Naimo

Kenyon et al 1997

An Evaluation of Relocation of Unionid Mussels
Into Artificial Ponds

Interim Progress Report for July 1, 1996 - November 30, 1996

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Submitted to:

Mr. Robert Leasure, Shell Exporters of America
Mr. Wayne Davis, Mussel Mitigation Trust Fund
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Preface

This report is a product of the Wisconsin Department of Natural Resources representing the project results obtained through November 30, 1996, for the federal and state cooperative mussel relocation project. The interpretative analyses of recovery and survival data are preliminary and subject to change.

WISCONSIN DEPT. OF NATURAL RESOURCES

State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES

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March 6, 1997

Dr. Richard Neves
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Dear Dr. Neves:

Enclosed is the fifth quarterly report summarizing our progress on the mussel relocation project. This May marks the beginning of our third project year! We are anxious to see how the mussels are faring, and new project data regarding mussel survival will be collected once again in September, 1997.

I am curious to know how your own salvage operation with Ohio River mussels is coming along. I am especially interested in Catherine Gattenby's progress in the development of suitable algal diets for juvenile mussels. I would appreciate any information you could forward to me with respect to this study.

Our future reports will be released only on an annual basis, with expected distribution occurring in March or April of each calender year. Any comments that you or your co-workers may wish to offer concerning the content or format of the report would be welcome.

Don't hesitate to call if you desire further information regarding progress on this study (ph 608-785-9993).

Sincerely,

Rhonda Kenyon

Rhonda Kenyon
Wisconsin Department of Natural Resources

INTRODUCTION

The introduction of the exotic zebra mussel, *Dreissena polymorpha*, into the Great lakes and its subsequent spread into many of the nations inland river systems has been the cause of concern for public and private entities which deal with native unionid mussels. The proliferation of the zebra mussel and the documented adverse impacts they have had on native mussels prompted biologists working with the Upper Mississippi River Conservation Committee to undertake an experimental relocation project in order to identify potential conservation strategies which could be employed if zebra mussel densities in the upper Mississippi River (UMR) exhibit the same geometric increases as seen in the Illinois and Ohio rivers.

The purpose of this study is to obtain quantitative data on the growth and survival of freshwater mussels following removal from the UMR and subsequent relocation into an artificial pond. The original study design investigated unionid progress at just one artificial site, however, uncontrolled winter events during the first year of research created a need for an ancillary study location. Mussels utilized in the second phase of research were placed in an ancillary study pond in June, 1996.

Data on growth and survival of mussels relocated to the two artificial holding ponds will be collected annually and compared to data obtained from mussels treated similarly but relocated to a natural setting in the UMR.

OBJECTIVES

This study will provide information useful for addressing the following objectives relevant to holding freshwater mussels in artificial ponds:

1. Evaluate the initial mortality associated with transferring freshwater mussels from their natural environment to established relocation structures in the artificial ponds and the river, and determine if the mortality is species-specific.

2. Compare the growth and survival of mussels relocated to the artificial ponds with that of mussels held under similar conditions in the upper Mississippi River.

3. Determine if species-specific differences exist in growth and survival of mussels in the artificial ponds compared with the river-relocated mussels.

4. Determine which treatment (Shoe-bag, buried substrate-filled tray, suspended substrate-filled tray, or corral; described in next section) yields the highest growth and survival.

EXPERIMENTAL APPROACH AND DESIGN

Phase I study efforts were initiated in the spring of 1995, and consisted of removing mussels from the UMR, confining them to a quarantine pond for 35 days, and subsequently relocating the mussels to either a 0.25 acre artificial pond at a National Fish Hatchery, in Genoa, Wisconsin, or back into the UMR. In both physical locations, live mussels were randomly selected and relocated into one of four placement options (treatments). Each of these treatments were replicated four times for a total of 16 treatments per physical location. The four treatments included:

1. Shoe-bag structures. Nylon mesh bags containing 24 pockets and measuring approximately 51 cm wide by 63 cm high. The bottom row of these vertically-suspended nylon structures was positioned three to five cm above the substrate.

2. Buried substrate-filled trays. One square meter metal baskets supported in a metal framework placed directly on the substrate. These baskets were filled with UMR dredge spoil material deposited before the initial appearance of zebra mussels.

3. Suspended substrate-filled trays. Similar to the buried substrate-filled trays, except these structures were placed approximately 46 to 61 cm above the substrate. These baskets were also filled with UMR dredge spoil material deposited before the initial appearance of zebra mussels.

4. Corrals. One square meter metal framework barrier around the natural substrate present in either Pool 9 of the UMR or the Genoa pond.

Phase II study efforts were initiated in May, 1996, and consisted of removing mussels from the UMR, confining the collected mussels to a quarantine pond for 33 days, and subsequently transferring the mussels to a 0.1 acre earthen pond at the Upper Mississippi Science Center (UMSC) in La Crosse, Wisconsin.

Thirty plastic glass racks were obtained from a restaurant supplier and utilized as treatment structures. Each 49.8 cm^2 rack contained 25 individual cells measuring 8.9 cm^2. Mussels were housed within the individual cubicles of the rack. Bottom liners, cut from one-eighth inch, plastic mesh, were utilized in instances where unionids were small and could potentially fall through the compartment bottom. The treatment structures were deployed across the pond in five rows using five plastic-coated cables. The cables were hung at 3 meter intervals, and six glass racks were suspended from each cable with a plastic-coated wire. All 30 structures were hung so that the bottom of the glass rack rested 38 to 51 cm beneath the water surface.

Mussels were randomly allocated to the experimental structures using a randomized block design (Cochran and Cox, 1957) which ensured that each mussel species appeared in each block (row). Each experimental unit (individual glass rack), contained 25 mussels of identical species in a 5 x 5 array. Of the 30 racks, 10 contained threeridge, *Amblema plicata* (n=250), 8 contained threehorn wartyback, *Obliquaria reflexa* (n=200), 8 contained mapleleaf, *Quadrula quadrula* (n=200), and 4 contained pigtoe, *Fusconaia flava* (n=100; because an insufficient number of *Fusconaia* were obtained, they occupied only 4 of the 5 blocks).

All phase I and II relocated mussels will be examined annually for a minimum of two years. At the time of examination, shell length, shell height, and wet weight will be documented. Dead and live shells will be returned to the treatment of origin following analyses.

METHODS

Water Quality

The quality of water was measured biweekly at all three experimental sites. Water samples were obtained from each experimental location at a depth of approximately 30 cm over the central area containing the relocated mussels. Dissolved oxygen (DO), temperature, and pH were measured in situ. A Model 57 Yellow Springs Instrument (YSI) was used to measure dissolved oxygen and temperature, and an Orion meter, Model 230A, was used to measure pH. Biweekly monitoring was also initiated in the spring of 1996, for turbidity, current velocity, and chlorophyll *a*. Turbidity and current velocity were measured in situ with a Hach turbidimeter, Model 16800, and a Marsh McBirney portable water current meter, Model 201D, respectively. It was established that current velocity was absent in the Genoa and UMSC ponds and consequently this measurement was only collected from the river location. Water samples for chlorophyll *a* analyses were collected in opaque, polyethylene bottles, stored on ice, and lab-filtered within two hours of collection. Filtered samples were foil-wrapped, packed in ice, and sent to the State Laboratory of Hygiene for analysis.

Total alkalinity and hardness were measured for both sites monthly, in the laboratory, on a chilled water sample, using the procedures in the APHA et al. (1992). Conductivity was also obtained monthly and measured in situ with a Hanna, Model 8733, conductivity meter.

