The Operation of Rotary Screw Traps in the River Spey 2008

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SUMMARY

Two rotary screw traps were installed on the mainstem Spey and proved to be powerful sampling tools for salmonid smolt populations. Data on the run time and age structure was determined along with the effects of environmental parameters such as water flow and temperature. Initial application of mathematical models allowed population estimates to be created although there is still a considerable amount of work to do to refine this approach. The RSTs provided excellent data for salmon smolts and although trout smolts were regularly caught the traps it did not appear to be as good at trapping them. Data on other fish species was also collected providing some new information and allowing comparison with environmental factors.

The use of RSTs in sampling smolts is recommended even in large water bodies such as the Spey. The data provided for salmon smolts is high quality and may in due course help determine the status of the salmon within the Spey SAC.

1. OBJECTIVES

The aim of this study was to:

1. Provide estimates of salmon and sea trout smolt production for the River Spey,
2. Collect baseline data on size, age and run time salmon and sea trout smolt runs,
3. Collect additional data on other species such as minnows, eels, lampreys that may be obtained as a bycatch.

2. INTRODUCTION

The River Spey is a Special Area of Conservation (SAC) for four species: Atlantic salmon (*Salmo salar)*, otter (*Lutra lutra*), sea lamprey (*Petromyzon marinus*) and the freshwater pearl mussel (M*argaritifera margaritifera*). The Spey salmon population supports long-term average catches of around 9000 fish per annum and the sport fishery brings considerable economic benefits to the local and national economy. It is essential that every effort is made to protect and where possible enhance the numbers of juvenile salmon produced by the Spey. To facilitate this high quality data is required to monitor the status of the salmon stocks.

Smolt data is considered to be the best measure of the health of salmon stocks in the river, but is hard to come by and usually requires the construction of an instream trap. Although this has proved successful in many areas it often requires a considerable amount of costly river engineering and has high staffing costs. For large wide fast flowing rivers such as the main stem of the River Spey it is not realistic and so rotary screw traps (Figures 1a and 1b) may offer an alternative approach.

Traps of this kind have been used extensively in Canada and the USA and are now becoming established in the UK. They offer several advantages; the trap requires little engineering other that a suitable anchor point, it is relatively moveable from site to site and will operate across a range of flows.

Two Rotary traps were trialed on the lower Spey during 2005-2007 and proved relatively successful. Results are presented in Laughton, Burns and Reid (2008).

This reports details the results from the operation of the two rotary screw traps in 2008 on the lower River Spey.

3. MATERIALS AND METHODS

Figure 1a: Rotary screw trap installed at Brae Beat 2, lower River Spey 2005-08.

Figure 1b: Rotary screw trap installed at Brae Beat 4, lower River Spey, 2006-08.

3.1 Trap Installation

The two 6ft rotary screw traps (RST) were installed in the lower Spey at Brae Beat 2 (332850 854900) and Brae Beat 4 (333300 857100) in accordance with trials from 2005-2007 (Laughton et al. 2008).

The traps are constructed with two large floats supporting a rotating drum in the centre. The drum faces upstream and is turned by the river flow. An internal screw allows any smolts entering the drum to pass freely into a holding box at the rear of the trap with out being removed from the water. Traps were anchored to the river bank by chain and rope attached to substantial steel girders at Brae Beat 2 and galvanised steel posts secured into rock revetments at Brae Beat 4.

Both traps were inspected daily, generally in the morning, and captured fish were removed for analysis. Traps were cleaned daily using brushes or on occasion a power washer.

Captured fish were removed from the holding box by dip net. Fish were anaesthetised (benzocaine) and species identified. Fish length was measured for all fish captured and a small sample of scales for age determination was collected from every tenth salmon and trout captured. All salmon and trout were assessed visually for there condition and classed as smolt, parr, brown trout, etc.

A proportion of salmon and trout smolts were marked using a spot of Alcian Blue dye for mark re-capture estimates. These fish were then transported upstream approximately 0.5 - 1km before release. Subsequent smolt catches were then examined for recaptures of marked fish. Initially different patterns of marks were used on different days allowing time between release and recapture to be estimated.

