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Improving the Accuracy of Atlantic Salmon Conservation Limits in SW Scotland

For

EMFF

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Summary

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Atlantic salmon, Conservation Limits, Angling Effort, Exploitation Rates, Water of Luce, River Bladnoch

Background

In recent decades, the abundance of Atlantic salmon in Scotland has declined. As a result of this decline, the Scottish Government in 2016 introduced conservation limits to conserve and protect Atlantic salmon stocks by controlling angling and netting exploitation rates. Marine Scotland Science (MSS) created a model to assign a conservation limits category to each river in Scotland based on the number of Atlantic salmon eggs available and the egg requirement of each river. This technique has been relatively well used internationally. However, designing a model which accurately assigns a conservation limit category to each river in Scotland is complex due to regional variation in many factors. Currently, the model assumes angling effort and exploitation rates to be the same for every river in Scotland. Therefore, this study aimed to investigate exploitation rates and angling effort on two lightly fished rivers in Scotland. This study would also collect biological data of Atlantic salmon.

Main findings

- Biological data was collected from 16 Atlantic salmon caught on the River Bladnoch. The fork length of the Atlantic salmon ranged from 558 mm – 776 mm.
- Scale samples were also collected from the 16 Atlantic salmon and were used to establish the age of Atlantic salmon when they smolted and how many years they remained at sea before returning to spawn. The majority of Atlantic salmon were two years old when they smolted and had returned to spawn as grilse (i.e. have spent one year at sea). Further biological data should be collected from Atlantic salmon to investigate this further.
- This study also aimed to investigate exploitation rates of Atlantic salmon on the River Bladnoch and Water of Luce. However, only 16 Atlantic salmon were floy tagged on the River Bladnoch and no Atlantic salmon were floy tagged on the Water of Luce due to exceptionally low water levels during the summer in 2018. These atypical conditions altered the behaviour of Atlantic salmon as they delayed entering rivers from the sea. Therefore, this study was unable to investigate exploitation rates of Atlantic salmon and

should be repeated to determine how exploitation rates vary between river catchments. It has been proposed, this study is repeated in 2019 with exploitation rates of Atlantic salmon on the River Bladnoch being investigated.

- Finally, this study examined angling effort on the River Bladnoch and Water of Luce. In total, 378 half days and 252 full days angling was recorded on the River Bladnoch and 115 half days and 213 full days angling was recorded on the Water of Luce.
- Angling effort was relatively low on both rivers and this should be considered when assigning conservation limit categories to rivers in Scotland.
- River levels were low during the summer of 2018, water temperatures were high and rod catches were very low. Therefore, this study should be repeated to understand how angling effort changes with water flows and temperature.

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1. INTRODUCTION

In recent decades, the abundance of Atlantic salmon (*Salmo salar*) in Scotland has declined. Atlantic salmon are an anadromous species, whereby they migrate between freshwater and the marine environment throughout their lives. In late autumn/early winter Atlantic salmon migrate from the marine environment to their natal spawning grounds in freshwater and spawn in gravel redds. The deposited eggs incubate for several months before hatching as alevin. Alevin remain in the gravel until they consume their yolk sac. Once the yolk sac has been consumed the alevin emerge from the gravel as free-swimming fry. The fry feed and grow for their first year before they develop into parr (1+ year old Atlantic salmon). Parr continue to feed and grow until they become smolts. Smolts go through an energy demanding process to adapt for survival in the marine environment. Once smolts reach the marine environment they feed and grow until they mature as adult Atlantic salmon. Atlantic salmon will either mature as adults after one year at sea (grilse) or multiple years at sea (multi-sea winter salmon). Therefore, anthropogenic impacts ranging from the freshwater to the marine environment, such as impassable barriers, past overexploitation, marine fish farms, reduced habitat availability and reduced water quality, have all contributed to the decline of Atlantic salmon. Therefore, due to the economic importance of Atlantic salmon, understanding their decline is a crucial but highly complex problem.

Historically, Scottish Atlantic salmon fisheries were regulated through legislation and, for most rivers, District Salmon Fisheries Boards (DSFB). DSFB's have the powers to appoint bailiffs, stocking salmon and raising a levy from riparian owners. DSFB's also protect and conserve Atlantic salmon stocks through voluntary restrictions on fishing methods, netting efforts and promotion of catch and release. However, as Atlantic salmon stocks have continued to decline, the Scottish Government in 2016 recognised the requirement for stronger conservation measures and implemented conservation to manage angling and netting exploitation across Scotland. Therefore, based on the relationship between stock and recruitment Marine Scotland Science (MSS) created a model which assigns each river in Scotland a conservation limit category based on whether each river has enough wild Atlantic salmon eggs for all areas accessible by Atlantic salmon within the catchment.

