This report has been produced by the River Forth Fisheries Trust with Trex Ecology, the University of Stirling, The Queens University of Belfast and Aqua EcoSystems BV.
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Executive Summary

The River Dee is currently undergoing a decline in the number of rod caught Atlantic salmon. These declines have been sufficient to lower the long term average in catches, a key indicator of a downward trend. As part of an investigation into arresting this decline, the Dee Board and Trust commissioned an independent study into the feasibility of stocking Atlantic salmon to boost rod catches to three levels, 100, 1000 and 5000 additional rod caught fish.

This study developed a three stranded approach to assess the issue. Firstly, it reviewed the biological information from both the published literature and from the distribution, abundance and habitat uptake of juvenile salmon on the Dee using available habitat and electrofishing data. This strand also aimed to identify to most suitable life history stage to stock. Secondly it costed a ‘paper’ hatchery build to produce sufficient numbers of juveniles to deliver the required increase in the fishery, and carried out a cost benefit analysis of that operation. Finally, it reviewed the legal frameworks, such as the Special Area of Conservation Designation on the Dee and the obligations of the Dee District Salmon Fishery Board and the National Park, and identified other management options which could deliver the required increase in rod caught fish.

Understanding the current population abundance is key when discussing stocking and it is difficult to robustly assess the numbers of returning fish to the Dee. The literature shows that catch has been a poor indication of total population sizes in Atlantic salmon. Although it is believed that on the Dee there is a link, this can only highlight the trajectory of change in the population, not quantify total numbers. Therefore, catch cannot be used as an estimate of population size. Information from two tributaries supports the view that catch and population size may be related, and that the numbers of returning adults have declined. Therefore, the evidence suggests that returning numbers are declining, but this cannot be quantified currently. These reports also suggest that smolt output may be independent of returning adults, but clearly there is a limit to this and at some point smolt output will decline if adult returns continue to decline also.

The literature review also conclusively demonstrated that stocking of Atlantic salmon on the Dee will risk the future of the wild population. The published scientific literature shows that stocking negatively impacts every life stage of naturally produced salmon stocks, either through direct competition for resources during freshwater life history stages, reduced marine survival, and via subtler, but still very important, genetic mechanisms leading to reductions in fitness and an inability to cope with environmental change at an evolutionary level. Survival rates of stocked fish are held to be very low, with 0 to 0.1% currently deemed probable. This view is now widely accepted by the academic, regulatory and management fields and has led to the banning of stocking in Wales. Other reports show that in rivers were active stocking has taken place, recovery in salmon populations may be caused by straying from adjacent rivers and not from stocked fish.

Reviewing the electrofishing data proved inclusive in determining the health of salmon juvenile populations. This is because the variety of drivers for data collection leads to incomplete coverage across the entire catchment, and the datasets are not long enough to paint an accurate picture over a number of years. The main concerns on the data collection regime are being addressed by the Catchment Health Monitoring programme; however, this does not represent a mature dataset sufficient to support a stocking application and more time is needed. Subsequently the report was unable to determine an appropriate life history stage to stock, and a precautionary approach via
stocking of smolts was proposed. This will limit the residence time of stocked fish in the river and their impact on the wild produced fish. However, by maximising a return the genetic risk will become greater.

Economically, the costs of building and running a hatchery to produce smolts are exceedingly high. To support a rod catch of 1000 fish, start-up costs of approximately £4 million with annual running costs of half a million pounds should be expected with no guarantee of any fish produced returning to the rod. These values were based on an economically realistic value of 4.5% return of produced smolts representing the central point in the range of stocked smolt survival rates published in the relevant literature. From a biological perspective this is very high and is unlikely to be attained in practice. It was used solely to produce a believable economic appraisal with the cost of producing 1000 returned rod caught salmon at 0.1% survival running into exceedingly high levels.

Values for producing 100 rod caught fish were excluded as this level of increase was deemed redundant, while the broodstock requirements to produced 5000 rod caught fish could be considered difficult to support.

Based on the accepted scientific advice, stocking of Atlantic salmon may risk the Condition Status of the Dee SAC. Any regulatory approval for stocking will need the stocking license applicant to demonstrate the cause of any decline in salmon population and clearly demonstrate that stocking will arrest and reverse this decline while maintaining the genetic integrity of the wild stock. These data do not currently exist to support any of these requirements. The applicant will also need to show that all other avenues to increase salmon populations on the Dee have been exhausted. Habitat access and quality are still seriously impacted by landscape and in-channel pressures on the Dee, and improving the production and survival of wild fish through returning the river to a more natural state should be prioritised prior to any stocking application.

Other important legal considerations are relevant. Although the Dee Board currently can grant a license to stock salmon, the license to remove broodstock is not granted by the Board and this will require the license applicant to satisfy Marine Scotland Science concerns. Ultimately however, due to the upcoming changes in the management of salmon in Scotland, it is very possible that the new Fishery Management Organisation on the Dee will not be able to license any aspect of stocking, and any decision on stocking should wait until the distribution of duties between local and the national FMO have been clarified.

All strands of investigation show that stocking of the Dee is not appropriate at this stage. Stocking will risk the biological integrity of the wild population, is enormously expensive and there is no guarantee of a license. Most importantly, there is also no guarantee that any fish will return. Approaches aiming to improve the quality and quantity of habitats in the river should be prioritised over stocking.

Although stocking of salmon is carried out in other rivers in Scotland, it has been shown to be ineffective, a measure of ultimate last resort in rivers which could not support a functioning fishery, or subject the claims which are unverified and not accepted by the wider scientific audience. Even in areas where stocking is perceived as successful, such as the Ranga, the Conon or the Bush, the level of difference between these rivers and the Dee in terms of size, structure and impacts are of such significance that they cannot be used as suitable comparisons.
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1. Introduction

1.1. Context
Over recent years the River Dee has experienced a reduction in rod catches of Atlantic salmon (*Salmo salar*). These reductions have been sufficient to cause a decline in the five-year average, indicating a decline in the number of fish caught. There is a now concern that extreme events, such as Storm Frank in 2015/2016, may exacerbate the declines in catches and perhaps impact the overall population. Therefore, as one of a number of possible mitigation measures, the Dee District Fishery Board have commissioned an assessment into the potential for a hatchery to provide a biologically sound, economically viable and technically feasible solution to boost catch numbers. Stocking of Atlantic salmon is not currently undertaken on the Dee.

Salmon stocks are subject to naturally driven variability, both cyclical (which can operate on annual, inter-annual, decadal and multi-decadal cycles) and random (e.g. an immediate response to major flood event) (Friedland *et al.*, 2003). Therefore, although at a given point in time any measure of population may demonstrate a decline (or rise) in numbers when compared with a previous year; when compared with population counts over an extended period of time these declines may appear quite normal. Therefore, it is possible that the Dee stock may be undertaking a downward trajectory as part of a natural cycle.

A key issue lies in determining the population size of salmon in the river and the cyclicity of the stock. Catches are often used as proxy indicators of fish population size, usually because they are the only long-term data to hand. Unfortunately catch is very often a poor indicator of population size (Hendry *et al.*, 2007). Therefore, at best they can show us that the Dee population is changing at an unspecific rate; at worst they present an inaccurate picture. The range of factors which influence whether an individual angler catches a fish during a fishing trip are substantial (including experience, fitness, weather, location, fish behaviour, fish cover, water temperature, migration stage and biological condition of the fish). An angler must be on a river to fish and often the perceived poor quality of a fishery relating to a bad year (or number of years) may result in a reduced fishing effort with subsequent decline in catches. All of these factors limit the ability of exploitation data to determine target population size.

The perceived benefits of stocking salmon are numerous. At the simplest level it will increase the number of juvenile fish in the river and by extension should increase the number of returning fish and subsequent catch. By boosting the number of returning adults, a fundamental tenet of stocking is that it will also boost salmon spawning with increased natural productivity as a result of increased returns. Stocking has historically been seen as intrinsic to managing fisheries, and potentially integral to creating a fishery on the Ranga in Iceland, the Bush, Burrishoole and Delphi in Ireland, and the Conon and Carron in Scotland. These programmes have been driven by a mix of fishery creation, fishery improvement, and salmon conservation. Two distinct forms of stocking are now considered, conservation stocking to restore critically endangered populations and fishery enhancement stocking to improve rod catches (Bacon *et al.*, 2015).

There have been a number of concerns raised about the stocking of salmonids to boost populations for the purposes of exploitation. Studies (e.g., RAFTS, 2014; Young, 2014; and references therein) have shown stocking may actually be implicated in the decline of salmon returns through factors such as increasing stock susceptibility to climate change (Jonsson *et al.*, 2003), increased rates of straying contaminating the gene pool of salmon from neighbouring systems (Isaksson *et al.*, 1997; McGinnity *et al.*, 2003) and changing key migration timings.
Artificial stocking can reduce the fitness of entire salmon populations through both inbreeding and outbreeding depression (outbreeding depression – this is where a parent can reduce the fitness of the next generation by introducing excessively different genes which are not evolved to the local environmental conditions). The effects of these events are exacerbated by the larger sizes of stocked juvenile fish which, due to their low energy, low predation and high calorie rearing environment, can outcompete naturally produced populations in the freshwater environment.

Although much of the recent focus on stocking has concentrated on the genetic factors, in-river resource availability is also key because habitats are limited and these limitations have repercussions for salmon production (Solomon, 1985). While the degree of limitation varies between rivers, all rivers have a maximum carrying capacity for production (Uusitalo et al., 2005). If a river which is already operating at carrying capacity were to be stocked, the impact on the overall population may be a reduction in production due density dependent factors, with the river unable to provide for all fish (P. McGinnity, pers. comm; Bacon et al., 2015), regardless of the physical condition of the individual.

At a practical level, economics and legal responsibilities are also a factor when discussing the decision to stock. Based on the economic value of the Dee (adapted and updated from Radford et al., 2004), each rod caught salmon may be worth over £2,600 pounds. Therefore, if that fish was stocked and the production cost of that rod caught fish was also over £2,600 then it may not be economically viable to run a hatchery. Other work has shown that a returned Atlantic salmon may be worth over £5,000 (Postle and More, 1996 – over £8,000 in 2016 with inflation) or just over £2,000 on the Tweed (SVQ, 2015).

Legally, the Scottish Environment Protection Agency (SEPA), Scottish Natural Heritage (SNH), Marine Scotland Science (MSS), the National Park and the Dee Board will all have input into the decision to stock and the varying requirements of all these groups need to be considered. This will range from granting of licenses to statutory consultee to recommended consultee.

1.2. The River Dee

The River Dee drains a catchment area of approximately 2100km², and is one of the largest river systems in Scotland. It rises in the Cairngorm Mountains and enters the North Sea at Aberdeen. Although often seen as an iconic ‘wild’ highland river, the Dee runs through significant sections of highly impacted landscapes, with upland land management for grouse and deer, lowland intensive agriculture and sections of significant urbanisation all affecting instream habitats, water quality, and hydrology of the catchment (SEPA, 2015).

Sections of the river and its tributaries are found in the Cairngorms National Park. This is the largest national park in Scotland and the UK, and was founded in 2002 with expansion into Glenshee and Perthshire in 2010. The River Dee is also designated a Special Area of Conservation (SAC) with Atlantic salmon one of the Primary Designating Features. The other designating features include the freshwater pearl mussel (Margaritifera margaritifera) and the European otter (Lutra lutra), both of which also rely on Atlantic salmon as host (Hastie & Young, 2003) and prey (Carss et al., 1990) respectively.

Additional environmental regulation of the Dee catchment is overseen by SEPA. Firstly, a license under the Controlled Activities Regulation (CAR) Act 2011 may be necessary for any hatchery. Secondly, the
Scottish Government has a requirement to improve the Ecological Status of rivers as part of the Water Framework Directive (WFD – European Commission, 2000) and implemented within the second River Basin Management Plan (RBMP) cycle. Fish community quality is an aspect of this Status.

Management of the Dee salmon stock is within the remit of the Dee District Salmon Fishery Board (the DDSFB or the Board), supported by the River Dee Trust (the Trust). The primary purpose of the Dee Board (under the Salmon and Freshwater Fisheries Consolidation Act 2003 and earlier legislation) and Trust is to conserve and enhance the fishery on the river, while also protecting habitats for these fish species which form the basis of the fishery. Therefore, it must explore all avenues for the continued success of the fishery.

1.3. The Dee fishery

The Dee is considered a multi-sea winter (MSW) salmon fishery, although multiple stock components are present. A time series of catches is presented below in Figure 1.1. This figure shows that both spring and non-spring catches have decreased since the 1950s. For further information on changes in run timings and by month changes see the Dee stock component reviews (Bilsby, 2008; River Dee Trust, 2013).

