Protocol for the assessment of risk of mortality of *Margaritifera* in drought and choice of action

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1. Introduction

The Department of Culture, Heritage and the Gaeltacht (DCHG) provides the legislative and policy framework for the conservation of nature and biodiversity in Ireland. It also oversees its implementation, based on good science, with particular emphasis on the protection of habitats and species. All survey and disturbance of *Margaritifera* must be undertaken under the terms of a valid licence from the Department.

The freshwater pearl mussel (*Margaritifera margaritifera*) is listed on Annex II and Annex V of the EU Habitats Directive, and is protected under the Irish Wildlife Acts (1976 and 2000). The freshwater pearl mussel is considered to be critically endangered in Ireland (Byrne *et al*., 2009) and Europe (Moorkens, 2011), and endangered worldwide (Moorkens et al., 2018). The conservation status of the species was bad when reported under Article 17 of the Habitats Directive in 2007, 2013 and again in 2019 (Moorkens *et al*., 2007; NPWS, 2013; in prep.).

Pearl mussels have a complicated life cycle (see Figure 1), involving native salmon or trout.

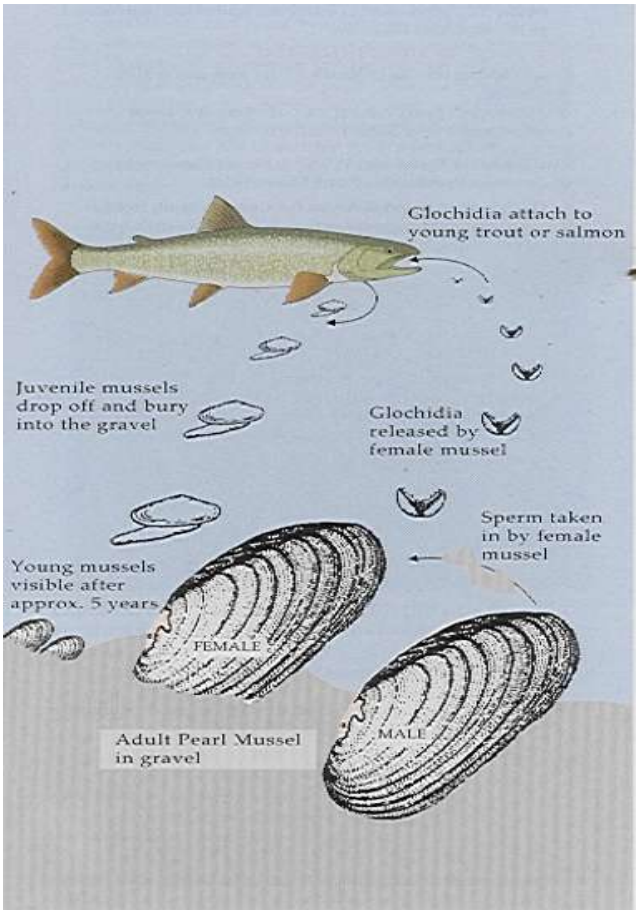


Figure 1. Life cycle of Freshwater pearl mussel *Margaritifera margaritifera*.

The key cause of decline in pearl mussel populations in Ireland is unsuitable habitat for juvenile mussels after they fall off the gills of host salmonids. This stage requires the safety of remaining within the river bed gravels, before growing to a size that allows the emergence of the filtering siphons into the open water body. While the juvenile mussels remain within the river bed gravels, they filter the interstitial water within the gravels.

Following excessive low flows or pollution, the gaps between the gravel stones get clogged with fine silt, either physical (from suspended solids entering the river) or organic (from algal growth and decay prompted by nutrients in the water). Interstitial clogging can also occur at natural levels of sediment, but in unnaturally low flows, when the velocity of water in the interstices becomes very restricted. Without adequate water movement and replacement, oxygen levels are exhausted and young mussels die. Under severe low flows, adult mussels can experience oxygen stress, and can use their powerful foot to move up to 1 metre per day to more favourable conditions.

In extreme low flow situations, mussel habitat can become dry and mussels become exposed before they can move to safety. These mussels can clam and survive for some time, but are at risk of death after a few days at high temperatures.

This protocol provides the steps needed to assess risk and, if necessary, rescue mussels.

