COMMISSIONED REPORT

Commissioned Report No.263

Development of a remote, deep-water survey method for freshwater pearl mussels

(ROAME No. F06AC606)

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COMMISSIONED REPORT

Summary

Development of a remote deep-water survey method for freshwater pearl mussels

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Background

Scotland is a global stronghold for the freshwater pearl mussel *Margaritifera margaritifera* (L.), a species which is now fully protected under the Wildlife and Countryside Act (1981) (as amended) of Great Britain. It is also listed on Annexes II and V of the EC Habitats Directive (Council Directive 92/43/EEC) and Appendix III of the Bern Convention. Recent estimates suggest that Scotland holds perhaps half of the world's known remaining viable populations.

Almost all Scottish freshwater pearl mussel survey work has been concentrated in shallow-water areas (<1m deep), where it is safe for wading. There are a number of reports indicating that important pearl mussel populations remain in river reaches that are too deep for safe wading and the status of these deep-water populations remains unknown. There are established protocols for surveying freshwater pearl mussels in shallow water that cannot be used in deeper water. SNH has previously tested a number of potential methods for surveying deep water sites, but only one methodology, scuba diving, proved suitable for surveying moderate to deep-water. However, scuba is very expensive and there are considerable Health and Safety concerns about divers operating in fast moving currents. Through this study, SNH is interested in testing the use of an underwater video camera from a boat, to determine if it is suitable for surveying deep-water sites for freshwater pearl mussels.

Main findings

- In September 2007 four deep-water survey methods using an underwater Spyball video camera were tested to see if they were suitable for surveying freshwater pearl mussels.

- One suitable deep-water survey method was successfully trialled and tested in three Scottish rivers. Live freshwater pearl mussels were found in all three rivers.

- A suitable deep-water 5m^2 spot-check survey protocol, similar to, and comparable with, shallow-water 5m^2 spot-check searches has been developed and successfully tested. The merits of the new survey methodology and its applicability to Scottish situations are discussed.

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1 AIMS

- To develop, recommend and test an underwater video method (or methods) for surveying freshwater pearl mussel populations in deep water (>1m) in three rivers in Scotland.

- Describe the distribution of pearl mussels at those sites surveyed.

2 INTRODUCTION

2.1 Background

During the past 100 years, the freshwater pearl mussel (*Margaritifera margaritifera* (L.)) has declined throughout its Holarctic range to such an extent that it is now listed as an endangered species (IUCN, 1991). Scotland is a global stronghold for the freshwater pearl mussel, a species which is now fully protected under the Wildlife and Countryside Act (1981) (as amended) of Great Britain. It is also listed on Annexes II and V of the EC Habitats Directive (Council Directive 92/43/EEC) and Appendix III of the Bern Convention.

The general decline of the freshwater pearl mussel across its range is well documented (e.g. Young *et al*., 2001a). Several reasons have been identified, one of which has been destructive pearl fishing. Recent estimates suggest that Scotland holds perhaps half of the world's known remaining viable populations (Young *et al*., 2001a; Cosgrove *et al*., 2000). However, even here the majority of populations have declined and many have disappeared completely. Populations of pearl mussels in Scotland are either extinct or no longer viable in almost 70% of historical sites that were occupied 100 years ago (Cosgrove & Young, 1998). Although the remaining populations are now provided better protection by the ban on pearl fishing and other measures, the fate of the pearl mussel in Scotland is by no means secure.

Pearl fishing predominantly took place (although not exclusively), and indeed continues to take place, by pearl fishers wading into shallow water in search of mussels. There are a number of reports indicating that important pearl mussel populations remain in river reaches that are too deep for safe wading. In such rivers, and river reaches, the status of the freshwater pearl mussel remains unknown. In order to adequately inform management of such sites it is important that a suitable survey method is developed.

There are established protocols for surveying freshwater pearl mussel populations in shallow water (Young *et al*., 2001b; Young *et al*., 2003), which are designed for water less than 1m deep. These methodologies cannot be used in deeper water. However, since reproducing beds of pearl mussels have been found at depths of >3m in large rivers (Cosgrove *et al*., 2001), there is an urgent requirement for a standard survey protocol for deep waters. SNH has previously tested a number of potential methods for surveying freshwater pearl mussels in deep water (Cosgrove *et al*., 2001). These methods included using viewing buckets and a borrowscope from a boat, and scuba divers. The study found that only one methodology, the scuba diving survey protocol, proved suitable for the survey of mussels in deep water.

scuba diving was the only method tested that provided data that was directly comparable to standard SNH shallow-water survey protocols.

However, scuba diving is a very expensive means of surveying freshwater pearl mussels and there can be considerable Health and Safety concerns about divers operating in fast moving currents. The work by Cosgrove *et al*. (2001) did not extend to testing the use of a video camera operated from a boat. If such a method can be developed it should allow for deep-water areas of rivers to be surveyed for freshwater pearl mussels from a boat or the river bank. It is acknowledged that the results will not necessarily be directly comparable with some of the existing shallow-water survey protocols (as the camera will not be able to determine the population structure). However, the resulting information about the presence of pearl mussels will allow for better targeting of any future management actions or subsequent scuba diving monitoring effort.

