The Flow Country Fisheries Management Organisation (FCFMO).

Draft Fisheries Management Plan

1. Background.

Following the Wild Fisheries Review, the Scottish Government intends that the management arrangements for fish and fisheries in Scottish rivers will change.

In outline, it is intended to replace the existing District Salmon Fishery Board (DSFB) system with a new management system based on a smaller number of larger units to be termed Fisheries Management Organisations (FMOs). In addition, whereas the existing DSFB system covers only migratory salmonids, the remit of the new FMOs will cover all fish species.

Following discussions among the present Northern, Caithness and Helmsdale DSFBs, it is proposed that their respective fishery areas should combine to form a new Flow Country Fisheries Management Organisation (FCFMO). The proposed FCFMO area covers that part of the north-eastern Scottish mainland outlined in Figure 1.

Figure 1. The boundary of the proposed FCFMO area.

From west to south the area encompasses the major river catchments of the Kinloch, Borgie, Naver, Strathy, Halladale, Forss, Thurso, Wester, Wick and Dunbeath Rivers, the dual Berriedale/ Langwell system and the Helmsdale River. In total, the proposed FCFMO area covers about 3000 km^2.

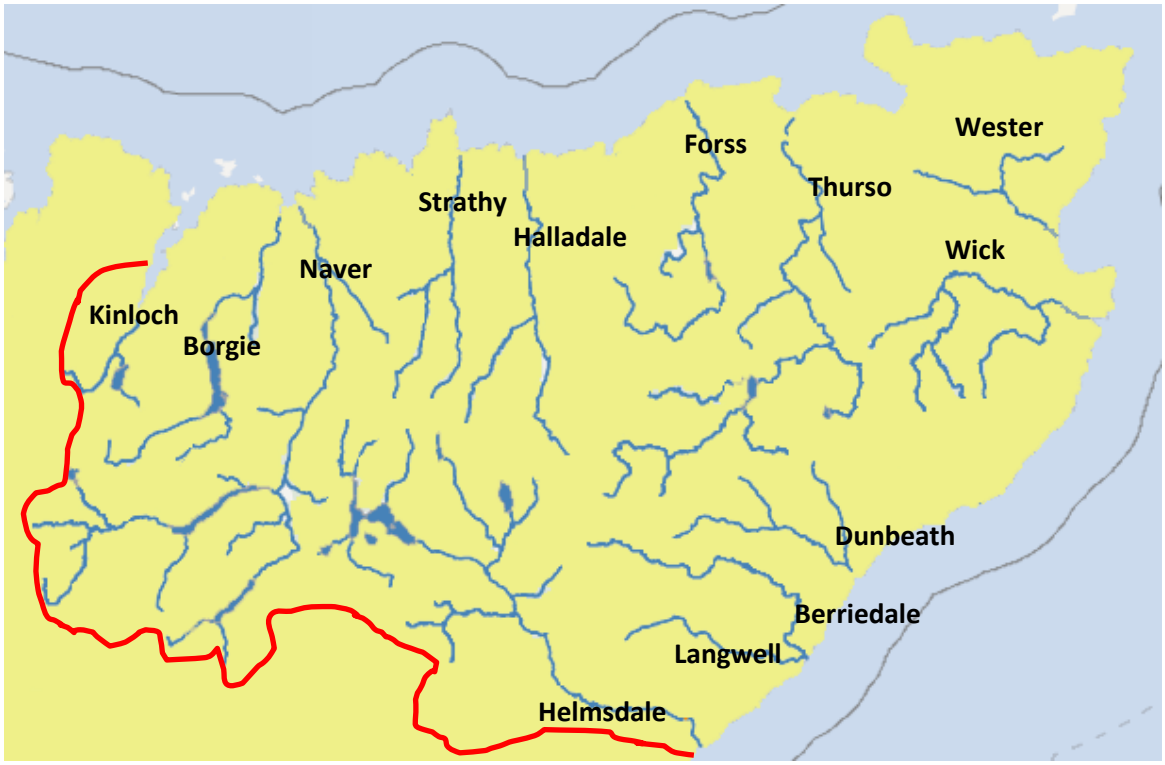

Figure 2. The FCFMO river network[1].

The majority of the area's larger river catchments (Fig. 2) are linked by having their origins in the unique ecology of the extensive blanket bogs that comprise the so-called Flow Country of Caithness and Sutherland.

Peat forms over long periods of time in cold, wet, acidic conditions where the rate of accumulation of plant material exceeds the rate of its decomposition. Most peat deposits form in depressions in the landscape. However, in the extreme conditions of the Flow Country, deep peat has also formed on flat or moderately inclining land surfaces to form the continuous cover characteristic of blanket bog. **Given their wide extent, the Flow Country peatlands have a major effect on the hydrology and hydrochemistry of the rivers that drain from them.**

The larger river networks are interspersed with smaller, less familiar catchments that originate nearer to the coasts. These include, for example, the Reisgill, Sandside and Armadale Burns. In the past these smaller stream systems have tended to be neglected by management because of their low economic value although they also constitute a potentially interesting natural resource.

Standing water is a characteristic feature of the poorly-drained peatlands of the Flow Country and the lochs of the FCFMO's area are literally innumerable. The landscape around Knockfin Heights, for example, which straddles the upper parts of the Halladale, Thurso and

[1] From Scottish Natural Heritage at https://gateway.sn.gov.uk/

Helmsdale catchments is dominated by an extensive system of multiple dubh lochans; many of these are tiny and many have no surface connection to their river network.

By contrast, Loch an Dithreibh, Loch Loyal, Loch Craggie, Loch Naver and the Loch Badanloch complex, are some of the high-volume water bodies In the central and western parts of the FCFMO area. These are intimately linked to their river networks and profoundly affect their characteristics – particularly their flow regimes.

The shallow, fertile lochs of lowland Caithness constitute yet another class of standing water. Many support notable populations of wild brown trout and associated sports fisheries.