In late August, three pounds of fertilizer (10-10-10, lawn and garden variety) were added to each of the artificial ponds in an attempt to increase phytoplankton productivity. The quantity of fertilizer was measured into a burlap bag and suspended near the inflow of each pond for gradual release of contents.

Mussel Characterization

Growth, survival, and recovery were assessed on September 17, 18, and 19, 1996, for all experimental mussels. Randomization lists generated prior to the recovery effort dictated the order of treatment assessment.

Unionids placed in the ancillary pond at the UMSC were the first to be recovered. At this study site, the experimental units (glass racks) were removed from the pond, one at a time, and placed in small wading pools filled with pond water. Mussels were then removed from the racks and carried in water-filled, 5-gallon buckets to nearby processing stations. The tag number, shell length, shell height, and shell condition were recorded for each individual unionid, and each was inspected for zebra mussels. Wet weights were also documented for each live mussel. Following processing procedures, unionids were carried back to the wading pool and replaced into the identical cells they previously occupied within the experimental rack. The rack was returned to the pond and another experimental structure was retrieved until all holding units had been processed.

Recovery efforts were carried out at the Genoa National Fish Hatchery pond, and the Pool 9, upper Mississippi River location, on the 18th and 19th of September, respectively. The nature of the treatments at these sites necessitated the need for a dive team in the recovery and replacement of mussels. Unionids were retrieved from a given treatment by divers and carried to the on-shore processing stations in mesh bags labeled with the appropriate treatment codes. Processing procedures were identical to those followed at the UMSC pond the previous day. All zebra mussels observed on unionids recovered from the river were enumerated and removed.

Unionid survival calculations were derived using information obtained from recovered mussels only to avoid biasing the results with assumptions about the status of unrecovered individuals.

RESULTS AND DISCUSSION

Water Quality

The quality of water was statistically similar in temperature, dissolved oxygen, and pH among all three locations (Table 1).

The three sites were all statistically different with respect to conductivity ($p < 0.0001$), alkalinity ($p < 0.0001$), and hardness ($p < 0.0001$; Table 1). Total alkalinity and total hardness have been consistently higher in the Genoa artificial pond compared to the river since the onset of the project. The UMSC data on these parameters is further discrepant of the Genoa pond, demonstrating even lower values than the river (Table 1). The difference in hardness between the Genoa and UMSC ponds is likely a result of differing well depths, while the alkalinity differences are probably due to variations in the water flow patterns. The UMSC pond receives its water directly, while the well water in Genoa flows through a highly fertile trout raceway, and a relatively large, densely vegetated pond, before reaching the study pond. It is likely that the eutrophic nature of the pre-study pond increases the alkalinity of the water before it reaches the study area.

Since conductivity values are a function of the relative ion concentrations, and therefore a reflection of alkalinity and hardness, it is reasonable that they too differed significantly among the three sites.

Despite the statistical significance of the alkalinity, hardness, and conductivity parameters, differences of this degree are not likely to have a significant impact on our study objectives.

The two artificial ponds were similar to one another in turbidity and chlorophyll *a*, but statistically different from the river for these same measurements ($p < 0.0001$ in each case). Since turbidity measures the quantity of organic material, such as plankton, and suspended material, such as silt and clay, it is no surprise that the riverine location demonstrated higher turbidity values than the two, artificial locations which receive their water from a well.

With respect to chlorophyll *a*, one erroneously high value (84.8 μg/L) obtained for the UMSC pond was removed from the data set. The sample in question was obtained under conditions of high filamentous algae production, and since the corresponding turbidity value did not show a similar increase, it can logically be assumed a strand of the algae was filtered, causing the reading to be abnormally high. The chlorophyll *a* differences between the river and ponds were large, with the river displaying a mean value of 55.6 μg/L, and the Genoa and UMSC ponds displaying average values of 2.6 μg/L and 5.5 μg/L respectively (Table 1). In an attempt to reduce the disparities between the natural and artificial systems, fertilizer was applied to each of the artificial ponds in late August. Results from the chlorophyll *a* analyses following the fertilization are difficult to interpret due to both increasing and decreasing fluctuations demonstrated in a desynchronized fashion by each of the pond locations. Furthermore, the river displayed natural fluctuations during these same sampling dates. Chlorophyll *a* in the river dropped from 96 μg/L in late August to 25 μg/L in early September, increased to 91μg/L in late September, and was 110 μg/L in early October. By November, however, all three locations demonstrated consistent declines in chlorophyll *a* levels.

It seems, at this point, that interacting factors are influencing the phytoplankton productivity within the artificial ponds. After two seasons of water quality analyses in Genoa, and one season in the UMSC pond, it appears phytoplankton growth in these systems is largely prevented by other plant domination. As previously mentioned, the well water in Genoa filters through a densely vegetated pond, before flowing into the study pond. It is likely the macrophytes in the pre-study site extract the majority of nutrients released from the trout raceway before they reach the project location. It was hoped that fertilizer placed at the inflow of the study pond would provide additional nutrients for a phytoplankton bloom. Unfortunately, it was also a possibility that fertilizing the pond would be futile, since a dense bed of macrophytes also existed within the study pond. The chlorophyll *a* results do not reflect any major changes and suggest that the existing plants may have effectively extracted the nutrients before the phytoplankton had a chance to develop.

Similar vegetation problems were experienced within the UMSC pond. Filamentous algae was problematic throughout much of the summer, covering the entire pond surface and growing in dense mats along the bottom. Despite repetitive removal efforts, the vegetation reappeared within a day or two. Phytoplankton blooms were absent at this site, presumably because of nutrient limitations and lack of penetrating sunlight due to the thick mass of algae upon the waters surface.

The vegetation issues will be confronted early in the spring of 1997. Early fertilization should assist in the initial establishment of hardy phytoplankton populations before other vegetation dominates. By coupling early fertilization with the physical removal of undesired vegetation, we can possibly retain phytoplankton blooms throughout the summer months.

Mussel Characterization

The UMSC pond yielded an overall recovery rate of 99% and an overall survival rate of 94% after the first 91 days of mussel placement. Survival was nearly identical to that observed in the river (95%), and much higher than that in Genoa (74%), after comparable holding time. After three months, the recovery rates for Genoa and the UMR were 93% and 84% respectively.

Recovery, evaluated in cumulative terms for the phase I project sites, was significantly different between the Genoa pond and UMR, Pool 9 location ($p < 0.04$). After 16 months, 93% of the mussels originally placed in the Genoa pond were recovered, versus only 82% of the river-placed unionids. Statistically, the difference occurred entirely at the level of the corral treatments within the river location (Table 2). Only 50% of the unionids originally placed in this treatment were recovered. The corrals in the river location not only demonstrated the lowest recovery, but they also contained non-experimental species, thus indicating that mobility in and out of the structures was possible. Furthermore, numerous untagged unionids, primarily fragile papershell, were recovered in the corrals. It is likely that some of these individuals simply lost their tags, but in cases where the number found exceeded the number placed, we can assume that immigrants were entering the treatments.

With respect to the other three river treatments, and the four pond treatments, mean recovery values in the range of 86% to 99% were demonstrated (Table 2); all of which were statistically similar .