2. Assessment of risk

The most important rule of the assessment of risk is to first do no harm. The assessment of risk of death should not be undertaken on a once-off basis. It requires an understanding of the way in which the lowering of river flows is progressing. Low flows occur regularly and mussels are often found in the shallowest possible conditions and can even suffer exposure for a short period. It is important not to clear these mussels from their habitat as they may be important areas for interacting with host fish, and for juvenile mussels, which often live below adult mussels in shallow areas.

It is very distressing to see extremely low flows in mussel habitat, but it is important to know that this is a natural, but rare, event in rivers with normally functioning hydrological flow regimes. It is unfortunately becoming more common in catchments with unsustainable hydrological function.

It is very important to understand the danger to mussels of moving them, even to a relatively close area. Killeen & Moorkens (2016) highlighted a high risk of stress and death from a number of factors, as summarised in Table 2.1.

Table 2.1 Factors that can contribute to poor translocation outcomes

Factor Number	Factor	Potential cause of stress
1	Stress levels of donor mussels	Even when mussel habitat is in good condition, a prior negative event (e.g. a severe low flow) can leave mussel individuals in a stressed condition and less resilient to handling and removal to a new environment. Where mussels are chronically stressed they have very little resilience to change in their environment.
2	Quality of donor habitat	Where donor habitat is normally excellent, translocated mussels may become stressed by responding to being moved to less optimum habitat. Where donor habitat has become poor, mussels may already be stressed and not have the ability to adapt to new environment.
3	Collection and handling quality	Although they appear to be robust, mussels are easily stressed by over-handling, the period of emersion, and the quality of the temporary transport environment.
4	Ease of transfer journey	The logistics of how the mussels have to be carried over land and road, the smoothness of the journey and the distance and time needed all contribute to stress levels.
5	Flow pattern differences in donor / receptor habitats	Mussels conditioned to living in fast flows will have strong muscular strength and may pull themselves out of slower flow areas in an attempt to move back to faster flows. Mussels that are stressed or conditioned to slower flows may not have the muscle tone quality to withstand faster flows and may be easily scoured out of the river bed and washed downstream.
6	Innate “righting response”	When mussels are “planted” in their normal two thirds buried position, they have an innate response to pull themselves out of the substrate and rebury themselves. This involves an additional stress and expense of energy reserves.
7	Flow conditions on the day or subsequent days	If flows increase significantly following translocation, the mussels are in higher danger of being washed downstream, especially if it follows a “righting” response.
8	Water temperature	Very high temperatures are associated with oxygen reduction and mussel stress and ability to move, burrow, right, and otherwise adjust to a more favourable position.
9	Time of year	Mussels have a complex life cycle and spend a high percentage of the year in gamete production. Females brood larval glochidia in their gills between June and September during which time they have reduced capacity for oxygen uptake and are very vulnerable to stress.
10	Similarity of receptor site	As mussels become adapted to their immediate environment, and most do not move during their lifetime, stress can occur from an inability to adapt to a change in flow, depth, turbidity and nutrient levels and of physical substrate type. Thus even a movement from poor habitat to good habitat may have an inevitable intrinsic level of stress.
	Quality of	The correct choice of receptor site on a macro and micro scale

11	receptor site	presents the greatest challenge as all the aspects of appropriate macro and micro habitat need to be present, including appropriate flows at all times of year, suitable substrate conditions for adult and juvenile mussels, appropriate local hydrological function including provision of juvenile food sources, appropriate host fish densities and conditions appropriate to young host fish congregating close to mussels, juvenile mussel habitat in areas where host fish are likely to congregate in early summer, and the stability to maintain their ideal conditions without interruption for at least ten year intervals (time needed for juvenile mussels to be robust enough to withstand flowing open water).
12	Genetic suitability (mussels and fish)	The translocation of mussels should not compromise the genetic component of the receptor site, e.g. it should not bring a different genetic profile to an area that already has mussels of a different genetic adaptation. The translocated mussels should be demonstrated to be compatible with the host fish strain of the receptor locations.
13	Phenotypic suitability	Mussel shape is relatively plastic and adult mussels can form shapes that are well adapted to their river bed conditions, particularly their flow and substrate burial conditions. Preston *et al.* (2010) recommend that phenotypic characteristics and particularly shell shape variation is taken into consideration when considering the translocation of adult *Margaritifera.*
14	Threat to mussels in the receptor site	Any movement of stressed mussels must ensure that the problem is not exacerbated for mussels already living in the receptor site. While the easiest way to recognise good mussel habitat is when other mussels already occupy it, this poses a risk of disease and competition for resources to the current site occupants. For this reason stressed mussels should be placed away from other mussels according to the recommendations of this protocol.