The common origins of the larger river networks in the peatlands determine much of the general character of the area's rivers and lochs and also the nature and extent of their fish populations. **The proposed FCFMO will therefore cover a distinct geographical unit centred on the unique ecology of the Flow Country.**

Large parts of the Flow Country are designated as the Caithness and Sutherland Peatlands Special Area of Conservation, as shown in Figure 2. The Peatlands Partnership[2] is an established initiative that already contributes greatly to many aspects of environmental management in the FCFMO area. **Integrated management of the peatlands by other non-fishery bodies offers an expansive background for fishery management and potentially valuable opportunities for collaboration.**

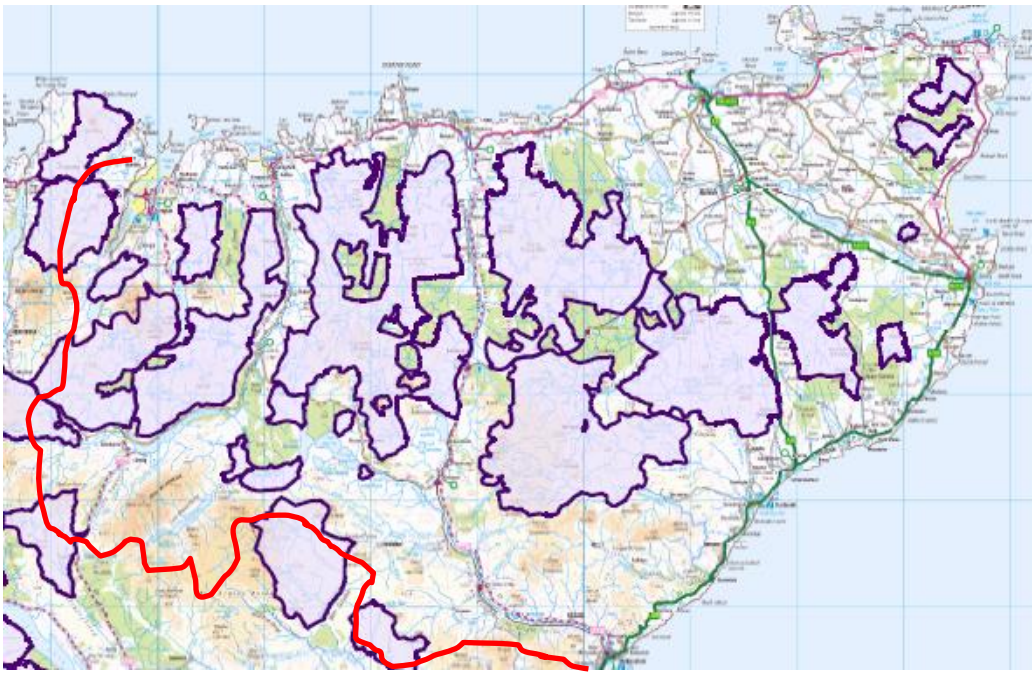

Figure 3. Caithness and Sutherlands Peatlands SAC.[3]

[2] http://theflowcountry.org.uk/about-us/the-peatlands-partnership/
[3] From Scottish Natural Heritage at https://gateway.sn.gov.uk/

2. Fish fauna of the Flow Country.

The FCFMO area is typical of northern Britain in being relatively poor in fish species. This is due to the geographical isolation of the Flow Country rivers in the aftermath of the last Ice Age and the consequent failure of strictly freshwater species to colonise, or re-colonise, northwards as the glacial ice-cover retreated.

The species list of freshwater and diadromous fishes comprises Atlantic salmon (*Salmo salar*), land-locked, resident and marine migratory forms of brown trout (*S. trutta*), Arctic char (*Salvelinus alpinus*), European eel (*Anguilla anguilla*), brook lamprey (*Lampetra fluviatilis*), sea-lamprey (*Petromyzon marinus)*, minnow (*Phoxinus phoxinus*) and 3-spined stickleback (*Gasterosteus aculeatus*). The flounder (*Platichthys flesus)* is more usually thought of as a marine species but it is regularly encountered in the lower reaches of the northern rivers.

Species such as pike (*Esox lucius*), grayling (*Thymallus thymallus*), gudgeon (*Gobio gobio*) and perch (*Perca fluviatilis*) are locally common in other parts of Scotland. However, deliberate or inadvertent introduction of such species to the FCFMO area have either not occurred or have been without lasting effect since, as far as is known, all such species are absent from the Flow Country.

Only two (enclosed) put-and-take fisheries for rainbow trout (*Oncorhynchus mykiss*) are, or have been, operative in the recent past. Otherwise, salmon and trout are the only species that support economic activity in the FCFMO area. Trout are essentially ubiquitous and salmon are present in all parts of the river catchments that are accessible from the sea. Four of the 11 FCFMO rivers - Borgie, Naver, Thurso and dual Berriedale/ Langwell system - are designated as Special Areas of Conservation (SACs) in recognition of the qualitative importance of their salmon populations in the national conservation context.

Several of the FCFMO catchments support sports fisheries for salmon that rank highly in the national context. The area also currently supports three coastal netting stations and a small number of additional estuary fisheries that currently operate intermittently in the vicinity of particular rivers.

Taken as a whole, the proposed FCFMO area accounted for about 14% of the reported Scottish rod catch of salmon and grilse in the most recent year for which figures are available (2015) and about 19% of the combined national rod and net catches. Sea-trout are also present in most rivers but comprise a relatively minor part of the fisheries. In 2015, the FCFMA's reported rod catch was 3% of the national total.

Notable sports fisheries for resident brown trout are pursued in many of the area's lochs but, in general, catches are not recorded or only partially reported.

In summary, the fish species list in the proposed FCFMO area is short and the local economic fishery resource is dominated by only two species - salmon and trout. However, the area supports a large number of varied and highly productive fisheries for these species. It is therefore fitting that substantial effort should be applied to maintaining and improving the fisheries in a sustainable way using appropriate forms of management.

