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Report of Site Condition Monitoring survey of freshwater pearl mussels in the River Spey during 2013 and 2014

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Report of Site Condition Monitoring survey of freshwater pearl mussels in the River Spey during 2013 and 2014

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Keywords

Freshwater pearl mussel; River Spey; Site Condition Monitoring; *Margaritifera*; *Ranunculus*

Background

The River Spey is a Special Area of Conservation and a Site of Special Scientific Interest for freshwater pearl mussels. The river was surveyed during 2013 and 2014 as part of SNH's routine Site Condition Monitoring programme. The results of that survey have been used to make an assessment of the condition of the pearl mussel feature in both the SAC and SSSI.

Main findings

- The survey recorded 15339 visible freshwater pearl mussels from a total of 54 survey locations.
- The survey recorded juvenile freshwater pearl mussels at 15 survey locations.
- The results were compared with those of an earlier survey conducted in 2000.
- The present survey recorded 50% fewer freshwater pearl mussels than in 2000.
- The present survey recorded juvenile pearl mussels across a greater range of locations than in 2000.
- The current status of freshwater pearl mussels in the River Spey SAC and SSSI is considered to be 'unfavourable declining'.
- The survey and further considerations have identified a number of pressures that appear to have contributed to the decline.
- Water quality is likely to be contributing to the decline in the status of pearl mussels in the River Spey.
- An apparent increase in the abundance of water crowfoot (*Ranunculus*) in the middle and lower River Spey appears to have killed a significant number of pearl mussels.
- Low river levels in the middle and lower River Spey have also killed established pearl mussel beds, probably during 2013.
- The survey found that illegal pearl fishing has badly damaged pearl mussels in at least one location in the River Spey.
- Water quality and/or low flows seem likely to be contributing to the abundance of *Ranunculus* in the River Spey.
- The survey found few, or no, juvenile pearl mussels in the middle to upper reaches of the River Spey. Without change, the distribution of pearl mussels will gradually contract.

Recommendations

The survey and analysis of results has produced a number of recommendations, listed below.

- To consider and implement the appropriate recommendations of Cooksley and Blake (2014) to help understand the water quality pressures on the freshwater pearl mussels. This should be extended along the main stem of the Spey.
- To investigate the potential reasons for the apparent increase in *Ranunculus* since 2000.
- To undertake a further survey of the extent and distribution of *Ranunculus* in the Spey to compare with past records.
- To identify appropriate water quality and flow targets that will support the conservation objectives for freshwater pearl mussel, with the intention of including them within the second Scotland River Basin Management Plan.
- To consider identifying the River Spey as a catchment for action on diffuse pollution in order to target action to reduce inputs from agricultural diffuse pollution.
- To continue the River Spey Riverwatch scheme to promote awareness of wildlife crime and encourage reporting of suspicious activity.
- To develop a method and implement a programme for monitoring fine sediment, and its effects on pearl mussels, within the River Spey.
- To further investigate the reasons for the low abundance, and poor recruitment, of pearl mussels in the upper River Spey.
- To identify the reasons for the lack of glochidia on fish in the tributary with reintroduced pearl mussels.
- To confirm the fish host specificity of pearl mussels in the River Spey.

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1. INTRODUCTION

The freshwater pearl mussel (*Margaritifera margaritifera*) is endangered throughout Europe as a result of inappropriate land use, pollution, river engineering, abstraction, declining populations of host fish, and exploitation by pearl fishers. Freshwater pearl mussels have a complicated life history, with a larval stage that is dependent on a salmonid host. The larvae harmlessly encyst within the host fish gills following their release by female mussels in summer. There they overwinter and grow before dropping off in the following spring. The few that survive initially remain buried in the river-bed substrate for several years. Older mussels typically are more visible on the river-bed and filter feed within the open water. The juvenile stages are more demanding of high-quality environmental conditions than adult mussels, emphasising the importance of defining and maintaining appropriate ecological requirements for the young stages.

The River Spey is designated as a Special Area of Conservation (SAC) and notified as a Site of Special Scientific Interest (SSSI) for its populations of Atlantic salmon (*Salmo salar*), otter (*Lutra lutra*), sea lamprey (*Petromyzon marinus*) and freshwater pearl mussel (*Margaritifera margaritifera*).

