An Experimental Test of the Crayfish (Orconectes immunis) as a Control Mechanism for Submerged Aquatic Macrophytes

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Table of Contents

List of Tables

LIST OF FIGURES

ABSTRACT

The ability of the crayfish Orconectes immunis to graze submerged aquatic macrophytes was evaluated experimentally. Crayfish at densities greater than 140-150 g/m^2 significantly decreased macrophyte biomass in all experiments. The rate of crayfish grazing in cages where significant decreases in macrophyte biomass occurred averaged 0.012 g of macrophytes consumed/crayfish/m^2/day.

INTRODUCTION

Aquatic macrophytes can be both a nuisance and benefit to an ecosystem (Nichols 1986). A macrophyte crop composed of a diverse species assemblage has an important stabilizing effect in aquatic ecosystems; they provide cover for fish, a constant oxygen supply, and food for select aquatic animals (Forest 1986; Moore 1987). Yet excessive aquatic macrophytes can have a detrimental effect on water quality, impede recreation, and cause concern to municipal water users (Peverly and Johnson 1987).

Mechanisms for the control of aquatic macrophytes include water level manipulations, harvesters, herbicides, dragging, floating platforms to reduce light, sediment covers (Moore 1987), and biological controls (Peverly and Johnson 1987; Seagrave 1988; Leslie *et al.*1987). Biological controls include mammals, fish and invertebrates such as crayfish (Peverly and Johnson 1987).

Crayfish are considered omnivorous (Groves 1985; Crocker and Barr 1968; Pennak 1953; Chidester 1912), and do show a preference for submerged aquatic plants (Dean 1969; Tack 1941; Flint and Goldman 1975; Seagrave 1988). Dean (1969) observed that macrophytes were controlled when high densities of the crayfish <u>Orconectes causeyi</u> occurred. Similarly Flint and Goldman (1975) have shown that the crayfish <u>Pacifastacus leniusculus</u> do graze on certain macrophytes.

The research reported here experimentally evaluated the ability of the crayfish <u>Orconectes immunis</u> to graze submerged aquatic macrophytes. Two questions were addressed: 1) At what density must crayfish be stocked to control the macrophytes; and 2) when should the crayfish be placed into an ecosystem so that optimum grazing occurs.

STUDY SITE

The northern end of Conesus Lake (Fig. 1) was selected for an inclusion-exclusion experiment to determine the effectiveness of the crayfish Orconectes immunis as a submerged aquatic macrophyte grazer. Conesus Lake, whose crop of submerged aquatic macrophytes is often considered the most luxurious in the region, is the most western of the Finger Lakes of New York State, (Bloomfield 1978). The macrophytes prevalent in Conesus Lake, Ceratophyllum, Elodea, Heterantera, Myriophyllum, Chara and various Potamogeton spp., frequently are preferred by crayfish (Makarewicz *et al.* 1991; Forest 1977; Dean 1969).

METHODS

To evaluate the effect of grazing crayfish on macrophytes during a period of active macrophytic growth three experiments were designed.

The first experiment (Pre-established, 7 July - 31 July, 1989) was designed to evaluate the crayfish grazing ability before the macrophytes became established, prior to the annual summer growth period of macrophytes. This experiment was terminated three weeks after a luxuriant growth of macrophytes developed in the lake and in the control cages. The second experiment (Post-established, 4 August - 31 August, 1989), was designed to evaluate the effectiveness of crayfish grazing on an established community of macrophytes. The third experiment (Continuous, 7 July - 31 August, 1989) evaluated macrophytic growth in the presence of crayfish over the entire summer.

Eighteen cylindrical cages constructed of 6.3 mm mesh hard-ware cloth were placed into a 4x3 random block design in the northern most end of Conesus Lake: six cages for the Continuous phase and 12 for the Pre-established. The cages from the Pre-established phase were relocated for use in the Post-established phase. Cage dimensions were 0.56 m in diameter x 1.5 m in height (area of crayfish grazing = 0.25 m^2). The edge of each cage was buried approximately 10 cm below the surface of the sediment and anchored into place with stakes and a metal fence post in approximately 0.5 to 1.0 meter of water. The cylindrical construction of the cages proved to be resistant to the occasional heavy wave action that occurred.