3.2 Environmental Data

River level data was recorded daily from a stage post installed close to the rotary screw trap. Spot temperature measurements were also taken daily generally between 08:00 and 11:00hrs each day. From 26th May 2005 onwards a Vemco Minilogger was used to collect temperatures on an hourly basis.

4. RESULTS

4.1 Fish Capture 2008

Table 1: Number, Mean Length and Size Range of each species caught at Brae Beat 2 (RST 1) between March and June 2008.

Fish Type	Number	Mean Length (mm)	Size Range (mm)
Salmon Smolt	2461	125	68 - 169
Salmon Parr	17	80	66 - 109
Salmon Fry	2	53	47 - 59
Trout Smolt	148	152	86 - 228
Trout Parr	5	80	74 - 88
Minnow	48	65	51 - 83
Lamprey (Brook)	8	122	103 - 255
Eel	9	245	126 - 316
Stickleback	2	45	41 - 48
Rainbow Trout	1	391	391
Pike	1	121	121

Table 2: Number, Mean Length and Size Range of each species caught at Brae Beat 4 (RST 2) between March and June 2008.

Fish Type	Number	Mean Length (mm)	Size Range (mm)
Salmon Smolt	4029	122	64 – 163
Salmon Parr	22	75	65 - 124
Salmon Fry	1	52	52
Trout Smolt	104	141	84 - 201
Trout Parr	6	84	68 – 101
Minnow	19	60	53 - 85
Lamprey (Brook)	15	124	93 – 327
Eel	8	315	187 - 583
Stickleback	1	39	39
Rainbow Trout	-	-	-
Pike	4	139	95 -160

Tables 1 and 2 indicate that eight species of fish, salmon, trout, minnow, eel, lamprey, stickleback, pike and rainbow trout, were captured during 2008. Salmon were the most abundant followed by trout and minnows. The Rainbow trout was a surprise catch on the 31st of March, and is likely to have originated from one of the put and take fisheries further upstream.

Salmon smolts ranged from 68mm to 169mm and mean length was 123mm. Less trout smolts were captured but exhibited a wider length range, 84mm to 228mm and a longer mean length of 147mm.

4.2 Salmon and Trout Smolt Age Patterns

Scales samples were collected each year from a proportion of the smolts captured. Approximately every tenth smolt captured throughout the study at RST1 was sampled and Table 5 indicates the percentage of scale samples obtained from the smolts captured in each year.

Table 1: Proportion of the smolts captured which were samples from scales 2005-08.

Year	Scale Samples % Salmon	Scale Samples % Trout
2005	11	75
2006	6	14
2007	3	6
2008	8.9	25

Table 2: Age classes determined for salmon and trout smolts at Brae Beat 2 during 2008.

Species	Age (years)				No Age Determined	Total
	1	2	3	4		
Salmon Smolts	2	137	57	1	12	209
%	0.9	65.5	27.3	0.5	5.7	-
Trout Smolts	-	15	11	3	8	37
%	-	40.5	29.7	8.1	21.6	-

Table 4 summarises the age classes of smolts captured during 2008. Age data was not available from a small percentage of salmon and trout due to scales being replacements. The table shows that the majority (65%) of salmon smolts were 2 years of age with 3 year old salmon being the second most abundant. Likewise, the most common age for trout smolts was two years with 40.5 of the scaled smolts followed by 29.7% coming in at 3 years of age.

