JTI000018

ELSEVIER

Biological Conservation 99 (2001) 183–190

BIOLOGICAL CONSERVATION

www.elsevier.com/locate/biocon

Conservation of threatened freshwater pearl mussel populations: river management, mussel translocation and conflict resolution

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Received 14 March 2000; received in revised form 22 August 2000; accepted 9 September 2000

Abstract

River engineering work has historically been responsible for the decline and extinction of a number of endangered freshwater pearl mussel [*Margaritifera margaritifera* (L.)] populations and potentially remains a significant threat. The impact of different types of river engineering work on a number of Scottish *M. margaritifera* populations is examined and discussed. *M. margaritifera* is now fully protected under law in most countries and guidance is urgently needed so that river managers can integrate ecological and socio-economic factors when considering the impact of proposed activities on *M. margaritifera* populations. To safeguard the remaining important populations, a simple conflict resolution framework is suggested for the appraisal of proposed developments in rivers with pearl mussel populations. Operations likely to harm mussels and permanently damage their river bed habitat should not proceed. In exceptional circumstances (outlined), the translocation of small numbers of adult mussels may possibly be considered as a potential management tool, but mussel translocation has been little used and should be considered experimental and last resort. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Margaritifera; River engineering; River manager

1. Introduction

The freshwater pearl mussel (*Margaritifera margaritifera* (L.)) is a rare and threatened species that inhabits clean rivers and streams which have healthy native salmonid populations (Young and Williams, 1983). It was once common across much of northern and central Europe, Russia and north-eastern USA/Canada. Several studies have shown that it has declined dramatically across its whole range due to a number of factors including organic pollution, over-exploitation by pearl fishing, decline in host fish stocks and river habitat degradation (e.g. Young and Williams, 1983; Bauer, 1986, 1988; Young, 1991; Lucey, 1993; Oliver and Killeen, 1996; Killeen et al., 1997; Beasley et al., 1998; Chesney and Oliver, 1998; Cosgrove et al., 2000a). In a recent review, based on all known pearl mussel populations, Young et al. (2000) estimated that possibly as few as 100 reproductively viable or 'functional' mussel populations may remain in the world today and unless urgent measures are taken, the species is likely to become extinct.

The conservation status of this species is recognised by domestic and European legislation. In Scotland, for example, which holds perhaps half of the world's known remaining 'functional' populations (Cosgrove et al., 2000a), the pearl mussel is protected under Schedule 5 of the Wildlife and Countryside Act 1981. It is also listed on Annexes II and V of the European Habitats Directive and Appendix III of the Bern Convention and so it and its habitat receive complete protection and it is an offence in most countries to knowingly harm or kill it.

Although several of the most important pearl mussel rivers are currently being designated for their importance, not all of the remaining 'functional' sites are in specially protected areas (Cosgrove et al., 2000b). The remaining populations face a number of threats, many of which are potentially avoidable. Pearl fishing is now outlawed in most countries (Young et al., 2000) and pollution control is being tightened throughout Europe (Raven et al., 1998). It is now widely accepted that physical habitat modifications have resulted in the loss

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0006-3207/01/$ - see front matter © 2001 Elsevier Science Ltd. All rights reserved.
PII: S0006-3207(00)00174-9

of a several *M. margaritifera* populations (Young and Williams, 1983), although very little research has been carried out, and the extent of the problem is largely unknown.

Many of the problems associated with river engineering work have been 'accidental' because little, if anything, was known about the presence of pearl mussels beforehand, or the legislation protecting the species and its habitat. The situation in western Europe has largely changed, with extensive river surveys identifying most of the remaining pearl mussel populations. In theory, heightened awareness, full legal protection, control over physical alteration of river channels and good information on the distribution and presence of pearl mussels means that 'accidental' damage to the remaining populations is preventable. However, in practice, the presence of pearl mussels is just one of many factors that have to be considered when managing a river.