Crayfish were purchased from a local aquaculture firm and placed in plastic mesh acclimation cages for 24 hours before introduction to experimental cages. The selection of the crayfish, Orconectes immunis, was based on its ability to survive in a lake habitat, and that it is native to New York State. Basic biological data was taken (sex, length, weight) on each crayfish before and after completion of each experimental time period (Pennak 1953). Length was taken from the anterior tip of the rostrum to the posterior tip of the telson with the uropods turned in towards the telson (Dean 1969). Each crayfish's wet weight was determined by placing it into a tared weighing vessel on a triple beam balance.

In the Pre- and Post-established experiments, four different levels of crayfish biomass were used: 0 g/m^2 (control), 40-48 g/m^2 (level 1), 140-150 g/m^2 (level 2), and 240-250 g/m^2 (level 3). Each biomass level of crayfish was replicated (n=3). The Continuous experiment was set up with three control cages and three experimental cages utilizing only level 2 (140-150 g/m^2).

At the end of each phase the macrophytes were harvested from both the crayfish and control cages by placing a steel hoop inside the cage to mark the location of the cage, removing the cage and harvesting the macrophytes within the hoop (above surface portions only). All macrophytes were placed in plastic bags and frozen until wet weight, dry weight (105^oC), and ash free dry weight (ignition for 6 hrs at 525^oC)

was determined (APHA 1985; Westlake 1963; Vollenweider 1974).

Throughout the study water chemistry was monitored periodically inside and outside the cages. The inside water sample was taken from inside one of the control cages, while the outside water sample was taken away from the cages. The water monitoring involved alkalinity, dissolved oxygen, chloride, pH, conductivity, turbidity, nitrates, phosphates (soluble reactive and total), sodium, calcium, potassium, and magnesium according to APHA (1985).

RESULTS

Crayfish significantly decreased macrophyte biomass in all experiments (Tables 1-3), but only at densities exceeding 140-150 g/m^2 in the Pre-established and 240-250 g/m^2 in the Post-established experiments. In cages where significant decreases in macrophyte biomass occurred, the rate of crayfish grazing averaged 0.012 g of macrophytes consumed/crayfish/m^2/day. Significance within each experiment was determined using student t-tests.

Throughout the study period, crayfish survival averaged 88% (range=85-92%), with an average increase in weight and length of 1.4 g and 0.5 cm per crayfish, respectively. As expected, lowest weight gain in crayfish biomass occurred at the highest stocking densities (Tables 4 and 5). Water quality was not significantly different between control cages and the lake (Alpha=0.05) (Table 6).

DISCUSSION

Biological control of macrophytes is possible when crayfish levels are at least 240 g/m^2 in a well established macrophyte community, or 140 g/m^2 in a pre-established early summer macrophyte community. Flint and Goldman (1975) reported a much lower level of crayfish biomass (69 g/m^2) as a minimum to reduce macrophyte biomass by Pacifastacus leniusculus in Lake Tahoe, Nevada. Lake Tahoe is a oligotrophic lake while Conesus is meso-eutrophic (Makarewicz *et al.* 1991). The apparent difference in ability to graze macrophytes may be due to enhanced growth of macrophytes in a meso-eutrophic lake and the presence of a larger crayfish in Lake Tahoe than the ones used in this experiment. A crayfish biomass value of 140 g/m^2 in Conesus Lake corresponds to 88 crayfish/m^2 or about 880,000 crayfish/ha or 356,275 crayfish/acre (Appendix 1).

Peverly and Johnson (1987) estimated that 1,000 crayfish/acre are required to disrupt macrophytic growth throughout a growing season in a predator-free environment, which is considerably less than the 360,000 crayfish/acre required to provide total elimination of macrophytes in three weeks in Conesus Lake. Using the combined grazing of 1,000 crayfish at the rate observed in this study, 25, 50 and 100% reduction in macrophyte biomass would occur in 2,104, 4,208, and 8,417 days, respectively (Fig. 2). Obviously significant reduction of macrophytes using this species is not possible within a growing season with 1,000 crayfish/acre. The effect of increasing abundance of crayfish is inversely proportional to the number of days to achieve a certain level of reduction on any grazing area (Fig. 2). Therefore, the choice of amount of reduction and area of grazing are very important considerations prior to crayfish introduction.