As part of SNH's routine Site Condition Monitoring (SCM) programme the River Spey was surveyed to determine its current condition during 2013 and 2014. This report describes the results of the survey, how they have been used to determine the condition of the freshwater pearl mussel feature in the River Spey SAC and SSSI, identifies some of the pressures that appear to be contributing to the current condition and makes some recommendations for conservation actions and further investigations.

2. METHODS

The survey was undertaken by contractors on behalf of SNH. The survey of the River Spey was part of a wider national survey, led by Waterside Ecology. The Spey survey was undertaken by Peter Cosgrove, Cameron Cosgrove, Stephen Corcoran, David Jarrett and Phil Boon.

The survey was conducted using the standard JNCC Common Standards Monitoring protocol for freshwater pearl mussel (JNCC, 2005a). The survey extended along the length of the River Spey, from the mouth of the river to the reaches downstream from Spey Dam.

The River Spey has previously been divided into twelve Evaluated Catchment Sections (ECSs) by Young *et al.* (2001) which are described in Table 1. Freshwater pearl mussels are present in nine of those, all of which were included in the present survey. The selected locations were those visited by the Young *at al.* (2001) survey, supplemented by others to improve coverage of survey locations across more ECSs, particularly in the lower reaches which support the vast majority of the resident pearl mussel population.

The survey was conducted during 2013 and 2014. In total 54 transects were surveyed. Mussels were recorded from the furthermost downstream transect, to a transect in ECS 9.

The aim was to include at least five 50 m transect locations in each ECS. In some this was not possible, due to the paucity of pearl mussels or because of access problems. As described in the standard method (JNCC, 2005a), at each survey location the surveyor entered the water and proceeded upstream for 50 m, counting all visible pearl mussels within a 1 m wide transect. Where transects had not previously been surveyed by Young *et al*. (2001), or the transect location could not be found again, transects were placed in areas of relatively high mussel abundance and/or where past records suggested mussels would be present.

At 10 m intervals along the transect, a 1 x 1 m quadrat was laid on the surface and all visible mussels were counted. All loose rocks, plants and mussels were gently removed and the underlying sediment disturbed, to reveal any buried mussels. These were counted and measured quickly, to determine the size profile of the population and the number of juveniles present (≤65 mm overall length). All stones and mussels were then replaced as securely as possible.

If it became clear that more than 250 mussels were present in a transect, a change was made to survey only five 1 x 1 m quadrats, placed at 10 m intervals. Direct extrapolation of the numbers from these five quadrats was then used to provide an estimate of the numbers present in the full transect.

During the survey, a range of habitat characteristics were recorded (e.g. substrate type, channel width, etc.), and noted any obvious pressures that may have been affecting the pearl mussels at each transect location were noted.

Within this report the pearl mussel abundance has been expressed both in absolute terms but also in standardised abundance codes. These are common to many surveys and relate to the number of visible (not buried) mussels found in a 50 m^2 transect (Table 2).

Table 1. Division of the River Spey into evaluated catchment sections (ECSs), based on physical characteristics of river and riparian zone. From Young et al*. (2001).*

ECS No.	Length (km)	Location	General description
1	6	Spey Bay to Fochabers	Coastal floodplain. Deep silty reaches and mobile pebble beds. Alternating fast and slow sections.
2	22	Fochabers to Craigellachie	Asymmetrical floodplain (very steep on either bank). Variable flow regime with large unstable reaches (large pebble deposits).
3	17	Craigellachie to Blacksboat	V-shaped valley (very steep in places) with a few scattered terraces. Variable flow regime (riffles/runs/pools common) and substrata.
4	23	Blacksboat to Cromdale	Shallow v-shaped valley with terraces. Variable flow but predominantly gentle.
5	10	Cromdale to Balliefurth	Shallow v-shaped valley. Very gentle flowing (long glides and pools). Large sand/silt deposits.
6	17	Balliefurth to Pityoulish	Lowland floodplain. Very gentle flow. Predominantly silty substrates.
7	15	Pityoulish to Kincraig	U-shaped valley with terraces. Variable flow (predominantly gentle) and substrata (large soft deposits).
8	9	Insh Marshes	U-shaped valley with wide floodplain (extensive marshland). Very slow flowing with silt/mud substrata.
9	12	Kingussie to Inver Truim	U-shaped valley with terraces. Variable flow regime and mixed substrata.
10	12	Inver Truim to Laggan	U-shaped valley with terraces. Gentle flow with mixed substrata (predominantly soft).
11	10	Laggan to Garva	V-shaped valley. Moderate but variable flow and mixed substrata.
12	12	Garva to Loch Spey	Gentle u-shaped valley. Variable flow (predominantly moderate–gentle) and substrata (predominantly soft).

