SECTION 2: SALMON

INPUT 2A: DETERMINE AND DEFINE THE STOCKS OF SALMON WITHIN THE TWEED SYSTEM AND THEIR LIFE HISTORIES

Rationale: The most basic information needed on the Salmon of the Tweed is their stock structure : Is there just one interbreeding stock throughout the whole catchment, or are there stocks differentiable by their life-histories and/or genetics - essentially, is there a Tweed salmon population or are there Tweed salmon populations ? If the full range of run-timings is to be maintained and managed in the Tweed, which is what gives the river its 10-month long Salmon fishing season, then it is essential have all its stocks defined so it can be assessed as to how well the spawning requirements of each are being met.

Current state of knowledge: Previous work has confirmed that there are different stocks of Salmon within the Tweed, with different run-timings and belonging to different parts of the catchment (see Appendix 2A). Studies have, however, shown that genetic differences between different parts of the catchment are weak, possibly due to the extinction and recolonisation of so many tributaries (Leithen, Gala, Leader, Whiteadder, Ale, Jed, Slitrig, possibly Teviot above Denholm and possibly also the Bowmont / Glen [the historical information on the obstacles that could have caused such extinctions on these last two is unclear or contradictory]). The exception to this is the salmon of the Whiteadder which are very different genetically from other Tweed fish possibly due to a severe genetic bottleneck during the period when they were excluded from the Whiteadder upstream of Edington Cauld, though Newmills Cauld, right at the base of the river could also have been a barrier at times. While it was generally reported that there were no salmon in the Whiteadder from the 1860s onwards, it appears that a small population did exist in this lower area (*information from local anglers and landowners*) and it may be this that recolonised the river generally once obstacles had been eased (Appendix 2A, Figs 1a ***)

Policies for the Sixth Edition of the Management Plan:

Policy 2A.1 – Map where fish of different run timings spawn within the catchment

(a) Samples from the Tweed were provided to MSS who have now found genetic markers that can identify early and late running salmon. This opens up the possibility of mapping the catchment to show where early and later running stocks of fish spawn.

Such mapping will then allow the data from the juvenile surveys undertaken as part of Policy 2C.1 to be recognised as belonging to particular run-timing stocks, allowing the strengths of the juvenile stocks of Spring and later fish to be determined for the first time. An indication of what such a map would look like was obtained after the floods of winter 2015/16 reduced the fry numbers of later running and spawning fish but not those of earlier running/ spawning fish (Appendix 2A, Fig 2)

Policy 2A.2 – Analyse the ages and sizes of the salmon of the Tweed and monitor any changes or trends (see also Policy 2D.2)

(a) Collect and read a representative sample of scales to determine the smolt and adult ages of salmon.

(i) Maintain a database of scale readings.

(ii) Produce an annual report on findings.

(b) Relate present day data on ages and sizes to past records to show up any long-term changes and trends. A YouTube presentation on this is available at www.youtube.com/watch?v=Lu4tt7078DM

(c) Continue collection of daily catch records from Index Beats on the Middle and Lower river for analyses of changes in sizes and timings.

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INPUT 2B: INVENTORY THE QUANTITY AND QUALITY OF NURSERY AREAS OF EACH STOCK OF SALMON

Rationale: Healthy stocks of Salmon can only come from a healthy aquatic environment, which is much more than simply a good chemical quality of water. The physical forms and shapes of streams and rivers are crucial - larger fish need deeper water but young fry need shallower, quieter flowing, areas so the ratio and mix of stream types, of runs, pools and riffles, is vital if every life-cycle stage is to find enough of the conditions best for it. Overgrazing weakens and destroys the bankside turf that separates soils from floodwaters and so accelerates bank erosion making streams become wider and shallower and less suitable for older fish and for young fish during spates and droughts. Over shading by dense trees kills off bankside vegetation and so has the same effect as overgrazing. Even the best quality of habitat is useless to fish if they cannot reach it to spawn in it, and the industrial history of the Tweed left behind many complete or partial barriers to fish migrations. Identification of any areas totally inaccessible to spawning fish or where access over instream structures is restricted to a narrow range of water flows is a management essential. Areas where juvenile abundances are limited by poor physical or chemical conditions also need to be identified, while areas that are in good condition need to be secured as such through protection by fencing.

The backlog of problems of habitat degradation and blocking of fish migrations in the District is a "by-product" of the farming, forestry, industrial and road-building methods of the past, but with relatively minor changes to traditional practices further problems should not be created and this must be a major aim of fisheries management. The changes in forestry practice brought about through the "*Forests and Water Guidelines*" demonstrate what can be achieved in this way.

The Current Situation: All but one of the man-made barriers to significant areas of salmon spawning that it has been practicable to deal with have been removed or eased and the protection of watercourses through buffer strips and riparian tree planting has become a mainstream land management practice. Repeated electro-fishing surveys have shown substantial and widespread juvenile salmon populations throughout the catchment except upstream of natural waterfalls and those artificial obstructions it is not possible to remove or ease (e.g. reservoir dams) [Appendix 2B, Fig 1]. The one remaining significant obstacle is the ford at Haughead on the Wooler Water which was eased successfully in the past but became impassable again after a series of massive spates. Plans to deal with this ***** currently under consideration at present.

Aerial surveys have been used to calculate the areas of spawning upstream of the fish counters on the river so that spawning targets (the number of eggs needed to fully stock them) can be set for those zones. An assumption can be made that if these zones are being fully stocked with eggs, as shown by the numbers of adults counted through to them, then other areas of the catchment with Spring or Summer fish (the counters are on Spring or Summer stock tributaries) will also be being fully stocked.