3 METHODOLOGY

The following investigation was carried out with an appropriate Animal Conservation Licence (No. 7443) issued by SNH under the terms and conditions of the Wildlife and Countryside Act 1981.

3.1 Site selection

SNH defined three rivers where the use of the video camera was to be extensively tested from a boat in deep water; Rivers A, B and C. The rivers were coded with letters, due to the continued threat posed by illegal pearl fishers.

3.2 Survey methodology

A team of highly experienced freshwater pearl mussel shallow-water surveyors tested four methods from a 4m flat-bottomed aluminium boat, with a centre consol, outboard motor, RTX GPS and Ohmex Portable Echosounder. The boat was skippered by a qualified and experienced coxswain. The boat requires a suitable (gently sloping) launch site where the vehicle and boat trailer can reach the water's edge safely (Figure 1). The boat trailer is carefully reversed into the edge of the water until the weight of the boat is supported by the water. The boat is untied from the trailer and launched.

Figure 1 4m aluminium boat, trailer and outboard engine at launch site

Such suitable launch sites on rivers are usually limited in number and may even be private launches. The limited availability of potentially suitable launch sites means that discussions with fishery/boating interests and perhaps a pre-survey site visit are necessary.

The video camera tested was the Submertec Spyball Model SB-CZ (Submertec, Rosyth). The Spyball combines a remote control underwater video camera with pan and tilt unit in one compact assembly that can rotate to look 360^o without restriction. The SB-CZ model is fitted with a high resolution colour video camera and 10x optical zoom lens for use in a range of applications where ambient lighting is adequate. An LED light source is also incorporated for use where visibility is reduced (Figure 2). For more detailed information on the Spyball camera and control unit, please refer to the manufacturer's website (http://www.submertec.co.uk).

Figure 2 The Spyball camera with back-up rescue rope to retrieve the camera if the umbilical cable detaches

Being only 160mm in diameter and with a smooth spherical body, the Spyball is designed to be used in areas with delicate features, fast flowing water and/or areas where entanglement is a potential hazard. Variable speed pan tilt, automatic or manual focus, laser focus and two speed power zoom features are controlled remotely on the boat from a video screen control unit (Figure 3).

Figure 3 The video screen control unit used to operate the Spyball camera

The water depth was recorded using the boat's sonar and water flow was recorded using an OTT current meter (No. 85285 Type C2, fitted with a 30mmØ pitch propeller on a 9mmØ rod) from the boat. If and when mussels were found, the time from the video recording was noted, which corresponded to the video footage on the associated DVD.

The following four deep-water survey methodologies were tested in September 2007.

3.2.1 50m^2 transect from moving boat using video camera attached to the end of a carbon-fibre pole

The camera was lowered to the river bed using a specially adapted carbon-fibre pole (extendable up to 5m – Figure 4). The Spyball was focused on the river bed and the boat coxswain slowly manoeuvred the boat 50m upstream to a predetermined point, marked on the bank. One surveyor manipulated the pole to ensure that the camera and pole did not collide with underwater obstructions, under the guidance of a second surveyor in the boat using the video screen control unit.

3.2.2 50m^2 transect from moving boat using video camera on an umbilical cable

The camera was lowered to the river bed using a weighted umbilical cable. The cable had a plastic fin attached (Figure 5), which was recommended by the manufacturer to stabilise the image. The Spyball was focused on, and held slightly above, the river bed and the boat coxswain slowly manoeuvred the boat 50m upstream to a predetermined point, marked on the bank (Figure 6). One surveyor manipulated the umbilical cable to ensure that the camera did not collide with underwater obstructions, under the guidance of a second surveyor in the boat using the video screen control unit.

Figure 4 *Specially designed carbon-fibre pole used for mounting the Spyball camera*

Figure 5 *5m² spot-check survey with Spyball camera attached to an umbilical cable (with blue stabilising plastic fin) being retrieved off the side of the boat.*

Figure 6 50m^2 transect survey with Spyball camera attached to an umbilical cable off the boat. The metal pole with the white disc on top is the boat's sonar rig/GPS.

3.2.3 5m^2 spot-check from stationary boat using video camera attached to the end of a carbon-fibre pole

The boat remained stationary over a potentially suitable survey location using an anchor, whereupon the coxswain used the boat's engine and rudder to ensure the boat held its position in the current. The camera was then lowered to the river bed using a carbon-fibre pole. The Spyball was focused on the river bed and one surveyor slowly made their way from the stern to the bow of the boat holding the carbon-fibre pole against the side of the boat. The surveyor carefully manipulated the pole to ensure that the camera and pole did not collide with underwater obstructions, under the guidance of a second surveyor in the boat using the video screen control unit.