Although it can be argued that all developments on sites with pearl mussels should be avoided, in reality this approach may be politically and practicably difficult to sustain, in light of other river management objectives, e.g. for public safety reasons such as flood defence work or repairs to bridge supports. It has been demonstrated that it is quite possible to move or translocate small numbers of adult mussels within a river system and this has occurred, with varying degrees of success (Young and Williams, 1983; Valovirta, 1995; Killeen et al., 1998). However, translocation as a 'conservation tool' has been little used and even less frequently monitored after the event and as such should be considered experimental. River managers may or may not be aware that mussel translocation is a potentially feasible option and many of them do not fully understand the ecological issues associated with it and whether or not it is an appropriate option to consider. It is very important that mussel translocation is considered in an objective manner and not simply as an excuse to circumvent protective conservation legislation. If it is considered to be feasible, translocation should be seen as a last resort and not the first option for river managers.

Integration of ecological and socio-economic factors is essential in deciding what sites or mussel populations should be conserved today. Biodiversity cannot be maintained in perpetuity on the basis of a few specially protected areas (Usher, 1997) and so all mussel populations must be conserved as a far as possible. Consequently, it is clear that there is a necessity to consider the needs of other river users outside protected areas. Currently there is no published guidance at all for river managers on how to appraise potential developments in pearl mussel rivers. Clearly this situation is highly undesirable for the conservation of pearl mussels throughout their range. For this reason, we consider that it would be very useful to have a general framework to protect important populations of *M. margaritifera* that is flexible enough to be adapted to local circumstances, different legislation and working practices, without being too prescriptive.

In this paper we present new information on the observed effects of river engineering activities on Scottish *M. margaritifera* populations, discuss their implications for the conservation of this species, and design an appropriate river management framework for undertaking river engineering work on rivers with mussel populations.

2. Impacts of river engineering on mussel populations

Several studies have identified that river engineering or development works, such as pipe laying, hydro-electric work, channel realignment, creation of cattle fords, bridge supports and fisheries management can all have serious impacts on *M. margaritifera* populations (Jungbluth and Kuehnel, 1978; Young and Williams, 1983; Valovirta, 1990; Ziuganov et al., 1994; Killeen et al., 1998; Cosgrove et al., 2000a). For example, Cosgrove et al. (2000a) found evidence that river engineering works were directly implicated in the decline of at least 26 *M. margaritifera* populations in Scotland. The exact nature of these and more recent examples of damaging river engineering activities are summarised in Table 1. Killeen et al. (1998) also reported on the total destruction of one entire river's population in north-west Wales by a dredging operation. According to Ziuganov et al. (1994), a number of mussel populations in north-western Russia disappeared following large-scale hydro-electric schemes.

Almost half of all the cases in Scotland involved activities directly related to fishery management (e.g. fish pool dredging, fishing platform/groyne (deflector) construction and bank reinforcement; Table 1). The scale of fishery-related activities, in terms of area of river bed disturbed ranged from <10 m^2 in small streams to >100 m^2 in large rivers. The impacts of dam construction and flood defence works (e.g. embanking, canalisation and channel realignment) on mussels were each observed in eight cases. In addition to the direct physical habitat disturbance created by dam construction,

Table 1
Number of Scottish rivers with *M. margaritifera* populations known to have been adversely affected by river engineering activities

Engineering activity	No. of rivers affected[a]	Proportion (%)
Fishery management	15	47
Dam construction	8	25
Flood defence	8	25
Road maintenance	3	9
Pipe laying	2	6

[a] Four rivers were known to be affected by two different types of river engineering activity.

it is possible that some mussel populations may have also been affected indirectly since natural runs of migratory host fish (which the mussels need to complete their life cycle) were completely blocked by dams in some rivers (pers. obs.). River engineering associated with road maintenance work (e.g. gravel extraction, bank reinforcement, road widening, bridge construction) and pipe-laying were observed in < 10% of cases. For the latter, only small-scale disturbances (< 10 m^2) were observed, although only small pipelines were involved in the cases recorded.

Table 2 provides examples of observed impacts of river engineering activities on *M. margaritifera* populations in Scotland. Estimates of mortality were either made from direct observation of dead mussels in the river and dredged spoil piles and/or were extrapolated from assessments of densities in adjacent unaffected mussel areas. Total mussel mortality and overall loss of river bed habitat ranged from 20 to 10,000 mussels killed and 1–95% of suitable habitat destroyed, respectively. Small, localised *M. margaritifera* populations appeared to be particularly vulnerable to fishery management 'improvements' (e.g. River A). Flood defence work also appeared to be particularly destructive in nature (e.g. River I). In the context of the examples provided (Table 2) any physical disturbance of the river bed habitat associated with river engineering resulted in significant mussel mortality.