4.3 Salmon Capture and Environmental Parameters

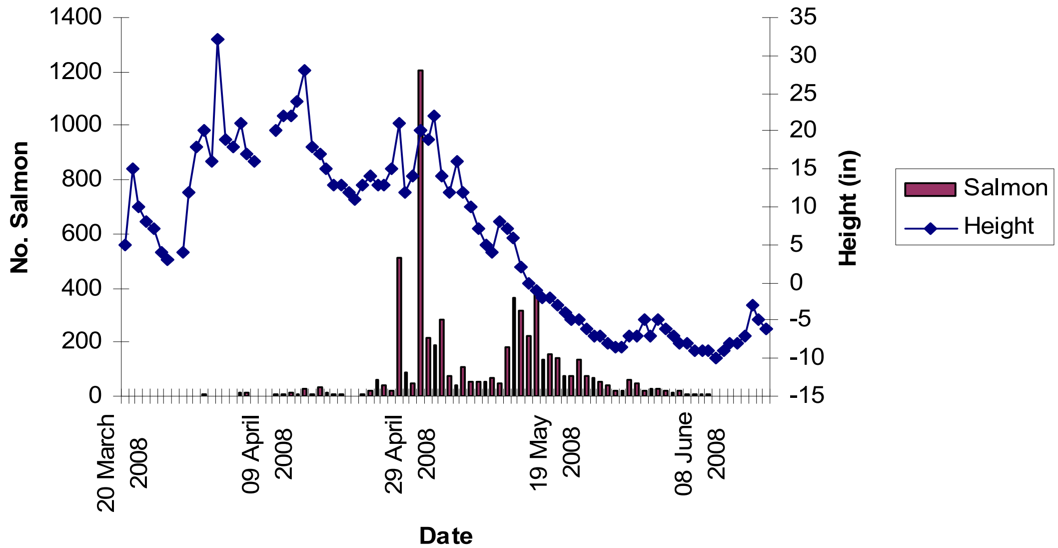

Fig.2: Salmon Smolt capture and River Height from March to June 2008.

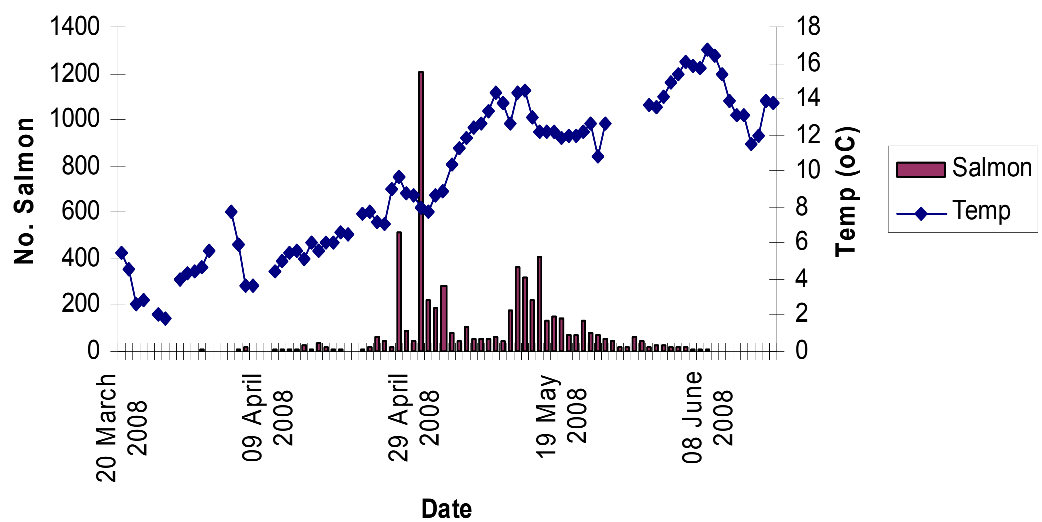

Fig. 3: Salmon Smolt Capture and River Temperature (°C) from March to June 2008.