In terms of productivity, the astonishing rod catch of 2010 of just under 23,000 salmon showed just how many smolts are being produced by this catchment, making the key issue their survival rather than their production.

Policies for the Sixth Edition of the Management Plan:

Policy 2B.1: Collect and Analyse Historical Data on Salmon Habitat Quantity and Connectivity.

(a) Continue the identification, and map the locations of historic man-made barriers, adding them to the Tweed Obstacles Database, and quantify the areas of spawning that were blocked or restricted by them. If resources allow, produce maps of the areas open to Salmon spawning in 1800, 1850, 1900 and 1950. *This is important in understanding the genetic structure of the salmon of the Tweed.*

Policy 2B.2: Survey and Classify Salmon Nursery Areas

(a) The comprehensive Tweed Obstacles Database, produced from past survey work, contains data and photographs of all present obstacles, large and small, found so far. Add any new obstacles to this.

(b) New technologies of aerial river survey offer a much more objective and practical way to survey and analyse habitat data and the development of these will be monitored and considered for use. The aim would be to quantify the various grades and types of salmon nursery habitat within the catchment.

(c) Support good land and riparian management by other agencies and bodies to preserve the productive capacity of the catchment

The NASCO guidelines are that Salmon management should:-
- protect the current productive capacity of the existing physical habitat of Atlantic salmon
- restore, in designated areas, the productive capacity of Atlantic salmon habitat which has been adversely impacted.

NASCO Plan of Action for the Application of the Precautionary Approach to the Protection and Restoration of Atlantic Salmon Habitat CNL(01)51

Policy 2B.3: Monitor the effects of instream structures on fish passage

(a) Where obstacles to fish migration have been eased with fish passes or breaches rather than removed completely, monitoring is required to check that these continue to work properly – their passability can change as erosion alterns the configuration and depth of the water downstream.

(*i*) Continue electro-fishing surveys upstream and downstream of such structures.

Policy 2B.4: Ensure the access and habitat problems of the past do not recur

(a) Collect information from the UK and abroad on best practice in Farming, Forestry and Road-building in relation to waters and fish populations.

(b) Disseminate this information amongst local land-users and provide practical advice on its implementation.

(c) Contribute to the Tweed Catchment Management Plan and work with local land management organisations to promote good riparian and catchment management.

INPUT 2C: MONITOR THE JUVENILE POPULATIONS OF EACH STOCK OF SALMON; THE INFLUENCE OF HABITAT CHARACTERISTICS ON THEM AND THE EFFECTS OF PREDATION

(There is a bit of uncertainty here as we have not yet seen the electro-fishing programme that MSS will suggest for the Tweed for Conservation Regulations – this section may need some re-writing once we have this.)

Rationale: Monitoring the abundances of juvenile salmon in the different parts of the catchment shows how well the spawning areas are being filled with young. If numbers of spawners of a stock were to fall to the extent that it reduced the numbers of juveniles at its monitoring sites, this would become apparent several years before the resulting adults were due to return, and catch regulations to reduce exploitation on them could be prepared in advance. Conversely, knowledge of how well the catchment is stocked with juveniles will also show if any fall in adult numbers is due to actual lack of juveniles or to some other reason. Once information from Policy 2A.1 is available, it should be possible to categorise at least some of the different areas of the catchment as being the home areas of particular runs of salmon and so be able to assess the health of the different runs from their juvenile stocks.

The value of such regular monitoring was shown in 2016 when fry numbers were found to be significantly lower in most of the areas surveyed: as comparisons could be made with several previous surveys there could be no doubt of the situation. The floods and long-lasting high water of winter 2015/6 were suspected as being the cause, so when the winter of 2016/17 turned out to be much quieter, a sample of the 2016 sites was re-surveyed in summer 2017 and fry numbers were found to have returned to normal. The knowledge that there were significantly reduced numbers of fry in 2016 will help in interpreting the adult returns of 2019 and 20 when they will return as Grilse and Salmon. The 2016 event also gave useful information on the types and times of high water that can impact fry numbers – previous large floods at different times of year had not had such an impact.

That timing is key was also demonstrated in 2016: the floods started on the 14th November, after the spawning on the Ettrick and Yarrow (where Spring and Summer fish dominate) had finished and the fry numbers there were completely normal, except at the bottom where late fish dominate.

In 2010 when genetic samples were needed from the Gala Water, it was found that there were very few salmon fry despite the Gala always having had abundant numbers before. This was eventually found to be due to a short, April, snow-melt spate, just at the time when fry were emerging from the gravel. If these samples had not been needed, however, this wipe-out of fry would have gone unnoticed as 2010 was not one of the years that sampling was scheduled for the Gala. The lesson learned from this was that it would be useful if a range of sites could be sampled every year throughout the catchment to serve as "trigger / early warning" indicators of events in the areas not being surveyed as part of the regular three-yearly cycle. If such sites showed that there had been some major impact, further samples and investigations would be made to detect the cause, as was done on the Gala in 2010. Such sites would also serve as "early warning" of the arrival of *Gyrodactylus salaris,* which would wipe-out salmon juveniles (See Policy 6.**)

Lower numbers in particular areas can indicate where there are access problems or where habitat restoration may be required. Knowledge of how abundances of juveniles varies from area to area and over time is necessary if those that need restoration are to be distinguished from those that are just naturally poor. The large number of sites covered using the Fry Index technique provides the data for such indications and analyses.