Essentially, based on prior research, the model converts the annual rod catch for each river into an estimate of the total number of returning female Atlantic salmon. The number of returning female Atlantic salmon is then converted into the probable number of eggs which would have been spawned that year, i.e. the number of eggs available in a river. The model then compares the number of eggs available each year with the egg requirement for each river. The eggs requirement for each river is calculated as the wetted area of a river accessible to Atlantic salmon multiplied by the egg deposition rate, which is defined by the number of eggs that is likely to result in a self-perpetuating population of Atlantic salmon. The resultant percentage egg requirement met is averaged across five years and used to assign a conservation limit category to each river. There are three possible categories; category 1 where rivers have met more than 80% of their egg requirement; category 2 were rivers have met 60-80% of their egg requirement and category 3 were rivers have met less than 60% of their egg requirement. By assigning a conservation limits category to each river, the degree of exploitation of Atlantic salmon can be controlled. If a river is assigned a category 1, it is deemed that there are sufficient numbers of spawning Atlantic salmon and exploitation may continue following DSFB river rules. If a river is assigned a category 2, it is deemed that although stocks of spawning Atlantic salmon are lower than required, exploitation may still continue as long as there are additional measures implemented by DSFBs to protect Atlantic salmon stocks from exploitation. Finally, a river is assigned a category 3 if there are insufficient numbers of spawning Atlantic salmon to allow exploitation to continue. Therefore, it is a criminal offence to retain any Atlantic salmon from category 3 rivers.

This approach by MSS to calculate conservation limits has been used internationally for salmonid management, although the methodology varies between countries. Designing a model to accurately assign conservation limit categories to each river in Scotland is complex due to regional variations in many factors such as egg deposition rates, exploitation rates and angling effort. Due to the MSS model being created using an empirical dataset from five reference sites several assumptions were made. The first assumption of the model was all rivers in Scotland had the same rate of exploitation of Atlantic salmon. However, it has been shown exploitation rates can be river specific and vary across Scotland. For example, exploitation rates for large heavily fished rivers on the east coast are likely to be higher than for rivers on lower populated areas of the west coast. A further assumption of the model is that angling effort is the same across Scotland. However, angling effort varies widely across Scotland due to individual riverine characteristics. For example, for some rivers it is possible to fish them throughout the angling season, whereas, other rivers are condition dependent (i.e. spate rivers). There are other factors which can affect angling effort which include marketing, accessibility and the condition of the river bank. Rivers which can only be accessed on foot and/or have overgrown river banks are less likely to be fished in the same way as rivers which have maintained river banks and easy access. Therefore, rivers with lower exploitation rates than predicted and lower angling effort are more likely to be assigned a higher category (i.e. category 3) than rivers which have higher angling effort and are fished throughout the season. It is critical Atlantic salmon stocks are conserved and conservation limits are an important part of the solution. However, it is essential the correct category is assigned to each river. If rivers are assigned a category too low, this could lead to over-exploitation of already vulnerable stocks. If a river is assigned a category which is too high, this could lead to decreased angling effort and have a negative economic impact. In cases, where angling effort decreases because of the assignment of a category 3, this will further affect the calculation of conservation limits in future years, as reduced angling effort will result in lower catch returns and the river will be more likely to be assigned a category 3 in future years as a result of lower catches rather than lower stocks.

The methodology used to calculate conservation limit categories has been changed and adapted to improve the accuracy of assignment. Changes have been made to the conservation limit model for 2019 by altering the estimated egg requirement and number of returning adults for each river. Previously, the egg requirement was the same for each river and was calculated based upon five reference sites. To improve the accuracy of the conservation limits model, 11 reference sites are now used which has resulted in the egg requirement for each river being catchment specific. The estimated number of returning adults has also been modified by changing exploitation rates from being the same throughout Scotland to being catchment specific. The changes which have been made to the model should increase the accuracy of the assignment of conservation limits for each river. However, there are still improvements which can be made. Therefore, the collection of empirical data representative of geographic regions across Scotland will improve the accuracy of assignment of conservation limit categories.