When should the crayfish be placed in the ecosystem for maximum effect? The experimental results suggest control is achieved with fewer crayfish when the macrophytes are not well established (i.e. early in the growing season). However, elimination of macrophytes early in the growing season will remove cover for the crayfish and potentially make them susceptible to predation. Any removal of the crayfish by predation would decrease their ability to control macrophytes and hinder further control in subsequent years.

One of the most researched and promising of the biological controls of aquatic weeds is the grass carp (Ctenopharyngodon idella). The grass carp, a native of the river systems of Asia, is a highly effective grazer of submerged aquatic macrophytes (Bauer and Willis 1990; Lembi *et al.* 1978; Leslie *et al.* 1983; Woltman and Goetke 1985). It has been shown that the stocking of 15-25 grass carp per metric ton resulted in complete elimination of Hydrilla verticillata in less than one year (Leslie *et al.* 1987). Leslie *et al.* (1987) also suggests that a stocking rate of 2 grass carp per metric ton of hydrilla would control macrophytes, if macrophytes are reduced prior the introduction of the carp by other methods of control.

Only recently has the use of certified triploid grass carp been allowed in New York State. Permits are required for both introduction and possession of grass carp which are monitored very closely by the New York State Department of Environmental Conservation (NYSDEC 1990). The nature of grass carps feeding habits and relative non-vulnerability to predators makes its use restricted.

Nevertheless, there are advantages of using crayfish over the grass carp.

Advantages include:

1) an exotic species would not be introduced into the lake ecosystem;

2) the non-selective nature of the crayfish plant diet while the grass carp exhibits selectivity of plants (Leslie *et al* 1987);

3) the crayfish may not have the side effects on the ecosystem that the grass carp has such, as increases in turbidity and nutrients;

4) the crayfish could provide a food source for a number of other species, not just large predators as is the case for the grass carp.

There are also disadvantages of using the crayfish over the grass carp.

Disadvantages include:

1) a considerably greater amount of crayfish is needed to control macrophytes compared to estimates of 15-40 grass carp/acre (Woltman and Goetke 1985);

2) the high cost of procurement;

3) the potential for predation on the crayfish and thus their demise;

4) low biomass of crayfish may enhance the growth of the macrophytes.

At the densities required to reduce macrophyte biomass, the initial cost of crayfish is high. The cost for 1000 crayfish is $65, for 50,000 the cost would be $2,750; the cost per thousand decreasing as more crayfish are purchased (S. Sanford, Aquaculturist, Wolcott, N.Y. Personal Communication 1991). In my estimation, it is feasible to purchase crayfish for the purpose of macrophyte control because no other cost is associated with their use and it may only take the initial introduction for years of macrophyte control. This is unlike other controls that require periodic maintenance such as mechanical harvesters and periodic application with herbicides.

The research completed certainly suggests crayfish may be an effective biological control of macrophytes. However, all the work done in this study were undertaken with crayfish protected from their predators including fish, birds, mammals and man. Further experimental work should be conducted to evaluate crayfish grazing with the presence of predators. For example, what impact does predation have on crayfish survival, grazing and reproduction at different macrophyte levels during different seasons of the year? Also, what will happen to crayfish after control is achieved; will they starve and die or be eaten by predators? Further, large scale experiments are suggested that cover an acre in size or more to validate the observations seen in this relatively small experimental area.

Why are crayfish not found in Conesus Lake in sufficient numbers to provide some macrophyte control? Anecdotal evidence from local residents suggests that crayfish were present in large numbers in Conesus Lake in the past. I have no evidence that suggests any hypothesis for a decrease in crayfish numbers in Conesus Lake. Possible reasons for a decrease include increased predation, loss of habitat and eutrophication. However, a major predator in the lake, the walleye, has decreased in recent years (Puckett 1989). Furthermore, the luxuriant macrophytic growth would suggest considerable cover from predators. Therefore, potential research presents itself to possible connections between decreases in crayfish numbers verses increases in macrophytic biomass in Conesus Lake.