![Figure 1.1 - Catches on the River Dee (1952-2015, shaded) with five-year averages for each stock component (lines) for spring and the remainder (rem) of the year](image)

This chart also demonstrates the varying relationship between catch periods on the Dee, with non-spring catches becoming increasingly dominant recently.

The link between catch and population size for Atlantic salmon is not very strong (Hendry et al., 1997). Therefore, while it is easy (and very tempting) to look at a catch count and assume it represents a like-for-like reduction in the total overall population; this is not the currently accepted view. However, there is a common perception the Dee catch might echo the general trend in population size, especially when certain datasets from two heavily monitored tributaries are reviewed.

Figure 1.2 charts the relationship between spring rod catch on the Dee and the number of females recorded entering the Baddoch and Girnock, two tributaries, while Figure 1.3 provides a direct
comparison. Both these figures suggest that periods of high catches may correspond with periods of high female counts\(^1\) (but, when extrapolating the counts of fish from two small tributaries to compare with an entire fishery, care must be taken).

**Figure 1.2 - Time series of Dee spring rod catch and trapped females from the Girnock and Baddoch**

<table>
<thead>
<tr>
<th>Year</th>
<th>Girnock females</th>
<th>Baddoch females</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td>21</td>
<td>181</td>
</tr>
<tr>
<td>1960</td>
<td>161</td>
<td>161</td>
</tr>
<tr>
<td>1970</td>
<td>141</td>
<td>141</td>
</tr>
<tr>
<td>1980</td>
<td>121</td>
<td>121</td>
</tr>
<tr>
<td>1990</td>
<td>101</td>
<td>101</td>
</tr>
<tr>
<td>2000</td>
<td>81</td>
<td>81</td>
</tr>
<tr>
<td>2010</td>
<td>61</td>
<td>61</td>
</tr>
</tbody>
</table>

**Figure 1.3 - Relationship between spring adult catches (Dee catchment) and trapped females in two Dee tributaries (Baddoch and Girnock)**

So, while there may be potential in determining the general patterns of population increases and declines using catch data on the Dee, there is still no way of using these data to determine the absolute number of fish returning\(^2\).

\(^1\) Due to a statistical anomaly, direct comparison may not be appropriate. Therefore a more mathematically correct (transformed) graph representing the comparison between Dee rod catch and female fish on the two tributaries is presented in Appendix A. Both charts reflect the explanation in the main text.

\(^2\) This does not suggest that local knowledge is not a key factor in understanding a fishery. Very often proprietors, ghillies and anglers are the first identifiers of problems, and previous discussions between the author and salmonid fishery managers has identified the urgent need to formally record this knowledge base as people retire or move on.
The most common option of establishing returning adult numbers is direct counting of migrating adults using fixed fish counters, as introduced above in Figures 1.2 and 1.3. There are two of these on the Dee catchment (Girnock Burn – Figure 1.4a) and Baddoch Burn – Figure 1.4b) and they are commonly used elsewhere (for a full, but perhaps slightly out of date, inventory in Scotland see Simpson, 2003). These structures require some way to ‘funnel’ fish into a space where they can be recorded by a number of means (e.g. resistivity or cameras) so, quite often they are placed on existing structures such as weirs and fish passes which provide a suitable platform to force fish alongside the recording apparatus. However, weirs and dams have negative implications for salmon populations, and even fish passes may not be considered fish friendly. (Despite perceived efficacy, there is a lack of robust and quantified data on fish passage and data suggests passage is much less than expected – Noonan et al., 2012). These structures also significantly impact the cleaning, renewal and creation of new habitats, especially spawning habitats.

![Fish counting devices on the Girnock burn (A) and Baddoch Burn (B)](image)

The location of the counter is also critical. To successfully count all the adult fish entering a system the counter must be located close to the tidal limit at the rivers’ confluence with the estuarine environment, or at least below the first major tributary. This is not available on the Dee, and considering uncertainty regarding fish passage beyond weirs and their severe impact on river habitat and communities (Poulet, 2007), building a structure simply to count fish will certainly have a negative impact on the Dee and should not be considered; only an existing structure or alternative method should be modified. So while the counter information on the Baddoch and Girnock are useful, like catch data they should be considered only as potential indicators of population health and general population.

The counting of juvenile fish is another approach to establishing the effective population size; either by direct surveying using electrofishing or by counting juvenile fish as they migrate to the sea as smolts. The assessment of population size using juvenile electrofishing can be an effective management tool, however accurate surveying requires a significant allocation of resources before a

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3 During discussions with H. Moir he stated that although the dataset on the Girnock is an excellent resource, the variation in river types found in the Dee tributaries might not make it the most appropriate dataset from which to draw inferences on the Dee catchment as a whole.
robust long-term picture of population health across an entire catchment is captured and, in reality, this may not be possible on the Dee. The Dee electrofishing data will be explored in Section 2.

The trapping of seaward migrating juvenile salmon on the Dee has many constraints in common with trapping migrating adults. Similarly, while it might be considered a suitable surveillance method, it might not be the best indicator of total population size. However, once again it can provide a general pattern of river health. Smolt data from the Girnock and Baddoch traps is presented below in Figure 1.5.

![Figure 1.5 - Smolt counts from the Girnock and Baddoch Burns](image)

These data show that, although there is a lot of variation in smolt counts when looked at on a year by year basis (interannual variation), over the longer term the outputs are relatively stable for both streams. This corresponds with a more formal analysis carried out by Gurney et al. (2008).

So, it is very difficult to pull together a robust and unequivocal snapshot of the current state of the Dee Atlantic salmon stock and how the size of this stock definitively relates to rod catch. Based on the information gathered from catch returns, there has been a general decline in the number of adult fish caught. A decline is also evident from counter data gathered from two tributaries. Although smolt output is clearly variable (for where we have information), there may not be an associated long term decline in the number of smolts migrating through the river. This information comes with many caveats, not least of all the fact these data only come from two small tributaries, but it does raise the question on whether the Dee (or areas of the Dee) may be approaching carrying capacity, through some mechanism controlling one or many juvenile stages, for smolt output.

Various methods of electrofishing can be used. The most effective and data rich involves netting off a section of river and electrofishing repeatedly until the majority of fish have been captured. While this is possible on small stream and burns less than 10m in width, surveying the main stem of the Dee in this fashion is often not possible.

See Appendix A – Figure A2 - for a more rigorous averaging method which demonstrates the stability in the smolt output.
1.4. Aims and objectives

The objective of this project is to answer the following question: Is a hatchery a practical, cost effective, sustainable and beneficial way of boosting rod catches of adult Atlantic salmon in the Dee?

This report aims to present an independent review of the requirement for a hatchery and stocking policy on the Dee based on all the factors raised above. This review will be impartial with no bias towards either outcome. It will produce outputs that illustrate how certain decisions were arrived at in a clear and concise fashion and will include consultation with the Dee Board and Trust at all critical stages. It will review the applicability of stocking to three rod catch levels of improvement; 100, 1000 and 5000 rod caught fish per annum.

Specifically, the following tasks will be undertaken:

Biology
- Undertake a high level literature review and incorporate this information with previous reviews to assess the applicability of such information to the Dee fishery;
- Review catch and juvenile density records to assess the long term stability of the Dee salmon population;
- Review the available in channel habitat to assess its use by salmon; and
- Identify the most appropriate life history stage to stock.

Practicalities/Economics
- Develop an indicative cost to develop a hatchery and yearly running costs to stock the identified stage; and
- Undertake a cost benefit analysis.

Legal
- The Board has an obligation to manage and ensure the continuity of the Dee fish stock. If a hatchery is not deemed necessary, then how can the board discharge these duties?
- If a hatchery is deemed necessary, then how can those operations remain consistent with regulatory agency requirements, especially with regard to the Dee’s SAC status and obligations under Natura?

Although not part of the original proposal, it was suggested that discussions with certain people could help support the project. The project team approached a number of individuals and the full list of people with whom discussions were held is presented below. Not all individuals will be credited with comment in this report.

- Colin Bean, Scottish Natural Heritage;
- Will Boyd-Wallis, Cairngorm National Park;
- Gavin Clark, SNH;
- Alastair Duguid, SEPA;
- Richard Kennedy, River Bush Salmon Station;
- Robert Kindness, River Carron;
- Ian Malcolm, Marine Scotland Science;
- Hamish Moir, cbec eco engineering UK;
- Simon McKelvey, Conon Fishery Board;
River Forth Fisheries Trust: River Dee Hatchery Assessment

- Phil McGinnity, University College Cork;
- Debbie Parke, Nith Catchment Fishery Trust;
- Brian Shaw, Spey Foundation;
- Eric Verspoor, University of Highlands and Islands; and
- John Webb.

A series of queries were supplied to a number of nominated stakeholders for short, structured responses. This was undertaken to gauge opinion and perception on the Dee stock and the state of the fishery and was not intended as a full and formal survey. Individuals contacted for comment were proposed by the Dee Trust and all respondents replied. Titles are based on the individual’s position at the time of receipt of the queries, prior to the September 2016 Board meeting.

The queries posed were:

1. In your opinion, do you feel that the Dee fishery is in a chronically bad state, or is it just going through a ‘bad period’ that you expect the river to recover from?

2. If you feel fishing on the river is undergoing a long term decline, what do you think are the three main causes of this decline?

3. Although stocking has been commonly used in the past as a management tool for Atlantic salmon fisheries, there appears to be a growing body of scientific evidence that stocking can do long term harm to salmon populations. How aware are you of this information, and how do you feel this information fits to the Dee?

4. Has this scientific information been communicated to you in an accessible and easily understood fashion?

5. Has your estate or fishery ever stocked salmon, and if so when was the last time you stocked?

6. In your opinion, how effective was this stocking, if it occurred?

7. How effective do you believe stocking on other Scottish rivers is?

8. If stocking was to be allowed on the Dee, how effective do you think it would be?

9. If stocking was not to be permitted on the Dee, which of these options would you support to increase catches and/or salmon population size:
   a. subsidised angling to increase fishing effort
   b. complete removal of weirs to ensure unhindered passage
   c. reforesting the catchment to improve nutrient retention in the headwaters and increase habitat diversity in the main channel
   d. river restoration projects to remove embankments and re-meander straightened sections
   e. funding research into improving marine return rates
   f. Stocking is the only option we should consider.
10. The decision to stock the Dee may not only be made by the Dee Board/Trust, and other agencies such as Scottish Natural Heritage/Cairngorms National Park and Marine Scotland Science may object to it. If this was to occur how would you feel about this?

11. Assuming a new building is required to house a hatchery to support stocking, at which point do you think the build cost is too expensive:
   a. £100,000
   b. £500,000
   c. £1,000,000
   d. £2,500,000
   e. £5,000,000
   f. £10,000,000
   g. Cost is irrelevant?

12. At which point do you think the yearly costs of running a hatchery become too expensive:
   a. £50,000
   b. £100,000
   c. £250,000
   d. £500,000
   e. Cost is irrelevant?

13. Would you be prepared to increase your levy contribution to fund stocking operations?

14. As a percentage, with 100% being no vacancies on your fishery, how many of your available fishing days are being used?

The responders are listed below:
- Ghillies Association;
- Aberdeen District Angling Association
- Park House;
- Dinnet and Kinord Estate;
- Kincardine Estate;
- Dess Estate;
- Lower Blackhall & Kinneskie and Invery; and
- Anon.

Responses are given in full in Appendix F, and referred to throughout. Not all queries were answered by all respondents.
2. Biological assessment of stocking on the Dee

2.1. Review of science and current thinking

Throughout its natural range, both within and between catchments, Atlantic salmon are commonly found as distinct populations adapted to local catchments with little interbreeding among them. These genetic differences are due to a combination of evolutionary factors (e.g. mutation and natural selection) over time, and they are maintained by both a salmon’s homing behaviour for breeding and local environmental pressures. The quantification and conservation of the levels and patterns of population genetic diversity in Atlantic salmon is now recognised to be of fundamental importance for the long-term sustainability of local populations. It is this natural genetic diversity that enables populations to respond (i.e. to adapt) to the continuously changing river environment and, hence, to persist over time.

As a consequence of human-mediated activities (e.g. urban growth, farming activities, loss and/or fragmentation of suitable spawning and nursery habitats, global warming, overfishing); salmon have declined throughout most of its natural range in the North Atlantic region (WWF, 2001). Decline in wild stocks has led to widespread releases of artificially spawned and reared Atlantic salmon in an attempt to supplement natural production and or to mitigate real or perceived wild population declines. In particular, hatchery releases are undertaken in an attempt to ‘enhance’ fishing for recreational angling and tourism, which are economically important in most countries where Atlantic salmon is still found (McGinnity et al., 2004).