2. AIMS

This project aimed to collect empirical data from two rivers in Galloway. Specifically, this study aimed to:

- Collect accurate data (including age of smolting, age returning to freshwater, weight and sex) from Atlantic salmon entering the River Bladnoch and Water of Luce throughout the angling season.

- Calculate exploitation rates of Atlantic salmon on the River Bladnoch and Water of Luce.

- Design and implement a methodology to collect angling effort data on the River Bladnoch and Water of Luce.

3. METHOD

3.1 Study area

The two river catchments examined in this study were the River Bladnoch SAC and Water of Luce. The River Bladnoch is a medium sized catchment which is a Special Area for Conservation (SAC) for its Atlantic salmon populations, which include spring run (multi-sea winter) Atlantic salmon. The River Bladnoch is a spate river which was designated as a category 3 river in 2018 and 2019. The Water of Luce is also a medium sized catchment and a spate river. The Water of Luce was designated a category 2 in 2018 and has been assigned a category 3 for 2019. Therefore, this project aimed to research angling effort and exploitation rates between these two neighbouring river catchments.

3.2 Biological data collection

The first aim of this project was to collect accurate biological data from Atlantic salmon on the River Bladnoch and Water of Luce. This was to be achieved by seine netting pools in the lower reaches of each catchment throughout the angling season.

On both the River Bladnoch and Water of Luce a pool was identified were this study would take place and was cleared of debris or tree roots which would cause problems during seine netting. The pool chosen on the River Bladnoch was previously used as a netting pool by a 'net and cobble' fishery. The fallen trees along the banking which were likely to cause problems during seine netting were removed (Figure 1). The pool chosen on the Water of Luce was a tidal pool which had previously been netted for broodstock. There were also trees in this pool which required to be removed before seine netting could take place (Figure 2).

Figure 1: Tree removal from pool in River Bladnoch

Figure 2: Tree removal from pool in Water of Luce

A 100 m by 10 m seine net was used to net each pool. The seine net is designed to have a lead line and a float line so it hangs vertically in the water column. The pools on the River Bladnoch and Water of Luce were netted slightly differently although the principles of seine netting remained the same. On the River Bladnoch the seine net was set (i.e. ready for deployment) onto a small boat. Prior to the net being deployed the top of the pool was 'stoned' (i.e. rocks where thrown from the banking to encourage Atlantic salmon to drop further downstream and into the area of the pool which would be netted). The boat was then launched and positioned for the net to be deployed. To deploy the seine net someone on the bank would hold one end of the net by a rope and walk slowly along the bank in a downstream direction pulling the net with them. Meanwhile, the net was deployed off the boat along the opposite bank. Once all the net had been deployed the net was walked along both banks towards the landing area. At this point the net had formed a bag shape, within which any Atlantic salmon would be caught. The seine net was then landed, maintaining the bag in the net and ensuring there are no gaps between the nets and river bed for Atlantic salmon to escape through. Once enough of the net has been pulled onto the bank, any Atlantic salmon caught were taken out using landing nets and placed into keep nets which were held in the flowing water of the river. This was to minimise any stress experienced by the captured Atlantic salmon.

The same principles were used to seine net the Water of Luce. However, instead of using a small boat to deploy the seine net, the net was deployed from the river bank by someone walking the net around the pool. Once full deployed, the net was walked to the landing area and pulled in. Again, any Atlantic salmon caught in the resulting bag of the net were removed using landing nets and placed into keep nets held in flowing water.

Any captured Atlantic salmon were then processed by placing each individual briefly in anaesthetic and each individual's weight, length and sex was recorded. A scale sample was also collected which would provide information on age of smolting, age each individual returned to the river from sea and whether each individual had spawned previously. A genetic sample was also taken. Once each Atlantic salmon had been processed, it was held in flowing water until it was fully recovered and ready to be released.

Seine netting both the River Bladnoch and Water of Luce was possible due to help from volunteers. Volunteers helped with holding keep nets in place and pulling in the seine net.

Originally GFT planned to hold two volunteer training evenings to discuss the project and how volunteers could help. However, after discussions with volunteers it was decided a better approach would be to show volunteers how they could help each time the river was seine netted. Volunteers were present at most seine netting sessions with 30 volunteers helping seine net the River Bladnoch and Water of Luce.