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Table 1. Results of crayfish grazing on macrophytes in the Pre-established experiment. Level I = 40-48 g of crayfish/m^2; Level II = 140-150 g of crayfish/m^2; Level III = 240-250 g of crayfish/m^2; Control has no crayfish; Lake refers to macrophytes biomass in the lake outside of the cages.

Macrophyte Biomass (ash-free weight in g/m^2)

	REP 1	REP 2	REP 3
CONTROL	38.19	22.22	14.41
LEVEL I	6.61	3.16	30.40
LEVEL II*	0.00	0.00	0.00
LEVEL III*	0.00	0.00	0.00
LAKE	9.45	37.03	48.92

* Significantly different amounts of macrophytes compared to controls at $P<0.05$, one-sided t-test.

Table 2. Results of crayfish grazing on macrophytes in the Continuous experiment. Level II = 140-150 g of crayfish/m^2; Control has no crayfish; Lake refers to macrophytes biomass in the lake outside of the cages.

Macrophyte Biomass (ash-free weight in g/m^2)

	REP 1	REP 2	REP 3
CONTROL	36.21	36.63	49.19
LEVEL II*	0.00	0.00	0.00
LAKE	44.56	27.74	64.77

* Significantly different amounts of macrophytes compared to controls at $P<0.05$, one-sided t-test.

Table 3. Result of crayfish grazing on macrophytes in the Post-established experiment. Level I - 40-48 g of crayfish/m^2; Level II - 140-150 g of crayfish/m^2; Level III - 240-250 g of crayfish/m^2; Control has no crayfish; Lake refers to macrophytes biomass in the lake outside of the cages.

	Macrophyte Biomass (ash-free weight in g/m^2)		
	REP 1	REP 2	REP 3
CONTROL	59.67	59.60	46.73
LEVEL I	75.14	39.69	72.16
LEVEL II	5.20	60.25	46.41
LEVEL III*	20.27	13.38	31.13
LAKE	70.78	46.24	49.66

* Significantly different amounts of macrophytes compared to controls at $P<0.05$, one-sided t-test.

Table 4. Percent survival, weight and length gain of individual crayfish in the Pre-established experiment, 7/8/89-7/31/89. Values are mean ± standard error.

CRAYFISH BIOMASS	AVERAGE WEIGHT GAIN (g)	AVERAGE LENGTH GAIN (cm)	PERCENT SURVIVAL
LEVEL #1 (40-48 g/m^2)	1.4 ± 0.3	0.6 ± 0.2	90
LEVEL #2 (140-150 g/m^2)	1.2 ± 0.1	0.7 ± 0.06	89
LEVEL #3 (240-250 g/m^2)	0.9 ± 0.09	0.4 ± 0.2	85

Table 5. Percent survival, weight and length gain of individual crayfish in the Post-established experiment, 8/4/89-8/31/89. Values are means ± standard error.

CRAYFISH BIOMASS	AVERAGE WEIGHT GAIN (g)	AVERAGE LENGTH GAIN (cm)	PERCENT SURVIVAL
LEVEL #1 (40-48 g/m^2)	1.5 ± 0.4	0.5 ± 0.1	92
LEVEL#2 (140-150 g/m^2)	1.9 ± 0.3	0.5 ± 0.1	91
LEVEL #3 (240-250 g/m^2)	1.2 ± 0.2	0.3 ± 0.07	88

Table 6. Ranges of water quality parameters throughout all experimental phases. In represents water chemistry inside experimental cages, and Out represents water chemistry outside the influence of the experimental cages.