Table 2. Standard relative abundance codes for 50 m transect counts.

Visible mussels /transect (50 m^2)	Abundance code
0	E
1-49	D
50-499	C
500-999	B
1000+	A

3. RESULTS

3.1 50 m transect results

In total, 15,339 visible pearl mussels were recorded in the 54 transects. The largest number of pearl mussels had an estimated 6,600 pearl mussels in $50m^2$. As in a previous survey, the greatest abundance of pearl mussels was found in some of the lower reaches of the Spey, particularly as far upstream as the confluence with the River Avon.

In 56% of the transects where pearl mussels were recorded, juvenile mussels were also found. In general, where juveniles were present in quadrats, they comprised 10-30% of the sample. This indicates that successful recruitment is taking place in many places within the River Spey.

As Table 3 shows, a wide range of mussel sizes were recorded, ranging from 9 to 138 mm. The presence of very small mussels (≤30 mm) indicates very recent recruitment; however, the overall population is dominated by much larger animals (Figure 1).

Pearl mussels continue to be present in low numbers in the lowest reaches of the River Spey, where the river is dynamic and provides relatively unsuitable habitat. In some of the upper reaches, pearl mussels are present in low numbers and in isolated locations. In the further upstream ECSs the survey also recorded little or no evidence of juvenile pearl mussels.