Cumulative recovery at the species level was also significantly different between the UMR and Genoa pond locations. The mean percent recovery for the fragile papershell, *Leptodea fragilis*, and the threehorn wartyback, *Obliquaria reflexa*, was significantly greater ($p < 0.03$ and

$p < 0.02$ respectively) in the Genoa pond than in the Pool 9, UMR location. This result was not entirely unforeseen after the recovery efforts of the previous year. Several fragile papershell had drifted from the confines of the treatments, especially dead mussels of this species, due to the light-weight shell. The divers had also experienced difficultly locating threehorn wartybacks amongst the cobble of the substrate-containing structures due to the size and texture similarity of the mussels to the rocks. River conditions only exacerbated the situation due to the low visibility and uncontrolled conditions. While no significant differences occurred in recovery among species placed in the Genoa pond, cumulative recovery within the river location was significantly higher for *Amblema plicata* than for *Leptodea fragilis* ($\alpha = 0.05$, Tukeys *hsd* ; Figure 1).

Survival, evaluated after just three months for the phase II mussels in the UMSC pond, was significantly different among species ($p = 0.0001$). *Obliquaria reflexa* demonstrated significantly lower survival than *Amblema plicata, Fusconaia flava,* and *Quadrula quadrula.* Twenty-nine of the 200 *Obliquaria* originally placed in this pond died within 91 days. No other significant differences existed among species. Since a randomized block design was utilized for determining mussel placement within racks in the pond, it is unlikely that placement effects occurred. It is more probable the mortality effect is one of species hardiness since a low survival was also observed for this species in the phase I efforts.

Cumulative survival for Phase I mussels, combined over all five species and all four treatments, was significantly lower in the Genoa pond compared to the river location ($p = 0.0001$). Mean percent survival rates after 16 months were 48% in the pond and 87% in the river (Figure 2). Comparisons between the pond and river locations demonstrated survival to be significantly higher in the river for every species ($p = 0.0001$; Figure 3) and for every treatment ($p= 0.0001$; Figure 2).

Additional comparisons within each site showed significant differences in survival among treatments at both the Genoa and UMR locations ($p = 0.0001$; Figure 2). Mean percent survival in the Genoa pond was significantly lower in the shoebags (27%) compared to either the buried substrate-filled trays (57%) or the suspended substrate-filled trays (63%; Figure 2). While this result follows the trend observed in the 1995 recovery effort, it must be evaluated with caution. All shoebag and suspended substrate-filled tray structures were subjected to direct air exposure the previous winter when the west-side dike of the pond collapsed. As a consequence of the lowered water level, the upper three rows of the shoebag treatments endured several hours in sub-zero temperatures. The September, 1996, recovery effort confirmed the anticipated mortalities of the exposed unionids; fortunately survivors remained in the bottom three rows of each of the shoebag structures. Nevertheless, the highest proportionate species survival in the shoebag structures was just 40% in the September 1996 recovery effort (Table 3).

Surprisingly high survival was demonstrated by mussels residing in the suspended-substrate filled trays which had also been exposed during the low water event. Survivals ranged from 46% for *Leptodea fragilis*, to 74% for *Quadrula quadrula* (Table 3). Mussel in these treatments had literally been frozen into the substrate, yet they displayed higher overall survival than the mussels confined to any of the other study treatments. Interestingly, survival was also highest in this treatment for the river-placed mussels (Table 3). In fact, the suspended substrate-filled trays in the UMR, Pool 9 location, demonstrated significantly higher mean survival (95%) than the corrals (74%; Figure 2). In interpreting this result, it is important to reiterate that the recovery for the river corral treatments was only 50%, and that the percent survival values are based upon recovered species only. Furthermore, recovery of dead specimens was more likely within the corral structures due to the inability of these shells to migrate from the treatment.

Significant differences in survival among species were observed in the pond-relocated mussels but not the river-relocated mussels (Figure 3). In the pond, the fragile papershell (*Leptodea fragilis*) did not fare well, and survival of this species was significantly different than the survival of each of the other four species in that location ($\alpha = 0.05$, Tukeys hsd). Only 16% of the fragile papershell survived the first 16 months of study. This was consistent with the survival pattern demonstrated by this species after the three month recovery. Only 48% of the fragile papershell had remained alive at that time. Mapleleaf (*Quadrula quadrula*) had the highest survival rate (63%) after 16 months (Figure 3), and the pigtoe, *Fusconaia flava*, which had demonstrated the highest survival after 3 months (84%), assumed the position of second place (58%) in the cumulative survival assessment within the Genoa location.

Cumulative species survival in Pool 9, UMR, ranged from 76% for the fragile papershell, to 96% for the pigtoe. No significant differences existed among species (Figure 3).

Cumulative growth of phase I mussels was also assessed and shown to be significantly different between locations. Shell length ($p = 0.0001$), shell height, ($p = 0.0001$) and wet weight ($p = 0.0001$) were all significantly higher for river-relocated mussels (Figure 4).

Mean percent growth increases ranging from 4% to 24% were observed in river-placed species, compared with mean percent increases not exceeding 4% in pond-placed species (Figure 5). Within the river location, the mean percent increase in wet weight for mussels relocated to the suspended trays (24%) was significantly higher than that demonstrated by similar mussels relocated to the shoebags (10%; Figure 5). Conversely, within the pond location, the wet weight variable exhibited a greater increase for mussels in the shoebag treatments relative to the other three treatments, however the difference was not significant.

Between site comparisons demonstrated the Pool 9, UMR location to have higher increases for all three growth variables, across all species, with one exception--the mean percent increase in height was not significantly different between locations for *Quadrula quadrula* (Figure 6).

Further species analysis within the Pool 9 location showed *Leptodea fragilis* and *Amblema plicata* to exhibit significantly larger mean percent increases in height relative to the other experimental species placed at this site. *Leptodea fragilis* also demonstrated a mean percent increase in wet weight (41%) which was significantly greater than the weight increase shown by any of the other species (Figure 6) in the river.

Due to the mean negative growth values generated within the Genoa location, no species comparisons were made within this site (Figure 6). Mean percent decreases in growth were demonstrated intermittently across all three growth variables and across all species except *Leptodea fragilis* (Figure 6). The negative growth effect was concentrated to the corrals when the data was sorted by treatment (Figure 5). Since the growth increases for the other treatments are quite minimal, it is likely the negative values are the result of normal measurement error.

The above interpretation of growth data should be considered preliminary, for it is important to note that the species composition and size distributions are no longer similar between locations and treatments due to mortality and species recovery problems. Since individual species are no longer represented proportionately between the two locations and within treatments, and because we know unionids growth patterns differ depending upon species and age, it is difficult to make comparison and assessments between treatments and locations without more thorough statistical procedures. More in depth analyses will be conducted to assess these effects later in the project, when growth increases are more substantial, but for now, the fact that overall positive growth is being demonstrated is significant to our objectives.

Zebra Mussel Abundance

The unionids recovered from the river treatments (after being scrubbed of zebra mussels one year earlier, in September 1995) contained an average of 13.8 zebra mussels per unionid (Table 4). Only 22% of the unionids were free of zebra mussels after one years time. The September, 1995, recovery effort had, after three months, demonstrated 49% of the unionids to be zebra mussel free, while 83% of the Phase II mussels collected from their natural river habitat in May, 1996, were devoid of zebra mussels.

Unionids in the corral structures experienced significantly lower zebra mussel infestation rates than mussels in either the shoe bags or suspended substrate-filled tray treatments (Table 4). Zebra mussel densities per unionid ranged from a mean of 23.6 in the shoe bag treatments to 2.0 in the corrals. The corral densities closely paralleled the zebra mussel densities observed on the Phase II unionids removed from the river three months earlier. While these mussels contained an average of only 0.3 zebra mussels per unionid, an increase to the level observed in the corral treatments would not be unusual following a full summer of copious zebra mussel reproduction.