3.2.4 5m^2 spot-check from stationary boat using video camera on a umbilical cable

The boat remained stationary over a potentially suitable survey location using an anchor, whereupon the coxswain used the boat's engine and rudder to ensure the boat held its position in the current. The camera was then lowered to the river bed using a weighted umbilical cable. The cable had a plastic fin attached (Figure 5), which was recommended by the manufacturer to stabilise the image. The Spyball was focused on the river bed and one surveyor slowly made their way from the stern to the bow of the boat holding the umbilical cable against the side of the boat. The surveyor carefully manipulated the cable to ensure that the camera did not collide with underwater obstructions, under the guidance of a second surveyor in the boat using the video screen control unit. Using the Spyball in this way it was possible to view ~0.5 x 1m of river bed below the stern, 4 x 1m along the port side of the boat to ~0.5 x 1m above the bow, giving a total survey area of ~5m^2.

3.3 Standard criteria used for describing and reporting the relative abundance of *M. margaritifera* populations

For conservation purposes, standard criteria are used to describe the relative abundance of *M. margaritifera* populations, and these are usually based on visible shallow-water transect counts of mussels (Cosgrove *et al*., 2000). The relative abundance terms used in this report (Table 1) are therefore based on the recommended terminology and, importantly, are directly comparable to those used to describe other Scottish mussel populations (Cosgrove *et al*. 2000).

Table 1 Standard relative abundance terms and codes for shallow water 1x50m transect and 1x5m spot-check counts.

Visible mussels/spot-check (1x5m)	Visible mussels/transect (1x50m)	Terminology	Abundance code
0	0	Absent	E
1-4	1-49	Rare	D
5-49	50-499	Scarce	C
50-99	500-999	Common	B
100+	1000+	Abundant	A

4 RESULTS

Rivers A, B and C were surveyed between the 6th and 12th of September 2007 by Peter Cosgrove, Lee Hastie, Allan Kelly and Craig Stephenson.

Survey conditions on Rivers A and C were optimal with bright weather, clear water and low water levels. The conditions on River B were variable, with bright weather, relatively clear water, but high water levels following a recent spate. 24 hours before the survey in River B, the water rose >2m as a result of heavy rain in the upper catchment. The water levels and flow also varied considerably during the survey of River B as a result of tidal influences.

4.1 Testing the video camera attached to the end of a carbon-fibre pole, from a moving boat while trying to survey 50m^2 of river bed

4.1.1 Quality of data/footage obtained

A full day was spent trying to film 50m^2 transects in deep water using the Spyball camera attached to a pole that would be directly comparable with shallow-water 50m^2 transects. The speed of the boat was slowed to <0.5 knots in an attempt to obtain good quality images. Unfortunately, after several hours testing this methodology, the images were of such poor quality that it was not possible to determine any substrate features whilst the boat was moving, regardless of speed. Video footage recorded at the slowest speed shows the poor image quality. The image moved too fast for either the manual or automatic focus to adjust to the river bed. Despite testing under several different current and boat speeds, the camera footage was very poor for each, failing to capture any utilisable images. The methodology of using the video camera attached to a carbon-fibre pole was subsequently abandoned for 50m^2 transects.

4.1.2 Logistical issues

The surveyor found it difficult and awkward to manually operate the carbon-fibre pole in the river current from a moving boat. It was physically demanding on the surveyor to stand up and hold the pole with the camera at depth against a strong current. It required constant movement of the upper body, shoulders and arms to maintain the camera in position. The pole could typically only be held for around 5 minutes in a strong current before the surveyor had to rest. The coxswain (in charge of Health and Safety onboard the boat) considered that standing up holding the pole in the moving boat was potentially hazardous, particularly if the camera or pole collided, or became entangled, with an underwater obstruction.

4.2 Testing the video camera on an umbilical cable, from a moving boat while trying to survey $50m^2$ of river bed

4.2.1 Quality of data/footage

A full day was spent trying to film $50m^2$ transects in deep water that would be directly comparable with shallow-water $50m^2$ transects, using the Spyball camera attached to a weighted umbilical cable. The speed of the boat was slowed to <0.5 knots in an attempt to obtain good quality images. Unfortunately, after several hours testing this methodology, the images were of such poor quality that it was not possible to determine any substrate features whilst the boat was moving, regardless of speed. Video footage recorded at the slowest speed shows the poor image quality. The image moved too fast for the manual or automatic focus to adjust to the river bed. Despite testing under different current and boat speeds, the image quality was very poor for each, failing to capture any utilisable images. The methodology of operating the camera from a moving boat on an umbilical cable was subsequently abandoned for $50m^2$ transects.

4.2.2 Logistical issues

The surveyor operating the umbilical cable manually held the camera as close to the river bed as possible before the coxswain moved the boat. Using the camera on an umbilical cable from a moving boat was potentially hazardous, particularly if the camera or cable collided or became entangled with an underwater obstruction. It also became quickly apparent that the Spyball camera was frequently bouncing along the uneven river bed without any control, potentially damaging the camera as well as providing images that bounced quickly from one location to the next. To control the image more, and protect the camera, a screw-in lead weight was added to the base of the Spyball camera. This helped to stabilise the image and protect the camera, but not sufficiently well to produce utilisable images from a moving boat.