The Tweed Fisheries District is home to significant populations of fish eating birds – Goosander, Cormorant and Grey Heron. The first two are of much the greatest significance as they feed purely on fish (Herons eat significant amounts of frogs, ducklings, rodents and insects as well as fish); Goosanders and Cormorants are also gregarious rather than solitary feeders which means that considerable flocks can form where they find fish available. As smolts are the "end-product" of up to three years of freshwater life, any loss to predation is irrecoverable and must result in fewer adult Salmon returning to the river.

The Current Situation: Most of the catchment is electro-fished on a three-year cycle with both timed and quantitative sites, while the Ettrick and Yarrow have been surveyed every year to date. At timed sites, sampling is for three minutes by stopwatch to give numbers per minute, and at the quantitative sites a section of a stream is netted off and fished through three times, to give results per square metre. With the new electro-fishing equipment now in use, timing will change from being by stopwatch to being by time electric-current flows, which will greatly improve standardisation. Depending on travel time, 10 to 15 timed sites can be done per day per team of two but only three quantitative sites with a team of four or five. The timed sites give widespread coverage of the catchment and show when changes in fish numbers are significant by whole groups of sites increasing or decreasing their results along a length of stream channel. Timed sites are on shallow riffles and target only fry, the "*young of the year*". Quantitative sites are also on shallow water but all species and ages of fish are targeted and results are compared with previous samplings. Quantitative sampling is too labour intensive to be used to give the coverage of the catchment that is necessary and not being in sequences along channels, as the timed sites are, it is never certain whether the results from a quantitative site represent what is happening generally in its area or just the site itself. Some of the quantitative sites on the Tweed have sampling histories going back to the 1980s but their physical shape and structure inevitably change over time, which affects their fish populations and can, indeed, be completely altered over a single winter. However, the quantitative sampling does give information on parr as well as fry and some long-term continuity, and the data is of the form used by SEPA for some of their analyses – these sites are part of the triennial programme and are sited mainly at the bottom of tributaries. Timed sampling does not suffer from the habitat changes that affect quantitative sampling – its sites are simply the shallow riffles at a grid reference and if that riffle moves upstream or downstream it does not matter.

Fry numbers in timed surveys are also more useful on Tweed for long term data as the ages at which salmon smolt vary over time as shown in the Salmon section of Chapter 3. When many salmon smolt at three years old, as over half did in the 1960s, it means that there are three age classes of juvenile living in the catchment: fry, I year old parr and II year old parr, while when most salmon smolt at two years old as they did in the 1930s and do now, there are only fry and I year olds. At present, in fact, almost half of salmon are smolting as I year olds, meaning that fry are the only age group that it can be certain will be complete at sampling time – parr that have left as one year old smolts will be gone by July when electro-fishing starts (fry have to be over 50mm in length for electro-fishing to be efficient). This variability in the proportions of parr that leave as one-year-old smolts is also geographical – warmer, more lowland areas have faster growth than colder, upland areas – so parr numbers cannot be compared across the catchment just as they cannot be compared over any great length of time.

The sequence of the electro-fishing sampling is: -

Three yearly:
Till, Teviot & middle Tweed minor waters
Whiteadder, Eye, Leet & Eden & Lower Tweed minor waters
Leader, Gala & Upper Tweed

In setting up this sampling rotation, care had to be taken to avoid following the same generational cycle of Salmon. The Ettrick and Whiteadder are dominated by five-year-old Multi-Sea-Winter salmon so if sampling was every five years, it would be same line of Salmon being sampled each time. To avoid this, the sampling periodicity for these sectors has to be any period other than five years. The other sectors are dominated by four-year-old Grilse and their sampling periodicity therefore has to be three or five years. However, a check has to be kept on this as there is the prospect of a higher proportion of 1.1 Grilse which have a three-year generational cycle and there is also an increase in the proportion of fish returning as salmon.

Every year:
Ettrick and Yarrow.

If resources allow, "Early Warning" sites distributed throughout the catchment in the areas not being surveyed as part of the three-year cycle.

The Ettrick and Yarrow are surveyed every year because of their importance as the main source of Spring Salmon and also because the numbers of adult fish entering them to spawn will be able to once again be counted at the fish pass of the Murray Cauld at Selkirk (from Spring 2018).

Additionally, where problems with access are suspected, surveys are made upstream and downstream of the structure annually until a definite finding is made.

Reports on the past electro-fishing surveys of the Tweed catchment can be found at http://www.tweedfoundation.org.uk/html/reports.html

Analysis of the stomachs of Goosanders and Cormorants provided by the RTC to the Institute of Terrestrial Ecology (and published as part of Marquiss, Carss, Armstrong and Gardiner 1998) has provided estimates of smolt consumption which when combined with counts made of these birds during the smolt season, has made possible the estimation of the potential economic damage to the local economy caused by their predation. Such estimates are made each year in support of the RTC's application to SNH for a licence to shoot to scare and kill a smaller number. However, since that data was produced, there has been a large scale reduction in Eel numbers in Europe generally and also on the Tweed. As Eels are a favoured prey of Goosanders and Cormorants, their lack may well have changed the diet of both bird species leading them to take more of other species, such as salmon and trout. Lamprey, of conservation interest on Tweed, may also be subject to extra predation because of this.