Across treatments, the species most susceptible to zebra mussel infestation was *Leptodea fragilis*, with an average of 18.7 zebra mussels attached to each individual (Table 5). *Obliquaria reflexa* demonstrated the lowest infestation rate, with an average of 6.1 zebra mussels per individual (Table 5). While a significant difference was detected between the number of zebra mussels attached to *Obliquaria reflexa* compared to *Amblema plicata*, the difference is likely attributed to size differences between these species.

Similar species differences were detected at the treatment level for the shoebags. Zebra mussel colonization was significantly lower for *Obliquaria reflexa* compared with *Amblema* *plicata* and *Quadrula quadrula* in these structures. No other significant differences were detected among species placed in the other three treatments.

No zebra mussels were observed on any of the unionids relocated to either of the two artificial ponds.

SUMMARY

Growth, survival, and recovery were assessed for all relocated mussels involved in the phase I and II efforts of the unionid relocation project. Ninety-four percent of the mussels placed in the UMSC pond survived the first three months of their new residence. Such positive survival suggests that the developed relocation protocol is minimally stressful to the unionids as defined by subsequent mortality.

Cummulative survival of the river-placed mussels was 87% after 16 months, while only 48% of the mussels placed in the Geona pond remained alive. Within the Genoa location, percent species survival was significantly lower for *Leptodea fragilis*, while no significant survival differences were exhibited among species placed in the river. This result is consistent with the trend observed last year, and continues to suggest that certain conditions in the pond are not conducive to the survival of this species. It was previously postulated that flow could be a primary limiting component within the artificial pond. It now appears that heavily vegetated conditions within the pond environment may also be contributing to reduced survival through the prevention of phytoplankton development--a necessary food-source of unionids.

Suspended substrate-filled trays demonstrated the highest treatment survivals at both locations, while shoebags displayed the lowest survival in the pond, and corrals the lowest survival in the river. The pond treatment effects are difficult to evaluate due to the low water event the previous winter. The superior survival exhibited by the suspended trays at both locations was, however, also demonstrated last year and suggests some advantage to this treatment. It was hypothesized in an earlier report that processes occurring in the water column may provide some additional benefit such as increased food availability.

The data on length, height, and wet weight suggest that a small amount of growth is being demonstrated by mussels placed in the artificial pond, and a significantly greater degree of growth is being exhibited by mussels in the river location. These results indicate that while human handling and relocation to the experimental structures may have temporarily hindered the growth processes, it did not entirely suppress them.

ACKNOWLEDGEMENTS

The progress obtained on this project has been largely a function of the generous support and hard work of many individuals representing several natural resource agencies. Specifically, a large debt of gratitude is owed to the Fisheries program of the Mississippi River Work Unit of the Wisconsin Department of Natural Resources for the many hours of underwater services they provided in the mussel recovery effort.

This project has been a truly cooperative venture with participation and support from ten different agencies and institutions including the staff from the Wisconsin, Iowa, Minnesota, and Missouri natural resource agencies, the U.S. Fish and Wildlife Service, the National Biological Service, Upper Mississippi Science Center, the Environmental Management Technical Center, and the Illinois Natural History Survey.

FINANCIAL SUMMARY

The summary of our financial account between July 1, 1996 and November 30, 1996 is presented in Table 6.

LITERATURE CITED

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Table 1. Mean (± 1 standard error) temperature, dissolved oxygen, pH, conductivity, chlorophyll a, velocity, turbidity, alkalinity, and hardness (ranges in parentheses) in Pool 9 of the Upper Mississippi River (UMR), an artificial pond at a National Fish Hatchery in Genoa, Wisconsin, and an artificial pond at the UMSC, La Crosse, Wisconsin. Mean measurements that are not accompanied by a common letter were significantly different among locations ($\alpha = 0.05$, Tukey's *hsd* procedure).

Location	Collection Period	Temperature (°C)	Dissolved Oxygen (mg/L)	pH	Conductivity (µs/cm)	Chl *a* (µg/L)	Velocity (m/sec)	Turbidity (NTU)	Alkalinity (mg/L as CaC03)	Hardness (mg/L as CaC03)
Pool 9, UMR	4/95-11/96	17.1 ± 1.5[a]	9.9 ± 0.3[a]	8.2 ± 0.2[a]	417 ± 19[a]	55.6 ± 9.6[a]	1.16 ± 0.02	20.1 ± 1.1[a]	141 ± 4[a]	198 ± 8[a]
		(0.4-28.0)	(6.0-14.7)	(7.0-9.3)	(168-565)	(23.0-111.0)	(0.03-0.36)	(11.3-26.0)	(89-185)	(113-264)
Genoa Pond	4/95-11/96	17.6 ± 1.3[a]	10.4 ± 0.3[a]	8.4 ± 0.2[a]	483 ± 15[b]	2.6 ± 0.5[b]	*	2.2 ± 0.2[b]	251 ± 5[b]	271 ± 5[b]
		(1.1-29.0)	(6.3-13.9)	(7.6-9.9)	(362-657)	(0.5-5.4)		(1.2-3.1)	(211-303)	(231-335)
UMSC Pond	6/96-11/96	16.0 ± 2.3[a]	10.5 ± 0.4[a]	8.6 ± 0.3[a]	289 ± 13[c]	5.5 ± 0.8[b]	*	2.3 ± 0.4[b]	86 ± 5[c]	118 ± 6[c]
		(2.0-23.1)	(7.8-12.4)	(7.4-10.6)	(259-350)	(2.0-7.8)		(0.8-5.0)	(67-95)	(97-134)

* Not Measured

Table 2. Mean percent recovery of all mussel species (*Amblema plicata*, *Fusconaia flava*, *Leptodea fragilis*, *Obliquaria reflexa*, and *Quadrula quadrula*) after 471 days in either Pool 9, upper Mississippi River, or an artificial pond at a National Fish Hatchery in Genoa, Wisconsin. Percent recovery values within and between locations and treatments that are not accompanied by a common letter were significantly different ($\alpha = 0.05$, Tukey's *hsd* procedure).

	Treatment			
Location	Shoe Bags	Buried Substrate-Filled Trays	Suspended Substrate-Filled Trays	Corrals
Pool 9, UMR	97[a]	95[a]	86[a]	50[b]
Artificial Pond	99[a]	95[a]	89[a]	91[a]
Mean	98[a]	95[a]	87[a]	71[c]

Table 3. Mean percent species survival among treatments after 471 days in either Pool 9, upper Mississippi River or an artificial pond at a National Fish Hatchery in Genoa, Wisconsin. Within a location and species, treatment means that are not accompanied by a common letter were significantly different ($\alpha = 0.05$, Tukey's *hsd* procedure).