Table 3. Observed shell size characteristics of River Spey mussels

N	Mean (mm)	Median (mm)	*SD* (mm)	Range (mm)
2388	82.0	83	19.9	9 – 138

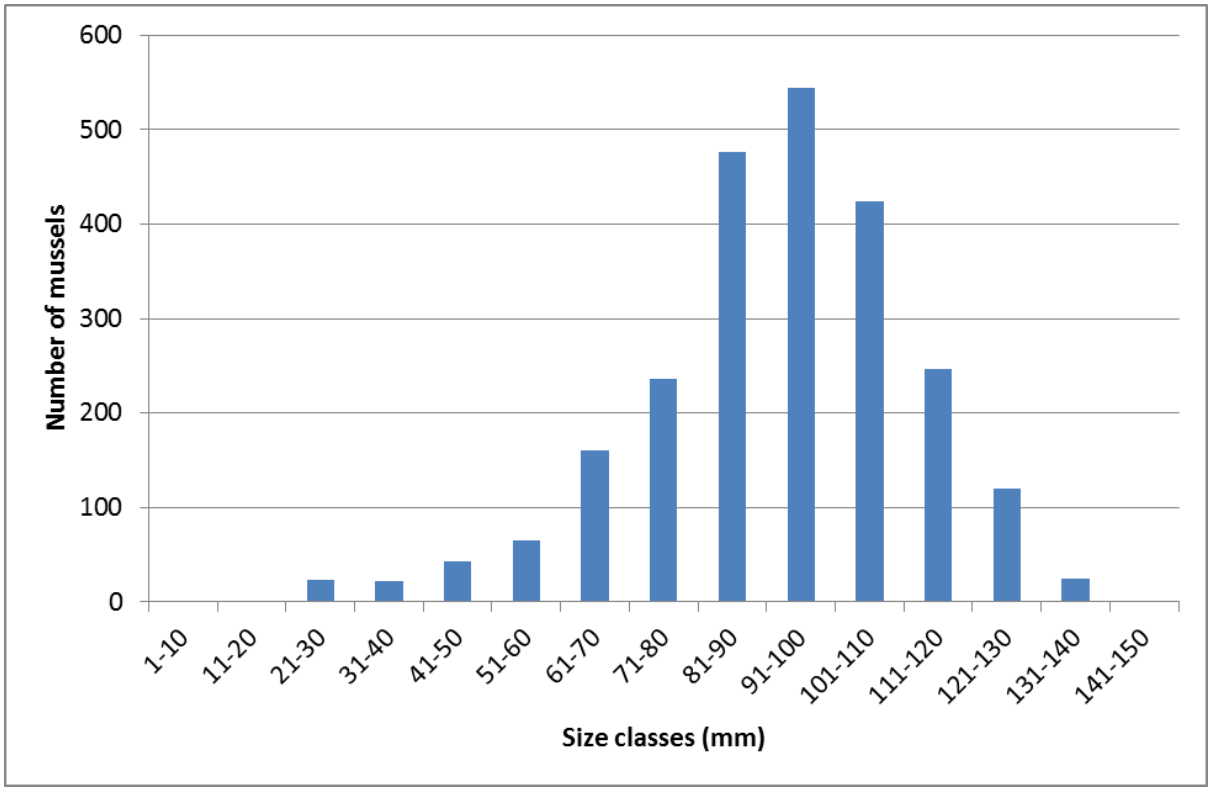

Figure 1. River Spey freshwater pearl mussel shell length frequencies, 2013-14

4. DISCUSSION

The results from the present survey can be compared with those of the last large scale survey of the River Spey, by Young *et al.* (2001). The results of the present survey can also be compared with favourable condition targets for freshwater pearl mussel, including analysis of available habitat information (JNCC, 2005b), in order to determine the condition of the pearl mussel population in the River Spey.

4.1 Comparison with results from 2000

The present survey included nearly all of the transects that were surveyed by Young *et al.* (2001), and added further transects to help fill in some gaps in coverage. The present survey recorded a total of 15,339 visible pearl mussels. Young *et al.* (2001) recorded 35,254 visible pearl mussels.

There are a number of issues to note in comparing these totals. The 2013-14 survey examined more transects in the Spey to gain a better understanding of the status of the species in a greater number of reaches. Also, during the present survey, surveyors were unable to find four transects that were surveyed as part of the 2000 survey. During the present survey, transects were surveyed at the locations given for these four transects although it was clear to the surveyors that they were not the original locations of those surveyed by Young *et al.* (2001) as they supported unsuitable habitat. To make more of a direct comparison between the two surveys the totals have been adjusted to exclude the numbers recorded in the four transects mentioned above, and those transects that were not common to both surveys. These comparative totals record 13,716 visible mussels in 2013-14, compared with 27,639 visible mussels at the same locations in 1999-2000. This represents a 50% drop in the recorded population during the intervening 14 years. Such a steep decline, in a population and river the size of the Spey, appears to be unprecedented in Scotland.

Comparing the results from the transects that were used to produce the comparative totals, the abundance code assigned to each transect has changed in many cases between the two surveys. Of the 39 transects that were common to both surveys, the abundance code has dropped at 20 transects, remained the same at 17, and increased at two between 2000 and 2014. It is worth noting that some of these changes have been very large, such as one transect which was abundance code ‘A’ in 2000, but dropped to ‘D’ in 2014.

Both the present survey and Young *et al*. (2001) recorded the number and percentage of juveniles within the quadrat searches in each transect. As with the changes in overall pearl mussel abundance, there also appear to have been significant changes in juvenile abundance between the two surveys. In comparing the totals, it is important to be aware of a methodological difference between the two surveys. Young *et al.* (2001) searched two 1 x 1m quadrats within each transect, whereas the present survey typically searched five 1 x 1m quadrats in each transect. Moreover, changes in river level on the day of a survey make it more or less challenging to search quadrats. This difference in method and potential changes in field conditions make it difficult to directly compare the absolute number of juveniles. However, the percentage abundance should be comparable, and the results show some marked differences in the presence and abundance of juveniles in the River Spey. At some locations, juvenile pearl mussels have been recorded where they were previously absent. More worrying is their apparent absence from transects where Young *et al.* (2001) had previously recorded them as a reasonable proportion of the resident pearl mussel population. Some of this can be explained by the difficulty in finding some original survey transects during the present survey. However at some locations, the population comprised 26% juveniles in 1999-2000, whereas no juveniles were recorded in 2014.