3. Approach to management.

The FCFMO will -

- Adopt a scientific approach to fisheries management. This means using the best available science to monitor fish populations, identify potential problems, disclose management options and their likely outcomes, prioritise remedial actions where these are both feasible and necessary, and monitor the outcome of management actions.
- Scan forwards in order to pin-point upcoming challenges and obtain appropriate new information in a timely and proportionate way.
- Report the results of data gathering and monitoring in a permanent form in order to form an archive for future reference.
- Share scientific information, knowledge and experience with other FMOs in order to expand the capacity of all FMOs to practise fisheries science of high quality in the wider context.
- Consider the area's fish populations in the wider ecological context of the local landscape, engaging as necessary with public bodies with regulatory or advisory duties in related areas.
- Engage with the research and higher education communities, seeking input and, in return, offering opportunities for research or training. The aims will be to (1) increase the quality and breadth of the FCFMO's knowledge by encouraging a diverse range of inputs to its work and (2) increase dissemination of sound advice and good practice in fishery management.
- Engage with local stakeholders, seeking their support and advice in pursuit of the FCFMO's aims and, in return, strive to deliver the economic and social benefits that will follow from sound scientific understanding and good management of the area's fish and its fishery resources.
- Engage with Scottish Government. To be edited in.

The approach to fishery management will be determined, firstly, in the context of the features of the coastal and freshwater environments that determine the distribution, abundance and demography of fish species and, secondly, in the context of the social

factors that determine present, and potential, patterns of economic and conservation activity.

The main aims of the FCFMO will be to spread economic and social benefits among the wider local community. This will be targeted by using the best fishery management practice to maintain or increasing the productivity of the fishery resource in a sustainable manner. The aims will be to encourage local and in-coming investment, secure dependant local employment, increase recreational opportunity and encourage wider community involvement in fishery and related matters. The FCFMO will encourage academic involvement in order to promote these objectives and, by working closely with the Environmental Research Institute (ERI) in Thurso, to encourage the development and retention of a high-level capability for fisheries science in the North.

4. The FCFMO Setting

4.1. Coastal waters

All the coastal waters of northern Sutherland and northern and eastern Caithness are classed by the Scottish Environmental Protection Agency (SEPA) as being of good quality[4].

The Pentland Firth and its approaches dominate the hydrography of the coastal waters between Duncansby and Dunnet Heads on the northern Caithness coast. The Firth forms a constricted passageway between the mainland and the southern Orkney islands and it generates extreme tidal currents. Elsewhere, the northern coast of Sutherland and Caithness faces the open ocean and the eastern coast of Caithness borders the outer Moray Firth. All are active or proposed areas of marine renewable energy development that will exploit tidal, wave or offshore wind resources.

The landscape of both the northern and eastern coasts is dominated by cliffs. On the east coast, the southern rivers (Helmsdale, Berriedale/ Langwell and Dunbeath) enter the sea directly through narrow valleys. By contrast, most of the westernmost rivers flowing to the north coast have estuaries associated with shallow beaches that intersect the cliff-line (Kinloch, Borgie, Naver, Strathy, Halladale).

The Wick and Thurso Rivers discharge into more extensive bays and these support the only port facilities in the FCFMO area. The Thurso River discharges to the sea about 2km from the port of Scrabster. The Wick River discharges through the Wick Harbour channel.

Thurso and Wick are the only major population centres in the FCFMO area.

[4] From SEPA at http://www.sepa.org.uk/data-visualisation/water-environment-hub/

4.2. River Network

Figure 3 shows the river network for the FCFMO area as documented by SEPA. It includes both the major river networks and minor streams. The colour codings are classifications for access for migratory fish.

Four access problems are identified. Three sites have man-made barriers associated with public water supplies. These are (1) Loch Calder and its minor feeder streams, (2) the Thrumster Burn, a minor feeder stream to Loch Hempriggs and (3) the Caen Burn, a minor tributary to the River Helmsdale. It should be noted that, in some cases, access to these streams may be impeded rather than prevented and fish of different sizes and the various fish species may be affected differently. Eels, for example, are capable of circumventing substantial barriers. In addition, access to the Vagastie Burn (4), a more substantial stream in the River Naver catchment, is compromised by the diversion of flow to the River Shin catchment (outside the FCFMO area) for electricity generation.