	Treatment			
Species	Shoe Bags	Buried Substrate-Filled Trays	Suspended Substrate-Filled Trays	Corrals
	Pool 9, upper Mississippi River			
Leptodea fragilis	89^a	79^a	100^a	0^a
Amblema plicata	89^a	93^a	89^a	77^a
Quadrula quadrula	96^a	89^a	96^a	87^a
Fusconai flava	92^a	92^a	100^a	100^a
Obliquaria reflexa	84^a	90^a	92^a	75^a
	Artificial Pond			
Leptodea fragilis	8^a	8^a	46^b	0^a
Amblema plicata	21^b	59^a	62^a	68^a
Quadrula quadrula	30^b	75^a	74^a	75^a
Fusconai flava	33^a	83^a	62^a	54^a
Obliquaria reflexa	40^a	59^a	70^a	30^a

Table 4. Treatment sample size and mean number, range, and standard deviation of zebra mussels found on unionids in the four treatments located in Pool 9, upper Mississippi River, near Victory, Wisconsin, during the annual recovery effort, September 19, 1996. Means among treatments that are not accompanied by a common letter were significantly different ($\alpha = 0.05$, Tukey's *hsd* procedure).

Treatment	Sample Size	Mean	Range	Standard Deviation
Shoe Bag	86	23.6[c]	2-79	17.7
Buried Substrate-Filled Tray	82	10.4[a,b]	0-74	16.2
Suspended Substrate-Filled Tray	76	12.5[a]	0-193	30.1
Corral	40	2.0[b]	0-12	2.9
Total	284	--	--	--
Overall Mean	--	13.8	0-193	21.6

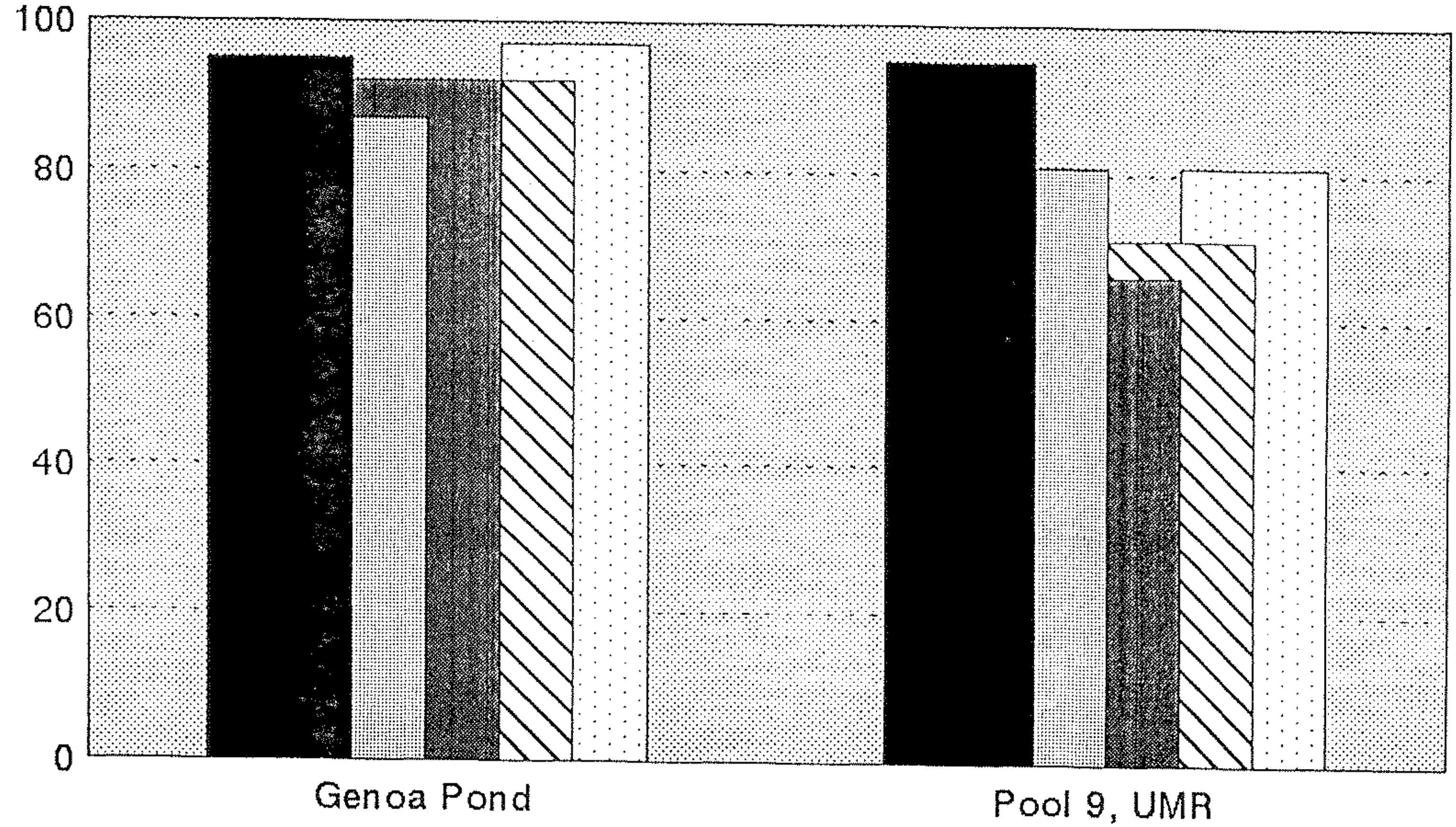
Table 5. Unionid sample size and mean number, range, and standard deviation of zebra mussels found on individual unionids sampled from Pool 9 of the upper Mississippi River near Victory, Wisconsin, during the annual recovery effort, September 19, 1996. Means among species that are not accompanied by a common letter were significantly different ($\alpha = 0.05$, Tukey's *hsd* procedure).

Species	Sample Size	Mean	Range	Standard Deviation
Leptodea fragilis	25	$18.7^{a,b}$	0-193	40.3
Amblema plicata	97	16.3^{a}	0-175	24.6
Quadrula quadrula	70	$16.0^{a,b}$	0-64	15.8
Fusconaia flava	37	$11.3^{a,b}$	0-79	16.6
Obliquaria reflexa	55	6.1^{b}	0-22	6.1
Total	284	--	--	--
Overall Mean	--	13.8	0-193	21.6

Table 6. Financial record of the mussel relocation project account between July 1, 1996 and November 30, 1996.

