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EVALUATION OF FRESHWATER MUSSEL RELOCATION AS A CONSERVATION AND MANAGEMENT STRATEGY*

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ABSTRACT

The relocation of unionacean mussels is commonly used as a conservation and management tool in large rivers and streams. Relocation has been used to recolonize areas where mussel populations have been eliminated by prior pollution events, to remove mussels from construction zones and to re-establish populations of endangered species. More recently, relocation has been used to protect native freshwater mussels from colonization by the exotic zebra mussel *Dreissena polymorpha*. We conducted a literature review of mussel relocations and evaluated their relative success as a conservation and management strategy. We found that 43% of all relocations were conducted because of construction projects that were forced to comply with the Endangered Species Act 1973 and that only 16% were monitored for five or more consecutive years. Most (43%) relocation projects were conducted from July to September, presumably a period when reproductive stress is relatively low for most species and the metabolic rate is sufficient for reburrowing in the substrate. The mortality of relocated mussels was unreported in 27% of projects; reported mortality varied widely among projects and species and was difficult to assess. The mean mortality of relocated mussels was 49% based on an average recovery rate of 43%. There is little guidance on the methods for relocation or for monitoring the subsequent long-term status of relocated mussels. Based on this evaluation, research is needed to develop criteria for selecting a suitable relocation site and to establish appropriate methods and guidelines for conducting relocation projects.

KEY WORDS: bivalves; conservation; management; mussels; relocation; river; translocation; transplant; unionidae

INTRODUCTION

The North American freshwater unionacean mussel fauna, once represented by about 297 taxa (Turgeon *et al.*, 1988; Neves, 1993; Williams *et al.*, 1993), has declined to about 276 taxa since the early 1900s due to overharvesting, commercial navigation, pollution and habitat degradation (Neves, 1993). Fifty-eight mussel species (21% of the remaining species) are listed as federally threatened or endangered (Code of Federal Regulations, 1993). Because of the drastic decline in the mussel fauna and the authority of the Endangered Species Act 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 (Ahlstedt, 1979; Sheehan *et al.*, 1989), to remove mussels from construction zones (Oblad, 1980; Harris, 1986; Berlocher and Wetzel, 1988; Dunn, 1991), and to re-establish populations of endangered species (Jenkinson, 1985; Hubbs *et al.*, 1991). More recently, relocation has been used to protect unionid populations from colonization by the zebra mussel (*Dreissena polymorpha*), an invasive introduced species (Ogawa and Schloesser, 1993).

Although relocation projects have been conducted for more than 20 years, their effectiveness for the conservation and management of unionacean populations has not been assessed. Moreover, there is presently little guidance on methods for relocation projects or for monitoring the subsequent long-term status of the 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, to evaluate the relative success of mussel relocation projects and to identify research needs.

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Table I. Summary of literature on relocation of unionacean mussels

Relocation site	Total no. of mussels relocated	Estimate of success	Reference(s)
Apalachicola River Jim Woodruff Dam, FL, USA	320	15% mortality of unreported recovery	Hamilton *et al.* (1993)
Buffalo River, TN, USA	1000	100% mortality (estimate based on 10% of relocation area sampled)	Jenkinson (1985) Hubbs *et al.* (1991)
Clinch River, VA, USA	281	No estimate	Ahlstedt (1979)
Clinch River, VA and TN, USA	2238	96% mortality of 4% recovered	Sheehan *et al.* (1989)
Clinch River, VA and TN, USA	475	35% mortality of 14·5% recovered	Sheehan *et al.* (1989)
Clinton River Oakland County, MI, USA	804	No estimate	Trdan and Hoeh (1993)
Detroit River Belle Isle, MI, USA	118	100% mortality of 90% recovered (due to zebra mussel infestation)	Trdan and Hoeh (1993)
Duck River, TN, USA	1000	98% mortality (estimate based on 10% of relocation area sampled)	Jenkinson (1985) Hubbs *et al.* (1991)
Duck River, TN, USA	1213	0% mortality of 20% recovered	Layzer and Gordon (1993)
Inner Long Point Bay Lake Erie, Canada	183	No estimate of mortality from 58% recovered	Hinch *et al.* (1986)
Kankakee River Kankakee, IL, USA	3800	11% mortality of 29% recovered	Berlocher and Wetzel (1988) Berlocher and Wetzel (1989)
Mississippi River Trempeleau, WI, USA	300	3% mortality of 97% recovered	Waller *et al.* (in press)
Mississippi River Trempeleau, WI, USA	865	11% mortality of 89% recovered	Waller *et al.* (in press)
Mississippi River Trempeleau, WI, USA	825	11% mortality of 91% recovered	Waller *et al.* (in press)
Mississippi River Moline, IL, USA	7096	0% mortality of 45% recovered from an 8% sample	Oblad (1980) Nelson (1982)
Mississippi River, MO, USA	2301	89% mortality of 5% recovered	Koch (1993)
Namekagon River, WI, USA	523	5% mortality of 85% recovered	Miller (1994)
Nolichucky River, TN, USA	1000	100% mortality (estimate based on 10% of relocation area sampled)	Jenkinson (1985) Hubbs *et al.* (1991)
N. Fork Holston River, VA, USA	1692	57% mortality of 12% recovered	Sheehan *et al.* (1989)
N. Fork Holston River TN and VA, USA	1000	94% mortality (estimate based on 10% of relocation area sampled)	Jenkinson (1985) Hubbs *et al.* (1991)
Ohio River Ripley, OH, USA	5158	65% mortality (estimate assumes 100% recovery)	Dunn (1991) Ecological Specialists Inc (1991) Dunn (1993)
Ouachita River Mount Ida, AR, USA	44	0% mortality of 25% recovered	Harris *et al.* (1992)
Reservoir-lake Danvers, MA, USA	87	100% mortality of unreported recovery	Clarke (1967)
Reservoir-lake Danvers, MA, USA	47	100% mortality of 2·1% recovered	Clarke (1967)
Saline River Saline, AR, USA	310	No estimate	Arkansas Highway and Transportation Department (1989)
Salt Creek, IL, USA	134	0% mortality of 65% recovered	Schanzle and Kruse (1994)