From a population restoration, supplementation and/or conservation perspective(s), salmon stocking involves the intentional release of hatchery individuals into the wild to boost natural production. The main rationale for stocking is that survival from ova to fry or parr in a well-protected hatchery environment is thought to greatly exceed that in the wild and, potentially, allows for a “cost effective” management approach to enhance natural production. Notwithstanding the presumed benefits, however, stocking practices have been increasingly and widely challenged/criticized for their low efficiency in preventing wild populations declines (limited usefulness and poor economic value) and their negative impacts on the fitness of individual populations, which is intrinsically linked to long-term population sustainability (Aprahamian et al., 2003; McGinnity et al., 2003, Araki et al., 2008; Fraser 2008; McClure et al., 2008).

The negative impacts of interbreeding between non-native and wild salmon are well documented in the scientific literature (e.g. Fleming and Einum 1997; McGinnity et al., 2003; Araki et al., 2007, 2009; Hutchings and Fraser 2008; McLean et al., 2008; Thériault et al., 2010, 2011). The unambiguous consensus is that changes in the genetic composition of wild populations caused by stocking has the potential to reduce the evolutionary capacity of populations to respond to changing environments and, hence, to compromise the long-term viability of local stocks. Indeed, in more extreme cases involving continuous interbreeding between wild and non-native salmon, stocking may potentially lead to localised population extinctions (McGinnity et al., 2003).

In an attempt to overcome potential problems related to interbreeding with non-local individuals, a common idea behind modern supplementation/restoration stocking programs is to establish hatchery fish from local broodstock (i.e. local adult females and males). The hatchery fish are reared fish in protected environments, and subsequently released at any stage of their life cycle (e.g. eggs, fry, parr,
and smolts) in to the wild. If broodstock fish are sampled on a yearly basis, it was historically thought that their offspring will closely reflect the natural spawning behaviour of wild adult salmon, hence diminishing the likelihood of impacting local wild populations. One relevant caveat of this approach, however, is that forced coupling may have genetic implications for the next generation (Neff et al., 2008; Anderson et al., 2012). Another important factor to consider in the hatchery environment is that mortality levels and hence selection pressures are very different from the wild. It is often the case that selection will decrease the fitness of hatchery fish once they are released into the wild (Araki et al., 2007).

There are many obvious differences between hatchery and wild environments including:

- Fish density;
- Changes in habitats;
- Interactions with other salmon and other fish species such as trout; and
- Food availability.

All of these are likely to lead to genetic differences linked to important traits (e.g. growth rate, fish morphology, and behaviour) between wild and hatchery fish (Metcalfe et al. 2003; Hawkins et al. 2008). For instance, it is well known that hatchery-reared fish generally have higher growth rates than their wild equivalents (Berejikian et al., 2000). These differences may influence the resulting life-history of stocked fish, in particular a reduction of the average number of winters they spent at sea in comparison to wild-born fish (Jonsson and Jonsson 2006; Kallio-Nyberg et al., 2011). As body size (and fertility) is affected by time spent at sea, the reproductive success of hatchery born/reared fish in the wild may be affected (Thériault et al., 2010, 2011).

Leading from this last argument, it is important to realise that the major assumption of supplemental stocking programs is that the hatchery-born fish will display a similar level of reproductive success in the natural environment in comparison to their wild born counterparts. From the arguments outlined above, this key assumption may not be the case. Indeed, a number of recent scientific studies, capitalising on modern genetic techniques, are challenging this. For instance, studies on the chinook salmon (Oncorhynchus tshawytscha), steelhead (O. mykiss) and coho salmon (O. kisutch), have clearly demonstrated that a single generation of hatchery rearing of local fish was sufficient to decrease the reproductive success of individuals once they were released into the wild (Araki et al., 2007, Williamson et al., 2010, Thériault et al., 2011).

Similar results have also been reported for Atlantic salmon. Milot et al., (2012) assessed the reproductive success of wild and hatchery derived Atlantic salmon in a small river in Québec. The stocking strategy involved yearly release of fish following a single generation of captive breeding. Among the adults returning to the river to breed, between 11% and 41% each year were born in the hatchery. The authors found out that the relative reproductive success (RSS) of the fish born in the hatchery was approximately only half of wild-born fish. The study concludes that being reared in a hatchery environment altered life-history strategies of hatchery born fish and negatively affected their future reproductive success.

In summary, current scientific evidence suggests that while stocking is a potentially feasible strategy for supplementing natural Atlantic salmon stocks, its use should be carefully considered. Indeed, the argument is that hatchery intervention should be the last option, and it should only be carried out as
part of comprehensive fishery management and biodiversity conservation plans and not as an independent approach. Thus, in the case of scientifically proven population declines, the first step, and prior to any management action, is to establish the reasons for the decline (e.g. limited number of spawners, lack of suitable spawning habitats, poor survival at different life-history stages, food limitation, habitat degradation, barriers preventing movement, water chemistry, temperature, etc.) in addition to the level of decline. This is consistent with the likely approach required by Scottish regulators.

Management actions should be based on evidence-based facts related to a particular environment and/or population. Thus, a given management strategy that may potentially work for one particular situation, may not work in other. For instance, if the low number of fish in a given environment is linked to food limitation and or suitable habitat (carrying capacity), stocking will result into increased competition, which, because of density dependent survival, may lead to even lower numbers of fish in the long run.

2.2. Assessment of fish and habitat data
This section provides a summary of the complete review presented in Appendix B.

A stock assessment review carried out by the Dee Trust in 2015 presented a classification of site quality based on a comparison of observed fish densities (O) against an expected density (E) calculated using Millar 2015. This report did not use this approach as it not only had to develop an indication of the catchment scale quality of the Dee juvenile stock, but also the quality of these data used to understand the long term stability and patterns of juvenile production and survival on the Dee with specific reference to the potential implementation of stocking. Therefore, this data review has a different remit to the Dee stock assessment which was tasked with understanding quality based on data benchmarked against a national model at the site scale.

Available data
Four main sets of data were provided to assess the distribution, density and habitat use of juvenile Atlantic salmon on the Dee. These were three electrofishing data sets from 2011 to 2015, fully quantitative, semi quantitative and timed, and the habitat walkover. Table 2.1 below shows the total size of these datasets ultimately used for the juvenile assessment. Figure 2.1 shows the location of all electrofishing data set against the sections of channel surveyed as part of the habitat walkover.

Table 2.1 - Electrofishing data description

<table>
<thead>
<tr>
<th>Type</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>Replicate sites</th>
<th>Habitat data</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timed</td>
<td>96</td>
<td>28</td>
<td>56</td>
<td>73</td>
<td>78</td>
<td>66</td>
<td>53</td>
<td>N/A*</td>
</tr>
<tr>
<td>SemiQ</td>
<td>15</td>
<td>30</td>
<td>34</td>
<td>49</td>
<td>48</td>
<td>49</td>
<td>22</td>
<td>11*</td>
</tr>
<tr>
<td>FullyQ</td>
<td>36</td>
<td>30</td>
<td>38</td>
<td>22</td>
<td>25</td>
<td>31</td>
<td>8</td>
<td>6*</td>
</tr>
<tr>
<td>Total</td>
<td>147</td>
<td>88</td>
<td>128</td>
<td>144</td>
<td>139</td>
<td>146</td>
<td>83</td>
<td>17*</td>
</tr>
</tbody>
</table>

* Incomplete data set
As Table 2.1 shows, not all data could be used in the juvenile assessment. Only sites which had repeated surveys could be used because the risk of an unusually low or unusually high event biasing the assessment could not be controlled if all data were used. Secondly only those sites which had corresponding habitat data could be used as part of the assessment included investigating the relationship between the biology data and habitat. Some data from 2016 were also provided to assess any impacts from the major flooding over the winter.

Assessment
The datasets were reviewed based on the median density at the site, the level of yearly change in the densities and the related habitat. As three separate surveys methods were used and these data might not be confidently compared across the three methods, individual assessments were carried out for each method. The local habitat, based on the location of the survey, was identified to establish the site conditions which could (or should) affect the density of juveniles and the life history stages present.

The relationship between 0+ fry and 1+ parr was also investigated, to help understand the patterns of survival in the Dee. This approach also can provide some information on the potential impacts of the severe winter flooding, and a specific comparison between the density of parr and fry between 2015 and 2016 was carried out.

Results
The distribution of the sites shows that significant sections of the catchment remain without robust data with which to assess the juvenile population. There is clustering of surveys in certain tributaries and sections of the main stem, but there is no long-term, consistent and repeated survey approach.
across the Dee. This means that some locations, such as the Gairn and Clunie have a good level of survey coverage, while others (especially the main channel) have fairly limited coverage.

The results show that the only location with a good characterisation of the juvenile communities is the Gairn, which appears to have a fairly stable juvenile population. Densities appear to be at medium or sometimes high levels relative to the rest of the catchment. However, due to the variable nature of the other sites, it is not possible to draw robust conclusions elsewhere. The habitat information shows that there is very little fry and spawning habitat associated with the survey locations, and parr habitat dominates.

When the survival of juveniles from 0+ and 1+ was reviewed there appeared to be a consistent rate throughout the years with available data, and this was consistent across survey methods. A direct comparison of densities showed that there may be an upper density of parr which is independent of the number of fry from the preceding year. However this is a very tentative observation and should only be used to justify further investigation into the relationship between the two life history stages.

A very small of amount of data (approximately ten sites each from semi quantitative and fully quantitative surveys) was available from 2016 to compare with the historic dataset (2011-2015). The overwinter survival rate (2016) was consistent with the previous winters, and there appeared to be no major declines in fry or parr observed between 2015 and 2016. These observations are very heavily caveated as the number of available surveys is too low to draw confident conclusions.

2.3. Conclusion

The biological review in Section 2.1 conclusively argues that stocking of salmon should be carefully considered due to the scale of potential negative impacts on the naturally produced Dee salmon stock. There is unambiguous evidence that stocking of salmon will reduce fitness of populations, exacerbate the impact of declining marine survival, and risk not only salmon from the Dee but potentially salmon from other catchments. It also makes the very important point that it should not be considered until the cause of the decline in salmon catch has been understood and quantified.

The collection of electrofishing data on the Dee is often project specific. This will allow the datasets to be used, in time, to establish the levels of success associated with a range of works and help with replicating any major successes. But the clustering of the locations makes it difficult to draw a catchment scale picture. The recently activated Catchment Health Monitoring programme should eventually deliver the detail required, but currently the electrofishing data does not lend itself to a catchment scale and robust juvenile assessment, and therefore cannot be used to determine the need for stocking, or to identify the most appropriate stage to stock.

This also affects any attempt to link habitat use and juvenile fish numbers (i.e. the carrying capacity) at the local level and catchment level. There appears to be shortage of spawning and fry habitats on the river based on a visual review of habitats from the walkover and the available habitats adjacent to the electrofishing survey sites, however when we look at the relationship between fry and parr there might be a (slight) suggestion that parr outputs are limited. However, it should be strongly caveated that this cannot be more than a suggestion from a very constrained dataset. Based on the walkover,
summer parr habitat is certainly not limiting, so we could perhaps focus on refuge and overwintering habitat as one of many potential limiting factors\(^6\).

The electrofishing and habitat data presented within this section is unable to identify conclusively any bottlenecks in productivity of juvenile salmonids. This is not because they do not exist; the evidence from the Girnock and Baddoch burns shows that smolt output is fairly stable irrespective of the number of females returning. Unfortunately, with regards to a catchment level assessment, the spatial extent(s), lack of data from the mainstem and the varying methods employed to collect that data all coalesce to reduce the effectiveness of the dataset(s). This is in agreement with the Dee 2015 stock review which, although being able to apply a more definite quality score to the electrofishing densities, stated that significant areas of the catchment were not categorised and the dataset used may not have allowed a full catchment scale assessment to be produced. The chart showing the relationship between 0+ and 1+ salmon hints at parr output being limited, but this interpretation is suggestive and subjective at this stage and should only be used as the basis for further investigation.

Therefore, based on the only robust available data, smolt output is limited (on the Girnock and Baddoch burns) and in the absence of any other information a conservative approach to stocking should be taken. The stocking of ova, fry or parr might not be effective and may unbalance density dependence mechanisms controlling production (P. McGinnity, pers. comm; Bacon et al., 2015), especially if juveniles are stocked into a potentially resource limited environment. These limitations can be overcome by stocking smolts. This is because the smolt stage will not take up any habitat in the river beyond migrating through them, and the risk of overwhelming habitats is not high. From a fishery perspective stocking of smolts is more likely to result in a returned salmon; however, from a population perspective this may increase the genetic risk (P. McGinnity, pers. comm).