	In	Out
Alkalinity (mg $CaCO_3$/L)	67.98-115.36	69.22-115.35
Dissolved Oxygen (mg/L)	5.1-13.2	5.2-13.2
Chloride (mg/L)	33.51-36.68	32.03-36.42
pH	8.35-10.08	8.38-9.77
Conductivity (umhos/cm)	256-340	260-338
Turbidity (NTU)	1.79-10.7	1.22-10.1
NO_2+NO_3 (mg/L)	ND-0.04	ND-0.06
Soluble Reactive Phosphorus (ug P/L)	1.1-28.7	4.0-20.5
Total Phosphorus (ug P/L)	23.6-76.1	7.7-53.3
Sodium (mg/L)	17.41-19.42	16.93-19.62
Calcium (mg/L)	16.88-35.06	17.02-32.19
Potassium (mg/L)	1.6-2.16	1.51-1.98
Magnesum (mg/L)	9.03-12.23	8.81-12.91

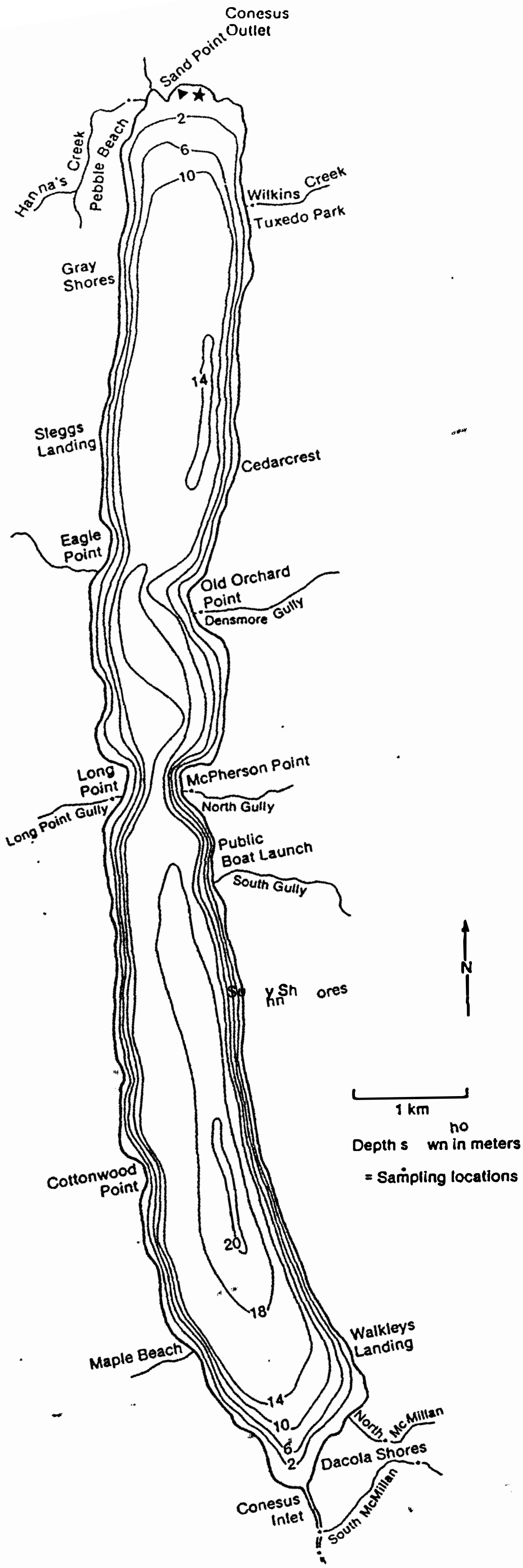

Figure 1. Experimental sites in Conesus Lake. ▲ -Continuous and Pre-established Phases, ★ -Post-established Phase. Livingston County, N.Y.