Policies for the Sixth Edition of the Management Plan:

Policy 2C.1: Monitor the Abundances and Densities of Juvenile Salmon at Sites throughout the Medium-sized Channels of the Catchment

(a) Continue the timed electro-fishing monitoring of juvenile Salmon abundances throughout the Tweed and Eye catchments on a rolling cycle: -

2018	2019	2020	2021	2022
Leader Gala Upper Tweed	Till Teviot Middle Tweed	Whiteadder Eye Leet Eden Lower Tweed	Leader Gala Upper Tweed	Till Teviot Middle Tweed

The Ettrick is sampled every year

(b) Continue analyses of electro-fishing results.
(i) Continue to develop the database holding the information from these surveys and linking this with physical, chemical and aerial survey data.
(ii) Analyse this electro-fishing data to show areas of higher and lower abundances of juveniles and explain such variation. Where areas have no natural explanation for having lower numbers of juveniles than would be expected, further investigations will be undertaken following the protocol in Appendix 2C.
(iii) If the information from **Policy 2A.1** is sufficient, categorise electro-fishing sites as being in the home areas of Spring, Summer or Autumn fish and analyse their results to show the condition of these run timing stocks.

(c) Continue the quantitative electric fishing sites on the same cycle as the timed to maintain continuity and to provide the data required by MSS, SEPA and the EA for their water body assessments under the WFD. These sites are shown on Map *
(i) Analyse this electro-fishing data to show any long-term quantitative trends.
(ii) Contribute the data from these sites to the SFCC national database.
(iii) If the information from Policy 2A.1 is sufficient, categorise this quantitative electro-fishing data as showing the densities of Spring, Summer or Autumn salmon and grilse juveniles and analyse the relative strengths of these stocks as juveniles.

(d) If resources allow, sample the "early warning" sites in areas not part of the three yearly sampling programme. If unusually low numbers are found at any such sites then: -
(i) Further electro-fishing should be carried out to confirm the situation.
(ii) Other information e.g. Autumn and Spring flow levels should be collected to see if these could explain the situation.
(iii) If no obvious physical factor can be found to explain the lack of salmon fry, the possibility of *G. salaris* or some disease should be considered and appropriate advice sought.

Policy 2C.2: Collect Data on Predators and the Effects of Predation on Juvenile Salmon, and on Smolts in particular

(a) Continue to count the numbers of Goosanders and Cormorants in January, April, May and October of each year.
(i) Use the information from these counts, and from published analyses of the diet of Goosanders and Cormorants on the Tweed, to make annual assessments of the potential impact that their predation on the smolt run has on the economic value of the Salmon fishery.
(ii) Analyse the results of the counts to show any geographical pattern to the distribution of Goosanders along the river. If any locations are found where the birds are regularly clustered

these could be "choke-points" where smolts are particularly vulnerable and special measures to protect such sites could be taken.

(iii) Find additional methods of counting with which to extend the proportion of the catchment covered and supplement the existing methodology.

(iv) Discuss methodologies and analyses with other Trusts and bodies to improve these as much as possible.

(b) Acoustic tag Salmon smolts where these can be trapped and track down to the sea:

(i) Determine success rate in reaching the sea, taking account of any handling / tagging mortality.

(ii) Determine causes of losses where possible and if there are particular parts of the main river in which losses are greater than in others.

(iii) Relate smolt movements and losses to the pattern of distribution of fish-eating birds on the main river during tracking.

(c) Record damage types and their levels on smolts sampled at smolt traps. At present, the assessment of damage done by predators is based only on the numbers of smolts actually consumed, there being no estimates as yet of the effect of damage by unsuccessful attacks leading to delayed mortality or reduced ability to survive at sea.

(i) Define the types of damage seen and the predators that were responsible.

(ii) Determine the levels of each type of damage.

(d) Investigate the habits and movements of fish predators within the catchment to see if these can show where and when predation on smolts is occurring.

(i) Identify tagging methods and regulatory requirements for tagging and tracking Goosanders and Cormorants.

(ii) Identify tagging methods and regulatory requirements for tagging large trout.

INPUT 2D: ANALYSE THE CATCH COMPOSITION AND TRENDS OF EACH STOCK OF SALMON.

Rationale: Historic records show how the sizes and run-timings of the fish have varied greatly over the years and give the context for assessing the present day situation. Establishing long-term trends shows if there are large-scale changes that cannot be countered, though could be managed. Variation outside known parameters from the past could be a warning sign of problems.

Analysis of catches from year to year for their composition shows which stocks (and areas of the catchment) are producing the fish that support the fisheries and how the ages and sizes of fish can change.

The Current Situation: All known long series of net and rod catch records were collected and computerised during the Catch Records study of 2001-04 and the total number of salmon scales collected had reached 22,539 by 2017, though with so many fish now being released, many fewer scale samples have been collected in recent years and ensuring scales from a representative sample of the fish coming into the river is now an issue. Scales taken from the fish netted for tagging at Paxton (**Policy 2E.1**) are therefore an important source, especially for earlier running fish. Analyses of net and rod catches and of the ages and types of fish being caught are given in Appendix 2D. The most significant features found have been:

1) There was a five-year cycle in numbers of Spring salmon caught that lasted for 20 years after a major flood on the Ettrick at the end of October 1977.
2) Changes between Spring and Autumn dominance can vary in their timing between different parts of the catchment.
3) Spring and Autumn / Salmon and Grilse catches have been found to have varied in cycles over the last 250 years and this has been found to relate to conditions in the North Atlantic (video presentation at https://www.youtube.com/watch?v=5DjuyMzxpt4)
4) The most recent change was from Spring Salmon to Autumn Grilse in the 1960s but there is now strong evidence that another major change is underway with a decline in Autumn Grilse and an increase in Summer Salmon.
5) Sizes of both Autumn Salmon and Grilse are declining, while those of Spring Salmon are increasing.
   More information on these is given in Appendix 2D.