4.3 Testing the video camera attached to the end of a carbon-fibre pole from a stationary boat while trying to survey $5m^2$ of river bed

4.3.1 Quality of data/footage

The images obtained were of a poor quality, but were better than any taken from the moving boat. Nevertheless, the footage was relatively poor, usually failing to capture any utilisable images. This methodology was only once successfully trialled on one slack-water section of the River A. After testing on both the rivers A and B, the methodology of using a carbon-fibre pole from a stationary boat was subsequently abandoned for 5m spot-checks because; (i) it was not successfully used in fast currents, and (ii) for logistical and Health and Safety reasons outlined below.

4.3.2 Logistical issues

The surveyor found it difficult and awkward to manually operate the carbon-fibre pole in the river current, even from a stationary boat. It was physically demanding on the surveyor to stand up and hold the pole with the camera at depth against a strong current. It required constant movement of the upper body, shoulders and arms to maintain the camera in position. The pole could typically only be held for around 5 minutes in a strong current before the surveyor had to rest. The coxswain (in charge of Health and Safety onboard the boat) considered that standing up holding the pole while walking along the edge of the stationary boat, no matter how slowly, was potentially hazardous, particularly if the camera or pole collided, or became entangled, with an underwater obstruction.

4.4 Testing the video camera attached to an umbilical cable from a stationary boat while trying to survey 5m^2 of river bed

4.4.1 Quality of data/footage

Excellent and remarkably clear images were obtained from 5m^2 spot-check surveys using the Spyball camera attached to a weighted umbilical cable (and stabilising fin) from a stationary boat (Figures 7, 8 and 9).

Once this method was well tested under different flow conditions and depths etc., it became apparent that the method was suitable under almost all conditions tested, producing usable images and data that could be compared with results from shallow-water 5m^2 spot-checks. The surveyor operating the consol always had to use the automatic focus (with a zoom if necessary) as there was found to be no time to control and adjust the image manually. Often the surveyor operating the control unit needed to cover their head and consol with dark material (e.g. a coat) to reduce surface glare from the consol video screen. As this methodology provided good images under all flow conditions it was selected for use on each of the three rivers.

Figure 7 *Freeze-frame shot of two adult mussels taken by Spyball camera during a 5m² spot-check survey from a stationary boat in River A.*

Figure 8 *Freeze-frame shot of 5-6 adult mussels taken by Spyball camera during a 5m² spot-check survey from a stationary boat in River A.*

Figure 9 Freeze-frame shot of three adult mussels taken by Spyball camera during a 5m² spot-check survey from a stationary boat in River A.

4.4.2 Logistical issues

The main advantage of using a Spyball camera on an umbilical cable from a stationary boat was that the speed the camera moved along the river bed could be controlled by the surveyor moving very slowly along the side of the boat holding the cable (from a sitting position, shuffling along). Having produced usable images, the surveyors tried to replicate the 5m^2 spot-check survey method used in shallow waters. The only potential difficulty lay with trying to survey 5m^2 of river bed from a 4m long moored boat. However, this difficulty was quickly overcome: the video screen control unit operator (who sat at the stern) held the weighted camera/cable 0.5m off back of the boat's stern. Once in place, the camera operator rotated the camera through 360^o before passing the umbilical cable to the sitting surveyor who very slowly moved and pulled the cable upstream (whilst shuffling along the boat) to the bow. The surveyor then stretched an arm out 0.5m from the top of the bow, completing the survey. As the camera was able to examine the 0.5m of riverbed on all sides, this provided a total survey area of 5m^2 (0.5m off stern, 4m along boat side, 0.5m off bow). The duration of the actual survey varied between ca. 2.5 and 5 minutes. The video screen control unit operator was able to regularly rotate the camera through 360^o to look for mussels along the 5m survey length. The images were so clear that under most circumstances, mussels were readily identifiable on automatic focus, which could then be followed up by zooming in to confirm the identification of pearl mussels if necessary.

To control the image more and protect the camera, a screw-in lead weight was added to the base of the Spyball camera. This helped to stabilise the image and was used throughout the testing of the 5m^2 spot-check survey methodology from a stationary boat (Figure 10).

Figure 10 *Lead weight (touching the water) attached to base of Spyball to stabilise image and to protect the camera when pulled/bounced along the river bed*

During the initial testing of this methodology, the wind speed increased and it became more difficult to keep the boat stationary. Despite the anchor, when a strong wind blew the coxswain had to use the outboard motor to hold position. However, the coxswain could do little about any waves or swell which, in turn, lifted and dropped the camera on and off the river bed. The surveyor holding the cable tried to compensate for this by loosening and tightening their grip on the cable, allowing more cable out when the boat was on the crest of a wave and pulling it back in a wave trough. This improved and reduced the image 'bounce' but could not stop it during particularly windy conditions in open and exposed stretches of water (such as occurred on River B at times). Thus, it became readily apparent, that wind speed was an important survey consideration. Such conditions also required a competent coxswain to manoeuvre and hold a steady position in the current and strong wind.

The 5m^2 spot-check with a camera attached to an umbilical cable from a stationary boat also had the advantage of being the safest method to use for the operator/surveyor. It did not require: (i) standing up, (ii) a moving boat, (iii) twisting, or (iv) pushing to hold a pole underwater. Furthermore, potential damage to the camera from being bounced along the river bed was minimised as the boat was stationary and the surveyor moved the camera very slowly (e.g. 1m in 30-60 seconds).