Based on very initial comparisons, there is no evidence that Storm Frank has reduced fry and parr densities in those sites with suitable data. Realistically, this dataset is not sufficient either in terms of the coverage of sites or the replication of surveys to determine any impact on the salmon population and it is not appropriate to draw any conclusions regarding that event at this time.

\(^6\) The mobility of fish does mean that they can travel significant distances when seeking overwintering habitat. This may mean that overwintering habitat is one of many potential controls.
3. The cost of stocking

Although stocking operations have previously been fairly *ad hoc* operations with small hatcheries run by a limited number of dedicated people or even individuals (for example the Carron), in practicality it is now a very large undertaking. For example, annual running costs on the Spey are between £60,000 and £70,000, and this has been scaled back significantly by the Spey Fishery Board in recent years (B. Shaw, pers. comm). This cost allows for the production of approximately 250,000 autumn parr, with attributed adult catch to the stocked juveniles varying from 0 to 1.8% of the annual rod catch over the course of five years (Coulson *et al* 2012; Stewart *et al*, 2015). (However the study period covered a period when stocking levels were much higher, with up to 2.2 million fed fry released instead of autumn parr.)

Annual running costs are only one aspect of the monetary cost, and clearly the costs associated with the Spey are not sufficient boost rod catches. Therefore we cannot assume the costs and magnitude of the Spey stocking programme will be sufficient to boost rod catches on the Dee. (For comparison, this study has been asked to investigate the requirements to boost the Dee by 100, 1000 and 5,000 fish – the Spey returned fractions of these values).

The small private hatcheries mothballed currently on the Dee are potentially no longer relevant to modern stocking operations. This is because:

- The previously perceived effectiveness is now seen as questionable;
- Changes to the regulatory and legislative environment (such as the creation of the National Park in 2003 and the SAC in 2005) mean it is no longer within the remit of the Board alone to action stocking; and
- Changes to best practice, such as holding suitable numbers of broodstock, mean they could be of insufficient size.

The planning permission process for building the hatchery is likely to be extremely onerous, while CAR licensing means significant assessment of the water needs of any hatchery will be required. There will also need to be other investigatory procedures (this will be explored further in Section 4) relating to the SAC. Other important considerations such as biosecurity are now strictly controlled, while it will no longer be acceptable on welfare grounds to accept the sporadic losses of year classes which often occurred. Regulation is now supported by accepted standards such as the RSPCA welfare standard for farming of salmon which would include hatchery operations for stocking (RSPCA 2015).

Consequently, the hatchery will need to be a modern, well designed and efficient building and operation developed to strict international standards. This project team has included hatchery designers from Stirling University and Aqua EcoSystems BV to assist in planning and costing the hatchery, while determination of capital costs (land, build costs etc.) have been developed by a chartered Quantity Surveyor.

3.1. How many fish?

The scope of the project required the team to investigate the size of hatchery needed to produce 100, 1000, and 5000 rod caught fish. To do this it first needed to answer two questions – what is the angling exploitation rate, and how many fish will return as adults.
Exploitation rates are difficult to assess, mostly because we simply do not have a very strong understanding of the number of fish which return to our rivers (see Section 1). Even in those systems where efficient counter operations are implemented, factors such as predation and poaching reduce the available stock for exploitation. Underreporting of catches is also a potential issue, while catch and release can blur the picture further (see Smith et al., 2014 for an assessment of the potential effect of catch and release). An additional factor is the potential differentiation between rod capture rates for separate stock components.

Exploitation rates of UK salmon range from 5% to 35% (Thorley et al., 2007). Of that reported range, only one figure was developed from the Dee - 15% (Webb 1998). Other Scottish figures included 5% – 30% from the Spey (Laughton, 1991). Unfortunately, as with many Scottish studies relating to this project, the number of samples used to develop these rates is very low. To reflect this uncertainty we chose to develop cases for three categories of angling exploitation (5, 15 and 30%) to represent low, middle and high rates within the published range.

As suggested in Section 2, the most appropriate phase for fishery enhancement is to stock is smolts. The ranching or stocking of smolts is a common occurrence, being implemented on the Ranga in Iceland (Johannson et al., 1996); the Rivers Bush (Kennedy & Crozier, 1982); Burrisquoole (Mills & Piggins, 1983); Delphi; Tay, Lochy, Dionard and Conon (Stewart et al., 2015) and Tyne (pre-smolts – Milner et al., 2004). Somewhat expectedly, there is a wide range of estimates for the survival of that stocked life history stage to the rod, ranging from no return (Tay - Stewart et al., 2015), to 8.2% return on the Bush (Kennedy & Crozier, 1993). These values also span over 20 years, during which period survival at sea has altered markedly. Therefore once again we set up a low, medium and high return rate for each life history class from Aprahamian et al., (2003 – and references therein), Coulson et al. (2014) and information from Hawkins (PhD thesis) which ranged from 0.1%7 to 8.2%, and as per the exploitation rate a low (0.1%) middle (4.5%) and high (8.2%) were determined. The number of smolts required for each rod return rate, survival rate and exploitation rate are shown below in Figures 3.1-3.2.

7 The lowest survival rate is 0, but this cannot be used when estimating the cost of a hatchery.
Table 3.1 - Estimated numbers of smolts to produce 100 rod caught salmon for a range of exploitation and survival rates

<table>
<thead>
<tr>
<th>Exploitation %</th>
<th>5</th>
<th>15</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult return</td>
<td>2000</td>
<td>667</td>
<td>333</td>
</tr>
<tr>
<td>Survival Value</td>
<td>High</td>
<td>Middle</td>
<td>Low</td>
</tr>
<tr>
<td>Survival %</td>
<td>8.2</td>
<td>4.5</td>
<td>0.1</td>
</tr>
<tr>
<td>No. of Smolts</td>
<td>24,390</td>
<td>44,444</td>
<td>2,000,000</td>
</tr>
</tbody>
</table>

Table 3.2 - Estimated numbers of smolts to produce 1000 rod caught salmon for a range of exploitation and survival rates

<table>
<thead>
<tr>
<th>Exploitation %</th>
<th>5</th>
<th>15</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult return</td>
<td>20000</td>
<td>6667</td>
<td>3333</td>
</tr>
<tr>
<td>Survival Value</td>
<td>High</td>
<td>Middle</td>
<td>Low</td>
</tr>
<tr>
<td>Survival %</td>
<td>8.2</td>
<td>4.5</td>
<td>0.1</td>
</tr>
<tr>
<td>No. of Smolts</td>
<td>243,902</td>
<td>444,444</td>
<td>20,000,000</td>
</tr>
</tbody>
</table>

Table 3.3 - Estimated numbers of smolts to produce 5000 rod caught salmon for a range of exploitation and survival rates

<table>
<thead>
<tr>
<th>Exploitation %</th>
<th>5</th>
<th>15</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult return</td>
<td>100000</td>
<td>33333</td>
<td>16667</td>
</tr>
<tr>
<td>Survival Value</td>
<td>High</td>
<td>Middle</td>
<td>Low</td>
</tr>
<tr>
<td>Survival %</td>
<td>8.2</td>
<td>4.5</td>
<td>0.1</td>
</tr>
<tr>
<td>No. of Smolts</td>
<td>1,219,512</td>
<td>2,222,222</td>
<td>100,000,000</td>
</tr>
</tbody>
</table>
When deciding on a survival and exploitation rate for this section it was important to focus on the economic, not the biological, and a strong driver was to produce an economically acceptable outcome. Therefore we provisionally sense-checked the numbers of smolts required against the cost to produce one smolt from Stewart et al. (2015) of £1.50. This is shown below in Table 3.4.

### Table 3.4 - Cost of production based on Stewart et al. (2015)*

<table>
<thead>
<tr>
<th>Survival rate</th>
<th>Exploitation rate</th>
<th>Catch</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1%</td>
<td>£3,000,000.00</td>
<td>100</td>
</tr>
<tr>
<td>4.5%</td>
<td>£666,666.00</td>
<td>1000</td>
</tr>
<tr>
<td>8.2%</td>
<td>£36,585.00</td>
<td>5000</td>
</tr>
<tr>
<td>0.1%</td>
<td>£30,000,000.00</td>
<td></td>
</tr>
<tr>
<td>4.5%</td>
<td>£6,666,660.00</td>
<td></td>
</tr>
<tr>
<td>8.2%</td>
<td>£365,850.00</td>
<td></td>
</tr>
<tr>
<td>0.1%</td>
<td>£150,000,000.00</td>
<td></td>
</tr>
<tr>
<td>4.5%</td>
<td>£33,333,300.00</td>
<td></td>
</tr>
<tr>
<td>8.2%</td>
<td>£1,829,250.00</td>
<td></td>
</tr>
</tbody>
</table>

Exploitation rate: 5, 15, 30

*Rounding error present

Based on the £1.50 unit price:

- Using the 0.1% survival rate; over 666,000 smolts would be needed to produce 100 rod caught fish at a cost of £1 million;
- This rises to £10 million for 1000 additional rod caught fish; and
- £50 million for 5000 fish.
- To use the 0.01% figure (the lowest non-zero return rate in Stewart et al., 2015) would have increased those estimated costs by ten.

These figures were deemed to be economically inappropriate.

The 8.2% figure was universally agreed to be too high a survival rate. Subsequently the 4.5% return rate was used. While the 4.5% value is only representative of a median of survival it is a useful level for an economic assessment with Table 3.4 demonstrating that the associated costs are potentially in line with expectation. From the biological perspective the only available Scottish data suggests that survival may currently be much lower and there should be an acceptance that a return of zero (or close) rod caught fish is very possible.

With respect to the exploitation rate, the task was made somewhat easier as 15% also corresponded to a published exploitation rate on the Dee.

Therefore a 4.5% return with 15% exploitation rate was used as the basis for costing a suitable hatchery. Using these rates, for 100 rod caught fish we will need approximately 14,800 smolts per annum; for 1000 fish 148,000 smolts, and for 5000 rod caught fish 740,000 smolts.
3.2. The hatchery cost
The description to plan, design, build and run hatchery are presented in Appendix C. Table 3.4 provides the initial investment cost, the initial investment and running cost per fish, and the subsequent running cost per fish. Further information on operational costs (opex) is presented in the Appendix.

Table 3.4 - Costs to build, run, and per fish cost of a Dee fish hatchery

<table>
<thead>
<tr>
<th>Catch</th>
<th>Smolts</th>
<th>Hatchery</th>
<th>Per rod catch cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Area of building ($m^2$)</td>
<td>Capital budget (incl. VAT)</td>
</tr>
<tr>
<td>100</td>
<td>14,815</td>
<td>535</td>
<td>£1,384,216</td>
</tr>
<tr>
<td>1000</td>
<td>148,148</td>
<td>2,176</td>
<td>£3,666,082</td>
</tr>
<tr>
<td>5000</td>
<td>740,741</td>
<td>5,608</td>
<td>£7,987,119</td>
</tr>
</tbody>
</table>

The value of running a hatchery to produce an additional 100 rod caught fish is highly debatable (P. McGinnity, pers. comm.) given the relatively large number of returning fish, and this level of enhancement is seen as a ‘drop in the ocean’. It will also be shown that this level of rod catch increase has been potentially provided by the removal of coastal nets on other catchments (See Section 4 – Legal).

Stocking to the 5,000 level would require the removal of 508 adult fish for broodstock. If these fish were removed annually by electrofishing, then this would be a loss of over 75 fish to the Dee fishery based on 15% exploitation. If we assume that the 4.5% survival rate was lower (e.g. 1%), then we would require 2,286 broodstock fish per annum with an annual food bill of over £200,000 (food bill for 508 broodstock fish is £55,000).

The 1000 level remains. This requires 102 fish for broodstock (£10,000 for feed p.a.), over 2000 square metres of work space, an initial outlay of over £3 million with annual running costs of over £500,000. This has been calculated using the middle range values of exploitation 15% and return survival of 4.5%. If stocked smolt return reduced are lower on the Dee (for example Table 3.2 shows that if survival is 0.1% then over 600,000 smolts will be needed), then the investment needed to produce 1000 rod catch will far exceed the costs presented here.

3.3. Cost Benefit
The price of a rod caught salmon is not standard across fisheries. The river being fished, the likelihood of capture, the confidence of the angler and the likelihood of capturing a large MSW fish all have a bearing on any value estimated.

The economic value is also relative and subject to fluctuation. A salmon caught in a fishery which is deemed to be underperforming or not performing will have a lower economic value than a salmon from a fishery which is perceived to be performing to a high standard (e.g., people will pay more to fish the Findhorn than the Forth). Similarly, if people can fish the Don for a fraction of the price of the Dee with the same perceived chance of catching a fish, then they are more likely to fish the Don. Therefore, depending on the returns from a fishery a salmon has a value which is more or less than
previously judged. And finally, with conservation plans now in place, an angler may pay a premium to be allowed to kill a fish. Therefore, the choice of value to use for a cost benefit analysis is subject to fairly broad range of factors and figures.