3. Theoretical and practical considerations for river managers

The conservation importance of all remaining pearl mussel populations should be recognised by river managers. Since *M. margaritifera* now has full legal protection, conservation issues must be considered when assessing any proposed river engineering works in and adjacent to surviving pearl mussel populations. In many instances this will be undertaken through some sort of environmental impact assessment or appraisal where all activities likely to harm pearl mussels should be identified and, where possible, mitigated. However, the complexity of the pearl mussel's life cycle and the longevity of the adult stage make it difficult to determine those factors that most influence its long-term survival (Gibson, 1998). In the context of each river, the potential impact or risk associated with any management proposals will principally be determined by three components; (1) the physical nature and scale of the river engineering activities, (2) the distribution and abundance of the pearl mussel population in relation to the engineering site, and (3) the ecological requirements of the mussels themselves at any given locality. Clearly, it is preferable to avoid any river engineering at or above areas within the river where mussels occur (Young, 1991), but in practice how should a river manager achieve this?

Table 2
Examples of river engineering activities known to have impacted on *M. margaritifera* populations in Scotland

River code and size category[a,b]	Type of engineering activity[c]	Specific details	Estimated mortality of mussels	Proportion of mussel habitat damaged (%)	Source
A (Small)	Fisheries	Series of salmon pools and groynes were created by dredging and removing almost all suitable mussel habitat from the river	Total extinction	> 95	Present study
B (Small)	Flood defence	500 m section of the middle reach was canalised	No data	~50	Henninger, pers. comm.
C (Medium)	Flood defence + fisheries	Dredging, channel realignment and salmon pool construction	No data	~30	McCormick, pers. comm.
D (Small)	Road maintenance	30 m section dredged and bank reinforced with boulders	~500	< 10	Present study
E (Small)	Dam construction	20 m section below dam canalised	~100	< 10	Henninger, pers. comm.
F (Medium)	Flood defence	400 m section dredged.	100–500	< 10	Present study
G (Medium)	Fisheries	200–300 m section dredged to create salmon pools	5000–10,000	< 5	McCormick, pers. comm.
H (Large)	Fisheries	500 m section dredged to create salmon pools	> 10,000	< 5	McCormick, pers. comm.
I (Medium)	Flood defence	200–400 m section dredged and realigned	5000–10,000	< 5	Present study
J (Large)	Fisheries	Major salmon pool construction and bank realignment	> 1000	< 1	Present study
K (Large)	Pipe laying	10 m pipe laid directly through small mussel bed	~20	< 1	Present study

[a] Rivers were code-lettered to maintain confidentiality because of present threat of illegal pearl fishing.
[b] Size categories (river length): small < 10 km, medium 11–50 km, large 51–200 km.
[c] All examples recorded post-1980, except for River B (post-1960).

3.1. Surveying for mussels

Whenever there is a proposed development within a pearl mussel river, the conservation importance of the *M. margaritifera* population should be ascertained at the earliest opportunity by a thorough survey of the proposed development area and a more general river-wide survey. A team of competent surveyors using some sort of standardised survey methodology should carry this out. There is no scientific agreement about what constitutes a standardised survey methodology for *M. margaritifera*, but Cosgrove et al. (2000a) attempted to provide one that also included a clear definition of what constituted a 'functional' mussel population, and this methodology has been widely used in the UK. By using and adapting this type of standardised survey methodology, it should be possible to estimate the relative abundance of mussels in the proposed development area and the area immediately downstream.

The size of the area to be surveyed should be determined by the scale of the proposed development. The potential effects of a small fish-pool, or bridge support construction are likely to be less than those of a major hydro-electric scheme and, consequently, the area surveyed should reflect this. The relevant competent authority or government departments are normally responsible for determining parameters and the exact detailed survey requirements. The results of any site-specific survey should be considered within the context of a river-wide survey, using a standard survey protocol and be comparable with other pearl mussel sites. For example, does the site have an especially good *M. margaritifera* population? Are juveniles present? Is there anything unusual or 'special' about the population? Does most of the river's *M. margaritifera* population lie within the proposed development area? If the answer to any of these questions is yes, then it would not be appropriate to carry out potentially damaging river engineering works.