Due to the concentration required by the surveyor operating the Spyball camera via the video consol, it was not possible to accurately count the number of mussels during each 5m^2 spot-check whilst in the boat. This was carried out in the office, where the video footage was transferred from the consol to DVDs in a format that was readily played using Windows Media Player. This has the added benefit of allowing independent third parties to assess the number of mussels present.

4.5 River A survey results

River A was surveyed at one site using the Spyball camera attached to an umbilical cable to conduct 5m^2 spot-checks from a stationary boat. The site is one of the deepest reaches on the river, being ca. 100m long, 40m wide and up to ca. 4m deep.

However, water >1m deep is only found within one 50m section, and so a series of 16 x 5m^2 spot-checks were carried out within this core 50m section. An additional and final spot-check test (spot-check 17) was undertaken in an area of slack current using the Spyball camera attached to the end of a carbon-fibre pole from a stationary boat (Table 2).

Table 2 *River A deep-water spot-checks, September 2007*

Spot-check	Depth (m)	Current velocity ($m.s^{-1}$)	No. of mussels & abundance code
1	2.3	0.60	0, E
2	2.5	0.69	0, E
3	3.5	0.56	1, D
4	3.4	0.17	3, D
5	3.4	0.25	1, D
6	2.9	0.40	2, D
7	2.0	0.14	0, E
8	2.1	0.08	11, C
9	3.2	0.24	9, C
10	1.9	0.40	0, E
11	2.5	0.52	0, E
12	1.0	0.35	0, E
13	1.3	0.70	13, C
14	1.5	0.51	17, C
15	1.8	0.31	75, B
16	1.8	0.31	11-12 dead shells
17	2.7	0.60	4, D

4.6 River B survey results

A long tidal section of River B was surveyed using the Spyball camera attached to an umbilical cable to conduct 5m^2 spot-checks from a stationary boat. The middle-upper tidal reaches of the river held pearl mussels (Table 3).

Table 3   River B deep-water spot-checks, September 2007

Spot-check	Depth (m)	Current velocity (m.s^{-1})	No. of mussels & abundance code
1	1.0	1.0	0, E
2	1.8	1.0	0, E
3	1.9	1.0	0, E
4	2.0	1.0	0, E
5	2.5	1.0	0, E
6	2.1	1.0	0, E
7	2.5	0.5	2, D
8	2.0	0.5	5, C
9	2.1	0.5	0 E
10	2.0	0.5	1, D
11	2.0	0.5	6, C
12	2.0	0.5	2, D
13	2.0	0.5	0, E

The lower-middle tidal area of River B (Table 4) were surveyed but found to be wholly unsuitable for freshwater pearl mussels. It was a wide (150-200m), slow moving, reed-lined and muddy channel. In some areas the water was found to be thick with underwater weed, which precluded the proper use of the camera as the lens quickly became covered in weed and sometimes the camera cable also became tangled.

Table 4 River B deep-water spot-checks, September 2007

Spot-check	Depth (m)	Current velocity ($m.s^{-1}$)	No. of mussels & abundance code
1	2.3	0.39	0 E
2	2.0	0.28	0 E
3	2.5	0.51	0 E
4	2.5	0.46	0 E
5	1.8	0.34	0 E
6	2.3	0.07	0 E
7	2.4	0.06	0 E
8	4.0	0.07	0 E
9	4.7	0.10	0 E
10	2.6	0.08	0 E
11	3.0	0.12	0 E
12	2.5	0.03	0 E
13	2.7	0.13	0 E
14	2.5	0.14	0 E
15	4.8	0.07	0 E

4.7 River C survey results

River C was surveyed using the Spyball camera attached to an umbilical cable to conduct $5m^2$ spot-checks from the outflow of a loch to a point 1.3km upstream where the water became shallow. Working in an upstream direction, spot-checks were undertaken every 100m along the left and right banks of the river channel (Tables 5 and 6).

Table 5 River C deep-water spot-checks (left bank - L), September 2007

Spot-check	Depth (m)	Current velocity ($m.s^{-1}$)	No of mussels & abundance code
1 L	0.9	0.10	0, E
2 L	1.1	0.07	0, E
3 L	2.0	0.04	0, E
4 L	1.6	0.08	0, E
5 L	1.5	0.04	0, E
6 L	1.5	0.04	0 (1 possible), E
7 L	1.5	0.08	0, E
8 L	1.2	0.05	2, D
9 L	0.8	0.03	1, D
10 L	1.3	0.05	4, D

11 L	1.3	0.05	0, E
12 L	2.2	0.03	0, E
13 L	0.4	0.07	0, E

Table 6 River C deep-water spot-checks (right bank - R), September 2007

Spot-check	Depth (m)	Current velocity ($m.s^{-1}$)	No of mussels & abundance code
1 R	0.7	0.05	0, E
2 R	1.7	0.07	0, E
3 R	1.6	0.04	0, E
4 R	1.5	0.08	2, D
5 R	2.1	0.03	0, E
6 R	1.9	0.07	2, +1 dead shell, D
7 R	2.2	0.07	5, C
8 R	1.2	0.06	0, E
9 R	0.8	0.06	0, E
10 R	1.0	0.06	0, E
11 R	1.4	0.04	0, E
12 R	3.5	0.07	0, E
13 R	0.4	0.14	0, E