Extremely low flows in mussel habitat can be very distressing to see

The following steps should be taken in assessment of risk:

a) Ensure that the locations of all NPWS permanent monitoring plots or transects are clearly known and left undisturbed, regardless of the condition of the mussels.

   Monitoring of *Margaritifera* in Ireland includes surveillance of permanent transects and count areas, and it is very important that such areas are not interfered with. Do not disturb monitoring areas are available from NPWS.

> Permanent monitoring transects and counts have had surveillance on a number of occasions and provide evidence of improvement, decline or other trends.
>
> It is important that the continuity of surveillance is not compromised by trampling or physical removal of mussels from these locations.
>
> A dedicated shapefile of permanent monitoring locations is being prepared, and these locations can be determined from monitoring reports in combination with available *Margaritifera* records in the *Margaritifera* Geodatabase

b) Be licensed and trained to rescue mussels under this protocol

   Any person wishing to rescue mussels should be trained in the use of this protocol and fully licensed to handle and place mussels for rescue purposes.

c) Survey the area vulnerable to low flow and mussel desiccation

   Decide which mussels are at unacceptable risk of death, and which should be monitored

d) Move the mussels at unacceptable risk of death according to the translocation protocol.

They must only be moved if they are in danger of imminent death, which is determined by the following:

Leave and monitor if:

- Mussels are in wet sand, or
- Mussels are *in situ* with siphons just exposed

Thesemussels should be monitored, along with the weather forecast , and their risk of death reviewed regularly. Mussels in very high temperatures (20°C or higher) with no forecast of rain or a change in the weather are at a higher risk of death than mussels in lower temperatures and intermittent rain. Monitored mussels should be moved if their conditions deteriorate to the following:

Move if:

- Mussels are lying on their side out of water
- Mussels are buried in situ in totally **dry** sand
- Mussels are lying on their side over water weed, with no likelihood of being able to move to safety

Examples of mussels to be left and monitored and mussels that should be moved are shown below.

Move if:

- Sand is dry
- Temperature is high
- Some mussels are dead
- No rainfall is forecast