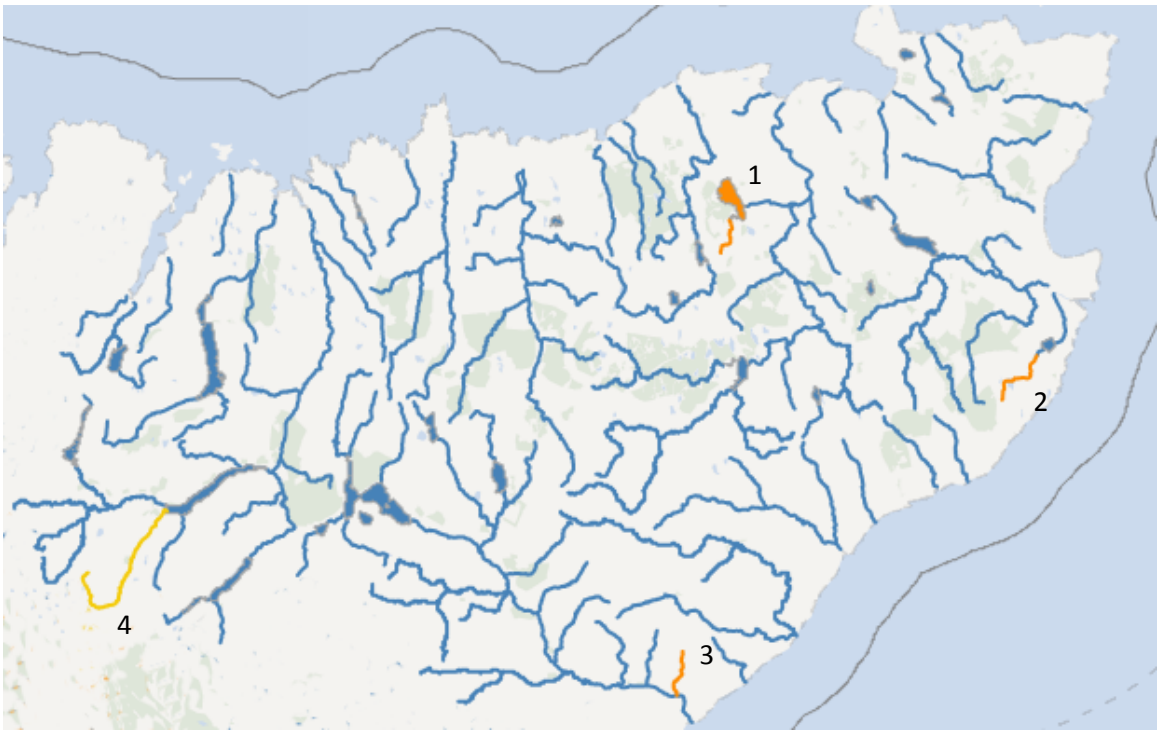

Figure 4. FCFMO river network: SEPA classification of access for migratory fish.[5]

Elsewhere, natural barriers exclude migratory fish from extensive areas of potentially productive habitat only at Glutt on the upper Thurso and in the lower eastern catchment of the Halladale (the Smigil, Trantlebeg and Dai's Burns).

In summary, man-made barriers to migration are few in number and most affect relatively minor streams. Natural barriers are also few in number and they prevent access to a

[5] From SEPA at http://www.sepa.org.uk/data-visualisation/water-environment-hub/

relatively small part of the total area of the river network, mostly in headwaters on the periphery of catchments. **Therefore, almost all the natural productive potential of the FCFMO river network is freely available to anadromous fishes**.

4.3. Landscape.

The general terrain of the FCFMO area is determined by the underlying geology and this is dominated by three types of feature (Fig.5). The bedrock of the low-lying eastern part of the landscape, bounded by an imaginary line from Reay to Berriedale, comprises Devonian sandstones. The central and western part comprises older metamorphic rocks of various related types. Igneous rock has intruded through these metaphorphic layers in several areas – around Loch Loyal, at Strathy and Melvich, along and southwards from Strath Halladale towards Braemore and Kinbrace, and around Helmsdale.

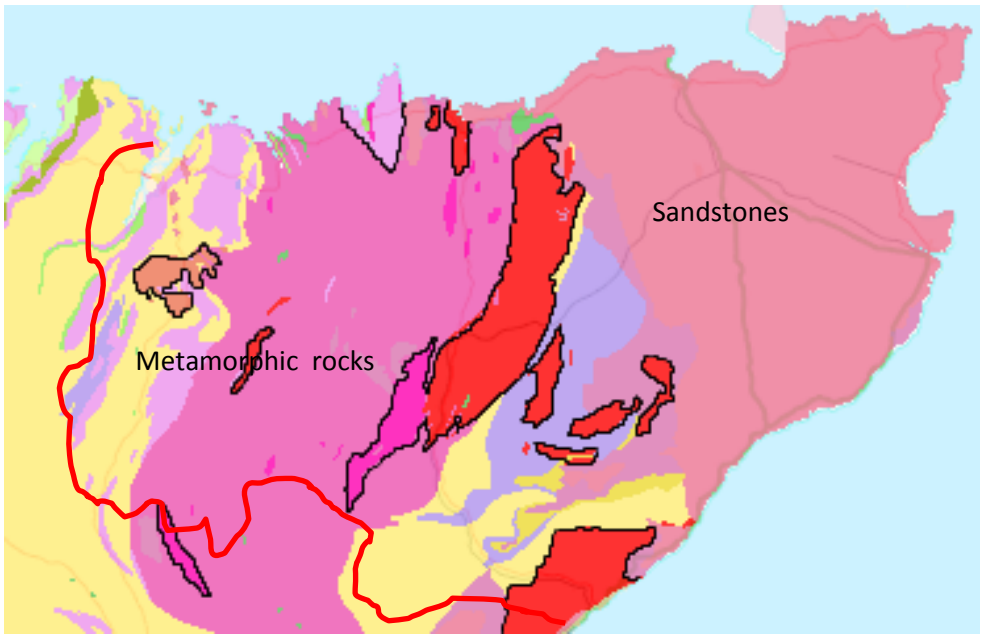

Figure 5. Bedrock geology.[6] *The main igneous intrusions are outlined in black.*

Although there are some areas of exposed bedrock in the FCFMO area, in most places the underlying geology is overlain by either of two main classes of surface material (Fig.6). The central and southern parts of the area are dominated by peat cover, often of substantial depth. Elsewhere, the superficial geology is dominated by glacial tills although some of the larger waterways are fringed by tracts of alluvial origin.

[6] From British Geological Survey at http://www.bgs.ac.uk/data/mapViewers which gives a full key to the colour code.