5 DISCUSSION

5.1 Survey methodology

The survey testing clearly demonstrated that it was possible to use a Spyball camera from a fixed position to undertake $5m^2$ spot-check surveys of river bed. The $5m^2$ boat-based spot-checks are directly comparable to $5m^2$ spot-checks undertaken in shallow water. As with the shallow-water spot-checks, the deep-water spot-checks only determine the presence or absence of mussels on the surface of the river bed and (visible) relative abundance scores for the areas searched, along with a broad-scale assessment of substrate composition (after Wentworth, 1922). Spot-checks do not allow for searches of hidden juvenile mussels and do not provide information on mussel length to determine population profiles. As long as these limitations (which also apply to shallow-water $5m^2$ spot-checks) are recognised, the deep-water $5m^2$ spot-checks provide a valuable tool for surveying deep-water sites under a variety of conditions.

If detailed information is required from deep-water sites, the successfully tested deep-water survey methodology allows areas where mussels are present to be identified and therefore further survey effort can be focused on those areas. These areas could be surveyed by scuba if searches for juveniles or population profiles are necessary.

The main lessons learned from the three survey methodologies that were tested but did not work were:

a) collecting usable footage of mussels on a variable river bed substrate from a moving boat using the Spyball camera was not possible (regardless of speed);

b) the use of a carbon-fibre pole was physically very demanding on the surveyor holding the pole; and

c) the use of the carbon-fibre pole within a small boat was considered potentially dangerous from a Health and Safety perspective.

The coxswain suggested that the Health and Safety concerns could perhaps be allayed by using a pole attached to some sort of pivot fixed to the back of a boat. However this would have required a different (larger) type of boat and a fixed position camera from the back of the boat would not have been able to carry out a $5m^2$ spot-check, so it is difficult to see how to resolve the issue of image speed and focus from a moving boat. From various discussions with other boat operators, the use of fixed cameras from the back of boats (and

ROVs) in the marine environment only tends to be suitable from slow moving craft working over a relatively level sea-bed. With a homogeneous substrate, the issue of rapidly changing substrate height and camera focusing does not appear to be as significant as it is within a heterogeneous river bed, which is typical pearl mussel habitat.

5.2 Comparison with scuba surveys

The use of the $5m^2$ spot-check survey methodology conducted with a Spyball camera has several advantages over scuba surveys (used by Cosgrove *et al*., 2001). These are compared and contrasted in Table 7.

Table 7 Comparison of the logistical considerations between Spyball surveys and scuba surveys

Logistical considerations	Spyball $5m^2$ spot-check survey	Scuba survey
Skill requirements	Little training needed to operate Spyball, but practice advisable. Experienced and qualified coxswain needed	Significant training needed to use scuba
No. of fieldworkers	3 person team	4 person team
Specialist equipment needed	Spyball camera, sonar and 4m boat	Full scuba equipment for divers, camera and back-up vehicle on site
Health and Safety considerations	Trained and accredited boat operator needed	All divers must be trained and accredited. Dive team leader needed on site
Access constraints	Boat must be launched from suitable location. Access permission needed from launch/landing site[1]	Diver team needs back-up vehicle on bank all day. Need to agree access with all riparian owners
Physical surveying difficulties	None, uses outboard motor and anchor in strong currents	Difficult to dive for prolonged periods in strong current
Importance of survey conditions	Low, main constraint likely to be high wind creating waves which 'bounce' camera image. Can use Spyball close to bank and in amongst tree roots and snags	Moderate, main constraints likely to be: (i) current strength, tiring divers, (ii) dangers of divers becoming entangled in tree roots and snags, and (iii) water temperature
Counting efficiency	Unknown, but comparable to shallow-water spot-check results	Unknown, but comparable to shallow-water spot-check and to $50m^2$ transect shallow water surveys (i.e. can search for juveniles and assess status)

[1] It is recommended (and common courtesy) that deep-water surveyors contact and liaise with fishing interests (e.g. local fishery board) when planning and undertaking survey work.

Logistical considerations	Spyball $5m^2$ spot-check survey	Scuba survey
Surveyor competency	Experienced pearl mussel surveyors needed to use Spyball	Divers need pearl mussel survey training to undertake surveys
Area of coverage	Can survey 2 to 2.5km of river per day	Likely to survey less than 2 to 2.5km per day, especially in strong current
Independent verification	All survey counts recorded on video	All survey counts can be recorded by specially housed camcorder
Limitations of survey	Provides only presence/absence and relative abundance data	Provides presence/absence and relative abundance data. Can also be used for detailed $50m^2$ transect surveys to determine population profile and status.
Equipment cost	Relatively low (e.g. Spyball costs £125 per day to hire or ~£10,000 to purchase (ex VAT)). Additional costs for boat and operator hire	Typical 4 person dive team hire costs ~£1,500 per day.