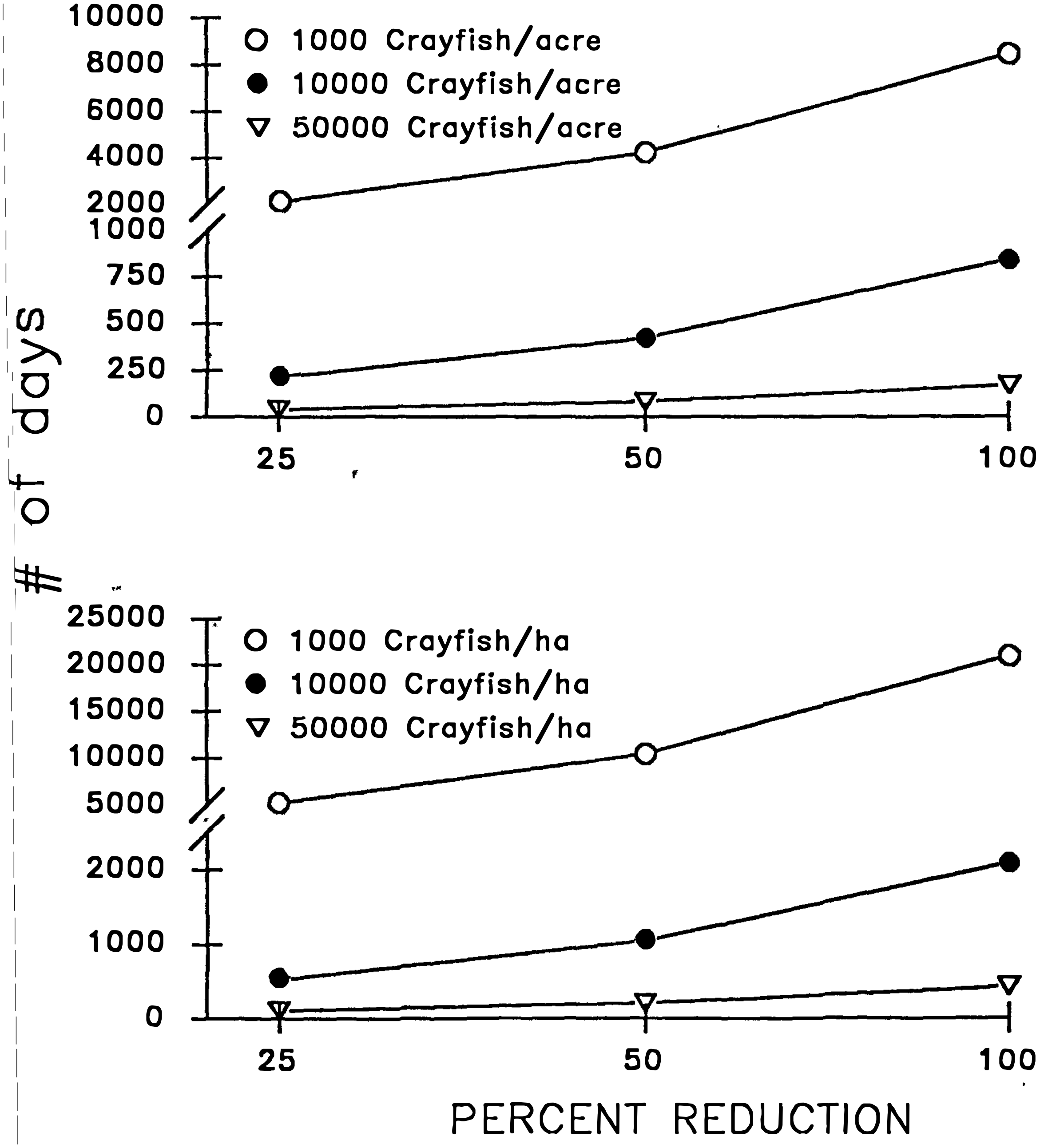

Figure 2. The relationship between number of days to achieve a given reduction in macrophyte biomass varying crayfish densities, in Conesus Lake.

Appendix

Appendix 1. Sample calculation for estimating amount of crayfish/hectare needed to control macrophytes to a zero level.

88 Crayfish/m^2 determined from the pre-established experiment.

x 10,000 Conversion from m^2 to hectare

880,000 Crayfish/hectare

Appendix 2. Sample calculation for consumption rate for crayfish in the post-established experiment.

55.33 g of macrophytes in control -

37.29 g of macrophytes in level 2 biomass of crayfish /

110 crayfish /m^2/28 days =

0.013 g of macrophytes consumed/crayfish/m^2/day.