Both the present survey and the survey by Young *et al.* (2001) recorded few, if any, juvenile pearl mussels in the upper reaches of the River Spey. Young *et al.* (2000) suggested that in the uppermost reaches this was most likely due to past pearl fishing in these more accessible parts of the river. There are encouraging signs, with the present survey recording juvenile pearl mussels in one transect where they were absent in 2000. However, the apparently poor or non-existent recruitment from Grantown upstream remains a major problem for the ability of the species to maintain its distribution in the River Spey. Without an improvement it is expected that the distribution of pearl mussels in the Spey will gradually contract.

Beyond comparing the results of the present survey with those of Young *et al*. (2001), it is noteworthy that a recent study by Hastie *et al.* (2010) also examined changes in the recruitment of pearl mussels in the River Spey. Hastie *et al.* (2010) examined changes between 1984 and 2007. They recorded an increase in modal size of the population, from 61 – 70 mm in 1984 to 91 – 100 mm in 2006. This agrees with the modal size range of 91-100 mm recorded in the present study (Figure 1). Hastie *et al.* (2010) also recorded an increase in abundance over the same time period, but it should be noted that their study looked at only one 100-150m^2 area of the river, rather than a far wider survey such as the present study. However, it is concerning that, over the last 30 years, Hastie *et al.* (2010) found evidence of a gradual increase in mussel modal range, which can indicate an aging population. Such a change could also be, at least in part, an artefact of reduced pearl fishing pressure, which would mean that older, larger mussels are no longer removed in such numbers.

4.2 Condition assessment

The results from the present survey have been compared with the current JNCC (2005b) favourable condition targets for freshwater pearl mussels. The attributes and targets are listed in Table 4.

Based on the number of targets that have not been met, and the deterioration in the abundance of pearl mussels since the survey by Young *et al.* (2001), the condition of the freshwater pearl mussel feature in the River Spey SAC and SSSI is considered to be ‘unfavourable declining’.

Table 4. Site attribute table and results of monitoring

Attribute	Target	Result of Monitoring	Target met? (Y/N)
Population density	≥ 5 mussels per m^2 within sample transects.	There are nine ECSs that support, or have supported, freshwater pearl mussel in the River Spey. In 2014 only two of the ECSs met the target, and there has been a marked deterioration since 2000.	N
Age structure	At least 20% of population ≤65mm in the quadrats and at least one mussel ≤30mm.	In 2014, two ECSs met the target for % of juveniles and four ECSs met the target for containing at least one mussel ≤30mm.	N
Water quality	Water Quality Class: A1: See explanatory text to right.	Since the JNCC guidance on assessing favourable condition was produced, the water quality classification scheme has been completely revised to comply with the requirements of the Water Framework Directive. Further to that, guidance describing the ecological requirements of freshwater pearl mussels has been drafted by the European Committee for Standardization (CEN). The current JNCC guidance for freshwater pearl mussels is being revised to account for these significant developments. As such the following water quality targets are suggested (assessed against data collected by SEPA):	
Soluble Reactive Phosphorus:	It is suggested that an annual mean soluble reactive phosphorus (SRP) target for all reaches with freshwater pearl mussel populations should be 5 µg L^{-1}.	Phosphorus data from some middle reaches of the River Spey suggests this target is not currently being met (Cooksley & Blake, 2014) and may be a contributory factor to the lack of, or poor, recruitment within the pearl mussel populations. Further downstream, data from SEPA suggests that concentrations may be closer to modelled 'reference' conditions (those predicted to occur without human impacts).	N
Nitrogen – ammonia	0.025: 95%ile un-ionised ammonia (NH_3-N, mg L^{-1})	SEPA data, which record total ammonia in milligrams of ammoniacal nitrogen per litre as 90%ile, suggests this target is being met in all relevant ECS.	Y
Biochemical Oxygen Demand	Mean BOD <1.0 mg L^{-1}	SEPA data suggest this target is being exceeded in a number of locations along the mainstem of the River Spey	N
Siltation	Not assessed as the "Proportion of Sediment-sensitive Invertebrates" index is not collected on the River Spey.		N/A
Eutrophication (Trophic Diatom Index)	Trophic Diatom Index (TDI) Ecological Quality Ratio should be an EQR of 1.0, equivalent to high ecological status.	Where the TDI is measured in the main stem of the River Spey, results shows that the target is missed in the lower reaches (River Avon to tidal limit) where the TDI is equivalent to good ecological status.	N
Flow	The original target is that it should be within 10% of the naturalised daily mean flow throughout the year. It has not proved possible to apply that target as	Recent classification information from SEPA appears to show that good ecological status for hydrology/impoundment is not being met in three water bodies along the mainstem of the River Spey (Spey Dam to Loch Insh; River Feshie to Nethy; and River Fiddich to tidal limit).	N