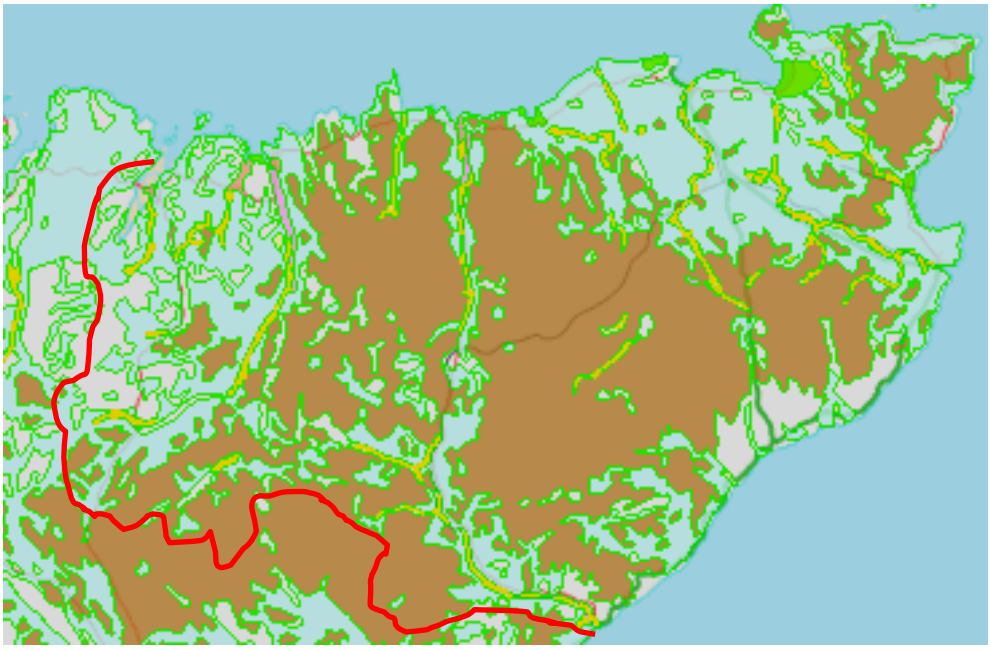

Figure 6. Superficial geology showing the extent of peat cover (brown), glacial tills (light blue) and alluvial material (yellow).[7]

Together, the physical characteristics of bedrock and superficial sediments combine and interact with other physical and biological processes to determine the characteristics of the soils that clothe the landscape.

It can be seen from Figure 7 that patterns of soil acidity largely mirror the distribution of the peatlands. Most of the area's soils are acidic but the peatland soils are often strongly so (less than pH 4). By contrast, the corridor of farmland between Wick and Thurso is composed of weakly acidic or near-neutral soils (pH 5 to 7). Elsewhere, pockets of weakly acidic soils (pH 5 to 6) occur locally - for example, along Kildonan Strath and Strath Halladale, and around Altnaharra, Armadale, Strathy and Achavanich.

[7] From British Geological Survey at http://www.bgs.ac.uk/data/mapViewers

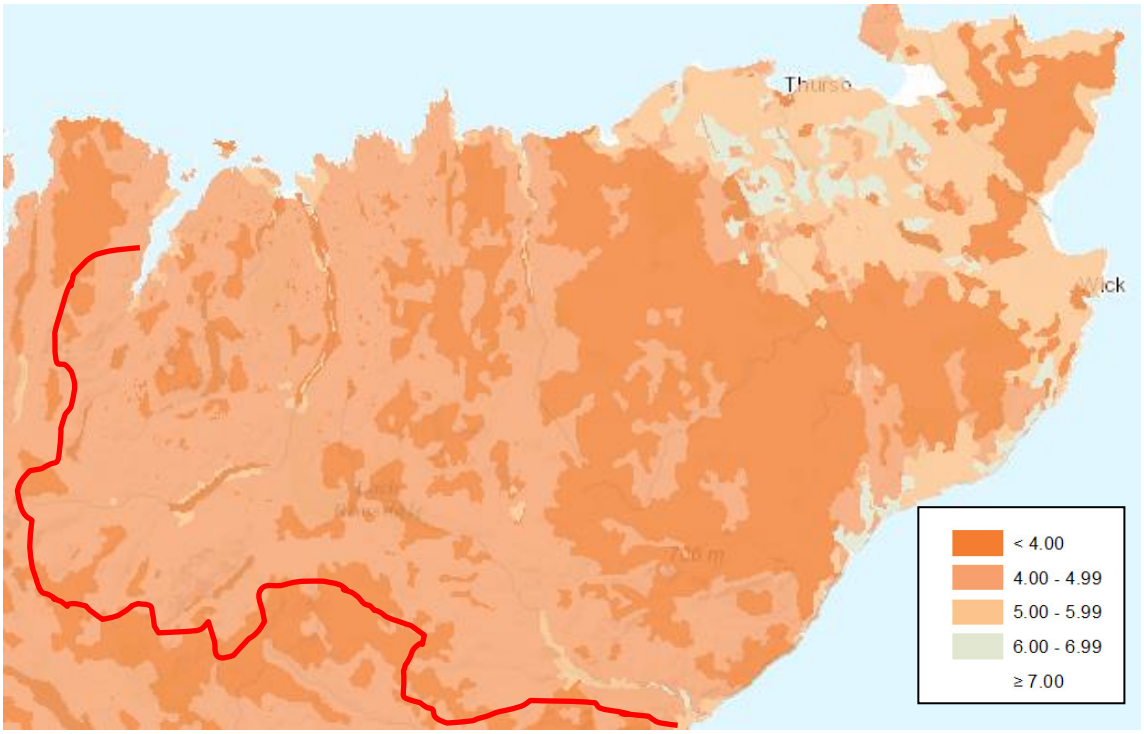

Figure 7. Soil acidity (pH).[8]

Soil acidity affects the range of land-use activities that are possible within particular catchments – wild land, managed moorland, rough grazing, farming or forestry. These activities, in turn, modify the physical and chemical characteristics of catchments in various ways and they also therefore affect the river networks that drain them.

Profound alterations in flow regimes and water chemistry are associated with forests and forestry practice and these can affect river systems and aquatic ecology in a range of adverse ways. Forest cover is not a natural feature of the landscape of the FCFMO area. There is no native conifer woodland. Where it occurs, natural or semi-natural tree cover is of broad-leaved species and often restricted to valley-sides where the gradient is sufficient to impede grazing by sheep or deer.

Extensive commercial planting of non-native conifers was undertaken several decades ago, usually on partially drained peatland. Figure 8 shows the recent distribution of forests in the FCFMO area.

Most of the forests are now at, or near maturity, and extensive felling is currently underway. Some of this activity has been associated with windfarm development and some with peatland management and restoration. In these cases, clearance is permanent. In other cases, however, felling is taking place as part of the normal forest cycle and extracted

[8] From UK Soil Observatory at http://mapapps2.bgs.ac.uk/ukso/home

timber will be replaced with new plantings. The new plantings will be less extensive than the existing ones as a result of changes in forestry practice.

As a result of all these factors, the pattern of forest cover as shown in Figure 8 is already out-of-date and it will continue to change in coming years. However, the effects of forests on rivers do not cease with clearance. The return to natural hydrological and hydrochemical regimes is slow and recovery times are measured in years or decades. Accordingly, the distribution of forestry activity as shown in Figure 8 will continue to be a valid reference source for fishery management activity for the foreseeable future.