3.2. What constitutes a mussel population worth conserving?

The best method for conserving pearl mussel populations is the protection of the breeding adults and the maintenance of juvenile habitat and these objectives should form the basis of any impact appraisal. Valovirta (1998) considered that effective conservation of a mussel population was possible and worthwhile where an average density exceeded one mussel per m^2. This density figure also ties in with a key criteria used by Cosgrove et al. (2000a) for describing the relative importance of Scottish *M. margaritifera* populations. Therefore, this 1 m^{-2} threshold could be used to describe the relative importance of a proposed development site. For example, if the proposed development site contains moderate to high densities (i.e. >1 mussel per m^2), there should be a presumption against a development proceeding if it would permanently damage or remove the substrate (i.e. the mussel habitat), or harm any mussels. In such situations, the protection of what would clearly be an important site in the context of the whole river should take precedence and it would be totally inappropriate to consider sanctioning a development and therefore translocating large numbers of adult mussels from such an important site.

Difficulties arise in rivers with small mussel populations. Many rivers, regardless of size, appear to have small numbers of individuals that are concentrated in small areas (Ross, 1988; Hastie et al., 2000a). In these circumstances the small populations per se may be particularly vulnerable to extinction (e.g. see Killeen et al., 1998). Therefore, it is important to consider if there is a significant proportion of the mussel population in the proposed development area in the context of the total population found during the general survey of the whole river. Recent work by Hastie et al. (2001) has shown that extreme climatic events, such as 100 year return floods, can cause high natural mortalities (5–8%) of total river populations. There is no published definition on what figure constitutes a 'significant proportion' of a mussel population, but perhaps it should not greatly exceed that of known high natural mortalities. Therefore, we suggest that an arbitrary figure of 10% of the total river population could be used. Any development likely to detrimentally impact on $>10\%$ of the population should consequently be rejected.

3.3. The special importance of juveniles

A distinctive and particularly worrying feature of most of the remaining *M. margaritifera* populations is a general lack of juveniles found in almost every population recently studied (Bauer, 1986; Ziuganov et al., 1994; Chesney and Oliver, 1998; Cosgrove et al., 2000a; Hastie et al., 2000a). Hence any locations or areas in a river where there are signs of recent juvenile recruitment are of particular importance in terms of the long-term viability of a mussel population. It is impracticable to move small vulnerable juveniles, since most small mussels (<30 mm shell length) lie buried in the substrate hidden from view and are rather delicate (Young and Williams, 1983). Their presence can only be ascertained through detailed quadrat searches of the substrate by trained surveyors (Cosgrove et al., 2000a; Hastie et al., 2000a). The practicalities of carrying out these detailed searches over large areas are considerable and it is inconceivable that surveyors would be able to find all juveniles. Since only about 100 rivers world-wide are known to have juveniles (Young et al., 2000), all river sites with juveniles are globally important and the

rationale is that their protection should take precedence over all site development proposals, in order to maintain the conservation status of the site.

3.4. Translocation of mussels

Difficulties arise where small numbers of adults, but no juveniles, are present (i.e. < 1 adult m^{-2}). Temporary damage to a site, e.g. laying a pipe under the river bed or shoring up a bank support, may be acceptable if the river manager ensures the restoration of habitat and that no mussels are harmed. In such situations, it might be possible to carry out river engineering works without directly harming the importance of the site, by moving or translocating small numbers of adult mussels. If such moves go ahead, the river manager should commit themself to a long-term recovery and monitoring programme, to ensure that information on the success, or failure of the translocation is available to inform future management decisions.

If translocation of a small number of adults is being considered, there must be a suitable 'donor' area of habitat, unaffected by any proposed development work, for the mussels to go. The issue of recognising potentially suitable donor areas is particularly important in rivers with either low numbers of mussels clumped in distribution or in small streams with limited amounts of suitable habitat. There are many rivers where the current mussel population is highly condensed but the river has many 'apparently' suitable areas of habitat (Ross, 1988; Hastie et al., 2000b). This may be the result of historic loss by pearl fishing with relict patches remaining, but it may equally reflect the progressive reduction of 'suitable habitat', a phenomenon that cannot be yet quantified (G. Oliver, pers. comm.). Such small and concentrated mussel populations are theoretically viable because they are able to produce glochidia to infect fish, but there may be no suitable juvenile habitat currently available. Since mussels can live for up to 100 years (Bauer, 1992), it is important to maintain those sites currently suffering recruitment problems in the hope that they may one day become suitable again.