During tendering, we proposed the value of a Tweed salmon, £2,055.78 (calculated from the £24 million value of the Tweed to the local economy – SQW, 2015 - divided by the five year average catch returns). Another value of £5,925 was proposed by Postle and Moore (1996), which would be currently over £8,000 based on a CPI inflation adjustment. However a value produced by the Dee Trust, updated from Radford et al. (2004) of £2,670 will be used.

Based on Table 3.4 (above) and the Dee valuation the cost benefit for a fish from the first smolt release (1000 rod caught level) would be 0.5. This means that for every pound invested a maximum of 50 pence would be returned. For succeeding releases the cost benefit would be 1.59. This benefit is based on a maximum return of 4.5% and exploitation of 15%. It should be expected that the return rate of 4.5% is highly unlikely and a return of zero probable in some years.

3.4. Timeline

Based on the design and operational details produced to support the economic assessment, the current timeline can be proposed. The Dee has historically been considered a MSW fishery. If stocking were to go ahead, how long would it take until the first hatchery reared MSW fish return? First, it should not be assumed that any fish will return; stocked fish have much lower survival rates than wild fish (Aprahamian et al., 2003). Secondly, there is no guarantee that these fish will return as MSW salmon (if at all). With those two caveats put to one side the following timeline is proposed:

1. Stocking actioned by the Dee board in November 2016 with one year to raise the funds;
2. Design and planning work would begin in November 2017 (18 months) and CAR and broodstock licenses;
3. May 2019 - At least six months for planning application objections;
4. November 2020 – build begins (10 months);
5. September 2021 build finishes and broodstock collection begins;
6. Spring 2022 – first hatch;
7. Spring 2024 – stocking license application;
8. Spring 2025 – first hatchery smolt release;
9. 2026 – first returning grilse; and
10. 2027 – first returning MSW salmon.

3.5. Conclusion

The stocking of smolts to improve the rod catch by 100 fish is not recommended on economic grounds. This is because it will deliver little definitive benefit for significant cost and this number of fish is a very small fraction of the rod catch (see Figure 3.1. below).
Secondly, even in the biologically unlikely event that 4.5% of smolts return, increasing the rod catch to 5000 is also difficult to justify. Leaving aside the huge numbers of broodstock required and assuming a Dee Board operating budget similar to 2016 of £624,660 (DDSFB, 2016), an additional £200,000 would be needed to operate the hatchery, along with the cessation of all other operations run by the Dee Board and Trust. Funding the hatchery build would need almost £9 million. These figures also do not take into account the loss of fish from natural production if the required broodstock were removed.

The 1000 level could be carried out if the Dee Board liquidated all its assets to fund 40% of the hatchery build costs, with additional contributions making up the £2 million shortfall. Operating costs for the hatchery reach 89% of the total 2016 Board operating costs.

Ultimately however, based on the broad range of survival rates in the literature there is no guarantee that any fish will return and the investment will not be of any economic benefit to the Dee fishery or any private individuals who would wish to donate to a hatchery.

The cost benefit assessment is based on the economics of building and running a hatchery only and additional costs are possible. Rivers stocked with smolts might have lower long term catches than rivers not stocked with smolts (Young, 2014). The potential loss to the naturally produced salmon rod catch on the Dee from the short and long-term negative impacts of stocking and loss of broodstock would need to be calculated and added to the cost benefit analysis to improve accuracy. It is possible that other items would need to be added to the ‘cost’ side of the calculation (such as potential impacts on the pearl mussel population and the reputational loss to the Dee of being a wild fishery) and a specific in-depth economic review assessment (similar to that carried out on the Tweed) may be required.

In addition to the other potential costs proposed above, stocking the Dee cannot simply be viewed as an investment into the build and operation of a hatchery. The figures presented here show that stocking would require the operating budget for bailiffing, management, angling development and maintenance cut. (Staff salaries of over £250,000 for 2015 could not be maintained under any of the three stocking scenarios).

This operating budget of the Board and Trust is also used to indirectly access much larger funds which can support improvements on the Dee. A key task currently is the development of programmes which bring in funding from central government, the EU and other agencies. (The Pearls in Peril project was...
originally judged to be worth £3.5 million, for an input of £100,000 from the Trust. In 2015 it contributed £126,000 to the Dee Boards’ budget, a figure which represents over 30% of the entire levy contribution.) Stocking potentially not only risks the viability of the salmon population on the Dee, but also all the other activities carried out by the Board and Trust to ensure the continuation of the fishery.
4. Legal
As mentioned throughout this report, there are a number of legal factors that could potentially influence the decision to stock the Dee. They are:

- The Dee SAC and other designations;
- The Cairngorm National Park;
- Licensing of issues relating to stocking;
- The change to Fishery Management Organisations as part of the Wild Fisheries Review; and
- The current legal obligation of the Board to protect, conserve and enhance the salmon fishery.

4.1. Protected sites
Designated sites protect Scotland’s natural heritage through statute. There are different types of designations, each conferring different levels of protection. The River Dee catchment contains numerous protected sites ranging from regionally to internationally important areas. Site designations of the River Dee catchment include:

- Natura 2000 sites – European level designations established under the EC Habitats and Birds Directives and including Special Areas of Conservation (SACs) and Special Protection Areas (SPAs). SPAs protect species of birds while SACs protect other habitats and species of community interest. Under the legislation, sites must be maintained in favourable condition. The protection afforded by these designations is generally applied through planning and licensing processes. If as a result of a planning application, activity or development there is ‘likely to be a significant effect’ upon the habitats or species featured in an SAC or SPA, then an Appropriate Assessment (AA) must be obtained along with advice from Scottish Natural Heritage as to whether the application can be accepted.

The establishment of a hatchery, because it may impact a notified feature of a site (Atlantic salmon) would likely require several Appropriate Assessments (AA) to be carried out each time a stocking event is carried out (C. Bean, SNH, pers. comm.). Both stages involved in the process – the removal of adult broodstock and the stocking of hatchery reared fish into the SAC – would have to be assessed against the conservation objectives of the SAC.

- Sites of Special Scientific Interest – UK level designations under the Wildlife and Countryside Act, 1981 and as updated. Provisions for protection and management of SSSIs’ were provisions recently improved by the Nature Conservation (Scotland) Act 2004 and the Wildlife and Natural Environment (Scotland) Act 2010. Planning authorities must consider whether a development will affect a site but they have considerable discretion in their decision making.

- National Parks – Scotland level designations under the National Parks (Scotland) Act 2000 to conserve countryside landscapes promote public enjoyment of them and promote sustainable economic and social development.
• Ramsar sites – International designations under the Convention on Wetlands of International Importance, 1971. All Ramsar sites in Scotland are also SPAs or SACs and their protection comes primarily from those designations.

• National Nature Reserves – In Scotland, these are declared by Scottish Natural Heritage. They contain areas of important natural and semi natural terrestrial and coastal ecosystems and are managed to conserve these habitats and to provide public recreation.

• Local Nature Reserves – These can be declared by Local Authorities (following consultation with the relevant statutory nature conservation agency). They are managed for conservation, education and recreation.

Protected sites within the River Dee catchment
There are many protected sites within the River Dee catchment. Many of these are SSSIs (Sites of Special Scientific Interest), SACs (Special Conservation Areas) and Ramsar sites with a focus on upland terrestrial habitats, wetlands, otters and standing waters. The whole of the upper catchment falls within the Cairngorms National Park and there is substantial overlap with the Cairngorm SAC and the Cairngorm Massif SPA. These protected sites give a picture characterising the catchment as a relatively unspoiled, highland catchment with low nutrient waters and healthy fish populations – ideal conditions for supporting high conservation value species such as Atlantic salmon and freshwater pearl mussels. The primary designation of interest and relevance to the river and to these species is the River Dee SAC.

The River Dee Special Area of Conservation
There are 17 river SACs in Scotland that feature Atlantic salmon. The River Dee is one of 11 that have Atlantic salmon as a primary qualifying reason for site selection.

The SAC includes the entire length of the main stem and almost all of the tributaries. Three interest features form the basis for the designation, all of them species that are primary reasons for designation. Habitats are not specifically mentioned in the designation (other than those supporting the named species). The three species are:

• Atlantic salmon (Salmo salar);
• Freshwater pearl mussel (Margaritifera margaritifera); and
• European otter (Lutra lutra).

Management of a salmon hatchery must consider the potential effects on all three interdependent species. Otters are the top predator in this species complex, with salmon and freshwater pearl mussel (FWPM) both used as food sources. However, with a wide range of alternative food sources available to them, they may not be expected to respond substantially to the magnitude of changes in prey composition that might result from any potential hatchery activity. Thus an AA may not necessarily be required for otter. However, disturbance to a preferred prey species, for example, the European eel undergoing a population crash, could make otters much more heavily dependent on salmonids for survival, and could change this situation.

Sea trout, brown trout and Atlantic salmon are the only known hosts for the larval stage of pearl mussel (Young and Williams, 1984). As 0+ salmon are generally more abundant than 0+ trout in most
rivers, salmon are considered likely to be the most important hosts of the FWPM. However, there are Scottish streams with few salmon yet they still support a mussel population, and these must be considered to be largely trout dependent (Skinner et al., 2003). Salmon are the dominant species on the River Dee, although there are also significant numbers of brown trout and a sea trout fishery. It is thought that salmon are likely to be the preferred host of FWPM in the River Dee system, as is the case for the neighbouring River Spey (I. Syme, SNH, pers. comm.), however, a study to confirm the relative importance of the two species as FWPM hosts would be useful to better inform any management decisions affecting either host species.

The long term survival of the FWPM depends ultimately on host availability and any significant changes in salmon stocks could threaten FWPM populations (Cosgrove et al., 2000). Whilst juvenile salmon densities throughout the River Dee system are generally well above thresholds for the continued existence of FWPM (RAFTS, 2014 and Skinner et al., 2003), it is still necessary to guard against localised impacts in areas where the salmon population may be augmented with stocking.

The relationship between salmon and FWPM is mutually beneficial. Adult mussels can filter up to 50 litres of water per day (Zuiganov et al., 1994 – in Skinner et al., 2003) which helps maintain water quality at a level favourable to salmonids. In addition, FWPM beds may provide a microhabitat for the invertebrates on which the salmon feed.

Conservation objectives
The River Dee SAC brings with it conservation objectives stipulating what protection must be afforded to the species identified in the designation, and to the structure and function of their supporting habitats. The River Dee SAC aims ‘to avoid deterioration of the habitats of the qualifying species or significant disturbance to the qualifying species, thus ensuring that the integrity of the site is maintained and the site makes an appropriate contribution to achieving favourable conservation status for each of the qualifying features’ (species).

In addition, the objectives are to ensure for the qualifying species that the following are maintained in the long term:

1. Population of the species, including range of genetic types for salmon, as a viable component of the site;
2. Distribution of the species within the site;
3. Distribution and extent of habitats supporting the species;
4. Structure, function and supporting processes of habitats supporting the species;
5. No significant disturbance of the species;
6. Distribution and viability of freshwater pearl mussel host species; and
7. Structure, function and supporting processes of habitats supporting freshwater pearl mussel host species.

Implications of the conservation objectives for hatchery stocking

Objective 1
The main constraint to salmon management emerging from these conservation objectives is maintaining genetic types for salmon as a viable component of the site (objective 1). This requirement has profound implications for management, particularly with regard to the use of a hatchery. Atlantic
salmon have been shown to exhibit genetic structuring between river systems (Webb et al., 2007; King et al., 2007), tributaries and even within tributaries. This genetic differentiation indicates that salmonids become adapted to their local conditions and benefit by homing to their natal areas where their offspring are likely to have optimal survival rates (Fraser et al. 2011). Inherited characteristics may include growth rate, run-timing (Stewart et al., 2006), variation in age at smolting (Englund et al., 1999), sea-age at maturity (Niemela, 2006), disease resistance and survival behaviours. The introduction of life stages from a hatchery which have not been subject to the natural selection pressures of the stocked area would likely lead to reduced survival within the local population (McGinnity et al., 2003). See Section 1 for further details.