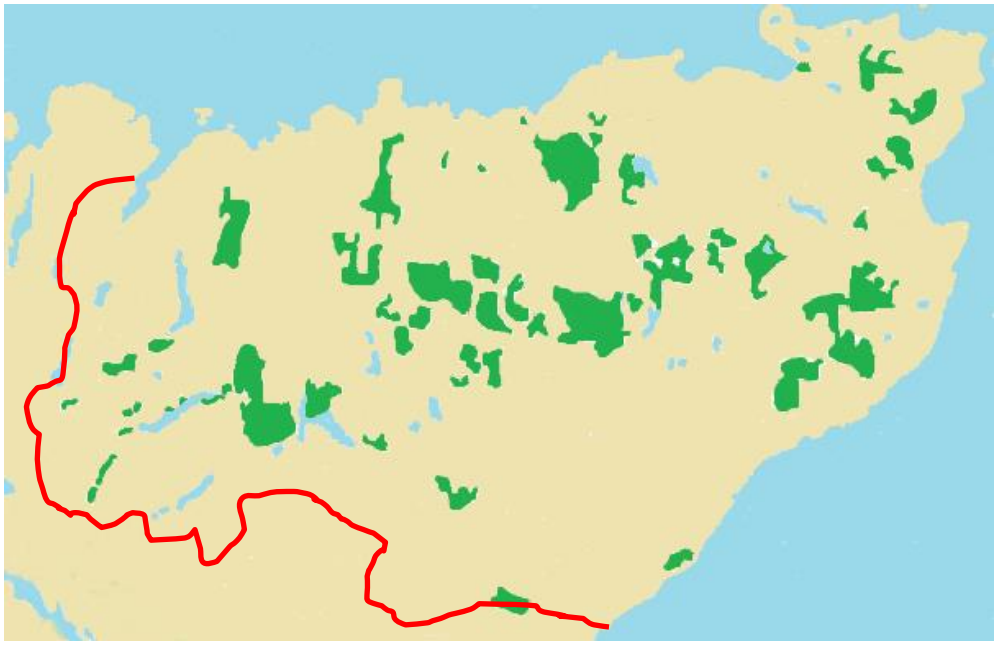

Figure 8. Forestry. From Google Earth (image dated 2004).

Forestry is distributed rather evenly across the central and northern parts of the FCFMO area. The northern catchments are all affected by forestry to some extent, with the exception only of the River Kinloch. In the southern sector, the catchments of the Dunbeath River and the Berriedale/ Langwell system are essentially free of forest cover and the River Helmsdale catchment is affected only to a minor extent.

Figure 9 shows that most farmland/ grazing land in the FCFMO area is restricted to a wide corridor between Wick and Thurso. This area extends westwards to Reay and also east and southwards along the coastal fringe to Berriedale. Elsewhere, crofting or grazing land fringes the Rivers Naver, Halladale and Helmsdale, for example, mirroring the distribution of alluvial soils shown in Figure 6. As expected, the distribution of farmland and grazing mirrors the distribution of soil acidity values shown in Figure 7.

Figure 9. Farmland and grazing. From Google Earth (image dated 2004).

Only the Wick, Wester, Thurso and Forss River catchments are at risk from the potentially adverse effects of intensive farming – diffuse pollution, changed patterns of drainage and bank erosion. Elsewhere, crofting activity is based on relatively small areas of improved grassland on valley floors and on low intensity rough grazing by sheep on adjacent tracts of peatland or grass moor.

4.4. Freshwater Environment

4.4.1. Flow. Rainfall or snow-melt reaches river networks via a wide range of hydrological pathways that vary in their directness. In the poorly-drained and saturated peatlands, precipitation augments and quickly displaces water already lying near the surface. As result, snow-melt or heavy bursts of rainfall result in brief spates of turbid, peat-stained water that rise and fall rapidly.

Under low-water conditions, the catchments continue to drain via a more restricted range of pathways. In the absence of rainfall, streams are charged by surface seepage from the blanket bogs and by discharge from a range of shallow groundwater sources; deep groundwater is not a source of river water in the FCFMO area. Groundwaters are filtered during transit through soils and sub-surface sediments. Groundwater sources contribute a greater proportion to river flow under low-water conditions and, as a result, turbidity and peat-staining are less intense.

From the hydrological point of view, all the rivers of the FCMO area are essentially spate rivers because of their origins in the peatlands. However, the flows of the larger rivers tend to be more stable than those of the smaller ones purely as a result of scale. In addition, variation in flow is further buffered in those rivers that include substantial lochs (the Rivers Borgie, Naver, Helmsdale and, to a lesser extent, Wick River). Finally, both the Helmsdale and the Thurso have impoundments in the upper catchments that are used to modify flow variation downstream.

SEPA continuously monitors river height at seven gauging stations[9] in the FCFMO area located on the Rivers Borgie, Naver, Strathy, Halladale, Thurso, Wick and Helmsdale.

4.4.2. Water quality. Rainwater interacts with vegetation (including forestry and farmland crops), with peat cover, and with soils and minerals during its passage to rivers and, as a result, its chemistry changes. River chemistry reflects the particular routes by which precipitation drains towards rivers, the time it spends in transit and the proportional contributions to river flow made by inputs of different provenance. In addition, human activity directly impacts river chemistry through inputs from public sewage treatment works or domestic septic tanks and, indirectly, through diffuse pollution associated with farming.

Spate rivers are inherently dynamic. This is matched by the complexity of variation in their hydrochemistry. This makes monitoring water quality problematic. Most assessments are based on pre-scheduled sampling and spot measurements. This approach supports an assessment of average condition but it must also be borne in mind that it risks missing short-lived transient changes of potential importance in a fisheries context.

SEPA makes assessments of overall water quality based on scheduled sampling. Figure 10 shows all the streams and rivers in the FCFMO area and the larger lochs. The great majority of these waterways are outlined in blue or green which denotes that their status is regarded as excellent or good, respectively.