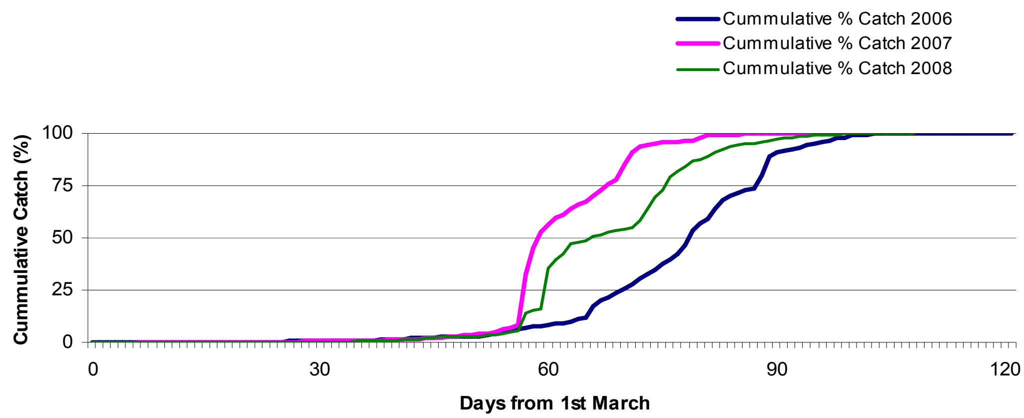

Fig 4: Cumulative salmon smolt catch (%) and time from 1st March in 2006 to 2008.

Figure 4 compares the cumulative smolt catch with the time from 1st March in 2006 to 2008. Data from 2005 is not used since only the latter part of the smolt run was sampled. Figure 16 indicates that there is a substantial difference in run time between the three years. During 2006 the run extended over a longer period with 50% of the catch being reached at 79 days after the 1st Match, while in 2007 the run was shorter duration and 50% of the catch was reached in only 59 days from the 1st March. In 2008, 50% of the catch was reached after 67 days. The cumulative catch data is further explored with temperature in Figure 5. The natural log of cumulative catch in 2006 and 2007 was plotted against natural log of river temperature.

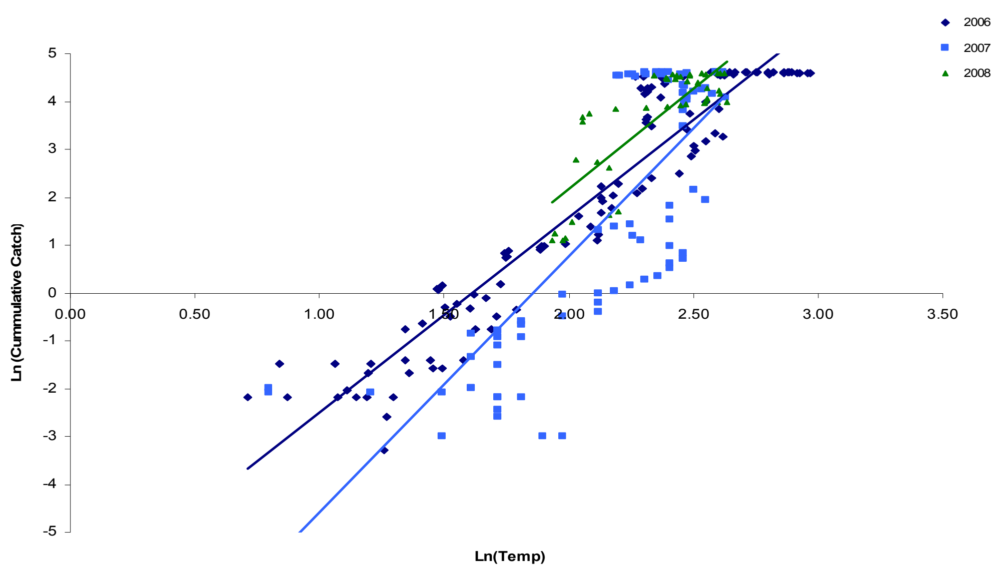

Fig 5: Ln(Cumulative catch) plotted against Ln(River temperature (^oC)) for 2006 to 2008.

From Figure 5 there is a clear relationship between catch and temperature with increasing temperatures in all three years leading to increased catch. The linear relationship between catch and temperature in 2006 was strong (Ln_{Catch} = 4.072(Ln_{temp}) – 6.5645, R^2 = 0.91) but not so strong in 2007 (Ln_{Catch} = 5.3519(Ln_{temp}) – 9.9459, R^2 = 0.63). In 2008, the linear relationship was again not as strong as 2006 (Ln_{Catch} = 4.1934 (Ln_{temp}) – 6.213, R^2 = 0.6338). This may be accounted for by the better temperature data collected in 2006. It should be noted that low flow affected trap operation towards the end of the 2008 run, especially at RST2. As suggested by Jonsson and Ruud-Hansen, (1985) the differences in cumulative catch illustrated in Figure 4 may well be due to differences in river temperatures between the two years.