Policies for the Sixth Edition of the Management Plan:

Policy 2D.1 - Identify Long-term Changes and Cycles

(a) Continue analyses of catch and environmental data to show any long term trends:
(i) Between catch levels and environmental factors.
(ii) In sizes or other features of the salmon of the Tweed.

Policy 2D.2 - Monitor Catch Composition

(a) Continue collection of salmon scales from rod fisheries along the course of the main river and the larger tributaries and the netting station at Paxton and add the readings to the scales database.

(b) Use this database to analyse scale readings to show: -
(i) Geographical and temporal patterns and age structures.
(ii) Lengths and weights of fish in relation to area, time of year and age.
(iii) The different stocks and age classes of fish being caught. This shows how dependent catches are on particular ages of fish and how success or failure of particular spawning or smolt years can be reflected in the catches of the resultant adults.
(iv) Whether high or low catch years are related through generational cycles i.e. whether they are spaced at intervals of common salmon or grilse ages.

(c) Develop and improve expertise in scale reading through collaboration and co-operation with scale-reading personnel in Trusts and Agencies.
(i) Work to ensure consistency of scale reading interpretation throughout the country.
(ii) Analyse Tweed scale reading results with those from other rivers to find differences and similarities.

Policy 2D.3: Monitor and Analyse Catch Trends

(a) Publicise the need to maintain the integrity of the rod catch record series now that most fish caught are released.
(i) Promote the use of landing nets with integral weighing scales so that the weights of the large numbers of fish caught and released are accurate and thus maintain the integrity of the catch record series which until recently has been based on the weights of fish killed and weighed.
(ii) Undertake checks to compare the sizes of fish recorded as being killed and those being released to find if these are comparable and if particular sizes of fish are being selected for release.
(iii) Encourage research towards finding a tag that is easy for anglers to use and does not require a hole to be made in fish so that the rates of recapture of released fish can be monitored.

(b) Continue to analyse the rod and net catch records for trends and changes and improve catch recording detail if possible:
(i) Improve the quality of rod catch records by recording the amount of fishing effort at least a sample of fisheries - the same total of fish caught with a little effort indicates a very different situation than if caught with a lot of effort. This improvement is of particular importance for the monitoring of Autumn Salmon and Grilse as these fish spawn largely in the main channel and at the bottom of the tributaries, they are unlikely to be monitorable by fish counters in the foreseeable future. Rod catch records with effort data therefore offer the only practicable way at present of monitoring this stock.
(ii) In particular, monitor the Spring catches for any signs of more five year cycles of poor catches developing.
(iii) Analyse rod catches in relation to fishing conditions to find influences and connections. This would allow "weighting factors" to be applied to annual catch totals to allow for the fishing conditions of that year.

(c) The catches of the season 2010 were so much greater than anything that had gone before that they make a "signature" event, one out of line with the norm. Such events give the opportunity to find their causes because the condition or conditions that produced them should also be exceptional. To see if this is indeed the case for the salmon catches of 2010 all the possible factors that could have produced such a large run should be examined:

(*i*) Conditions in the river during the smolt runs of 2009 and 2008.
(*ii*) Conditions immediately offshore during the smolt runs of 2009 and 2008.
(*iii*) Marine conditions during the periods when the fish of 2008 and 2009 were at sea.
(*iv*) Fishing conditions within the river during the fishing season of 2010.
(v) Catches in other countries and in Scottish and Northumberland rivers in 2010 should also be compared and contrasted as a way of detecting the possible causes for the exceptional run of 2010 in the Tweed.
(*This would be best done as a student project*)

INPUT 2E: ESTIMATE THE CATCH RATE OF EACH RUN OF SALMON

Rationale: If fish are tagged at the bottom of the river, the proportion then caught by anglers upstream will give an indication of the proportion of all fish entering the river that are caught by anglers. This then allows estimations to be made of the total number of fish of different stocks that run the river and the potential effect of different catch and release policies.

The Current Situation: Salmon are tagged at the Paxton netting station through the year and recapture rates produced. Data so far shows that the later running fish are, the lower their catch rate, so that less than 10% of Autumn fish are caught by anglers. *Scales and data on disease and predator damage are also recorded from the fish netted for tagging – see Policies 2D.2, 2G.4 & 11.2*

Policies for the Sixth Edition of the Management Plan:

Policy 2E.1: Tag Salmon on the lower river to find their angling catch rates

(a) Continue the estimation of the rod catch rate of salmon through tagging and recapture, using the netting station at Paxton.
(b) Use this data to estimate population numbers.
(c) Contribute this data to MS for the formulation of the Conservation Regulations for the Tweed.

Policy 2E.2: Acoustic tag Salmon on the lower river and track them upstream to show: -

(a) Relationships between the time of year fish are tagged and where they go to in the catchment.

(b) Non-angler mortality. The ordinary, external, tagging shows the proportion caught and reported by anglers, but cannot show what proportion die in the river due to other causes (predation, poaching, disease etc.) nor how the fish move within the river. Tracking to show these has been done with radio-tags from 1994-96 and with acoustic tags in 2010 and 2011. Results are given in Appendix 2E. During such tracking, data can also be collected on:-

(i) The speed of movement upstream of Salmon.
(ii) How their movements relate to the pattern of angling catches.
(iii) How quickly the fish pass obstacles / find and use fish-ladders.