	naturalised daily mean flow is not determined in Scotland and has been overtaken by WFD. Therefore, a revised target is proposed: Ideally, flow targets included in CSM guidance for river habitat (JNCC, 2008) should be used, as these are intended to support a healthy, naturally functioning riverine ecosystem which protects the whole biological community and individual species to a degree characteristic of the river. As a minimum, UKTAG standards for good ecological status under the Water Framework Directive should be met.		
River morphology	The target is the same as for riverine habitat (JNCC, 2008).	Due to the lack of River Habitat Survey data it has not been possible to assess this attribute. However it is noted that several WFD water bodies in the mainstem of the River Spey (River Feshie to Nethy; Spey Dam to Loch Insh) are classified at moderate ecological status due to morphological pressures and in need of restorative action that may benefit pearl mussels.	N/A
Fine sediment		A method has been developed to collect redox measurements in open water and the river bed, to help determine the effect fine sediment or excessive algal growth may be having on pearl mussel habitat. Unfortunately it was not possible to deploy the method in the present study.	N/A
Filamentous algae	<5% cover across assessment units	During the present survey, it appears that filamentous algae were not recorded.	N/A
Host fish populations: juvenile salmonid densities	Should be abundant (redefined as >0.1 native juvenile host salmonids m^{-2}).	Available data suggest this target is being met throughout, although that is based on an assessment of juvenile densities in tributaries as the mainstem is extremely difficult to electrofish. One limitation, however, is that any potential discrimination between trout and salmon as the host fish in the Spey remains unknown.	Y
Negative indicators: Signs of disturbance	No disturbance of existing mussel beds by instream activities or evidence of pearl fishing	While there is no evidence of damaging unauthorised instream engineering works, the present survey found evidence of damaging illegal pearl fishing.	N

4.3 Factors potentially affecting pearl mussels

During the present survey, surveyors recorded any obvious pressures that may have been affecting pearl mussels at each transect, to help account for the noted changes in pearl mussel abundance. Three particular pressures appear to have affected a large number of transect locations, particularly in the middle to lower River Spey, where most of the pearl mussel population is located.

One pressure was the presence and abundance of *Ranunculus* at many transect locations. This plant has previously been identified as adversely affecting freshwater pearl mussels in the River Spey and appears to be non-native to the river (Laughton *et al*., 2004). It is present from near Grantown-on-Spey to the sea (Laughton *et al*., 2004). During the present survey it was clear that at several locations the growth of the *Ranunculus* roots had enveloped pearl mussels and the accumulated sand had smothered them. A previous survey of *Ranunculus* distribution in the Spey identified some high levels of abundance around Grantown, Rothes and Aberlour with abundance being lower away from these areas (Redgewell & Laughton, 2003). Young *et al.* (2001) did record *Ranunculus* as being present at some survey locations but did not note it as being a particular pressure on the presence or abundance of pearl mussels.

It would appear from the results of the present survey that *Ranunculus* in the Spey has increased in abundance such that it is adversely affecting some previously large populations of freshwater pearl mussel. At several transects in the middle and lower Spey it would appear to be the primary reason for the marked decline in the abundance of pearl mussels. There could be many reasons behind an increase in *Ranunculus*, which would be difficult to disentangle. However Redgewell & Laughton (2003) did suggest it was more abundant downstream from sewage treatment outfalls, which would correspond to other observations that the species increases in biomass in response to increased nutrients (Hatton-Ellis & Grieve, 2003). Thus, any increase in eutrophication could be helping to increase the abundance of *Ranunculus* in the River Spey. Beyond that, it may be that a winter with relatively mild spates before the survey did not scour out as much *Ranunculus* as might otherwise be the case, allowing the plant to grow from a stronger early season stock during the survey seasons of 2013 and 2014.