The River Dee was included in a recent project looking at genetic structuring within a range of Scottish rivers (the FASMOP project8). It was found that fish could be correctly assigned to one particular tributary of the River Dee – the Water of Dye – 90% of the time (Coulson et al., 2013). This indicates a high level of unique adaptation to that particular tributary. Stocking the Water of Dye with hatchery reared fish using broodstock from elsewhere in the River Dee may have a profound negative effect on survival rates. The management implications of these findings are therefore that hatcheries must be tributary (or preferably reach) specific. There is a strong likelihood that this structuring will be found elsewhere on the catchment. For this reason, only broodstock from a particular tributary or section of main stem should be used to stock that area. This will be very difficult to achieve, as although an adult may be taken from a certain section of the river for artificial breeding, unless it is taken from a redd site, there is no guarantee that is the watercourse where that fish will breed (and even then, this fish may move to spawn in another location (Taggart et al., 2001). Practically, removing sufficient broodstock for a tributary based stocking operation is a significant investment in time and capital and will require a large team operating across the catchment.

Restocking a river with hatchery reared stock from elsewhere has been successful in some cases, and where there is no existing population (as per guidance from RAFTS, 2014). (However, evidence from the Tyne and Thames is that stocking simply maintained the fishery while straying from elsewhere rebuilt the natural population – Milner et al., 2004; Griffiths et al., 2011). The Dee is currently in favourable condition for both adult stocks and juvenile densities (RAFTS, 2014) using the SAC monitoring procedures. Any hatchery on the River Dee system must therefore use only tributary or reach-specific local broodstock and be strictly controlled to avoid damaging the salmon populations that are already in place.

In addition to location of broodstock, the number of breeders must also be considered as having a profound effect on the genetic heterogeneity and health the population. A large number of adult broodstock are required to avoid inbreeding. 50 mating pairs, chosen at random, should be used as broodstock (Bailey & Kincaid, 1989). The River Tay hatchery maintains a broodstock of around 300 fish, based on reconditioning kelts.

Other principles, drawn from Mills (1991), that should be adhered to when managing a hatchery to preserve genetic integrity include the following:

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River Forth Fisheries Trust: River Dee Hatchery Assessment

- Broodstock should not be kept in captivity for more than one generation and should be obtained from the wild each year that stocking is to take place;
- Collection of spawners should encompass the entire spawning migration period;
- Some pristine stocks should be maintained and conserved in each geographical area;
- One-on-one matings should be the norm wherever possible, i.e. males are only used once; and
- Robust monitoring must be carried out to ensure the stocking programme is having the desired outcome.

A post stocking monitoring plan is imperative to determine whether the hatchery is contributing to an increase in returning adult salmon available for the rod fishery, whether it is delivering value for money and most importantly - not causing harm to existing stocks. Broodstock must be genetically typed so that returning hatchery produced fish can be identified in the relevant fisheries. This will determine the effect of stocking on rod catches. Annual electrofishing of stocked areas is necessary to determine the level of survival of hatchery juveniles (in the event freshwater stages are stocked). In areas where naturally spawned juveniles are also present, genetic testing will determine the relative abundance of stocked and natural juveniles and determine the extent to which one replaces the other. This is of particular importance on the River Dee as it is likely that stocking will take place in areas where natural populations are also present, and damage to the natural population must be avoided at all costs and to comply with the conservation objectives of the SAC designation.

Objective 2

Objective 2 states that the current distribution of the species within the river system should be maintained. Stocking should not therefore be carried out in a way that raises the likelihood of causing detriment or decline in the natural salmon population.

Detailed analysis of fry densities in seven tributaries of the River Dee and one main stem site during the most recent round of Site Condition Monitoring revealed a ‘high variability in fry density across the catchment, possibly reflecting local differences in juvenile productivity’. This could point to some tributaries having degraded or unsuitable habitat or insufficient numbers of spawners (However, yearly variation may not indicate long term patterns of decline or increase (see Sections 1 and 2). Stocking in areas that already have a head of salmon present is not effective and can do more harm than good (see Section 2.1).

It has been established that sufficient numbers of local broodstock should be used to stock a given area. This may give rise to a logistical problem of obtaining sufficient broodstock from an area of lower productivity. There is also increased risk associated with removing rare broodstock from an area where the population is already under pressure. This should only be attempted if there is strong evidence to suggest that productivity and survival would be higher with the hatchery in place. Adults found in sub optimal areas may not necessarily breed there, instead moving off to more suitable areas to breed, where spawning success and juvenile survival would be higher. In addition, males that may have spawned multiple times would be unable to do so if removed to a hatchery (where they are to be used only once). Both of these scenarios would cause stocking to result in a lowering of natural productivity.

To address the problem of removing adults from a degraded area, mended kelts can be reconditioned following spawning and used as broodstock (as in the Tay). There is significant cost associated with
reconditioning kelts in an appropriate installation, particularly as they can only be used once in order to avoid inbreeding, therefore new kelts must be reconditioned each year.

**Objective 3**
Distribution and extent of habitats supporting the species. Hatchery and stocking activities are unlikely to have any impact on habitats.

**Objective 4**
Structure, function and supporting processes of habitats supporting the species. Hatchery and stocking activities are unlikely to have any impact on the structure, function and supporting process of habitats.

**Objective 5**
No significant disturbance of the species. As mentioned above, hatchery activities are unlikely to disturb otters as they have a wide range of preferred and alternative food sources they can utilise. The intention of stocking would be to increase the number of salmon in the River Dee system, but as discussed above, unless hatchery activities are very stringently controlled and strict principles are adhered to, there is the potential to cause damage to the existing populations, to reduce genetic fitness and survival. Any such negative impact would no doubt have a follow on effect upon the FWPM that are dependent on their salmon hosts.

**Objective 6**
Distribution and viability of freshwater pearl mussel host species. Since the host species, juvenile salmon, are also protected as a feature of the SAC designation, the impact of a potential hatchery on their distribution has already been addressed in objective 2 above.

**Objective 7**
Structure, function and supporting processes of habitats supporting freshwater pearl mussel host species. Since the host species, juvenile salmon, are also protected as a feature of the SAC designation, the impact of a potential hatchery on the structure and function of their habitat has already been addressed in objective 4 above.

**Other Atlantic salmon SACs in Scotland**
There are 17 SACs in Scotland that include Atlantic salmon as part of their designation. Some are also, like the River Dee, designated for freshwater pearl mussel and otter. Each species can be considered either a primary or a secondary reason for designation, and this will affect the level of protection accorded to the species and its supporting habitats and has implications for management. The species designation for each of the 17 SACs is shown in Table 4.1.
Table 4.1 - Atlantic salmon SACs in Scotland, showing salmon, freshwater pearl mussel and otter as primary or secondary reason for designation (marked 1 or 2 accordingly, or – where the species is not included)

<table>
<thead>
<tr>
<th>Special Area of Conservation</th>
<th>Atlantic salmon</th>
<th>Freshwater pearl mussel</th>
<th>Otter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berriedale and Langwell Waters</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>River Bladnoch</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>River Borgie</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>River Dee</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Endrick Water</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Langavat</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Little Gruinard River</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>River Moriston</td>
<td>2</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>River Naver</td>
<td>1</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>North Harris</td>
<td>2</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>River Oykel</td>
<td>2</td>
<td>1</td>
<td>-</td>
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<tr>
<td>River South Esk</td>
<td>1</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>River Spey</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>River Tay</td>
<td>1</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>River Teith</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>River Thurso</td>
<td>1</td>
<td>-</td>
<td>-</td>
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<tr>
<td>River Tweed</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
</tbody>
</table>

Of the 17 designated sites, only the River Spey SAC has the same range and level of interest features as the River Dee SAC. The two sites have the highest possible tier of protection compared to the other SACs, with the same three interdependent species as primary reasons for designation.

The Spey Fishery Board runs a hatchery operation that now observes many of the principles discussed above e.g. local source of broodstock and genetic testing of broodstock for comparison with the rod fishery. The hatchery is targeted primarily at areas with low salmon productivity due to restricted access rather than degraded habitat, for example, upstream of impassable or partially passable man made barriers (areas upstream of natural barriers are not considered for stocking as this would disturb the unique gene pools of long-established and isolated brown trout populations). Fish are released as 0+ fry and electrofishing monitoring of juveniles and genetic sampling of broodstock and returning adults are carried out to determine the effectiveness of the hatchery and its contribution to the number of returning adults. Stocking activity on the Spey has become more stringent, reduced and targeted over time, and it is acknowledged by the Spey Fishery Board in their 2015 annual report that:

‘A more sustainable strategy, that will benefit the whole river, is to conserve stocks to ensure there are adequate fish available to spawn, and to ensure that the habitat in the nursery areas is as good as possible, so as to promote enhanced survival through the parr and ultimately smolt stages of the salmon life cycle.’

Genetic analysis of rod caught fish in 2010 and 2011, compared to hatchery released juveniles of four and five years previously, showed that hatchery fish contributed less than 2% to the rod fishery (SFB
Annual Report, 2013). The Board note that since broodstock were taken from the wild, they are likely to have spawned naturally in any case, and so this 2% is not a direct measure of hatchery contribution. The actual additional contribution from the hatchery activity is likely to be considerably less than this (if any). These figures indicate that a hatchery, run appropriately, constitutes a significant monetary outlay for what is likely to be a vanishingly small gain.

During discussion, Colin Bean of SNH queried the case for stocking the Dee based on recent poor catches. Reiterating the conclusions from the 2013 IBIS workshop on stocking that it should not be a tool of first use, the evidence base for stocking was raised. Secondly, it was stated that stocking could be a potential long term risk and that the activity may not be compliant with conservation objectives of the SAC.

Therefore, two appropriate assessments would be required (for broodstock removal and for stocking) and it should be shown that the number of potential eggs removed during broodstock gathering should be at least matched by the stocked return. However, matching is unlikely to prove a sound basis of the economic argument for stocking.

Cairngorm National Park was also interviewed with respect to stocking. Prior efforts at stocking the Dee would have occurred before CNG was established. Therefore there was no planning panel when it came to construction of a hatchery. Currently, if it is deemed that any planning permissions were needed for the construction of the hatchery, access routes to the hatchery or associated structures, the planning decision could be sent to the Park board. The representative of the Park stated that the Dee was crucial to the Park but that a balance should be struck between the economic and conservation aims of the park. Any stocking process should review all the factors but other avenues, such as improved catchment and land management would be a start point for the CNG before stocking. It was stated that there is value in a feasibility study but there would be a certain amount of concern over stocking and that physical habitat is paramount.

SNH are of the view the stocking is a potential risk to the Conservation Objectives of the SAC, and legislation requires that the scale and impact of such risks must be fully assessed before such activities can be carried out. To allow such an assessment to be carried out, supporting information on adult and juvenile numbers will be required, as well as sound rationale for carrying out this activity.

Another licensee outwith the Dee board is Marine Scotland Science. MSS will need to grant a license for broodstock removal and Brian Shaw of the Spey has stated that MSS are applying greater scrutiny to that Board’s stocking license applications every year, and that a stocking panel is convened every year within the Board to continually reassess the need for stocking internally. Therefore it is likely that there will be a significant input from the Dee Board and Trust to stocking applications and, if stocking were to be given the go ahead, this does not guarantee that permission will be granted in future years.

4.2. Legal Obligations of the board: Management of salmon
The management of Atlantic salmon is currently within the remit of the Dee District Salmon Fishery Board. However, following the Wild Fisheries Review (Scottish Government 2014) and the publication of a consultation paper on draft provisions for a Wild Fisheries (Scotland) Bill and Strategy (February 2016), it is abundantly clear that the current structure of management will cease. A new hierarchical structure will instead be activated, comprising a national Fisheries Management Unit (FMU) dealing with strategy and other high level operations, with a number of local Fisheries Management
Organisations (FMOs) delivering practical management of all wild fish species in the designated FMO areas. This will mean that powers currently within the sphere of the Board may be given to the National Management Unit. This may include the license to stock Atlantic salmon. Therefore, prior to instigating any formal license application studies, the final position of responsibility for stocking within the new management system should be clarified.

An in-detail description of the legal requirement of the Board, the relevant legislation and upcoming changes is presented in Appendix E

4.3. Legal obligations of the Board: Alternatives to stocking
The factors which influence the survival and productivity of Atlantic salmon are numerous. Subsequently, any actions which can mitigate negative pressures can boost salmon productivity.

These negative pressures can come in two forms; natural ecosystem pressures such as predation and anthropogenic pressures. The purpose of this report is not to investigate limiting ecosystem pressures and limiting populations of species such as seal, dolphin, otters, cormorant, and other piscivorous birds should not be considered acceptable fishery management practice. This does raise an issue as the majority of stakeholders responded that predation by dolphins, seals, and birds were a pressure. (Carss et al., 1990, suggested that predation, in this case by otters, had little impact on the Dee.) It will be difficult for the Dee Board to persuade a regulator that predator control is a viable management strategy.