Estimating the Smolt Run for the Spey

4.3 Petersen Mark Recapture Model

To estimate the salmon and trout smolt run from the Spey a mark-recapture scheme was initiated. Throughout the spring sampling periods a proportion of both salmon and trout smolts were marked using a simple Alcian Blue dye mark, transported approximately 1km upstream and released. The numbers of marked smolts recaptured were then recorded. Initially a simple Petersen mark-recapture equation (Volkhardt, *et al,* 2007) was used to estimate the overall population as follows,

$$N_i = n_i (M_i/m_i)$$

Where:

N_i = Estimated number of downstream migrants during period i

n_i = Number of fish capture during period i

m_i = Number of marked fish captured during period i

M_i = Number of fish marked and released during period i

This equation also provides a measure of trap efficiency e_i as follows,

$$e_i = (m_i/M_i)$$

Table 5: Salmon smolt run estimates for the River Spey for 2005 to 2008 using Petersen mark-recapture method (from Volkardt, *et al* 2007).

Simple Petersen Recapture Model					
Year	Total Salmon Smolts Captured (n_i)	Marked Smolts (M_i)	Marked Smolts Recaptured (m_i)	Estimate of Population Size (N_i)	Trap Efficiency (e_i)
2005	2199	1135	4	623966	0.004
2006	5302	2752	9	1621234	0.003
2007	8035	4884	64	613171	0.013
2008	6490	6087	53	745370	0.009

Table 6b: Trout smolt run estimates for the River Spey for 2005 to 2008 using Petersen mark-recapture method (from Volkhardt, *et al* 2007).

Year	Total Trout Smolts Captured (n_i)	Trap Efficiency (e_i)	Estimate of Population Size (N_i)
2005	195	0.004	55331
2006	255	0.003	77973
2007	358	0.013	27320
2008	273	0.009	30576

4.6.3 Carlson, Coggins and Swanton (1998) Model

Volkhardt *et al,*(2007) offers further models for estimating smolt production and in particular a model developed by Carlson, Coggins and Swanton (1998) may provide a better fit to the experimental structure used on the Spey. This model assumes that researchers are using a single trap marking a portion and re-releasing them upstream. The recaptured marked smolts are then accounted for in the modelling equations and confidence limits are also readily calculated. Carlson *et al* (1998) advocate the following equations to estimate total production **U**, associated variance **Var(U)**, and 95% confidence limits,

$$U_i = \frac{u_i (M_i + 1)}{m_i + 1}$$

Where:

U_i = Number of unmarked fish migration during discrete period i

u_i = Number of unmarked fish captured during discrete period i

$$Var(U_i) = \frac{(M_i + 1)(u_i + m_i + 1)(M_i - m_i)u_i}{(m_i + 1)^2(m_i + 2)}$$

$$95\%\ CL \qquad U \pm 1.96\sqrt{V(U)}$$

Table 17: Salmon smolt run estimates for the River Spey for 2005 to 2007 using Carlson *et al* (1998) mark-recapture methodology (from Volkhardt, *et al* 2007).

Year	Salmon Smolts Captured (n_i)	Marked Smolts (M_i)	Recaptures (m_i)	Unmarked Smolts (u_i)	Estimated Population Size U_i	95% CL
2005	2199	1135	4	1064	241741	187289
2006	5302	2752	9	2550	702015	399351
2007	8035	4884	64	3151	236810	45883
2008	6490	6087	53	403	45435	3066

Table 17 illustrates the salmon smolt output for the Spey using the Carlson *et al* (1998) model for the 2005, 2006, 2007 and 2008 sampling seasons. Since no marked trout smolts were recaptured the model is not used for trout estimations. Again data from 2005 was only collected for part of the smolt run but is also included to illustrate the methodology. Data for 2005 and 2006 is for RST1 only while data from 2007 is for RST 1 and RST2 combined.

5. DISCUSSION

The use of rotary traps to estimate smolt outputs has increased considerably in the last few decades. The approach was initially developed in the USA and Canada (Volkhardt, *et al* 2007) and adopted in the UK during the 1990s. This report details the establishment of two rotary screw traps on the River Spey during 2008.