However, five lochs, two large streams and seven small streams are depicted in yellow indicating that their water quality is regarded as only moderate. Most of the affected locations lie in farmland in the eastern sector of the FCMO area. There are no “poor” or “bad” classifications.

The Sleach Water (1), a tributary of the River Thurso, is impacted by nutrient enrichment and acidification associated with forestry. The Sleach Water is a tributary to Loch More (2) which is also impacted by nutrient enrichment associated with forestry. The forest in the Sleach Water catchment is currently being felled and, in time, the status of the stream itself and Loch More should improve.

[9] http://apps.sepa.org.uk/waterlevels/default.aspx?sm=t

Near Castletown, the Murkle Burn (3), the Burn of Garth (4) and the Midsand Burn (5) are all impacted by diffuse pollution from rural sources, probably associated with farming. Further east, St John's Loch (6), the Burn of Ham (7) and Loch Heilan (8) are affected in the same way.

In the Wick River catchment, the Quoynee Burn (9 and 10), Loch Scarmclate (11), Loch Watten (12), the Burn of Winless (13), the Achairn Burn (14) and the Thrumster Burn above Loch Hempriggs (15) are all impacted by diffuse pollution. In the case of Loch Watten, moderate water quality is probably attributable, in part, to nutrient inputs from a large winter population of roosting geese

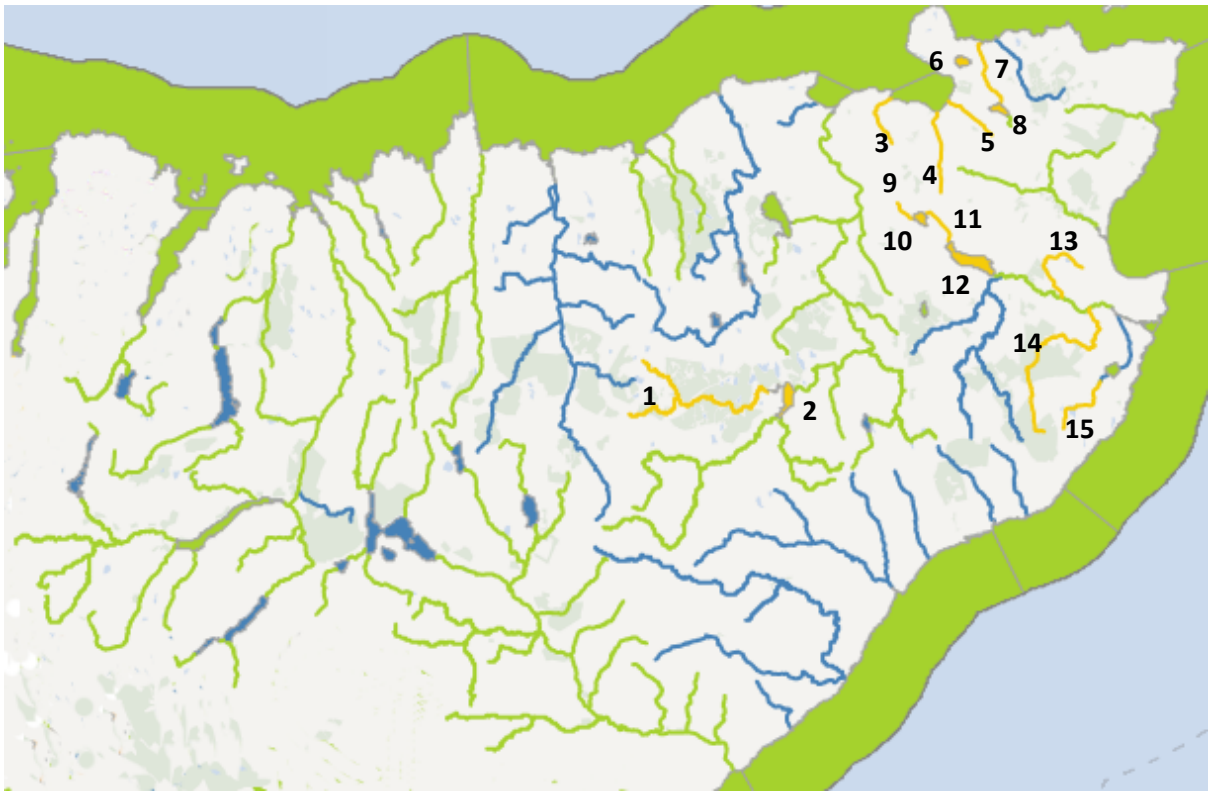

Figure 10. SEPA assessment of water quality (2014). [10]

In summary, water quality in most of the river network in the FCFMO area is classed as excellent or good. Many of the locations classed only as moderate are concentrated in the farmland of the River Wick catchment or in the same setting around Castletown and Dunnet. Many of the affected streams are very small. Biological monitoring by SEPA has not indicated significant adverse effects on the stream ecology of the locations in question.

4.4.3. Overall quality. SEPA constructs an overall classification of fresh waters. In addition to the two crucial fishery parameters considered above - accessibility (Figure 3) and water quality (Figure 10) – classification is based on physical condition, ecological condition and

[10] From SEPA at http://www.sepa.org.uk/data-visualisation/water-environment-hub/

presence or absence of invasive species. Overall condition defaults to the value of the lowest-rated component.

Figure 11 shows that, again, most of the waterways of the FCFMO area are classed as being of high or good overall status. The exceptions are generally those identified, above, as being classed as moderate for water quality or access. However, consideration of physical modification has caused further downgrading of some of these sites and qualified the status of an additional number.

Over the years, river and stream reaches in many locations have been modified, usually to reduce flooding of adjacent farmland using a mixture of dredging, re-alignment and embankments to constrain water courses. In some cases, notably the Mallart on the upper Naver, in-river works were specifically undertaken to remove obstacles to the passage of migratory fish. However, only the following sites are regarded by SEPA as being functionally compromised by past works of these kinds.