INPUT 2F: MODEL SALMON POPULATIONS UPSTREAM OF FISH COUNTERS

Rationale: The most basic need of a stock is that enough fish should escape all the pressures on them to spawn and fully seed their nursery areas for the next generation and this is best known if fish of each type of run-timing stock can be counted separately. Fish counters provide objective, reliable numbers, free from the distorting effects of fishing effort and fishing conditions that make rod catch data difficult to use. The Tweed has something of an advantage for fish counting in its large tributaries with pre-existing caulds which narrow fish passage down to fish ladders where it is much easier to install counters than in open channels. Given that there is no size difference between Tweed Salmon and Tweed Sea-trout – the former can be 2lbs in weight and the latter 20lbs – the only useful types of fish counters for the Tweed are those that allow identification of each individual fish counted to species. There is a further advantage in that different tributaries host different run-timing stocks e.g. the Whiteadder has mainly Spring fish, the Ettrick mainly Spring and Summer fish while the Gala has mainly Summer and early Autumn running fish. Counts of fish and measurement of their sizes allow the number of eggs being transported upstream through a counter to be estimated and then compared with estimates of the number needed to fully stock the area upstream. Counts of fish made in a year can be compared with the fry numbers the following year to see if more adults result in more fry: if they do, then it means that fry numbers are being limited by the number of adult spawners – and if they do not, it means that number of spawners is not a limiting factor. Counts can also be related to rod catches, both in the local area of the fish counter and to the river generally to see how catches relate to the number of fish around: this highlights seasons when poor fishing conditions have limited catches.

As well as giving the basic number of fish passing upstream of it other data can be collected by a counter: the seasonal timing of runs, the daily timing of fish passage, movements in relation to water flows and how the size of fish running one tributary compare to the sizes in others.

The Current Situation: A fish counter was installed on the Ettrick, in the fish ladder of the Murray Cauld (by Selkirk) in 1997 and counts of adult fish going upstream to spawn were made till the cauld was re-constructed in 2009 with a larger fish pass. These counts of adults were then related to the abundance of fry the following year made by intensive annual electro-fishing surveys. These showed that while fry numbers in the Ettrick generally were not related to the number of adults counted up the previous year, fry numbers at the top of the Ettrick were closely related to the number of adults counted through before the end of June the year before, showing that numbers of the very earliest running fish were too few to fully stock the top of the river and that that type of fish required measures to protect it. Similarly, it was found that the numbers of fry in the lowest zones of the Ettrick and Yarrow, just upstream of the cauld were being limited by the number of very late running adults getting through the counter – this though was due to the fish pass being a "temperature barrier" late in the year. Details of these relationships are given in Appendix 2F. With the support of the Scottish Government, a new fish counter was installed at the Murray Cauld in the Spring of 2018 and while some time will have to be taken to calibrate it and make any necessary alterations, counts from the Ettrick should be available again from 2019.

Another VAKI fish counter, with video, was installed in the Skinworks Cauld in Galashiels in 2007 to count the fish running up the Gala Water. While the Gala joins the Tweed only a few kilometres downstream of the Ettrick, it has a very different stock of salmon, mainly Summer fish.

A third video VAKI counter was installed on the Whiteadder, at Ahlstrom's Mill at Chirnside, late in 2010. Unlike the others, this does not give a full count as it is possible for fish to get over the faces of the cauld in some water conditions. As the main issue for the Whiteadder is low flows and the value of the freshet releases from the Whiteadder Reservoir to fish, this was not a disadvantage – and the counts do give valuable information on fish numbers and sizes.

At all three counters the area of spawning upstream has been calculated from aerial photographic surveys and estimates of the number of eggs required to fully stock these have been made using data from the scientific literature on how many eggs are needed per area of spawning. As the counters measure fish sizes, the number of eggs being carried by females of different sizes can be calculated and the total number of eggs being transported to the spawning grounds upstream of the counters can be estimated. While figures on fecundity (numbers of eggs per weight of fish) were at first taken from the scientific literature, this data is now being collected directly from Tweed fish.

Results from all three counters, egg deposition estimates and fecundity data are all given in Appendix 2F.

Policies for the Sixth Edition of the Management Plan:

Policy 2F.1: Continue counts at the Ettrick, Gala and Whiteadder fish counters and identify other possible counters sites

(a) Improve and upgrade the existing counters as new technologies or software become available.

(b) Identify possible sites for more counters.

(*i*) Gather information on fish counter types, with particular regard to those that could be used on existing caulds and other in-river structures: There are a number of these in the lower reaches of Tweed tributaries that it might be possible to adapt to carry counters.

(*ii*) Monitor developments of other types of counters that do not need to be based on structures e.g. sonar-based, and which could be used on the larger channels.

Policy 2F.2: Improve the spawning targets set for Salmon upstream of the Ettrick Gala and Whiteadder counters and set targets for any new counters established.

(*i*) Refine the estimates of the number of spawning adults needed, using any new techniques that become available.

(*ii*) Refine and improve the data on size of salmon counted, sex ratios and the number of eggs produced by each size.

(*iii*) Use data from electro-fishing surveys of juveniles to check that juvenile abundances upstream of fish counters are at the highest possible level and are not being restricted by lack of spawning adults.