Adult mussel micro-habitat requirements are more general than those of juvenile mussels, but they also require areas of clean sand or gravel (Young and Williams, 1983; Hastie et al., 2000b) and 'suitability' of potential donor sites should be assessed on the basis of the presence of adult mussels already there. Furthermore, transfers between different river catchments should not occur, because the whole purpose of translocation is to maintain the viability of the remaining 100 or so functional mussel populations and there is evidence from Finland that mussel survival after transfer between rivers may be particularly low (Valovirta, 1995).

3.5. Benefits to other species

Freshwater pearl mussels can live for 100 years buried or partly buried in clean sand and gravel and subsist by inhaling and filtering up to 50 litres of water per day for minute organic particles (Ziuganov et al., 1994). In rivers with common or abundant mussel populations it is possible that this filtration acts to clarify the river water by reducing the suspended organic load, to the benefit of other species including juvenile Atlantic salmon (*Salmo salar*) and brown/sea trout (*Salmo trutta*; Woodward, 1994). In recent years there has been a dramatic decline in these migratory salmonid stocks across Europe and this has been matched by a similar recruitment failure in *M. margaritifera* (Cosgrove et al., 2000b). One of the many factors attributed to this fishery decline has been the loss or degradation of suitable spawning and nursery areas (Maitland, 1997). In the past, mussels filtered much of the water in these spawning and nursery areas, but in recent times many of these mussel populations have been lost and the salmonids perhaps have been indirectly affected (Cosgrove et. al., 2000b). Therefore, the protection of the remaining functional or viable mussel populations may benefit economically important fish and other species of importance to river managers.

4. Discussion

Whilst many studies have implicated general river engineering in the decline and extinction of a number of mussel populations (e.g. Young and Williams, 1983; Ziuganov et. al., 1994; Cosgrove et. al., 2000a), only a few have described the scale and nature of the impact of such activities (e.g. Killeen et. al. 1998). The data presented in this paper illustrate the range of potentially damaging river engineering operations that have impacted on *M. margaritifera* populations in Scotland. It is not known how widespread the use of such operations is outside Scotland, but it is strongly suspected that mussel populations in other countries may also have been adversely affected by similar activities.

With hindsight many of the damaging operations could have been avoided if the river mangers were aware of the issues associated with the ecological (and legal) requirements of the species. If river managers are able to understand why the conservation of pearl mussels is important and how their actions directly relate to it, then the number of inappropriate and potentially damaging developments put forward should significantly reduce. To this end, a transparent conflict resolution framework, which identifies the theoretical and practical considerations associated with assessing the impacts of proposed river engineering developments on *M. margaritifera*, will help reduce potential acrimonious conflicts