Comparisons with other potential survey methods, that were also not included in the work by Cosgrove *et al*. (2001), such as ROVs, have not been undertaken in the current report as other alternative survey methods were not tested in rivers.

5.3 Suggested deep-water survey protocol

As with shallow-water freshwater pearl mussel surveys, there are a variety of situations where deep-water surveying for freshwater pearl mussels may be required. These can usually be divided into two categories: (i) broad-scale surveys of large areas of river (e.g. where several kilometres of deep-water survey information is required); and (ii) detailed localised surveys over small discrete distances of river bed (e.g. a deep pool). The former surveys are often required to provide base-line information about the distribution of pearl mussels within a river catchment. The latter surveys are often required where small-scale site-specific information is required (e.g. as part of an ecological assessment of a proposed river engineering development). The $5m^2$ spot-check method tested is suitable for both of these situations, providing information on the presence or absence of pearl mussels at particular locations as well as relative abundance data on visible pearl mussels.

5.3.1 Broad-scale survey

To correspond with the way that SNH conducts shallow-water broad-scale surveys, the boat should begin surveying at a defined $5m^2$ spot-check location and work upstream stopping every 100m as far as a defined upstream limit. At each survey location the surveyor lowers the Spyball camera over the side of the boat on the weighted umbilical cable and slowly carries out one $5m^2$ spot-check. Depending upon the size of the river, this could also be carried out near the left and right banks (as was carried out on River C), providing a series of paired $5m^2$ spot-checks every 100m up a river section. If the river is particularly large, it may be possible (and desirable) to survey a mid channel $5m^2$ spot-check too, providing 3 spot-checks per 100m of river.

Based on the experiences of surveying the 1.3km of River C (with paired left bank/right bank spot-checks every 100m), it should be possible to survey 2-2.5km of river using this methodology per day (assuming there is no need to launch the boat more than once). It should be noted that the logistics of setting up equipment and launching a boat are a significant additional time constraint.

5.3.2 Detailed localised survey

Several $5m^2$ spot-checks could be carried out if information is required for a relatively small localised area. This type of information is relevant to inform assessments of proposed river engineering developments, where the water is too deep for standard shallow-water surveys. Where detailed information may be required it is important to survey sufficient areas of the river bed to avoid reporting false negatives. Furthermore, surveyors, when undertaking what may amount to a continuous survey of a defined area larger than a $5m^2$ spot-check, need to be aware of the potential risk of resurveying the same pearl mussels/area of river bed.

It should be recognised that the status of a deep-water pearl mussel population (i.e. recruiting, functional etc.) cannot be determined from a Spyball camera from a boat because an assessment of the population structure, including the presence of juveniles, would be needed. It is likely that SNH would want developers and their surveyors to provide information on population structure as part of an assessment of a particular proposal, wherever it is reasonable for that information to be gathered.

Based on the experiences of surveying the large deep pool on River A, it should be possible to survey 2 or 3 deep-water pools within reasonably close proximity of one another, using this methodology, per day. However, it should be noted that the logistics of setting up equipment and launching a boat are a significant additional time constraint.

5.3.3 *Boat Health and Safety issues*

There are significant Health and Safety considerations when working in and around water and especially from a boat. Launching the boat requires a shallow, gently sloping gradient. During this project, finding such sites was generally not a problem, but situations can be envisaged where suitable launch sites may be limiting. Life jackets should be worn at all times and an experienced and fully trained and licensed boat handler/coxswain should control the (fully equipped) boat during survey work. Three people are needed in the boat, the coxswain, the consol operator (who moves the camera angle and records the video footage) and the Spyball surveyor (who moves the cable along the side of the boat).

5.3.4 *Survey conditions*

Unlike shallow-water surveys, water level may not prevent the survey but turbidity can. Deep-water surveying can be undertaken on cloudy days, as the use of the LED light in deep water illuminates the surrounding substrate. The main weather constraints relate to wind speed which generates swell and wave action. If the water is choppy, the camera image bounces as the cable and camera are lifted up and down on each wave. Additionally, it is also more difficult for a coxswain to control the boat and maintain a static position in windy conditions.

5.3.5 *Equipment use*

It is recommended to use the Spyball camera and associated equipment as detailed in the Methodology chapter (section 3.2.4). Very slow movement of the camera obtains the best footage, with the lens angled forward into current, looking ahead at approximately 90^o from the substrate. If the camera lens faces directly down onto the river bed the image tends to move too quickly and has a reduced field of view. The best coverage of the search area is obtained when the camera operator stops the surveyor moving the cable and scans the camera through 360^o using the video screen control unit to look for pearl mussels every metre along the $5m^2$ spot-check.

To enable video footage to be easily analysed it is recommended that a large writing board is used to record site details. The camera is switched on and records an image of the writing board at each spot-check prior to the camera being lowered under water.

5.4 River A deep-water mussel population

On the 29th of September 2001, a series of deep-water trials using scuba were carried out on River A to develop suitable protocols for freshwater pearl mussels in deep-water areas (Cosgrove *et al.*, 2001). Pearl mussel beds (with many juveniles) were discovered at depths of 3 to 4m by divers surveying a deep pool. The divers noted highly variable substrate, some suitable and much unsuitable within the survey area. Four $50m^2$ dive transects were surveyed across suitable habitat areas in the deep pool and the number of recorded mussels varied between 74 and 108, with an abundance code of C (scarce) (Cosgrove *et al.*, 2001).