A number of actions have taken place in the past to manage *Ranunculus* in the River Spey, including chemical treatment, manual cutting and hand pulling (Laughton *et al*., 2004). At present the Spey Fishery Board and others are investigating the potential use of herbicide to manage *Ranunculus*. Clearly *Ranunculus* is a native part of the flora, although not within the River Spey. In other rivers the species can co-exist with freshwater pearl mussel. There are rivers in the UK designated as SAC both for freshwater pearl mussel and riverine habitat characterised by Ranunculion fluitantis and Callitricho-Batrachion vegetation. Despite that, in the River Spey it is obvious that the introduction of *Ranunculus* and the plant's colonisation of pearl mussel habitat is having a significant effect on the status of the pearl mussel population. Given the extent and scale of *Ranunculus* coverage it appears impossible to eradicate the species from the river. The most obvious way forward would seem to be to understand what has caused the increase in abundance in recent years and address those issues.

A further pressure that was recorded during the current survey was some apparently low water levels that resulted in areas of river bed that had previously held pearl mussels becoming dried out. This affected several transect sites in the middle to lower Spey. At eight transects variable numbers of dead shells were recorded in the margins of the river channel which had become exposed during low flows. At one of these locations 224 pearl mussels were found to have died in the margins of the river channel. The pearl mussels ranged in size from 35 to >120mm in length. If this area became exposed reasonably

regularly, such a range of mussel sizes (and therefore ages, particularly juveniles) might not be expected. Table 4 also identifies flow as a target that has not been met, correlating with the observation made during surveys. An initial analysis of river flows at gauging stations in the River Spey between 1955 and 2013 appears to indicate that during the time when the present survey recorded apparently desiccated mussels (2013), the river did not experience relatively prolonged periods of low flows (Annex 1). Further investigation is recommended to determine the cause of the low flows that damaged the pearl mussels. It is noteworthy that the analysis of targets in Table 4 also recorded locations in the main stem of the River Spey which appear to be at moderate ecological status due to hydrology. Further analysis of the reasons for those failures to achieve good ecological status should form part of any consideration of river levels and abstractions in the River Spey.

During the present survey incidents of wildlife crime were also recorded. This was most acute at one location, where the present survey recorded several thousand fewer pearl mussels than in the last survey. This finding, and other information about suspicious activity, was reported to Police Scotland for investigation.

Beyond those pressures identified by the surveyors, the analysis of targets in the site attribute table (Table 4) also provides important information about pressures affecting pearl mussels in the River Spey. An important attribute, identified as high priority by Cooksley & Blake (2014), was water quality, particularly phosphorus concentrations. Not only can this adversely affect pearl mussel by encouraging algal growth that prevents oxygenated water reaching buried pearl mussels in the sediment (Skinner *et al.*, 2003), but it may also be contributing to the apparent increase in the abundance of *Ranunculus* in the River Spey. In ECS 5 (Table 1), which marks the upstream limit where juveniles have been recorded, water quality may be a key factor limiting recruitment (*Ranunculus* is absent from some of these reaches where recruitment is low or absent). It will be important to address this issue and this can most effectively be achieved by following the management process set out in a recent consultation (Scottish Government, 2013) that should allow the development and implementation of appropriate water quality targets within the next Scotland River Basin Management Plan. Although there are several pressures affecting water quality in the River Spey, from both point source discharges and diffuse sources, given the scale of the decline in the pearl mussel population and the well-known difficulty in managing diffuse pollution, there are likely to be benefits from considering making the River Spey a catchment for priority action. This would enable important resources to be targeted at the catchment. In addition, the recommendations made by Cooksley & Blake (2014) should also be considered and implemented where appropriate.

An important water quality knowledge gap surrounds the role played by fine sediment and its effects on pearl mussels in the River Spey. Young *et al.* (2001) noted that some areas of fine sediment deposition may be having an adverse effect on pearl mussels. This was not noted in the present survey, aside from the smothering effect of fine sediment accumulation associated with *Ranunculus* growth. The development and implementation of a monitoring programme for fine sediment (e.g. redox measurements) should take place to help understand the scale and location of any significant problems.