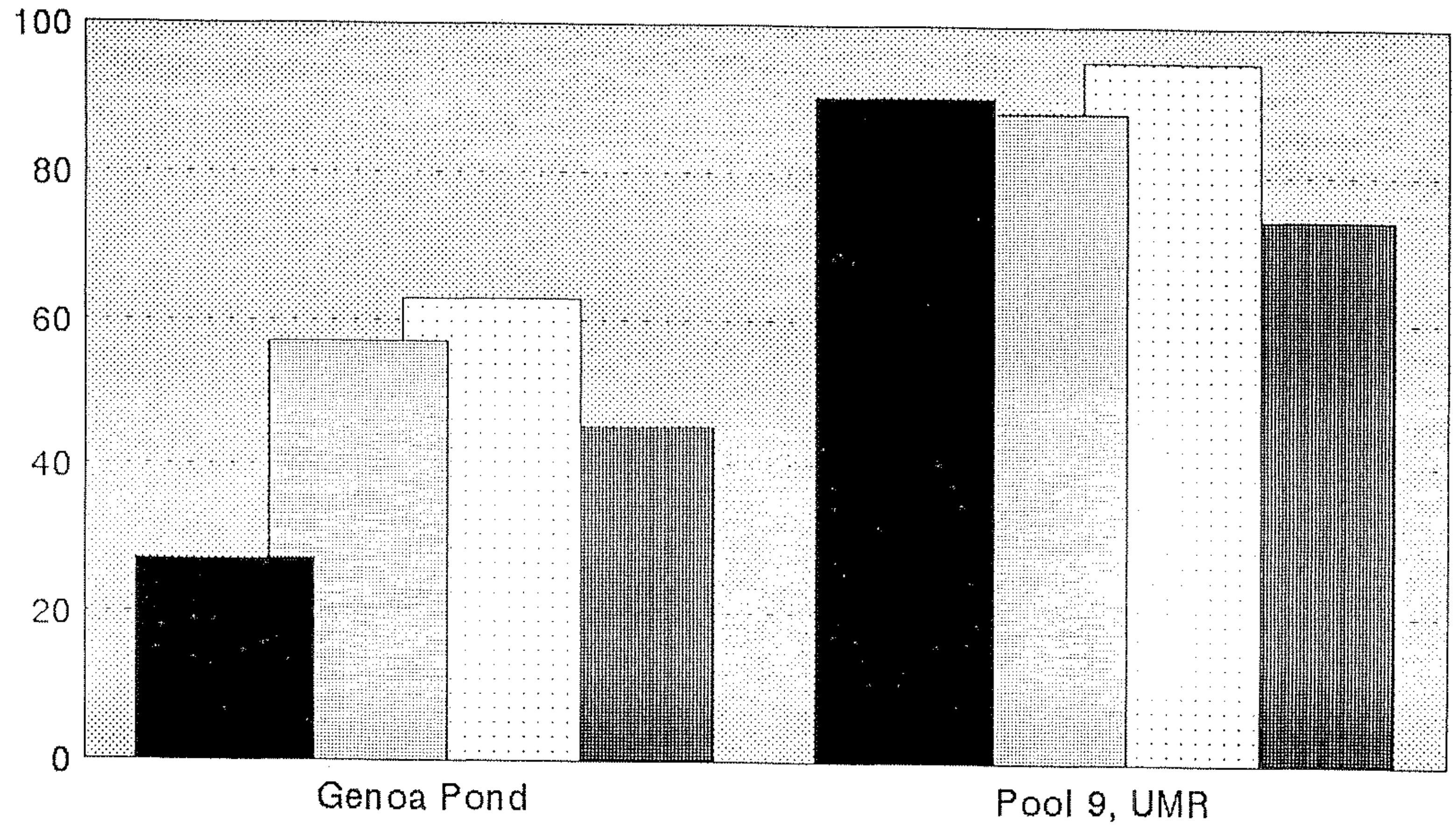
Transaction	Credit	Debit	Balance
	Shell Exporters of America and Mussel Mitigation Trust Account		
Total balance in account			**$0.00**
	Mississippi Interstate Cooperative Resource Association Account		
Starting balance	$7053.07		
Lab supplies		$200.00	
Scuba diving expenses		$210.00	
Water quality sampling and analyses		$125.00	
Mileage		$120.00	
Data entry, analyses, reports and meetings		$2100.00	
Total balance in account on November 30, 1996	--	--	**$4298.07**
Total project balance on November 30, 1996	--	--	**$4298.07**

Figure 1. Mean percent recovery of species after 471 days in either Pool 9, UMR, or an artificial pond at the Genoa NFH. Mean percent recovery values within a location that are not accompanied by a common letter were significantly different ($\alpha = 0.05$, Tukey's hsd procedure).



	Genoa Pond	Pool 9, UMR
Amblema plicata	95 [a]	95 [a]
Fusconaia flava	87 [a]	81 [a,b]
Leptodea fragilis	92 [a]	66 [b]
Obliquaria reflexa	92 [a]	71 [a,b]
Quadrula quadrula	97 [a]	81 [a,b]

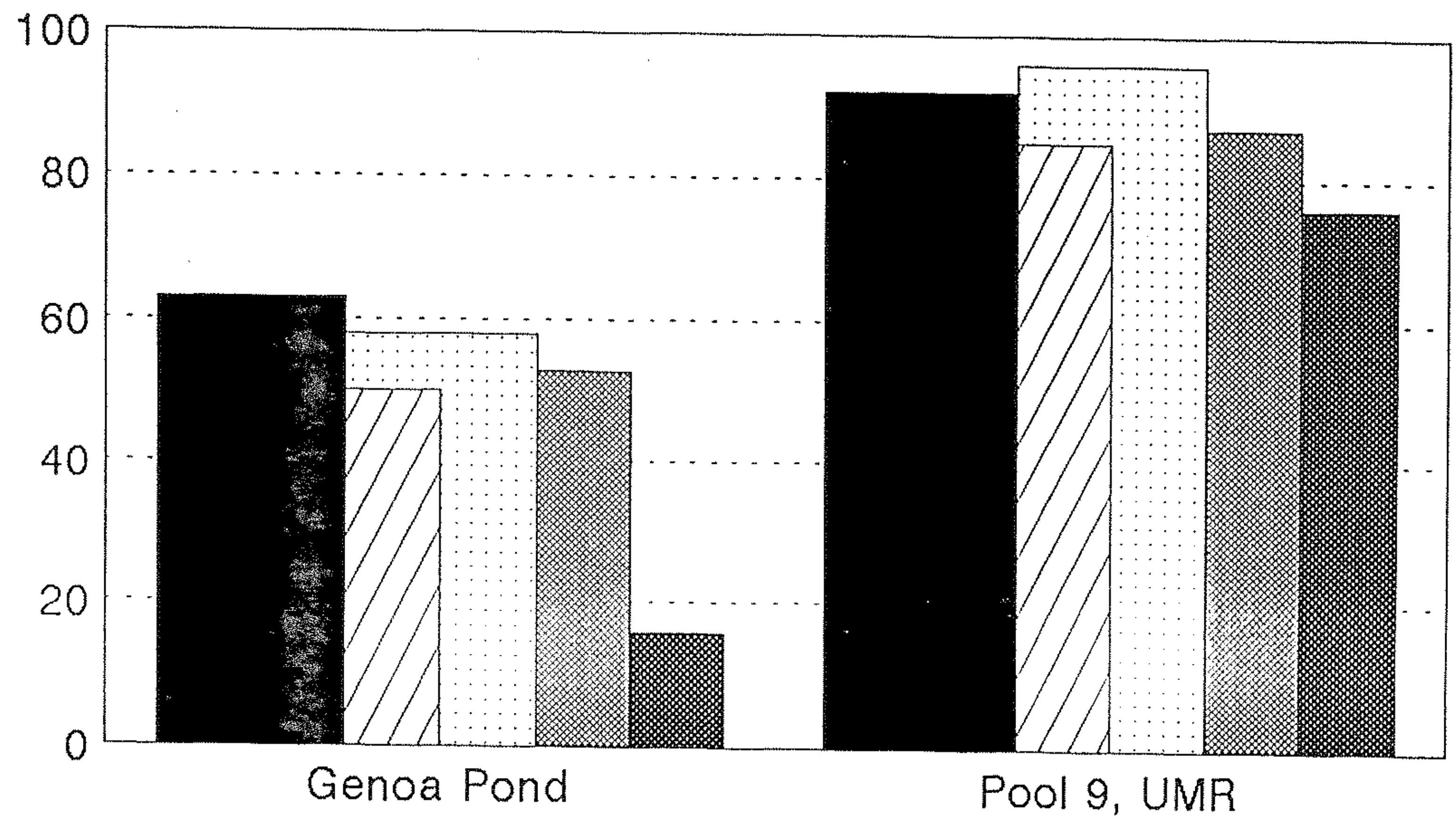
Figure 2. Mean percent survival among treatments and over all mussel species after 471 days in either Pool 9, UMR, or an artificial pond at the Genoa NFH. Treatment means within a location not accompanied by a common letter were significantly different ($\alpha = 0.05$, Tukey's hsd procedure).