3.3 Exploitation rate

Atlantic salmon caught seine netting was tagged using a floy tag (Figure 3). The floy tag had a unique identification number and was inserted under the skin of each individual Atlantic salmon. A record was made of the floy tag number, as well as, the biological characteristics listed previously. Once released, any anglers which captured a floy tagged Atlantic salmon were asked to contact GFT and report the floy tags number. This information would then be used to determine exploitation rates on the River Bladnoch and Water of Luce by comparing the number of Atlantic salmon caught seine netting with the number of Atlantic salmon caught with floy tags by anglers.

Figure 3: Floy tags used to examine exploitation rates on the River Bladnoch and Water of Luce

Figure 4: An Atlantic salmon which has been tagged with a floy tag

3.4 Angling effort

There are several different methods which can be used to calculate angling effort. However, their effectiveness varies depending on the type of system being surveyed, such as marine, lacustrine and riverine. One type of method which has been used in previous studies is creel surveys (or angler surveys). This is a type of survey which involves counting the number of anglers on a river, as well as, conducting face-to-face interviews on dedicated survey days. This is a costly process and would be difficult on river systems which are sporadically fished. However, this survey method does provide detailed information about angling effort and angler behaviour. Another type of survey is using questionnaires which would ensure all anglers/ghillies were surveyed for a river system. For example, a study on the Seven Estates, River Spey examined angling effort and rod catches to determine seasonal patterns of catch per unit effort (CPUE). Therefore, this study aimed to collect data on angling effort in 2018 using questionnaires which were distributed to all anglers via beat owners on two small, lightly fished river systems, River Bladnoch and Water of Luce.

The beats on the River Bladnoch and Water of Luce are fished slightly differently with some beats being fished by angling clubs, syndicate members, holiday lets and private fishing. It is also highly unlikely a ghillie would be present on any of the beats. Therefore, to collect information on angling effort, personalised forms were created to suit each type of angler and distributed to the owner or lead angler on each beat. It was concluded after consultation with MSS that angling effort would be defined as half days (less than four hours) and full days (four hours or more). This was a coarse definition of angling effort and it was recognised that anglers who typically fish for an hour would be recorded as fishing for half a day. It was also noted that recording angling effort this way would make it impossible to draw detailed conclusions on Catch-Per-Unit-Effort (CPUE) but it was important angling effort forms where quick and simple to complete. Draft angling effort forms were created and a consultation was held with anglers from the River Bladnoch. These anglers represented syndicate beats, angling clubs, holiday lets and private beats. During this consultation the project was discussed, whether the forms created would suit each type of angler and what modification could be made to the angling effort forms. From this consultation angling effort forms were produced for each month of the season (Figure 5). Each beat on the River Bladnoch and Water of Luce were contacted about the project, with GFT contacting each beat on the River Bladnoch and Stair Estates contacting each of their

syndicate members or lessees. Angling effort forms were then collected throughout the season from the beats which had agreed to participate.

Name:

Month:

Beat:

Angler's name	Half Day	Full Day	Number of salmon caught

Figure 5: An example of an angling effort datasheet for syndicate holders

4. RESULTS

4.1 Biological data collection

4.1.1 River Bladnoch

Biological data was collected from adult Atlantic salmon captured seine netting the lower River Bladnoch. In total, 16 Atlantic salmon were captured during eight seine netting sessions (Table 1). The fork length of Atlantic salmon caught ranged from 558 mm to 785 mm and their weight ranged from 2.14 kg to 4.62 kg. The sex ratio of the Atlantic salmon caught was 1:1 and the majority were grilse (i.e. returned to spawn after one year at sea).

Table 1: Biological data collected from Atlantic salmon caught on the River Bladnoch

Fish ID	Date	Length (mm)	Weight (kg)	Sex	Age	Notes
BLA_01	10/08/2018	614	3.98	Male	2.1^{+}	Red Vent
BLA_02	10/08/2018	599	2.46	Female	2.1^{+}	Fin Damage
BLA_03	10/08/2018	558	2.58	Male	2.1^{+}	Red Vent
BLA_04	10/08/2018	598	2.14	Male	3.1^{+}	Red Vent
BLA_05	10/08/2018	625	2.56	Unknown	2.1^{+}	Red Vent
BLA_06	10/08/2018	593	2.28	Female	2.1^{+}	Red Vent
BLA_07	10/08/2018	588	-	Male	2.1^{+}	Red Vent
BLA_08	10/08/2018	643	-	Male	unknown	Circular wound on side
BLA_09	10/08/2018	634	-	Male	2.1^{+}	Red vent, sea lice
BLA_10	10/08/2018	621	-	Female	2.1^{+}	Sea lice
BLA_11	10/08/2018	776	-	Female	unknown	
BLA_12	10/08/2018	739	-	Female	2.2	
BLA_13	10/08/2018	603	-	Unknown	2.1^{+}	Sea lice
BLA_14	14/08/2018	785	4.62	Female	2.2^{+}	Damaged tail
BLA_15	06/09/2018	623	2.42	Male	2.1^{+}	
BLA_16	06/09/2018	615	2.46	Female	2.1^{+}	