The traps were maintained and operated by two members of staff. However, during periods of high smolt passage additional staff was required to deal with the high volume of fish. For safety purposes a third dedicated staff member would be desirable.

Nine species of fish were captured by the trap, including salmon, trout, minnow, eel, stickleback, Rainbow trout, pike, river lamprey and Brook lamprey. Salmon smolts were the most abundant followed by trout smolts and minnows. A few adult salmon and sea trout were also captured along with various other age classes and forms including finnock and kelts. One of the most pleasing surprises was the capture of an adult river lamprey which, to our knowledge, is the first definite report of one in the Spey. The capture of juvenile pike was also unexpected this low down the river. The likely origin of these pike is from a backwater area a short distance upstream of the trap. It seems likely that some adult pike have moved down from further up the Spey and spawned there.

The mean length of salmon smolts captured in the mainstem ranged from 122mm in 2005 to 125mm in 2006-07. This is similar to data from other Scottish rivers such as the North Esk where the mean length in ranged from 120mm to 130mm. (Shearer, 1992). Shearer (1992) further indicates that salmon smolts will vary in length and age structure from through out a large catchment with those originating from upper areas often being longer and older than those from lower down. He also indicates that the mean age of smolt varies through out the season with the mean age of smolts older in April than in May. Spey smolts ranged from 1 year olds through to 4 year olds and the majority were from the 2 year old age class. Older smolts were larger than younger ones and this pattern was consistent throughout each month of the salmon smolt run. However, unlike Shearer (1992) there was no consistent pattern regarding the mean salmon smolt age each month. Indeed one year old smolts were caught in March and April while four year olds were caught in May and June. However, the current scale sampling programme only takes one sample from every tenth smolt plus some unusually large or small smolts. This provides a good sample during the main run but additional samples during the early and latter parts of the run may provide an improved picture of age structure.

Elliot (1994) indicates that sea trout smolts range from 140mm to 250mm for the British Isles and the size range observed for the Spey is generally similar although some quite small trout smolts were also recorded (<120mm).

Three age classes (2, 3 and 4 year olds) of trout smolts were generally captured and the majority were 2 and 3 year olds. A single 1 year old was captured in May 2007. The older smolts were larger than the younger ones and this was consistent across each month in all sampling years. There was a pattern in the mean monthly age with an increase from March to May and then decline in June. This appears to differ from previous studies on sea trout smolts such as Le Cren (1985) where the older smolts are observed to migrate earlier.

This difference for sea trout smolts and the additional lack of pattern for salmon smolts ages may simply reflect the size of the Spey. Growth is related to temperature and the older, larger smolts will originate from the headwaters of the Spey. The distance to travel down to the lower Spey is considerable and so they may only reach the trapping area at a similar time as those smolts originating from the lower reaches.

Smolt capture was generally during the night and on the occasions when the trap was inspected through the day no significant numbers of smolts were present. A number of studies have indicated that salmon smolts largely migrate during the night (Thorpe, Ross, Struthers and Watts, 1981; Moore, Ives, Mead and Talks, 1998) and the pattern of capture here generally supports this. However, smolts have been observed migrating through daylight hours on the Spey. During underwater filming while testing an acoustic fish counter in the lower Spey shoals of smolts were filmed swimming through the acoustic beam (Brotherston, 2002). The smolts may well be able to see the rotary trap during the day and so avoid it. Some further work in this area is required to ensure the trap is not missing smolts during the day time.

The capture rates of salmon and trout smolts both showed a relationship with environmental parameters such as water flow and river temperature. More smolts were captured shortly after spates than in periods of stable or falling water flows. This is similar to other studies such as Allen (1944); Hvidsen, Jensen, Vivas, Bakke and Heggberget, (1995).