	Genoa Pond	Pool 9, UMR
Shoe Bags	27[b]	90[a,b]
Buried Trays	57[a]	88[a,b]
Suspended Trays	63[a]	95[a]
Corrals	45[a,b]	74[b]
Mean	48	87

All Treatments Significantly Different Between Locations (p = 0.0001)

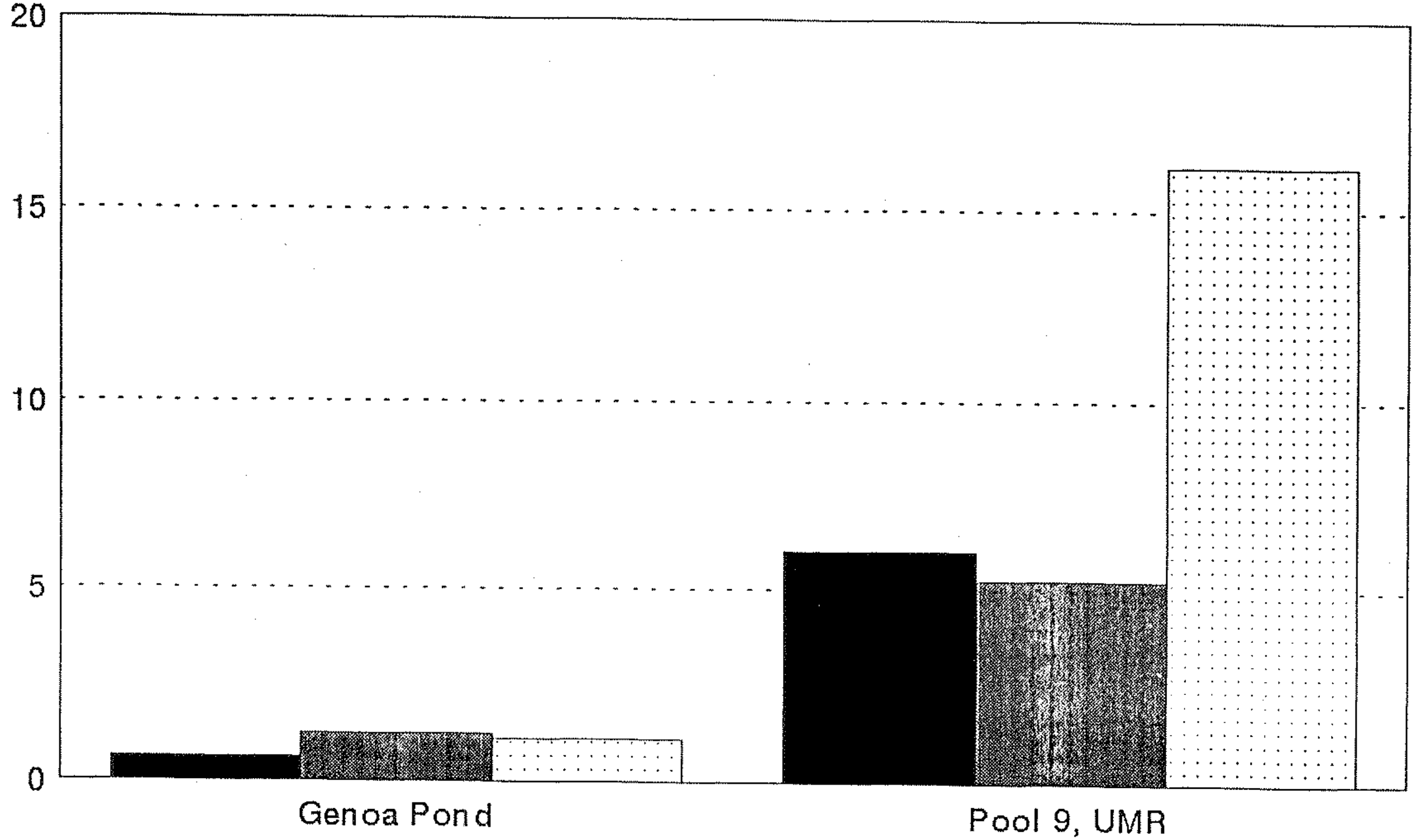
Figure 3. Mean percent species survival after 471 days in either Pool 9, UMR, or an artificial pond at the Genoa NFH. Percent survival values within a location not accompanied by a common letter were significantly different ($\alpha = 0.05$, Tukey's hsd procedure).



	Genoa Pond	Pool 9, UMR
Quadrula quadrula	63[a]	92[a]
Obliquaria reflexa	50[a]	85[a]
Fusconaia flava	58[a]	96[a]
Amblema plicata	53[a]	87[a]
Leptodea fragilis	16[b]	76[a]

All Species survival significantly different between locations ($p = 0.0001$)

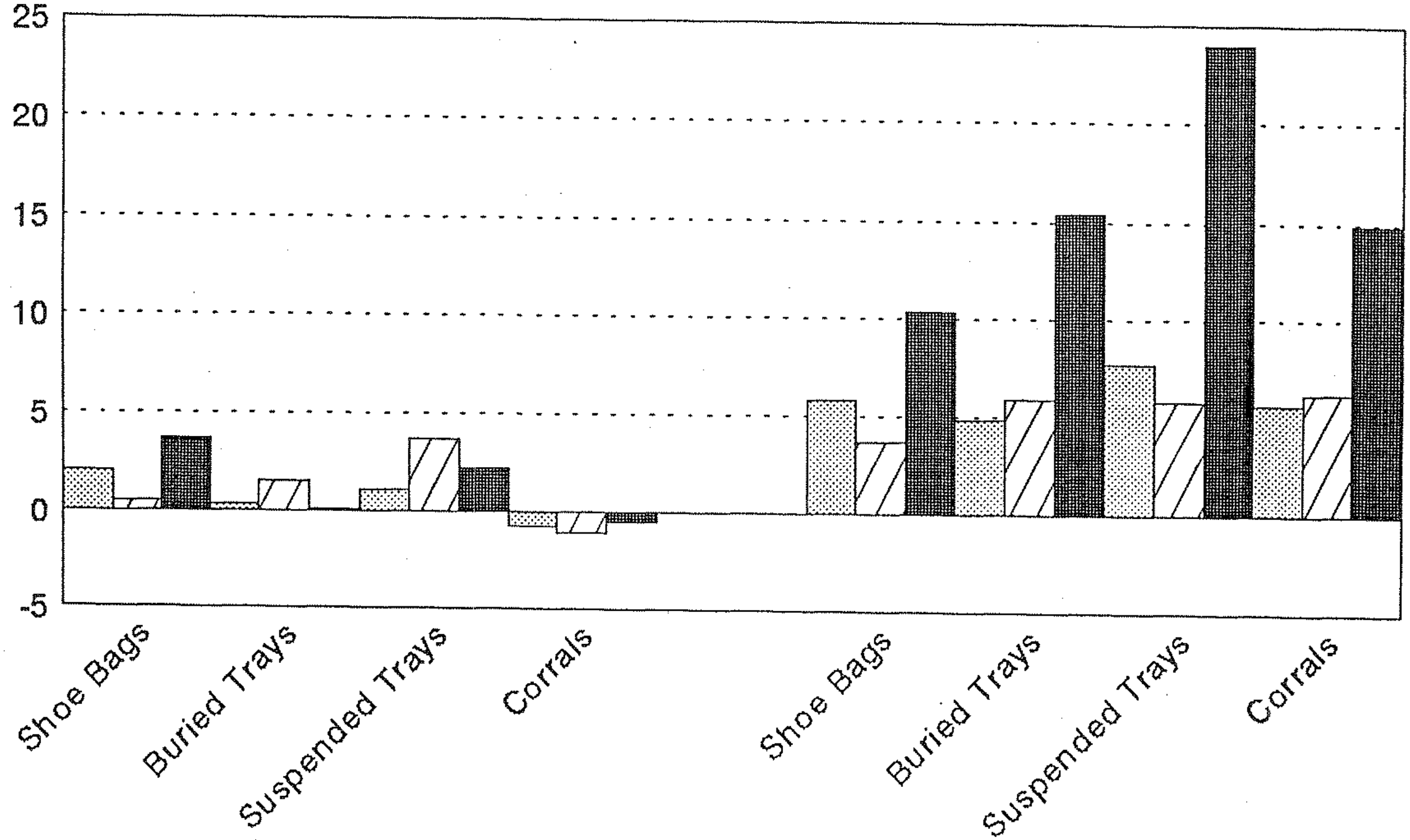
Figure 4. Mean percent increase in length, height, and wet weight over all mussel species after 471 days in either Pool 9, UMR, or an artificial pond at the Genoa NFH.