Netting
As part of the changes to fishery management in Scotland, coastal netting is to temporarily cease. The Dee board annual report 2015 stated that although the netting operations on the Dee have practically stopped, 18% of net catch from a neighbouring catchment were Dee fish. Therefore, by closing these netting stations the Dee will see an increase in returning salmon this year. 2015 catch returns from fixed engine netting on the Esk were 2803 salmon (MSS catch statistics). By closing this fishery an additional 504 salmon would have returned to the Dee. Based on the exploitation rate of 15% on the Dee, this could have corresponded to an additional 75 rod caught fish. With all coastal netting station closed as part of the new Conservation Regulations, it is most probable that a related increase of returning fish could supply the additional 100 rod caught requested by stocking. Therefore, the lower level increase in rod catch proposed by the Dee Trust will be met by changes in salmon management. This cessation of coastal netting will last for three years, and seeking an extension of this closure should be a Dee Board (or FMO) priority.

Fish passage, habitats and morphology.
Figures 4.1 to 4.3 (fish passage, morphology and water quality respectively) show the range of pressures on the Dee system as determined by SEPA's WFD monitoring (SEPA, 2015). Areas considered to have good or better quality are highlighted in blue and green, other colours represent reduced quality. These figures have been reproduced from the SEPA River Basin Management Plan (RBMP). With the exception of water quality, it is clear that work remains to bring the catchment up to an acceptable standard for habitats and fish migration.
It is commonly believed that the issue of weirs has been managed on the Dee catchment (stakeholder survey respondents). However, there are 149 individual barriers which remain, 11 of which are still impassable (see Figure 4.4. from the Dee walkover). While it is often tempting to think of weirs exerting a pressure only on upstream passage of fish, they also prevent the formation of new habitats, especially gravel habitats. Another factor, mentioned previously, is that fish passes do not operate as effectively as believed. Very little peer-reviewed information is available on this; however Noonan et al., 2012 found that maximum passability ranged from only 70% to 20% (dependent on the type with less natural-type passes proving less passable). There was also a major impact on juveniles, with 30% of attempted downstream passes unsuccessful. If this pattern of effectiveness is applicable to the Dee, then clearly there will still be a major impact on the migratory patterns of salmon.
The cumulative impact of weirs, whether deemed passable with fish passage or without, should bear further investigation. Weirs of only 30cm have been shown to retard migration (Gerlier and Roche, 1998). Even with facilitation of passage, factors such as increased catchability, opportunistic predation, disease, parasitism and increased susceptibility to pollution can cause mortality (de Leaniz, 2008) and reduced breeding success (see Figure 4.5 for an incidence of disease outbreak at a weir with an operational fish pass). Often, the simple presence of a weir (even with passage) can cause a cessation of migration (Solomon et al., 1999). Instream barriers also prevent new gravels from being transported downstream, with old redds having reduced survival of ova when compared with new ones (Wheaton et al., 2004). Therefore it is too simplistic and probably incorrect to state that the issue of barriers has been solved on the Dee and, in general, there are still significant knowledge gaps when it comes to understanding the impacts of weirs of fish migration (Milner et al., 2013).
Figure 4.5 - Two of approximately 100 salmon killed during a low flow event at Westfield weir on the Allan water during 2016. A functioning fish pass is present on the structure.

River Restoration

In addition to the impact from weirs, the abundance, diversity and relative presence of instream habitat plays a role in limiting salmonid populations. Habitat complexity and wood in rivers have been shown to increase juvenile survival (Quinn & Peterson, 1996); elevate fry density (Venter et al., 2008, Floyd et al., 2008); and increase spawning (Floyd et al., 2008). (Conversely an absence of wood is linked to reduce growth rates of juvenile salmon (Finstad et al., 2007)).

Recent work by SEPA on the Dee highlighted that there still remain significant areas of damage to instream and bank structure and habitats on the Dee, including the mainstem. These are shown below in Figure 4.6. Ten of these channels have been selected for SEPA funded restoration work to improve instream habitat.

Figure 4.6 – Areas of reduced physical habitat quality (morphology) on the Dee (from cbec, 2011)
In addition to these areas, many areas of the upper Dee and its tributaries have historically been affected by tree removal or grazing pressure preventing tree growth (see Figure 4.7).

![Image](image.jpg)

**Figure 4.7 – The upper Dee near the Linn of Dee**

This can lead to a reduction in the number of pools (Montgomery et al., 1998), biological refuges (Gurnell et al., 2005) and increase sediment input into channel (Haigh et al., 2004) making the channel less suitable for older juvenile fish such as parr. Although the Dee Trust are currently planting significant number of trees in the catchment, it will take many years before those trees mature and become established and the benefit of these trees can be mimicked by placing wood directly into rivers.

One of the results of Storm Frank was to reveal considerable lengths of previously unrealised river modifications on the channel (H. Moir, pers. comms). These works, which are possibly related to the Muckle spate (1829), will have resulted in a lack of lateral channel movement over a significant period of time. Although often seen as a negative from the human perspective, channel movement is important in creating new habitats and recycling gravels trapped in the floodplain and events such as the storms experienced in 2015/16 are often critical in the long term evolution and function of rivers. An indication of the static and straightened condition of the Dee at Bielside is illustrated in Figure 4.8.
Calculations based on maps are often crude, as actual river wetted area will change on any given day, and older maps often less accurate. However, the reduced diversity of the channel from the mid 1800s is clearly demonstrated, perhaps reflecting channel modifications related to extreme flood events (H. Moir, pers. comm). Additionally, based on these maps the total wetted area from 1750 to the 2000s may have decreased by a half, while the decrease from the 1850s to the 2000s is by about a third. Quite simply, less river area equals less production and on the Dee catchment there are clearly significant lengths of channel that continue to be constrained by human influences.

Habitat restoration is now a common tool for returning to a more functioning natural state, and, experience with stream restoration for the enhancement of salmonid populations in northwest USA suggest that, when projects are implemented correctly, sizeable increases in fish production can be achieved (Roni et al., 2010). However, making direct links between channel restoration or enhancement activity and improved fish stocks and fishery performance is often difficult (Roni et al., 2008). They reported that a poor understanding of fish stocks before restoration, limited scope and poor monitoring made it difficult to fully assess the benefits. They did provide evidence that barrier removal or mitigation measures and instream habitat enhancement actions increased local fish populations.
The effectiveness of restoration at improving fish populations was reviewed by Kemp, (2010). Improvements varied enormously and were influenced by many other factors (Armstrong et al., 2003); life-stage and seasonal changes in habitat use (Heggenes & Gunnar Dock, 2001), the size of the rivers restored (Miller et al., 2008), and the relatively small scale of the interventions\(^9\) (e.g. Roni et al., 2002). As a result, many programmes report inconclusive results on fish populations or may appear to have failed to demonstrate any improvement. In a review presented at the River Restoration Centre conference in 2013 by McDermott, out of 320 hundred reviewed restoration projects, less than five conclusively proved an ecological benefit. This was not due to the lack of benefits but more simply because of the poor quality of, or even complete absence of, a monitoring programme.

Despite over-ambitious expectations, limited scales of application and inadequate monitoring programmes (Liermann and Roni, 2008) some examples do exist where positive responses in salmonid production have resulted from habitat intervention. Nislow et al., (1999) have shown that the introduction of instream structures to increase the abundance of preferred habitats led to increased retention of juvenile salmon during the critical first summer period. Gargan et al., (2002) reported improvements to the populations of Atlantic salmon parr in reaches of 13 Irish streams following creation of in-stream structures to restore substrate and flow complexity. Jong et al., (1999) show a positive response in Atlantic salmon parr abundance in response to instream structures placed into Newfoundland streams, attributing increases to improved habitat complexity reducing competition. Solazzi et al. (2000) provide evidence of a doubling of smolt production in Coho salmon (Oncorhynchus kisutch) in the four years following establishment of in-stream structures to improve habitat quality in small catchments (<20km2) in the Pacific northwest.

In Scotland, two highly visible programmes on the Spey and Tweed have demonstrated the benefit of river restoration. Sections of the Allt Lorgy (Spey) and Eddleston (Tweed) were restored with salmonid spawning observed in the very first winter following completion and fish densities potentially responding to this restoration (salmon fry densities are higher and on a distinct upward trajectory when compared with a control location – however this pattern requires further investigation and validation with further years’ data – Spey Foundation, unpublished) restoration efforts in the Nith District have been complicated by stocking. However, it is possible that habitat improvement has been the paramount influence on population recovery (D. Parke, pers. comm). While these examples may demonstrate increased incidence of spawning or fish densities, their benefit to the rod catch remains to be quantified.

The cost of restoration can be high. However in areas where willing landowners, space, and an absence of major infrastructure is present (like areas of the upper catchment) it can be much cheaper than stocking, would be much more likely to gain regulatory approval and would be significantly more beneficial to fish. The Allt Lorgy project, which restored a significant stretch of channel above Carrbridge, cost in the region of £50,000 with sea trout observed spawning in the new channel two

\(^9\)It is worth remembering that in many cases these works are aiming to undo decades or even centuries of damage to river systems – it is unsurprising that improvements cannot be detected by a small number of electrofishing samples.
weeks after completion. The Eddleston, which has the complicating factor of a rail line and road cost somewhat more at approximately £650,000\(^{10}\) (Luke Comins, pers. comm).

River restoration has been, and continues to be, the key management tool on the Dee for improving smolt output and should be seen as the primary mechanism for boosting juvenile salmon production and survival. Although certain high visibility projects such as the Culter Dam mitigation, catchment riparian planting and Pearls in Peril demonstrate the breadth of projects; significantly more works are carried out. Currently there are over 150km of buffer strips being actively managed and maintained, varying between six and over 100 metres in width. Major croy and embankment removal projects have been delivered in the last four years, while over 30 barriers have been eased in the last 10 years. Fencing (specifically developed to exclude livestock, deer, or both) to protect developing riparian habitats is being increased in partnership with landowners yearly, and almost 1000 tree enclosures have been created. These works are ongoing and deliver an increasing protective cushion against highly intensive land management practises. As these schemes develop, they will also deliver habitat benefits to the river. However, as discussed these will take time to mature, and it is possible that the benefits of the tree planting won’t be maximised for 30 years. The restoration works carried out on the Dee are internationally recognised, with the CASS (Conservation of Atlantic Salmon) project, which included significant works on the Dee, winning the ‘Best of Best’ LIFE Nature award in 2010.

\(^{10}\) Corresponding to 2km of remeanders, 66ha of new riparian woodland, 16km of fences, 19 wetlands and 89 flow restrictors using wood. That project also was responsible for preventing Peebles from flooding during Storm Desmond. Heavy rainfall in the winter of 2015/16 raised the river to a level which had previously flooded the town. In that one event the Eddleston restoration is likely to have returned a significant portion of its capital investment.
5. Discussion

The stocking of Atlantic salmon has been a cornerstone of fisheries management and salmon population management across the Atlantic for decades. The extent of stocking across the salmon’s home range is remarkable, and the complete inventory of rivers stocked (and where the fish used to stock these fish came from) is an unknown for many older programmes. Currently there is a consensus that salmon are in decline (MSS, 2016; Bacon et al., 2015) and the Dee echoes this. But the decline is not a consistent pattern across all stock components (MSS, 2016) and stocking may not yet be the appropriate management response. The Dee SAC is in favourable condition status and the available information (e.g. SNH, 2011) suggests that the Dee population is not at risk (C. Bean, P. McGinnity and S. McKelvey, pers. comm), therefore any current efforts to stock the Dee should be considered fishery enhancement stocking.

The now mature body of information that stocking of salmon is counterproductive to both the fishery (Young, 2013) and salmon populations (RAFTS, 2014, Young, 2013 – and numerous references therein) should have provided a strong case for the cessation of fishery enhancement stocking in Scotland. This case has been made so forcefully that practitioners of stocking are now reviewing their entire datasets in light of this information (for example, a current project on the River Bush) and Natural Resources Wales banned all stocking of hatchery reared Atlantic salmon in 2015. There is also a developing acceptance that what has worked on one river may not work on another (The Tay District Salmon Fishery Board has stated that releasing smolts on that system is not warranted currently and unlikely to reap benefits for the fishery when compared with the Ranga (TDSFB, 2011)).

There has been a failure in the translation of this scientific advice into a form that stakeholders can accept. It is true that the concepts underpinning the science are often only understood by the practitioners of that individual field; however this is not an excuse. More effort should be made to ensure the central message is understood and accepted. However, it should also be accepted that the scientific work forming the basis for stocking advice is often complex and the information within primary sources may not always be accessible to individuals (including other scientists and managers) lacking the formal training in genetic and statistical methods.