4.1.2 Water of Luce

This project aimed to collected biological data from adult Atlantic salmon captured seine netting the lower Water of Luce. However, due to river conditions in 2018 it was only possible to net the Water of Luce twice. Therefore, if biological data was to be collected from adult Atlantic salmon on the Water of Luce, an alternative methodology would need to be used.

4.2 Exploitation rate

This project aimed to investigate exploitation rates of Atlantic salmon on the River Bladnoch and Water of Luce. However, due to a small number of Atlantic salmon being floy tagged on the River Bladnoch and no Atlantic salmon being tagged on the Water of Luce, it was not possible to establish exploitation rates. Therefore, this project should be repeated to establish exploitation rates of Atlantic salmon.

4.3 Angling effort

Angling effort was investigated on the River Bladnoch and Water of Luce in 2018 using angler survey forms. Angling effort forms were distributed to the lead angler or owner on each beat and collected each month of the season.

4.3.1 River Bladnoch

The River Bladnoch supports a mix of fisheries for Atlantic salmon, pike and brown trout. There are 15 fisheries on the River Bladnoch which include syndicates, private fisheries, holiday lets and an angling club. Of the 15 fisheries, two only fish for pike, one did not wish to participate, one did not return angling effort forms, a further fishery submitted their angling effort as part of the angling club and three fisheries did not fish in 2018. Therefore, angling effort forms were distributed to nine fisheries.

There were 378 half days and 252 full days fishing reported on the River Bladnoch during 2018 (Table 2). Angling effort varied between fisheries, as well as, between months. Angling effort was highest for the holiday let fishery, whereby anglers typically fished for a full day (Table 2). The River Bladnoch is a spate river and typically fishes best during high water (Figure 6). Therefore, during months with higher water levels angling effort was greater than months with lower water levels (Table 3; Figure 6). As such angling effort on the River Bladnoch was greatest during August.

Table 2: Total number of half and full days fished at each fishery and the number of Atlantic salmon caught throughout the season

Fishery	Half days (less than four hours)	Full days (four hours or more)	Number of Atlantic salmon caught
Fishery 1	7	0	0
Fishery 2	69	45	16
Fishery 3	37	0	0
Fishery 4	49	0	3
Fishery 5	70	2	7
Fishery 6	129	196	20
Fishery 7	17	9	1

Table 3: Angling effort on the River Bladnoch for each month of the 2018 fishing season

Month	Number of half days	Number of full days	Number of Atlantic salmon caught
February	28	9	0
March	63	5	3
April	53	33	2
May	41	26	3
June	16	34	1
July	10	4	0
August	60	61	13
September	54	59	13
October	53	28	12

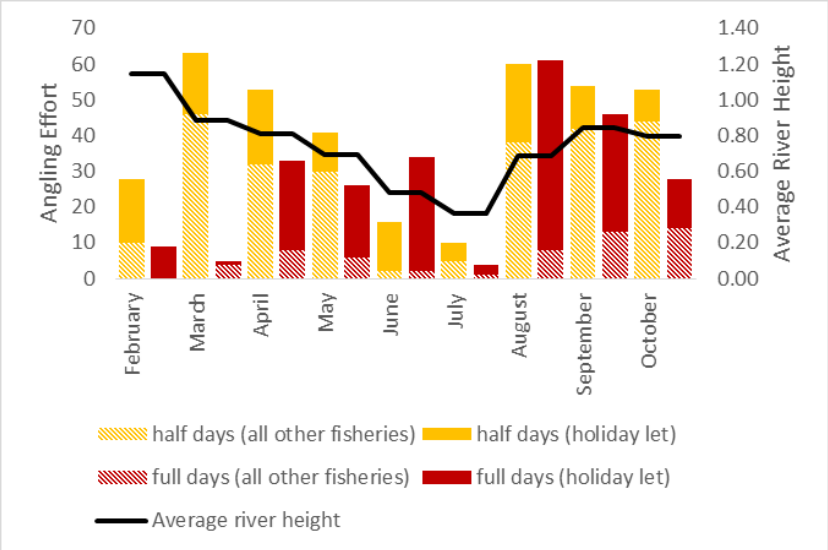

Figure 6: Angling effort on the River Bladnoch per month for holiday let and all other beats compared with average river height