Policy 2F.3: Monitor the attainment of the spawning escapement targets set for the Ettrick and Gala salmon populations using their counters.

(a) Check the numbers of salmon counted upstream each year against their spawning targets and advise the RTC of any shortfall. If these targets are being met, it is a reasonable assumption that all the different populations of the same run-timing type within the catchment are also at adequate numbers, though the more counters spread through the catchment there are, the more secure this assumption is.

Policy 2F.4: Develop the Gala Water as an Index Tributary for the Salmon of the catchment and construct a stock-recruitment curve for the area upstream of the counter.

(a) Install a smolt trap on the Gala Water beside the fish counter so that the numbers of salmon leaving as smolts and returning as adults to the Gala can be found.

(*i*) Estimate total smolt numbers by marking a sample of those caught in the trap and releasing them upstream. The proportion of these marked fish that are recaptured in the trap will show the proportion of all smolts that is taken in the trap (*this is a standard technique*).

(*ii*) Measure and take scales from a sample of smolts to show their size and age structures.

(*iii*) Relate smolt numbers to the fry abundances found from the electro-fishing surveys to show how levels of fry relate to final smolt outputs and how this can vary with environmental conditions.

(*iv*) Collect and store scales and fin clips (and possibly swabs of fish glaur/slime) for genetic analyses.

(b) PIT* tag large samples of smolts of each age/size class and install PIT tag readers in the Gala fish pass so that tagged fish returning as adults will be detected. This will show:

(*i*) The number of adults produced from the known number of smolts tagged in any year. This would be found after two seasons – grilse returns in the first year, salmon in the second. Adding these two totals will give the total number of returns from the smolts tagged.

(*ii*) The relative proportions of grilse and salmon in the population each year – the PIT tags will show in what year a fish left.

(*iii*) Whether smolts of different sizes have different survival rates.

(*iv*) Take tissue samples from PIT tagged smolts to show their sex ratio. When these return, this will also show the sex ratio of returning adults and whether this has changed from the smolt ratio.

(*v*) Whether size / age of smolt is related to return as grilse or salmon.

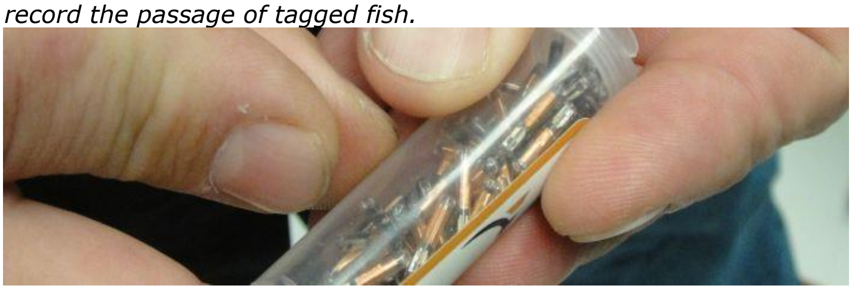
(*vi*) Whether lower or higher flows for migration down the main river significantly affect return rates.

(*vii*) Repeat spawning rates would also be found.

(c) Detailed genetic analyses of the family background of smolts are now possible. For example, if tissue samples are kept of the all PIT tagged smolts leaving the Gala, the genetic profiles of those returning as adults (as shown by them being recorded passing upstream through the fish ladder) can be compared to those of the smolts that did not manage to return and it can be seen if some families returned at a higher rate than others. Similarly, the families of fry sampled during electro-fishing can be identified and compared to the families represented in the smolt runs to see which survived best to the smolting stage. Evidence from this sort of work elsewhere has shown that survival can be very variable, with a restricted number of families producing a large proportion of the smolts. Work like this could only be done by academic organisations, but the taking and storage of tissue samples for later analyses has almost no cost.

As it is known that 1,000-2,000 adult salmon return to the Gala, tagging of around 2,000 smolts (taking a return rate of 5%) should result in around 5-10% (100) of returning adults having a tag. It might be possible to synchronise the PIT tag reader with the fish counter, so lengths of returning tagged fish could be known as well.

** PIT (Passive Integrated Transponder) tags are the sort used to "chip" pets. Each has a unique ID code and as they have no batteries (are "passive") they are very small (photo below) and can be inserted in to the body cavity of a fish through a very small cut or with an injector. They are read when they come close to a reader, which activates them with a small electric current. PIT tag readers can be mounted in fish passes, e.g. on the Galloway Dee, and so record the passage of tagged fish.*



(d) Estimate the three different components in the loss rate of fish, which are:-

(1) In-river smolt mortality, from the Gala Water to the sea.

(2) Marine mortality from the time of leaving the estuary as a smolt, to the time of return to the estuary as an adult.

(3) In-river mortality as an adult running back upstream to the Gala Water.

(*i*) Component (1) can be estimated by acoustic tracking smolts down to the estuary (**Policy 2C.2b)**. There is still some uncertainty over the effect of acoustic tagging and tags on smolts and one possible way to look at this is to tag a sample of pre-smolt parr upstream of an acoustic detector in the Autumn before migration. Any then smolting and passing the detector the following Spring would obviously be fit and healthy and their return rate could then be compared with that of fish tagged directly as smolts. It may be possible to mount such an acoustic detector along the crest of the Skinworks cauld.

(*ii*) Component (3) is the angling and other in-river mortality which is estimated by tagging fish in the lower river and seeing how many of these get back upstream to the Gala **(Policy 2E.2).**

(*iii*) If Components (1) & (3) can be estimated independently as above, then if subtracted from the total mortality, it would give the out-at-sea marine and estuary mortality for this population.

