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## FRESHWATER MUSSEL RELOCATION PROJECTS EVALUATED

The North American freshwater unionacean mussel fauna, once represented by about 297 taxa, has declined to about 276 taxa since the early 1900's because of overharvest, commercial navigation, pollution, and habitat degradation. Presently, 58 mussel species (21% of remaining species) are listed as federally threatened or endangered. Because of the drastic decline in mussel fauna and with the authority of the Endangered Species Act of 1973, resource agencies have attempted to mitigate the effects of human activities on unionacean mussels.

Relocation has been used as a conservation and management technique by state and federal agencies to recolonize areas where mussel populations have been eliminated by prior pollution events, to remove mussels from construction zones, and to reestablish populations of endangered species. More recently, relocation has been used to protect unionid populations from colonization by the zebra mussel (*Dreissena polymorpha*).

Although relocations have been conducted for more than 20 years, their effectiveness for the conservation and management of unionacean populations has not been assessed. Moreover, little guidance is available on methods for relocation projects or for monitoring the subsequent longterm status of relocated mussels. Little is known about the habitat requirements of mussels or the biological responses of mussels to removal from the substrate, handling, transporting, and relocating to a new

site. Our objectives were to summarize the literature on mussel relocation, evaluate the relative success of mussel relocation projects, and identify research needs.

### SUMMARY AND RELATIVE SUCCESS OF MUSSEL RELOCATION PROJECTS

We found 31 papers on mussel relocation—only three appeared in the peer-reviewed literature. The rest were either in the published gray literature or in unpublished reports, which were not widely available. We found that nearly 90,000 mussels have been relocated in 34 discrete projects.

The main reasons for mussel relocation were protection from construction projects, management efforts such as reintroductions, and research. Most (47%) relocations were conducted because of construction projects that were forced to comply with the Endangered Species Act of 1973 (Fig. 1a). Construction projects included those associated with bridge construction, bridge demolition, and dredging and channel maintenance. The rest of mussel relocations were attributed to management efforts (32%) such as reintroductions and to research (21%).

The longterm survival of relocated mussels was not routinely monitored. Only 76% of all relocation projects reported followup monitoring. Most (43%) projects were monitored for 1 year or less, and only 12% were monitored for 5 or more consecutive years (Fig. 1b).

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The mortality of relocated mussels varied widely among projects and species, and was difficult to assess. To ensure equitable assessment of mortality among projects, we evaluated mortality on the basis of the percentage of mussels recovered in relation to the total number of mussels relocated. Mortality was unreported in 32% of projects and was greater than 70% in 24% of projects (Fig. 1c). Mean mortality of relocated mussels was 47%, based on an average recovery rate of 45%. Mortality was greater than 90% in some projects, and the greatest percentage often occurred within the first year after relocation.

About 50% of the mussel relocations occurred in the southern and southeastern United States, regions that are known to contain the highest diversity of mussel species. The timing of relocation projects coincided with the warmest season of a geographic region. Most (40%) relocation projects were conducted from July through September (Fig. 1d), presumably a period when reproductive stress is relatively low for most species and metabolic rate is sufficient for reburrowing in the substrate.

#### CRITICAL FACTORS INFLUENCING MUSSEL SURVIVAL

On the basis of our evaluation, the physical characteristics of mussel habitat at both source and destination sites and the methods of relocation are especially critical to the survival of mussels that are relocated. Existing criteria for selecting a suitable relocation site have been largely qualitative and observational. The presence of live mussels or the apparent similarity of habitat have often been used as criteria for site selection, but do not ensure that a site is suitable for relocation. For example, decreased survival of relocated mussels has been attributed to changes in habitat at the destination site, primarily due to substrate instability.

Standard protocols for conducting mussel relocations do not presently exist. Moreover, there is little guidance in the literature regarding relocation related variables such as methods for handling, transporting, and tagging mussels; the appropriate time of year to relocate mussels; minimum and maximum allowable water temperatures; maximum allowable period of aerial exposure; and methods for replacing mussels in the substrate. We found that the methods described for most of the relocation projects that we reviewed were generally insufficient in detail to repeat the project.