River engineering was a potential pressure identified by Young *et al.* (2001). Since then, particularly with the introduction of the Controlled Activity Regulations, any pressure from engineering operations has reduced significantly. A number of locations on the main stem of the Spey are classified as moderate ecological status because of morphological pressures. Restorative action to address those pressures could benefit the resident pearl mussel population by restoring habitats and/or making them more sustainable. During the present survey, the surveyors noted that recent river engineering works downstream of Laggan may have made some areas more unsuitable for pearl mussels. Previous studies have also examined the changes to river morphology in the same reaches of the River Spey (Gilvear,

2000). As part of any actions to restore pearl mussels in the upper reaches of the River Spey it seems particularly important to consider continuing morphological pressures that may be affecting the long term sustainability of habitats for pearl mussel.

Since the survey in 2000 it is worth noting a number of important restoration measures that have been implemented and should be contributing to the conservation of pearl mussels in the River Spey. These include the reintroduction of pearl mussels to a tributary that, historically, had supported pearl mussels (Hastie, 2007). This reintroduction was judged a success as many of the pearl mussels remain in the tributary. However, when they were last monitored the pearl mussels were found not to be breeding properly, as no glochidia (larval pearl mussels) could be found on the gills of resident fish. It is recommended that further investigations are undertaken to determine the potential reasons for the failure of this population to breed before further reintroductions take place.

Other conservation actions include continuing vigilance to prevent further invasive species reaching the River Spey, including *Gyrodactylus* and American signal crayfish. The Conservation of Atlantic Salmon in Scotland LIFE project removed a number of barriers to fish migration in tributaries of the Spey which may indirectly benefit the pearl mussels by helping to sustain their host fish populations. However, since 2000, there in good evidence that in Scottish rivers pearl mussels may be using either salmon or trout as their host. Previously it was assumed that pearl mussels could use both species when they were present. It is recommended that the identity of the pearl mussels' fish host be identified in the River Spey, in order to assist future conservation measures.

The Pearls in Peril LIFE project has fenced 6 km of river bank along the River Spey at Boat of Garten to encourage improved riparian woodland. This should help improve the instream habitat and reduce diffuse pollution from grazing animals.

5. CONCLUSIONS

The present study has recorded a substantial decline in the abundance of freshwater pearl mussels in the River Spey. Given the size and scale of the pearl mussel population recorded in 2000, a decline of 50% seems almost unprecedented for this species in Scotland.

The present survey did record juvenile pearl mussels across a wider range within the Spey, compared with the previous survey in 2000. However, in the upper Spey there continue to be only a few, isolated pearl mussels that are not recruiting. Without restorative action it is expected that the distribution of pearl mussels will gradually contract.

Given the decline in abundance of pearl mussels, and the failure to meet a number of habitat targets (Table 4), the status of the freshwater pearl mussel population in the Spey is "unfavourable declining".

The survey and analysis of results has produced a number of recommendations, listed below.

- To consider and implement the appropriate recommendations of Cooksley and Blake (2014) to help understand the water quality pressures on the freshwater pearl mussels. This should be extended along the main stem of the Spey.
- To investigate the potential reasons for the apparent increase in *Ranunculus* since 2000.
- To undertake a further survey of the extent and distribution of *Ranunculus* in the Spey to compare with past records.
- To identify appropriate water quality and flow targets that will support the conservation objectives for freshwater pearl mussel, with the intention of including them within the second Scotland River Basin Management Plan.
- To consider identifying the River Spey as a catchment for action on diffuse pollution in order to target action to reduce inputs from agricultural diffuse pollution.
- To continue the River Spey Riverwatch scheme to promote awareness of wildlife crime and encourage reporting of suspicious activity.
- To develop a method and implement a programme for monitoring fine sediment, and its effects on pearl mussels, within the River Spey.
- To further investigate the reasons for the low abundance, and poor recruitment, of pearl mussels in the upper River Spey.
- To identify the reasons for the lack of glochidia on fish in the tributary with reintroduced pearl mussels.
- To confirm the fish host specificity of pearl mussels in the River Spey.

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ANNEX 1: ANALYSIS OF NUMBER OF DAYS OF LOW FLOW PER ANNUM IN THE RIVER SPEY 1955-2013