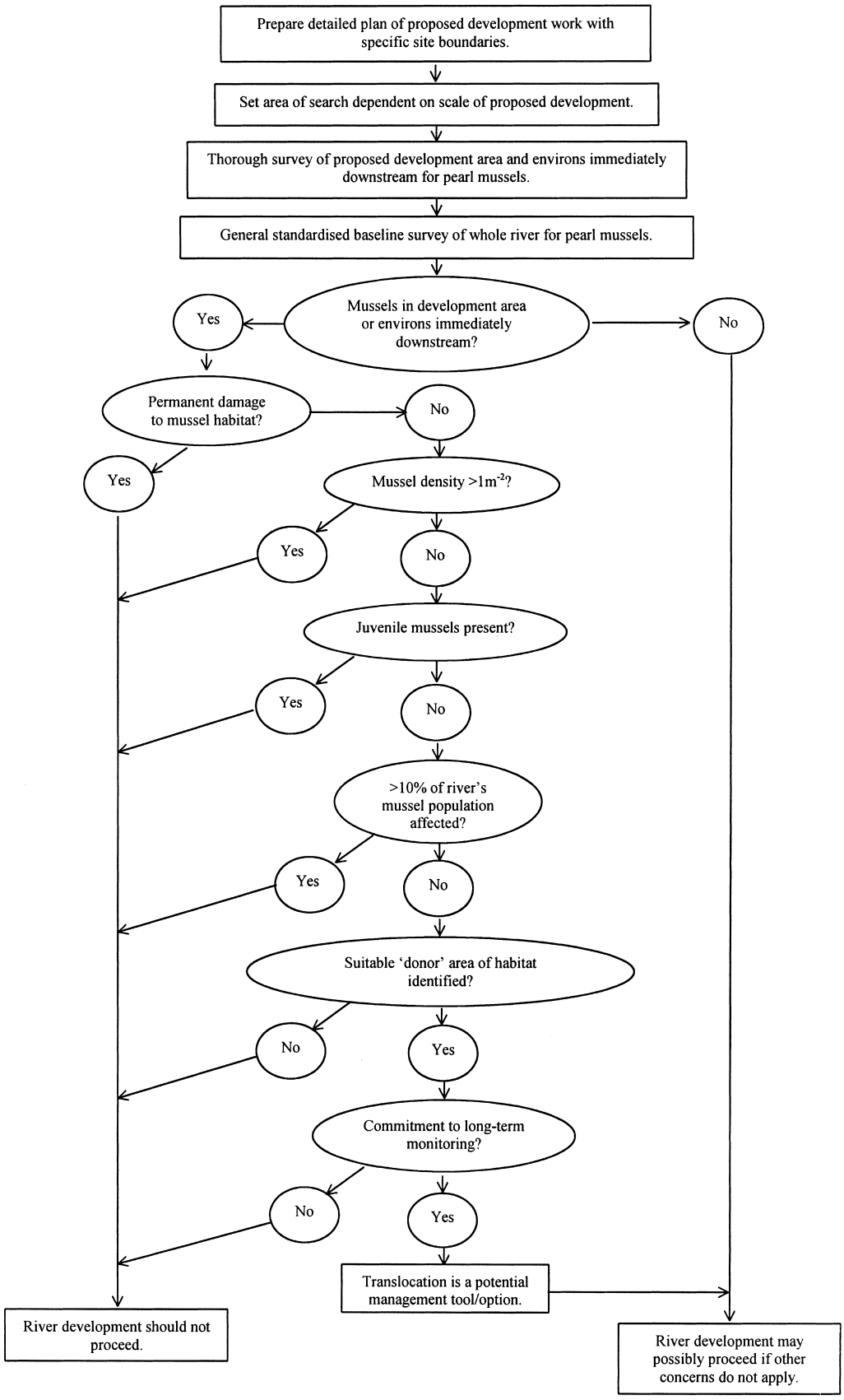

Fig. 1. Ecological 'decision tree' for river development proposals in rivers with *M. margaritifera* populations.

and ensure that river management activities complement and enhance, rather than oppose, the conservation of this highly endangered species.

Each case should be considered individually, but it is also important to consider that precedents are not set which might have detrimental consequences for other sites in the future. To ensure this, it is suggested that applicants use a 'decision tree' (Fig. 1) incorporating the key issues discussed in the paper to determine whether a river engineering proposal is ecologically appropriate or not. Such an approach should, at the very minimum, be developed for each of the remaining 100 known 'functional' populations in rivers world-wide, because they are so important internationally.

Although the final decision on any development is likely to rest with the relevant government department or statutory authority, an agreed voluntary conflict resolution framework, such as the one outlined in this paper, could significantly reduce potential conflicts between different river users. This would save time and money and ensure a more secure future for this highly threatened species. This type of conflict resolution framework could also have wider applications for the sustainable management of other endangered species.

Acknowledgements

We would like to thank Jackie Farquhar for her initial comments and practical help in improving an early draft of this paper. Birgit Henninger and Neil McCormick provided us with detailed accounts of damaging river engineering activities and we appreciate access to their unpublished data. We are particularly grateful to Graham Oliver, Mark Young, Phil Boon and an anonymous referee for their constructive comments on this manuscript. We are also grateful to a number of Scottish Natural Heritage's local area staff who alerted us to the practical difficulties involved in the appraisal of proposed engineering developments on pearl mussel rivers.

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