The results from the present Spyball camera survey are remarkably similar to the 2001 scuba surveys of the same site, with spot-checks confirming the patchy distribution of mussel habitat and mussels in the same deep pool. The average density of mussels from the four 50m diver transects undertaken in 2001 was 1.73 mussels m^{-2}. The average density of mussels from the 15 x $5m^2$ Spyball spot-checks was 1.76 mussels m^{-2}. Four spot-checks (8, 9, 13, 14: Table 2) had an abundance code of C (scarce). Higher densities of mussels were found during one spot-check (15), with an abundance code of B (common). Despite the results of the current survey not including any pearl mussels buried in the river bed, it suggests the two survey methods are directly comparable.

River A has been the subject of an extensive survey for freshwater pearl mussels using the standard shallow-water methodology. That survey recorded many areas as being too deep to survey using the shallow-water methodology. Until the species was afforded complete legal protection in 1998, the shallow-water areas of the River A were heavily exploited annually by pearl fishers. It has long been considered that important deep-water refuge populations may exist and that most of these would not have been exploited to the same extent as shallow-water populations. The deep-water survey methodology successfully tested at the deep pool, provides the opportunity to establish if pearl mussels are present in these deep-water areas of River A (and other Scottish rivers) for the first time using a cost-effective survey method.

5.5 River B deep-water mussel population

Between the 6th and 10th of September 2007, the tidal reaches of River B were surveyed using the deep-water $5m^2$ spot-check methodology. No mussels were found in the lowest tidal reaches, where the substrate was found to be unsuitable. The survey conditions varied considerably during this period with both high water due to spates and extreme tidal movements. Live freshwater pearl mussels were found at two discrete locations in the mid-upper tidal reaches. At one of these locations (spot-checks 7 to 13 in Table 3) seven 5m^2 spot-checks were carried out and mussels were recorded in five of these. The average relative abundance of mussels in the 35m^2 surveyed was 0.53 mussels m^{-2} with abundance codes of D to C (Rare to Scarce).

Although no live mussels were recorded in other tidal areas of River B, the survey reach was large (ca. 20km long) and only a tiny area of the overall area of potentially suitable habitat was searched. Thus, an absence of mussels from other tidal areas does not mean that pearl mussels were absent from these deep-water areas. To ascertain the presence of the pearl mussels in this deep-water reach, a broad-scale survey (Section 5.3.1) from the first area of potentially suitable habitat should be undertaken upstream to the limit of tidal influence.

5.6 River C deep-water mussel population

River C is relatively short with a deep lower reach that flows into a loch. There are several historical pearl mussel records dating back to 1885 (Cosgrove, 1997). Most of the historical records referred to a rapidly declining mussel population, directly attributed to intensive destructive pearl fishing.

During the national freshwater pearl mussel survey, Cosgrove and Young (1998) surveyed a short shallow-water stretch of the river, but found no live mussels, despite the substrate and water quality appearing suitable. Cosgrove and Young (1998) concluded that pearl mussels appeared extinct in the shallow-water areas, but acknowledged that their search was poor in terms of coverage of deep-water areas. As much of the river was not searched and recent records of shells from the river had been reported, Cosgrove and Young (1998) concluded that River C probably had a functionally extinct population as a result of heavy pearl fishing.

Twenty-six deep-water 5m^2 spot-checks were carried out in River C and live pearl mussels were recorded in seven of these spot-checks. The average relative abundance of mussels in the 130m^2 surveyed was 0.12 mussels m^{-2} with abundance codes of D to C (Rare to Scarce). The deep-water section was 1.3km long and ca.15m wide. This equates to 19,500 m^2 of potentially suitable substrate. Using the relative abundance figure of 0.12 mussels m^{-2}, and using a very crude calculation (and also assuming pearl mussels are equally distributed through the survey reach), this provides a possible population of 2,340 individuals. Due to the limitations of the spot-check methodology, it cannot be said if the population includes juveniles.

The survey findings from River C are the first confirmed records of live pearl mussels from this river since the mid 1990s (Harris, 1994). The presence of pearl mussels scattered throughout the deep water (Tables 5 and 6) suggests that a modest, remnant pearl mussel population survives in the lower reaches of River C. Based on present information, it is believed that this is the only known remnant pearl mussel population in this part of southern/central Scotland. Given that the largest recorded declines in freshwater pearl mussels have occurred in the south and west of Scotland (Cosgrove *et al*., 2000), River C is considered a nationally important site. It is possible that further detailed survey work in upstream shallow-water reaches of River C might find localised pockets of mussels (including juveniles) that were missed by pearl fishers and surveyors during the national survey. Since the range of pearl mussels in Scotland has contracted so severely, it is considered important to assess the conservation status of the freshwater pearl mussel population in the full River C catchment. This would require a combination of survey approaches including shallow-water survey, deep-water survey and possibly using scuba divers to search for juvenile mussels in deep-water.

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