4.3.2 Water of Luce

The Water of Luce is managed by Stair Estates and is mainly syndicate beats although day tickets are available and some of the upper beats are leased. Angling effort forms for the Water of Luce were distributed to the lead angler for each syndicate beat or leased beat and collected by Stair Estates. In total, there were 108 half days and 193 full days fishing on the Water of Luce in 2018 (Table 4). There was also a total of 48 Atlantic salmon recorded caught on the Water of Luce angler effort forms in 2018 (Table 4). Angling on the Water of Luce was recorded between July and October with the highest angling effort being recorded in August (Figure 7). Similarly to the River Bladnoch, the Water of Luce fishes best with high water. However, Atlantic salmon ascend the Water of Luce later in the angling season and as a result angling effort on the Water of Luce for Atlantic salmon occurs during the last few months of the season.

Table 4: Angling effort on the Water of Luce for each month of the 2018 fishing season

Month	Number of half days	Number of full days	Number of Atlantic salmon caught
February	0	0	0
March	0	0	0
April	0	0	0
May	0	0	0
June	0	0	0
July	15	42	2
August	42	54	20
September	36	55	20
October	15	42	6

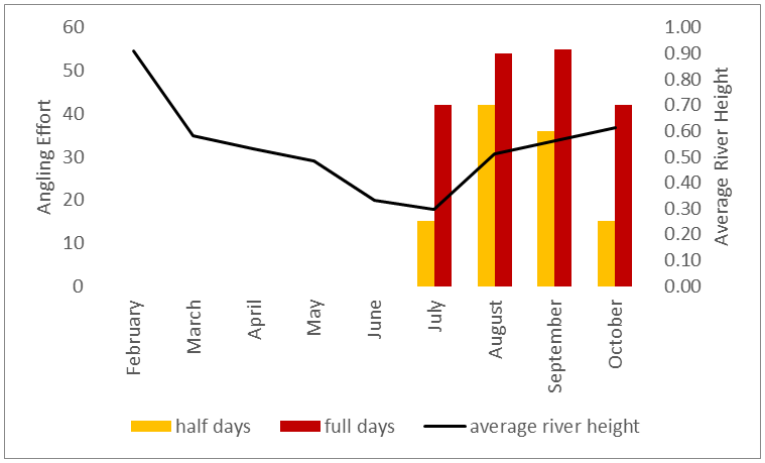

Figure 7: Angling effort on the Water of Luce per month compared with average river height

5. DISCUSSION

First introduced in 2016, conservation limits have been used to protect and conserve Atlantic salmon in Scotland by managing angling and netting exploitation rates across Scotland. To achieve this MSS produced a model which assigns a conservation limit category to each river in Scotland based upon whether there are enough Atlantic salmon returning to meet the egg requirement of each river. It is complex to produce a model, which accurately assigns a conservation category to each river due to regional variation in many factors included in the model such as egg production, angling effort and exploitation rates. The model currently assumes angling effort is the same throughout Scotland. However, as has been previously discussed angling effort varies substantially between rivers. A further assumption of the model is exploitation rates are the same across Scotland. Again, exploitation rates vary between rivers due to differences in angling effort and river conditions. The model used by MSS to calculate conservation limit categories for each river is continuously. Therefore, this project aimed to investigate exploitation rates, angling effort and collect biological data from Atlantic salmon on two rivers in Galloway, the River Bladnoch and Water of Luce.

