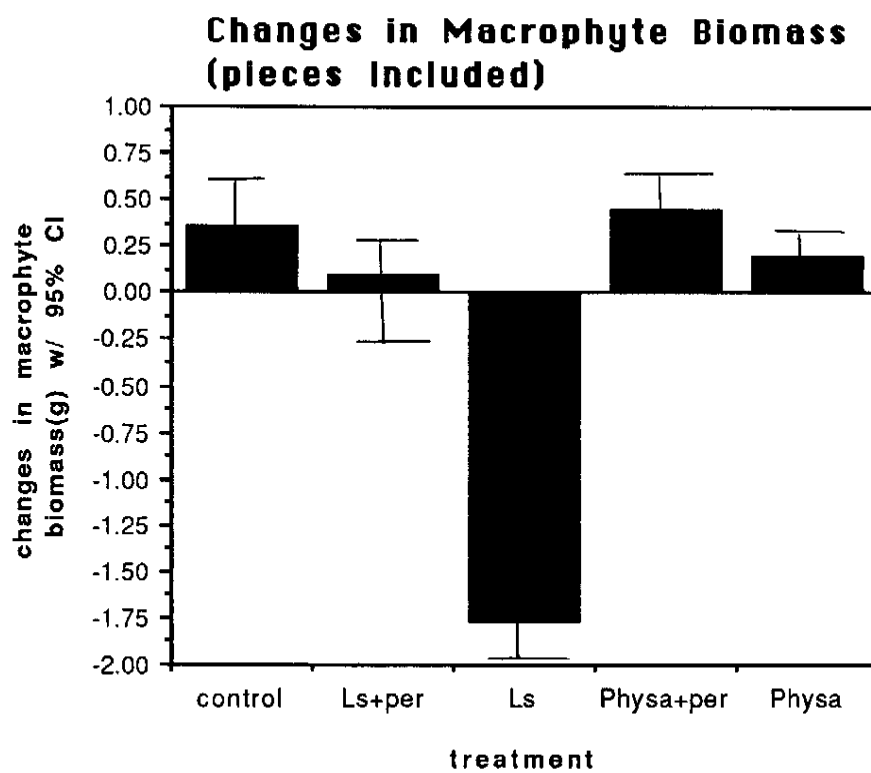
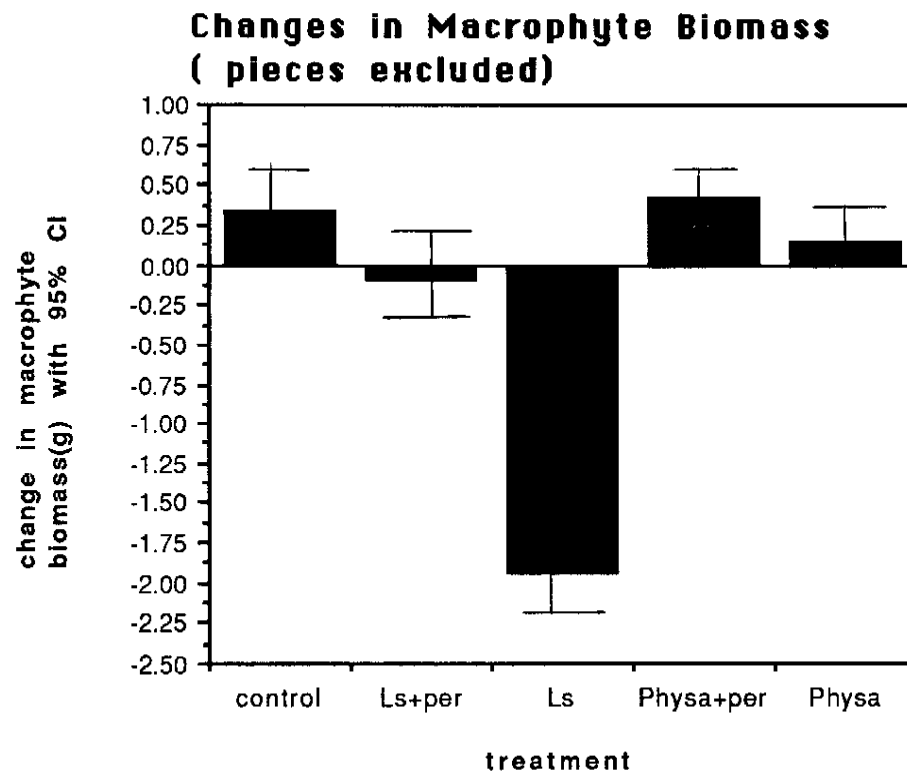


Figure 2





Appendix 1  
Changes in Macrophyte Biomass with pieces (g)

Rep	Ls+per	Ls	Physa +per	Physa	Cont.
1	+03	-1.58	+22	+08	+53
2	+29	-1.73	+46	+36	+62
3	-.18	-1.97	+82	+31	+01
4	+30	-1.70	+80	+29	+73
5	-.05	-1.72	+44	+33	+29
6	-.66	-2.03	+35	+19	+62
7	+39	-1.98	+39	-.09	+35
8	+37	-1.30	-.01	-.13	+07
9	+30	-1.98	+49	+43	-.04
Mean	+09	-1.77	+44	+20	+35

Appendix 2  
Changes in Macrophyte biomass without pieces (g)

Rep	Ls+per	Ls	Physa+per	Physa	Cont
1	-.26	-1.74	+19	+07	+50
2	+27	-1.94	+46	+24	+60
3	-.36	-2.02	+77	+24	+01
4	+30	-1.76	+80	+29	+73
5	-.23	-1.85	+44	+33	+29
6	-.76	-2.23	+35	+14	+62
7	+02	-2.16	+37	-.10	+35
8	+09	-1.40	-.01	-.17	+07
9	+22	-2.29	+49	+38	-.04
mean	-.08	-1.93	+43	+16	+35

Appendix 3  
Temperature (°C) and DO (mg/L) Measurements

Date	Time	Treatment	Temperature	Dissolved Oxygen
7/2	10:30 P.M.	Experimental	21.8	Not taken
7/2	10:30 P.M.	Tenderfoot lake	24.5	Not taken
7/3	12:45 P.M.	Various	20.5-21.0	Not taken
7/3	12:45 P.M.	Tenderfoot Lake	25.2-25.0	Not taken
7/4	4:15 P.M.	Ls+periphyton	21.5-22.4	3.0-3.1
7/4	4:15 P.M.	Ls w/o per	21.7-22.4	4.3-4.5
7/4	4:15 P.M.	Physa +per	21.5-22.2	3.8-4.5
7/4	4:15 P.M.	Physa w/o per	21.8-22.0	6.2-6.3
7/4	4:15 P.M.	Control	21.8-21.9	7.6-7.8
7/4	4:15 P.M.	Tenderfoot lake	25.0	8.0-8.1
7/4	10:40 P.M.	Various	22.0-23.2	5.2 -7.6
7/4	10:40 P.M.	Tenderfoot Lake	24.0	6.0
7/7	5:30 P.M.	Various	15.8-16.3	Not taken
7/7	5:30 P.M.	Tenderfoot Lake	20.6	Not taken