This study also indicated that temperature played a part in smolt migration. Capture rates were greater when river temperatures rose above 10^{O}C and when good temperature data was available, as in 2006, a strong relationship between temperature and cumulative smolt capture was evident similar to that described by Jonsson and Ruud-Hansen (1985). Although temperature data wasn't as robust in 2007 this helped to explain some of the difference in the salmon smolt run time and duration between 2006 and 2007. Both water flow and river temperature are clearly important factors in the timing of the smolt migration, other factors such as moon phase and social interaction were not explored here but have also been cited as important factors Hvidsten *et al*, (1995), these may be examined further as the operation of the traps continues on the Spey.

One of the key aims of this study was to estimate the numbers of salmon smolts originating from the Spey. This has been attempted previously by using results from traps in the Spey catchment at Spey Dam, the Cally Burn and River Fiddich (Spey Fishery Board, 2005). From these traps it has been estimated that the maximum smolt output ranges between $2/100m^2$ and $5/100m^2$ of riverine habitat, with lower output at higher altitudes. Similar figures have been found by FRS on the Girnock Burn, Diver Dee, and by the Conon Fishery Board on the River Brahan (*Mckelvie, S. pers com.*). Juvenile surveys suggest that most of the suitable habitat within the naturally accessible area is well populated by juvenile salmon, and therefore maximum smolt output is probably being maintained. The accessible area available to for salmon to spawn is estimated at 11.06 million m^2 and assuming an optimal output of 5 smolts/100 m^2 the Spey may be producing 553,100 fish annually.

Two models were used to provide an estimate from the mark-recapture technique employed in the current study. The simple Petersen mark-recapture model as illustrated in Volkhardt *et al* (2007) was initially tested and provided encouraging results. The Petersen model depends on a number of assumptions including, the population is closed, all fish have the same probability of re-capture, all fish have an equal probability of capture in the first sample and similarly in the second sample, marking does not affect the catchability, fish don't lose their marks, and all recovered marked fish are reported. Not all these criteria are adequately met. It is debateable if a migratory smolt population can be considered as a closed population. In general we assume that catchability remains the same between each sample and we are confident that the dye marks used will remain on the fish for the short time period required. Trap operators were experienced in marking techniques and although some may have been missed during periods of high capture numbers, losses due to lack of observation is not thought to be significant. However, the Petersen model did appear to be well above the area based estimate for the Spey. This approach provides and initial insight but is perhaps too simplistic (Seber, 1982).

An alternative model is offered by Carlson *et al* (1998). In our study smolts were marked and re-released above each trap in this case the marked fish should not be included in the population estimate. In 2007 for example when both traps were operated the salmon smolt run was estimated at 236,810 smolts, confidence limits were quite tight indicating that the approach may be more robust. However, this is considerably lower than the area based study (Spey Fishery Board, 2005).

Trap efficiency varied considerably between the two locations with the lower trap RST2 proving to be the more efficient in terms of recaptured marked smolts. Trap efficiency can also vary throughout the sampling period (Schwarz and Dempson, 1994; Thedinga, Murphy, Johnson, Lorenz, and Koski, 1994) and can be related to environmental conditions such as water flow (Volkhardt, *et al* 2007). This provides a relationship which allows the prediction of catches to be developed and this can be then utilised when the trap is not operational due to debris jams etc. Inclusion of these estimates would further improve the overall population estimate. However, further data across a wider range of flow rates is required before a robust relationship of this kind can be fully developed for the Spey.

The model approaches used here illustrate some of the problems associated with attempting to estimate large populations from partial trapping. Many factors including environmental and man-made influence the results of the traps and the estimated population. In addition the trap set up and project design is important. The existing Spey set up does not quite match the requirements for the Carlson, *et al* (1998) model. Although this model addresses the issue of re-releasing marked smolts upstream of a trap the existing Spey set up includes two traps. Our approach was to mark fish from both traps and release them above their respective traps of capture. Marked smolts from the upper trap could be captured in the lower one and this could affect the overall estimations. However, different marks were used for each trap and where possible the estimations were adjusted accordingly. The data from both traps was combined before applying the model and there may be merit in treating each trap as a separate unit. Further consideration to the sampling design and trap set up is recommended. Other modelling approaches are also available (Mantyniemi and Romakkaniemi, 2002) and further exploration of these may also be fruitful.