Prior to the 2019 season, the model used by MSS to calculate conservation limits is based upon five reference sites from across Scotland. However, this did not capture all of the regional variation with regards to Atlantic salmon egg production and targets and the number of returning adult Atlantic salmon. The model used by MSS is continuously evolving to improve the accuracy of assignment of conservation limit categories. Therefore, for the 2019 season the model is based upon 11 reference sites. Although this improvement captures some of the regional variation of Atlantic salmon it is vital further region specific biological data is collected for the accurate assignment of conservation limits categories. During this study, biological data was collected from 16 Atlantic salmon captured on the River Bladnoch (Table 1). The fork length of Atlantic salmon caught ranged from 558 mm – 776 mm and their weight ranged from 2.14 kg – 4.62 kg. The majority of Atlantic salmon caught were coloured and would have entered the river sometime before they were caught. The age of most Atlantic salmon caught was 2.1^{+}, which means they smolted after two years in freshwater and had returned as grilse to spawn (i.e. after one year at sea). There were two Atlantic salmon which had returned as multi-sea winter salmon and one Atlantic salmon which smolted after three years in freshwater and returned as a grilse. The River Bladnoch is an SAC for its Atlantic salmon populations, which includes spring run Atlantic salmon. The majority of Atlantic salmon were caught in August and although they provide insights into salmon populations on the River Bladnoch they do not truly represent the variation of Atlantic salmon on the River Bladnoch. The atypical weather conditions in 2018 resulted in little rainfall during the summer and as a result water levels were very low and water temperatures were high. There were also few reports of Atlantic salmon entering rivers during this period in all rivers in Galloway. The low water levels and high water temperatures resulted in objections to seine netting during this period and as such seine netting did not begin until August. This prevented the River Bladnoch from being seine netted more than eight times during 2018. Therefore, this study should be repeated to fully understand the river age and sea age of Atlantic salmon on the River Bladnoch with seine netting sessions taking place throughout the year. This study also aimed to collect biological data from Atlantic salmon on the Water of Luce. However, no Atlantic salmon was caught seine netting the Water of Luce. The Water of Luce tends to have a later run of Atlantic salmon in comparison to the River Bladnoch and seine netting took place on the Water of Luce from August onwards. However, unlike the River Bladnoch, the Water of Luce has few areas with deep pools which are accessible in the lower reaches and the pools chosen for this study where difficult to successfully net. Therefore, if this study was to be repeated on the Water of Luce, either seine netting would need to take place further up the catchment or an alternative methodology should be used.

Another important variable in the conservation limits model is exploitation rate of Atlantic salmon, which has been assumed to be the same across Scotland. Recently, the model has been

adapted to include region specific exploitation rates for each river for the 2019 season. However, this has been based upon 11 reference sites. Therefore, this study aimed to establish exploitation rates on the Water of Luce and River Bladnoch. On the River Bladnoch 16 Atlantic salmon were tagged with floy tags to establish exploitation rates. However, one Atlantic salmon died a few days after being tagged and no tagged Atlantic salmon were captured and reported to GFT during this study. This could lead to the conclusion that there is no exploitation of Atlantic salmon on the River Bladnoch. However, this is impossible as 45 Atlantic salmon were caught and reported on the angling effort forms on the River Bladnoch by angling in 2018. Therefore, in order to understand exploitation rates on the River Bladnoch this study would have to be repeated. Again, due to no Atlantic salmon being captured on the Water of Luce this study would have to be repeated to understand the rate of exploitation of Atlantic salmon.

The final variable in the conservation limits model which is assumed to be consistent across Scotland is angling effort. It is understood that there is regional variation in angling effort across Scotland, due to differing river conditions. However, there is a lack of empirical data on angling effort, mainly due to the difficulty in collecting this data. There is a wide range of beats, such as syndicate beats, beats used for holiday lets, private beats and beats used by angling clubs. Therefore, designing a methodology which enables angling effort to be recorded from different river systems can be a complex task. There have been a few previous studies in Scotland which have examined angling effort, such as on the River Spey (Smith et al., 1993; Butler et al., 2009). Therefore, this study aimed to establish angling effort on two lightly fished rivers in Galloway, the River Bladnoch and Water of Luce.

Angling effort on the River Bladnoch and Water of Luce was recorded as half days (less than four hours) and full days (four hours or more) fishing. There were 378 half days and 252 full days angling on the River Bladnoch. To understand how many anglers fished during half and full days, one fishery recorded angling effort in hours. This showed 61% of half days fishing were less than two hours and 63% of full days fishing was between four and five hours. The holiday let fishery accounted for half the angling effort on the River Bladnoch. However, this is most likely a result of the low water levels in 2018. This can be seen when examining angling effort and river height (Figure 6). Angling effort on the River Bladnoch decreased from March to July as did river heights and as river heights increased in August angling effort also increased.