#### MONITORING RELOCATION SUCCESS

The greatest obstacles to evaluating the relative success of the mussel relocation projects that we reviewed were the lack of longterm, quantitative monitoring and the lack of universal reporting of mortality and recovery data. A majority (67%) of relocation projects were not monitored or were monitored for 1 year or less. An estimated 22,000 mussels (25% of those relocated) perished in 34 relocation projects; however, this number is an underestimate of actual mortality because 24% of projects were not monitored and only 68% of the projects that were monitored reported mortality. The relatively low recovery rate (45%) of relocated mussels in the projects evaluated does not necessarily correspond to mussel mortality, but may be partly attributed to sampling design, selection of an inadequate relocation site, or other factors. Alternatively, the lack of recovery may be due to mussel mortality and the movement of empty valves downstream with water currents.

#### RECOMMENDATIONS AND IDENTIFICATION OF FUTURE RESEARCH NEEDS

Our review of the literature on mussel relocation revealed that the methods of relocation—when reported—varied widely among projects, the survival of the relocated mussels was generally poor (~50%), and the factors influencing survival of relocated mussels were poorly understood. For mussel relocation to be a successful conservation and management technique, more consideration must be given to habitat characterization, at both source and destination sites. Optimally, the water and sediment conditions should be monitored at both source and proposed destination sites over at least an annual cycle, not just once during the year, because flow regime and other key variables may change seasonally. Moreover, this type of information could be used to develop a complete set of site selection criteria.

In addition, future mussel relocation projects should be monitored for at least 2 years, but 5 years would allow documentation of recruitment—the true indicator of a successful relocation. Mortality, recovery, and sublethal indicators of relative condition should be measured for each species to assess variation in the sensitivity to relocation. Research is needed to develop criteria for selecting a suitable relocation site and to establish appropriate methods and guidelines for conducting relocation projects.

Finally, our literature search demonstrated the need for better access to methods and results of relocation projects. Most results from relocation projects were available only as intraagency reports that are not widely available. Studies evaluating mussel relocation, as well as those evaluating mussel communities, should be designed to yield quantitative and statistically valid results, and should be published in the peer-reviewed literature so that others may benefit from this information.

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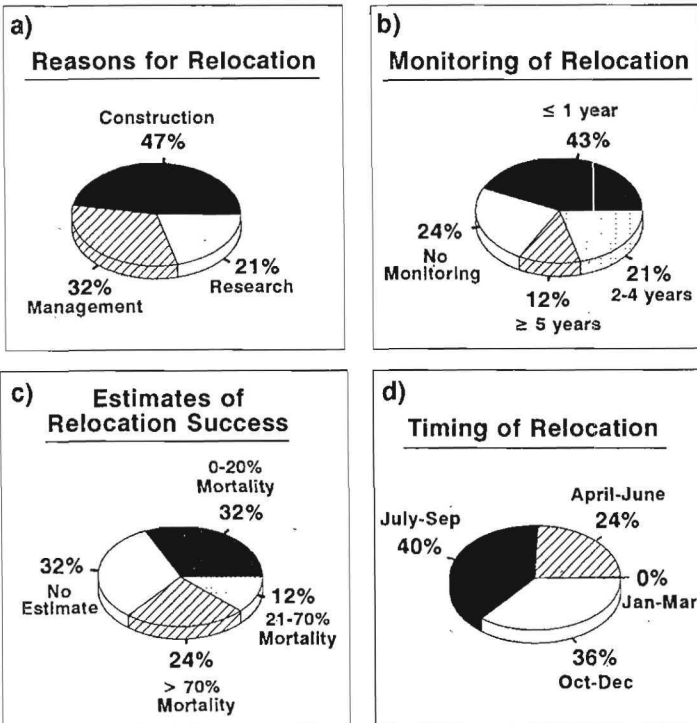


Figure. Pie charts showing a) the primary reasons for mussel relocation, b) the frequency of monitoring mussel relocation projects, c) the estimates of success for mussel relocation projects, and d) the timing of mussel relocations.