	Genoa Pond	Pool 9, UMR
Length	0.6	6.03
Height	1.22	5.26
Wet Weight	1.08	16.15

All growth variables significantly different between locations ($p = 0.0001$).

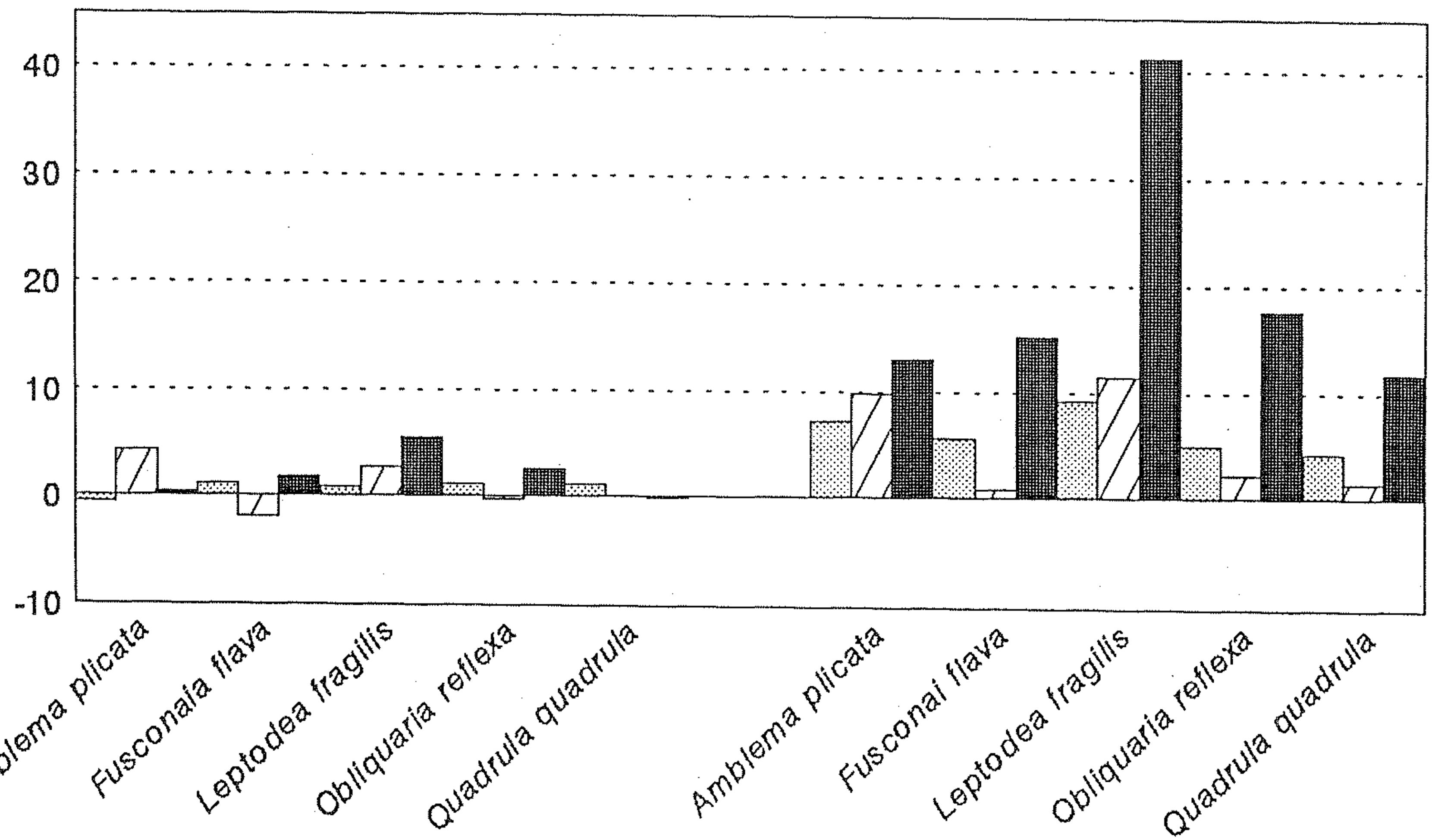
Figure 5. Mean percent growth increase among treatments and over all mussel species after 471 days in either Pool 9, UMR, or an artificial pond at the Genoa NFH. Means within a location and among treatments, that are not accompanied by a common letter were significantly different ($\alpha = 0.05$, Tukey's hsd).



	Shoe Bags	Buried Trays	Suspended Trays	Corrals		Shoe Bags	Buried Trays	Suspended Trays	Corrals
Length	1.97[a]	0.27[a,b]	1.08[a,b]	-0.81[b]		5.82[a]	4.87[a]	7.73[a]	5.65[a]
Height	0.44[a]	1.49[a,b]	3.63[b]	-1.09[a]		3.67[a]	5.9[a]	5.86[a]	6.27[a]
Wet Weight	3.68[a]	0.08[a]	2.17[a]	-0.54[a]		10.32[a]	15.38[a,b]	24.02[b]	14.85[a,b]

Genoa | River

Figure 6. Mean percent growth increase among species and across treatments after 471 days in either Pool 9, UMR, or an artificial pond at the Genoa NFH. Means within a location and among species, that are not accompanied by a common letter were significantly different ($\alpha = 0.05$, Tukey's hsd procedure).



	Amblema plicata	Fusconaia flava	Leptodea fragilis	Obliquaria reflexa	Quadrula quadrula		Amblema plicata	Fusconai flava	Leptodea fragilis	Obliquaria reflexa	Quadrula quadrula
Length	-0.61[a]	1.14[a]	0.81[a]	1.2[a]	1.21[a]		7.19[a]	5.58[a]	9.16[a]	5.08[a]	4.25[a]
Height	4.22[a]	-1.93[a]	2.74[a,b]	-0.21[c]	0.06[b]		9.82[a]	0.87[b]	11.55[a]	2.17[b]	1.4[b]
Wet Weight	0.34[a]	1.82[a]	5.53[a]	2.53[a]	-0.13[b]		13.09[a]	15.24[a]	41.3[b]	17.66[a]	11.88[a]
	Genoa						River				