Part of the problem is caused by a failure to translate the message into terms that are comparable with the contrasting argument. Stocking is tangible; young fish can be observed growing in hatcheries and being placed into the river system. They can be seen swimming off and there is a definitive and immediate effect observed. When this is coupled with the highly variable and cyclical nature of adult returns, it is no surprise that many (including many well respected fishery managers and scientists) find it so attractive to link a year of high return with a stocking programme. When we counter this with scientific arguments based on genetic fitness, insufficient monitoring programmes (“more study is needed”), the relevance of statistical probability and the reluctance of scientists to make firm unequivocal conclusions based on what in other walks of life would be deemed certainty, it is clear why the argument for stocking remains. But this failure by scientists to communicate the results of their work effectively does not mean it is incorrect.

Further complicating the matter is the fact that, in some isolated but very well publicised occasions, fishery enhancement stocking appears to have worked. The Icelandic Ranga is the prime example. However, it should be abundantly clear that comparing the Dee and the Ranga is not a practical exercise. The Ranga is an exceptional case, atypical of even Icelandic rivers, and due to its geographic
location, its physical state and the land through which it flows is certainly not comparable to an east coast Scottish river like the Dee. The unsuitability of the river for salmon spawning coupled with a remarkable difference in both return rates and catchability of Ranga fish puts it apart from all rivers. Without stocking there would be no salmon in that system and it is being completely and artificially sustained by ranching. This has come at the cost of concern regarding the straying of these fish (Isakson et al., 1997).

Stocking also occurs in rivers such as the Tay and Spey. While these rivers are located close to the Dee, they are structurally different in terms of catchment size, tributary sizes and geology, and reviewing preliminary rod catches on those rivers for 2016 (www.fishpal.com) clearly highlights the differences in the fisheries. (The Spey is enjoying a bumper year; catches on the Tay are somewhat suppressed despite the high Pitlochry dam fish count; the Dee catch is an improvement on 2015). And, most importantly, it appears that stocking does not result in any significant positive impact on rod catch on those rivers; in fact, the scientific evidence suggests that stocking may be harming the salmon stock of those rivers. In rivers in Scotland where stocking has been deemed successful they occur either in rivers so impacted by human pressure that the stocking programme could be deemed conservation stocking with a major fishery benefit (the Conon), or that the actual and unequivocal effect of stocking operations has yet to be formally verified (the Carron – Curran et al., 2015).

A rivers’ size is another consideration when reviewing potentially successful stocking programmes. Stocking seems to be most successful in small, accessible Atlantic rivers where angling exploitation rates can be higher (as there is much less river to cover and fish are concentrated into a small number of small pools). Translating any perceived stocking success from these river types to the Dee, with its vast areas of channel, is simply not feasible (S. McKelvey, P. McGinnity, E. Verspoor, pers. comm). And again, based on figures presented in Stewart et al., (2015) the question remains whether stocking on any of the big east coast Scottish rivers has contributed anything other than a small token return to the rod.

There is absolutely no doubt that Atlantic salmon are undergoing a critical period as a species in Scotland. Marine mortality rates are increasing (MSS, 2010) with rising sea temperatures affecting post-smolt survival (Friedland et al., 2005); growth of adults at sea (Friedland & Todd; 2012); and the number and size of returning adults (NASCO, 2012). But stocked salmon are much less likely to survive the marine environment than naturally reproduced salmon (MSS, 2015; Aprahamian et al.; 2011) and survival by stocked fish during periods of low sea survival is relatively less than during high survival phases (McGinnity et. al., 2004). Naturally produced salmon are more likely to survive this current period of oceanic uncertainty and therefore it is this wild-born stock which should be supported, most effectively through ensuring habitat quantity, quality and diversity can support them across the range of climactic conditions and anthropogenic pressures.

Therefore fishery enhancement stocking in a system which is still healthy (although potentially declining), extraordinarily large, and with an overarching impact from outwith the river environment is not appropriate. It is not appropriate because firstly there is a mature body of information that it is harmful to a still functioning population, that those natural fish who can be most impacted by stocking are the best equipped to deal with increasing problems at sea and that the other methods of boosting fish populations, especially river restoration and returning the river to a more natural state have not
been exhausted. The fact that stocking operations may have worked elsewhere simply does not translate to the Dee.

Set against the challenges that now face salmonids, which are often linked to global climate change, the only real effort that can be made by fishery managers is within their individual river systems. Other than stocking, quick win options are limited. The role of barriers in rivers has been discussed, but this discussion should be formally expanded to include not only upstream fish migration, but the role of these structures in retaining gravels for spawning and altering natural flow patterns. Because many of the barriers on the Dee have been made passable it is assumed that their impact has been negated. This might not be accurate. It is also clear that the number of barriers recorded during the Dee walkover has come as a surprise, and this data should be formally reviewed in depth.

It is a similar case with river restoration. The channel evolution map in Section 4 has provided an example of the changes in the river over time and should hint at the scale of task needed to restore the river back to anything approaching a more natural state. One of the reasons for the lack of measureable responses in fish communities is that river restoration has not been appropriately scaled and although significant efforts have already been made on the Dee in this area more needs to be done. For example, a common response among stakeholders when asked about additional tree planting is that it has been ‘done’. Nonetheless a quick drive through the upper Dee and tributaries will demonstrate the lack of tree cover; there are still enormous lengths of watercourse to be reforested. Where trees have been planted, they are still young and immature and this point leads to a critical component of river restoration – it takes time; sometimes a lot of time. While this message must be communicated better, river restoration and physical habitat improvement should be considered the most appropriate approach to increase long term and stable improvements in smolt output.

Broadly speaking the stakeholder responses were evenly split between support for stocking and not stocking. Among those who supported it there was some indication that that they would support an increase in costs to support stocking, but this was not unanimous. Other key issues which were raised were that predation was a major driver of declines and catches had declined to such an extent that fishing effort was no longer related to catch. The responses from the stakeholders demonstrated the expected well informed and engaged nature of the group. This survey was very limited in its application and its purpose was simply to gauge the breath of opinion. A more inclusive survey will probably be necessary to formalise these opinions.

While stakeholder survey responses show that uptake of days on the Dee is commonly at between 25 to 50%, there is a belief that reduced angling effort is not linked to reduced catches. This may be true but seems counter-intuitive and it (the assumed link between catch and population) needs tested. Claiming that reduced catches definitely demonstrate a collapse in salmon stocks while also claiming those catches are independent of fishing effort is a contrary view, and may be seen as such by regulators. Even if reduced effort only contributes to a minor reduction in overall catch, this reduction needs some quantification.

It should still be considered that new and exciting research is continuously emerging about salmon productivity in healthy catchments. A good example of this is research looking at the loss of nutrients from catchments and that recovering and retaining these nutrients could increase and perhaps even double fish production (Williams et al., 2010; Williams et al., 2009; Nislow et al., in press). Fishery
enhancement stocking cannot even begin to approach such increased productivity on a river like the Dee and during a phone discussion it was stated that the authors feel the maximum productivity boost has not yet been realised (S. McKelvey, pers. comm). However; once again the necessities of scientific rigour have made it difficult to establish these responses with absolute certainty at this current time.

This report looked at three strands of evidence to decide on stocking. The first was the biological. The evidence from the published sources has been presented (Section 2), and the problems with translating that message discussed. The second part of the biological argument was the review of data from electrofishing and habitat walkovers. These data have been collected for a number of reasons, and the differing purposes are evident. Ultimately the dataset was assessed as insufficient to provide the required level of information to inform on the need for stocking.

As a first measure, a baseline data collection programme of fixed locations with fixed methods is required, and the temptation to move to different locations (or methods) in response to short term pressures avoided. The current catchment health monitoring programme being carried out by the Dee Trust should be considered the answer, however it will take time to develop this dataset to the point where it can be used to inform on any future conservation needs. With regard to enumerating adult returns, although the walkover data does not identify a main stem weir low down, potential locations should be investigated for a fish counter to operate.

The second strand, the economic appraisal, has demonstrated that the cost to stock the Dee is enormous. Although there may be a weak argument for stocking on economic grounds of at the 1000 level, three factors should be considered when accepting this at face value:

- The estimated start-up costs exceed £3.5 million and the yearly running costs exceed £500,000. Even considering an enormous donation, this is a huge outlay and there is no guarantee of licenses to stock in future years;
- The survival/return values represent a range. While these are taken from the literature the lowest figure for return rates is not uncommonly zero. Operation of a hatchery cannot guarantee a return; and
- The cost benefit assessment does not include the loss of natural productivity caused by the removal of broodstock and their progeny.

The final strand of investigation related to the legal obligations of the board to the fishery and the SAC designation of the Dee. These are very well covered in the relevant section and in the Appendices. Considering the level of protection given to the Dee, the granting of a license to stock salmon under the current scenario is highly unlikely and would be an extremely resource intensive data collection exercise. However, even if these data already existed and regulators were amenable to fishery enhancement stocking, the changes to the management structures for wild fishing in Scotland mean it would be prudent to wait until this process has been resolved and the body ultimately responsible for the application identified before proceeding. There are still a wide range of other options open to the Board to assist the salmon population on the river. The proactive approach to restoration has initiated a trajectory of habitat improvement on the river, but the scale of habitat improvement needs to be expanded enormously and these efforts will need time.
5.1. What next?

Even if broodstock collection was actioned this year and a mothballed hatchery of suitable capacity existed, it might be the early 2020s before the first runs return. Given that an immediate start is unlikely to meet licensing, planning and animal welfare requirements, multi sea-winter returns would probably not be seen until the latter half of the 2020s.

Although this report has identified numerous biological, economic and legal constraints to fishery enhancement stocking, there are scenarios under which stocking may gain regulatory approval. These are catastrophic crashes in the Dee population or sub-catchment sub-populations, most likely to be related to marine survival, of a scale that conservation stocking is required. There should be a plan for this event outlined within a new Dee stocking policy and should include a procedure for dealing with any private license applications, to the Board or future FMO, for stocking of salmon.

The first and most important piece of this plan should be the continued development of a dataset (the catchment health monitoring) to support the detailed catch records and data from the Girnock and Baddoch burns. This dataset can be used to determine the health of the population and should be linked to the SAC site conditions assessments (i.e. reviewed at regular intervals). This will provide cost benefit to both SNH and the future Dee FMO. The datasets should be regularly reviewed from a statistical perspective to ensure any conclusions taken are justified, and survey methods should be fixed. A first specific avenue of investigation could be the relationship between fry and 1+ parr.

A complete inventory of the genetic differentiation within the Dee catchment should be established with individual subpopulations identified, and plans to remove broodstock from those areas developed and suitable storage facility should be identified. Some of this information on the genetic composition of the Dee stock(s) already exists (Coulson et al., 2013), however spatial coverage is low (16 sites) and it was unclear if the observed lack of diversity related to the methods used or true genetic similarity.

Discussions should be held with all the relevant licensing authorities to establish a way to expedite hatchery operations in the event of a crash. Ultimately, although this report has found that the time for stocking has not yet arrived, the Dee should have access to a hatchery to use for conservation stocking. Therefore, an inventory of mothballed hatcheries should be made along with a formal determination of production capacities and identification of the upgrades required to bring these operations on-line.

Efforts to increase the level of smolt output should continue and should concentrate on increasing the parr carrying capacity in the river. This should involve a catchment review of the more subtle impacts of in-channel barriers, along with an independent review of the restoration approaches on the catchment. The catchment health monitoring dataset should be used to understand the catchment scale effect of these efforts and quantify the benefit to the rod.

5.2. Conclusions

The consensus of this report, based on the reviewed data and other information developed within is that it is currently not appropriate to stock the Dee with Atlantic salmon of any life history stage.

This is because:
• The link between catch and population size is not conclusive and there are still knowledge gaps relating to the population size and juvenile production and survival;
• The only available evidence suggests smolt productivity is stable;
• Catches have declined, but there has also been a major decline in efforts to catch salmon;
• Stocking of smolts is excessively expensive;
• Stocking is seen as a potential risk to the conservation status of the Dee SAC and possibly contrary to the objectives of the Cairngorm National Park and a risk to the natural population;
• A license activity is not guaranteed and cannot be supported with currently available data;
• There are still numerous other options available to potentially improve smolt output including further habitat improvements (with appropriate time being for those improvements to mature) and efforts to reduce the impact of weirs;
• There will be an increase in returning fish is 2016 due to the closure of coastal netting in Scotland;
• The upcoming changes in salmon management mean it is not clear who would regulate, authorise, fund and be responsible for stocking;

Other information based on analysis of the biological data and on more detailed data sets from the Girnock and Baddoch burns show that there may not be an issue with natural production of smolts, and that numbers of returning adults have not reached the level at which this smolt production level is at risk. Further work should be carried out to determine the applicability of this theory across the Dee catchment.
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