To move

To leave
and monitor

Monitor

- Daily checks
- Weather forecast
- Check after rain

To move

To leave
and monitor

Monitor

- Daily checks
- Weather forecast
- Check after rain

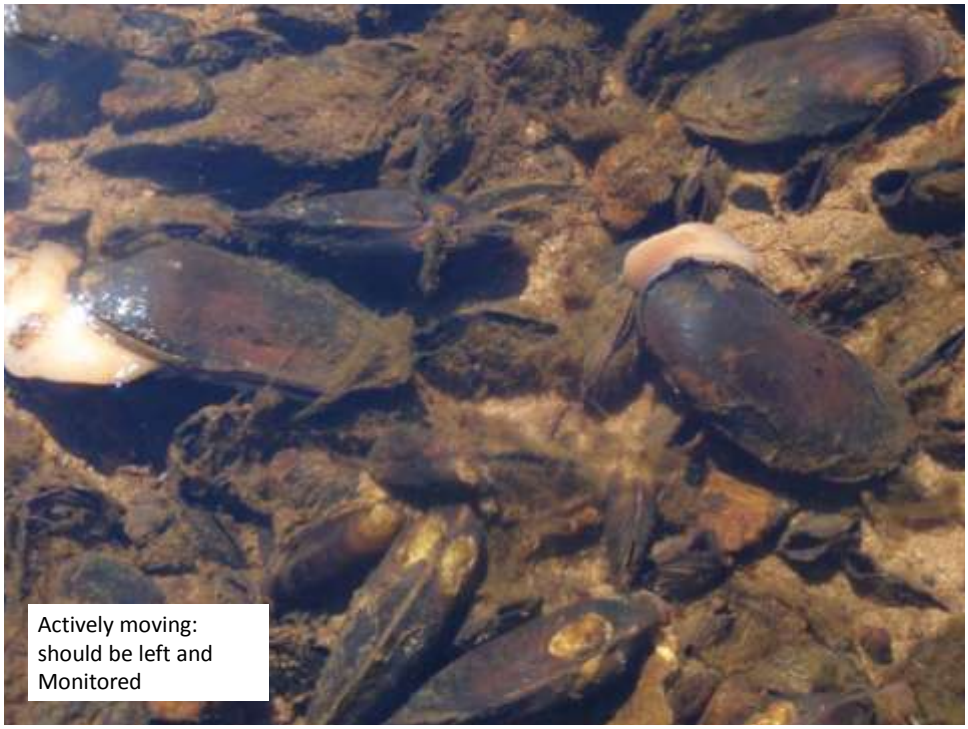
To move

To leave
and monitor

All should be left and Monitored

All should be left and Monitored

All should be left and Monitored



Actively moving: should be left and Monitored

Mussels to leave *in situ*

Mussels to leave *in situ*

Mussels to leave

Mussels to move

	
Mussels in wet sand may be protecting juveniles underneath	This dead shell had wet sand with 4 juvenile mussels

3. Translocation protocol

As there is a risk of continued stress and death of compromised mussels, it is important not to place them in a) fast flowing water (which they will not have the muscular tone to endure) or b) with other mussels (as they may have succumbed to disease that could be spread, or die and rot causing pollution in the local area).

The ideal location for rescued mussels is a slow flowing pool. This should not be so deep that they cannot be retrieved. Pools are not normal habitat and thus moved mussels will not become a disease and pollution problem for other mussels if they end up dying anyway. These mussels are usually very stressed by the time they are found – in the worst cases they are already dying by the time they are first found, in the best case they will be very stressed and vulnerable to the next flood such as the summer storm that can often follow a drought. By placing them in a pool (0.8 – 1m depth is ideal) the flow is slower and they can recover from stress over time before replacement as close as possible to the place they were removed from, thus continuing the former area of occupancy. In a pool the pollutants resulting from dead mussels are isolated to some extent.

The equipment needed for this protocol:

- Bathyscope and waders/ wet/ dry suit
- Buckets to fill with water
- Stones painted with environmentally friendly bright coloured paint
- Wire flags
- GPS
- Waterproof camera

The sequence of this protocol is as follows:

1) Identify permanent transect locations associated with the area of stress and place wire flags at the ends of transect locations that cannot be interfered with.
2) Identify mussels that should be moved.
3) Identify the nearest slow flowing pool.
4) Remove mussels in small batches to a bucket. While one person removes a mussel, a second person marks the removal site with a coloured stone. If possible each mussel should be numbered, such as with a gold gel pen on its shell. This may not be possible if mussels are very stressed.
5) The mussels are placed in the pool area, half to two thirds buried in the river bed, with siphons facing the direction of flow.
6) Photographs and GPS are taken of the donor and receptor areas.
7) When the workers are satisfied that the locations of the marked stones can be accurately refound, the stones may be removed to be used elsewhere.
8) Mussels from the same general area can go into the same pool, but mussels from a different area should go into a separate pool, so that mussels can be replaced into the area that they were removed from.
9) All locations and numbers of mussels that were moved and left in situ should be carefully noted and counted for the licence return

Mussels left in place to be monitored should
When the drought is over and normal flows have resumed:

10) Mussels in the donor and receptor areas should be resurveyed to check how the mussels left in situ survived, and if any mussels have moved into the gaps left by removed mussels. The coloured stones can be used to recreate the pattern from the drought removal, and a photograph taken of how nearby mussels have reconfigured.
11) The numbers of mussels that survived in the pools and any dead shells noted, including their numbers, if they have been labelled.
12) The mussels should then be returned to their original locations, half to two thirds buried in the river bed, with siphons facing the direction of flow.
13) The mussels should be left to settle until they are observed to be filtering. A further photograph should be taken, and then the coloured stones removed.
14) A further check and photograph should be taken after one month to check that these mussels have survived and are filtering.