Similarly, the Water of Luce recorded low angling effort during 2018. There was a total of 108 half days and 193 full days fishing in 2018. Generally, fishing for Atlantic salmon on the Water of Luce begins in July. The Water of Luce is fished for both Atlantic salmon and sea trout which could mean that angling effort recorded was actually for both Atlantic salmon and sea trout. This is likely the case in July when water levels were low and the majority of fishing was most likely for sea trout. It is difficult to separate angling effort for Atlantic salmon and sea trout on rivers which fish for both species but as can be seen in this study, angling effort on the Water of Luce was still low and less than the angling effort on the River Bladnoch. For both the River Bladnoch and Water of Luce, it is likely angling effort in 2018 was lower than usual which was due to river levels being low. Therefore, unlike rivers which can be fished throughout the season the River Bladnoch and Water of Luce are only fished during rising waters which will result in angling effort varying between seasons.

There is relatively little empirical data collected regarding angling effort in Scotland. This study has shown it is possible to collect information on angling effort, but each fishery may require a modified method of collection. The collection of angling effort in this study was completed by asking the lead angler or owner from each beat to complete an angling effort form. However, this can be a daunting task for the lead angler, especially from large syndicate beats or angling clubs. Therefore, after some discussions from anglers, it was felt that modifications should be made to the forms if angling effort was to be collected in the future. This is of particular relevance as in 2019, Marine Scotland have asked for angling effort to be collected from each fishery in Scotland. Angling effort forms distributed to large syndicates and angling clubs need to be made

as simple as possible, with the enormous task of collecting angling effort not left to the lead angler. After discussions with the chairman of the angling club on the River Bladnoch, if this study was to be repeated, booklets could be created which each member of the club could collect with their season ticket. These booklets would have a small form for each month of the year, in which angling effort could be collected. After the season if complete the booklet could then be returned.

In conclusion, angling effort on the River Bladnoch and Water of Luce was relatively low, with most angling effort occurring between August and October. Angling effort on the River Bladnoch was greater than angling effort on the Water of Luce but a similar number of Atlantic salmon was caught on each river. This study should be repeated to understand how angling effort varies with seasons and if angling effort increases during years with more rainfall.

6. FUTURE RECOMMENDATIONS

The importance of collecting biological data from Atlantic salmon and examining exploitation rates to ensure the assignment of conservation limits categories are accurate was highlighted in this report. During this study, seine netting was used to capture Atlantic salmon on the Water of Luce and River Bladnoch. However, there was little rainfall and high river temperatures during 2018 which prevented GFT from seine netting during summer months. Therefore, seine netting was delayed until autumn due to the atypical river conditions. The River Bladnoch has an ideal pool for seine netting which was previously used by a 'net and cobble' fishery. In comparison, although the pool used in this study on the Water of Luce had previously been used to collect broodstock, it was difficult to access and to seine net effectively. If this study was to be repeated, GFT would alter their approach and concentrate on one river catchment, the River Bladnoch and, if river conditions allow, begin seine netting the river from April. The biological data collected from Atlantic salmon and calculation of exploitation rates will help provide more accurate assessment of conservation limits categories.

This project also aimed to collect information on angling effort from two lightly fished rivers as well as provide MSS with feedback with regards to how angling effort was collected and whether anglers were willing to participate in the project. A discussion about the project will be held with MSS in February 2019. There are many different types of anglers on the Water of Luce and River Bladnoch including, anglers on private beats, holiday let anglers, syndicate members and angling club members. Therefore, angling effort forms had to be personalised for each type of fishery. This was to ensure the collection of angling effort was straightforward and to ensure the participation of as many anglers as possible. This approach was relatively successful and after feedback from a few owners/ lead anglers for beats it was concluded at least 80% of anglers completed angling effort forms. However, a caveat of modifying forms for each fishery is that care must be taken to ensure the correct information is collected. For example, if a fishery wished to collect angling effort for both sea trout and Atlantic salmon, care must be taken to ensure there is a clear distinction on the forms between angling effort for sea trout and angling effort for Atlantic salmon. Angling effort was collect as half days (less than four hours) and full days (four hours or more). This was a successful approach for collecting angling effort, with almost all fisheries agreeing to collect angling effort this way. A couple of fisheries collected angling effort as hours spent fishing, which provided useful insights into angler behaviour. As demonstrated in this report a half a day angling was typically less than two hours and a full days fishing was 4 to 5 hours. However, it would be recommended in the future angling effort is collected as half days and full days. Understanding how angling effort can be collected and the success of collecting this data is particularly important with MSS collecting angling effort from 2019. With the wide range of fisheries, it is important that there is a clear and concise methodology for collecting angling effort and there needs to be a support system as it is an enormous task for the lead angler/ owner of each beat to collect this information.