Table I. Summary of published work on relocation of unionacean mussels (continued)

Relocation site	Total no. of mussels relocated	Estimate of success	Reference(s)
Salt Creek, IL, USA	178	0% mortality of 71% recovered	Schanzle and Kruse (1994)
Silver Lake Wilmington, MA, USA	66	100% mortality of unreported recovery	Clarke (1967)
South-central Ontario Lakes, Canada	150	No estimate of mortality from 88% recovered	Hinch and Green (1989)
Spring River Ravenden, AR, USA	3372	No estimate	Arkansas Highway and Transportation Department (1984)
St Clair River, MI, USA	85	No estimate	Ogawa and Schloesser (1993)
St Croix River Prescott, WI, USA	7976	90% mortality of 14% recovered	Heath (1989) Burke (1991)
St Francis River Madison, AR, USA	7825	No estimate	Harris (1986)
St Francis River Madison, AR, USA	2321	53% mortality of 1·4% recovered	Jenkinson (1989)
Tennessee River Kentucky Dam, KY, USA	18 300	No estimate	Jenkinson (1994a)
Tennessee River Pickwick Dam, TN, USA	7300	No estimate	Jenkinson (1994b)
Wolf River Shawano, WI, USA	8120	1% mortality of 1·9% recovered	Havlik (1992) Havlik (1994)

RESULTS

Summary of relocation projects

Our literature search revealed a total of 33 papers on mussel relocation, of which only three appeared in the peer-reviewed literature. The remainder were either in the published grey literature or in unpublished reports which were not widely available. We found that nearly 90 000 mussels have been relocated in a total of 37 discrete projects (Table I).

The main reasons for mussel relocation included protection from construction projects, management efforts such as re-introductions and research (Figure 1a). Most (43%) relocations were conducted because of construction projects that were forced to comply with the Endangered Species Act 1973. Construction projects included those associated with bridge construction (Arkansas Highway and Transportation Department, 1984; 1989; Heath, 1989; Burke, 1991; Harris *et al.*, 1992; Havlik, 1992; Trdan and Hoeh, 1993; Miller, 1994), bridge demolition (Berlocher and Wetzel, 1988; 1989) and dredging and channel maintenance (Jenkinson, 1989; Ecological Specialists Inc., 1991; Dunn, 1993; Hamilton *et al.*, 1993; Trdan and Hoeh, 1993; Jenkinson, 1994a; 1994b). The remainder of mussel relocations were attributed to management efforts (30%) such as re-introductions (Ahlstedt, 1979; Jenkinson, 1985; Sheehan *et al.*, 1989; Hubbs *et al.*, 1991; Koch, 1993; Layzer and Gordon, 1993) and to research (27%) (Hinch *et al.*, 1986; Hinch and Green, 1989; Schanzle and Kruse, 1994; Waller *et al.*, in press).

The survival of relocated mussels was not routinely monitored on a long-term basis. Only 78% of all relocation projects reported follow-up monitoring. Most (38%) projects were monitored for one year or less and only 16% were monitored for five or more consecutive years (Figure 1b).

The mortality of relocated mussels varied widely among projects and species and was difficult to assess. Because of the lack of uniform reporting of mortality and recovery data in all projects, and to ensure

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