(*iv*) If the PIT tagged Smolts were also adipose fin-clipped:

a) Data on catches by anglers and nets would be available.
b) Some estimate of straying by adults would become available, i.e. if clipped fish were caught upstream of the Gala or a different part of the catchment altogether.
Both these would mean anglers and netsmen reporting clipped fish so their PIT tags could be read.

INPUT 2G: COLLECT INFORMATION ON TWEED SALMON AT SEA: THEIR MIGRATION ROUTES, EXPLOITATION AND PREDATION

Rationale: the movements and fates of Tweed salmon at sea have always been poorly known due the difficulties of finding and identifying them at sea, but if a fully rounded picture of their state and of the impacts on them identified, much better information is required. The development of marine renewables, particularly windfarms, on the possible migration routes of both smolts and adults is an issue of increasing importance and there is therefore some urgency in finding the routes used by Tweed salmon at sea.

The Current Situation: New tracking and genetic techniques are rapidly improving the ability to track and to find both smolts and adults at sea. It is now possible, for instance, to identify West Greenland as a place where salmon from the "*South and East Scotland Region*" are the single largest proportion (around 40%) of the local catch http://www.nasco.int/sas/pdf/archive/papers/2014/SAG_14_5.pdf . Similarly, it is now known that the majority of the salmon caught in the North-east England drift nets are of Scottish origin and while identification to river is not yet secure, the indications are that that the Tweed salmon is the largest source of the salmon caught in these fisheries (Gilbey *et al,* 2012).

Older tagging techniques have given still vital information on where Tweed salmon go at sea (Appendix 2G) though the route that Tweed smolts take across the North Sea is still unknown. Rapid advances are being made in tagging and tracking techniques for both smolts and adults and it is intended to apply these to Tweed fish as and when it becomes practical.

Policy 2G.1: Collect and collate historic data on recaptures of tagged Tweed fish at sea
(a) Work out GIS and other locations for recaptures for mapping.

Policy 2G.2: Identify opportunities for tagging and tracking Tweed smolts and adults at sea

(a) Find opportunities to have Tweed salmon genetically identified to river level so any captures at sea can be identified.

Policy 2G.3: Map locations of marine renewable developments, existing and planned, in relation to what is known of the distribution of Tweed fish at sea

(a) Collate research on the impacts of windfarms on smolt and adult migration, including their possible effects in attracting predators to previously open waters.

Policy 2G.4: Collect and collate data on the types and frequencies of predator damage on salmon returning to the Tweed.

(a) Continue identifying and recording predator damage (including lamprey marks) on the fish netted at Paxton.
(b) Collect and collate information on numbers of marine predators in the areas offshore of the Tweed.

Policy 2G.4: Collect and collate data on exploitation of Tweed salmon forth of the Tweed

(a) Collect and collate information and data on the West Greenland fisheries.
(b) Collect and collate information and data on the North-east England net fisheries (Existing data in Appendix 2G).

BASIC RESEARCH NEEDS IDENTIFIED FOR SALMON:

For INPUT 2B

(1) Aerial survey of the catchment. This would allow good estimates to be made of the amount of juvenile habitat to be stocked by spawning salmon and therefore better estimates of the number of spawning fish needed. It could also provide the physical data on habitat for analysis with the electro-fishing survey results of Input 2.C, so that salmon fry abundances could be related to catchment features and factors, though techniques may have to develop before this is possible.

For INPUT 2C

(1) Monitoring juveniles of large channels. It should be noted that all the electro-fishing sites monitored as part of this policy are in small to medium sized channels -the furthest downstream monitoring site on the Tweed itself is at Innerleithen, on the Ettrick it is at Lindean and on the Teviot at Kirkbank. The standard techniques for quantitative electro-fishing are basically unsuitable for very wide channels - but such main channels can form 60% to 70% of the total area open to spawning Salmon in a catchment. On the Tweed, Salmon spawn as far downstream as Coldstream (at least) and juveniles can be found throughout the middle and lower river. The lack of coverage of this huge area of main channel is a weakness in the monitoring programme, particularly as this is the area of a particular stock, the Autumn Salmon and it is obvious that some method of sampling has to be devised for this type of channel. The matter has been recently considered by the SFCC but no method suitable for the middle or lower Tweed was produced. However, genetic techniques are becoming available that can estimate the numbers of different parents of samples of fry and this is starting to come in to use to estimate population sizes e.g. Bacles *et al*, 2018. This may be a possible way to monitor the populations of the larger channels and developments will be monitored.

(2) Comparison of the results of the Tweed with those found elsewhere. At present, the scale on which electro-fishing results are assessment is self-referential, based only on Tweed data. While this is very useful for management purposes here, it would also be useful to know how our results compared with elsewhere, e.g. whether a site that is rated first class in terms of salmon fry abundance here would be rated as such elsewhere. This would require the electro-fishing data from a range of rivers in Scotland to be analysed to draw up regional and national assessment scales.

For INPUT 2D

(1) With more and more Catch-and-Release, the consistency of catch records over the years has something of a question over it – how many fish are now caught more than once? This needs a very easy to use tag that anglers can put on fish they release, that does not require them to put holes in fish. Some sort of "Velcro" band to put round the wrist of the tail would be the simplest thing to do (and tags like these appear to be used for the necks of swans and geese). A six-month life-span (or even less, for the Autumn) would be all that was needed.

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