The Badanloch complex (1) in the upper Helmsdale catchments is classed as moderate due to physical modification. Elsewhere, the Allt n an Eaglaise (2) and the lower mainstem of the River Halladale (3) have been realigned and the Burn of Lyth (5), the Kirk Burn (6) and the Winless Burn (7) are affected in the same way. All are classed as poor or bad because of these changes. Loch Hempriggs (8) is of bad status due to water storage and extraction.

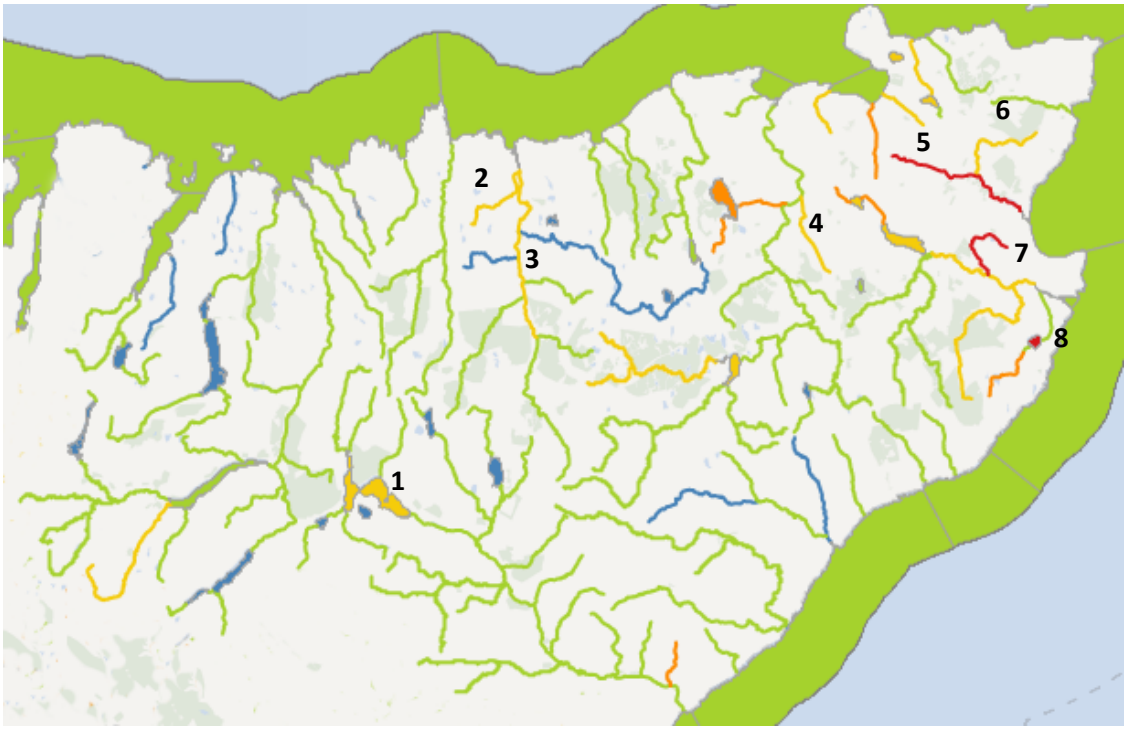

Figure 11. SEPA assessment of overall condition in 2014 [11]

[11] From SEPA at http://www.sepa.org.uk/data-visualisation/water-environment-hub/

In summary, **most of the FCFMO river network is classed as being of high or good overall status. Where lesser classifications apply they mostly concern small streams** and most of these are confined to the farmland of eastern Caithness.

From a fishery perspective, the proportion of productive habitat that is below good status is very small. As far as is known, significant constraints on fish production arising from the condition of the river network are present only for the Vagastie Burn in the River Naver catchment and for the River Wester in eastern Caithness (see below).

In view of this, **the primary focus of a fishery management strategy must be to monitor fish populations in the much larger part of the FCFMO river network that is classed as being at high environmental status. The aim will be to ensure that the large part of the area's river network that is at good, or better, status is fully productive of fish.**

5. Salmon populations.

When they return from the ocean, salmon home to their original river. They also home towards the same reach of stream that they occupied as juveniles. As a result, the populations that drive the fisheries are somewhat separate from one another. Any deficit – in eggs, fry, parr, smolts or adults - in one location cannot be compensated by a surplus generated at any great distance away.

There is a link, therefore, between the numbers of young fish leaving any location to go to sea and the numbers of adult fish passing upstream towards the same location one or two years later. Equally, there is a link between the number of spawners returning to any location and the numbers of eggs and fry that are subsequently available to replenish it.

One of the principal aims of fishery management is to assess fish populations. The aim is to ascertain that fish numbers are maximal or at least sufficient to ensure full production in the next phase of the life-cycle. In order to do this effectively, fishery management must adopt an approach that attempts to match the spatial structure of fish populations.

There are two main ways in which fish abundance can be established. Firstly, the number of adult fish can be gauged by examining the catch figures and, secondly, juvenile populations can be assessed by electric fishing. For the other stages of life, abundance cannot be investigated without using a specialist or research approach. **Analysis of adult catch data and electric-fishing surveys of juvenile populations are therefore the conventional mainstays of practical fishery assessment.**

5.1. Salmon and sea-trout catches (1952 – 2015).

Marine Scotland holds data for the reported catches of salmon (MSW), grilse (1SW) and sea trout for all the fisheries for each year extending back to 1952. Data are compiled separately

for each month for the coastal bag-nets (fixed engines), the estuary sweep-nets (net and coble) and the rod fisheries. The latest year for which data is available is 2015[12].

5.1.1. Net catches. The reported catches of the coastal bag-nets of the FCFMO area (Fig. 12) have declined over the period of the record. In the early 1980s, the combined annual catch of salmon and grilse was greatest and usually around 20,000-25,000 fish; the peak value was achieved in 1982 at around 29,000 fish. Catches fell after 1990, largely due to reductions in the number of fisheries and the shortened operating season of those that remained. **In 2015, the bag-net catch in the FCFMO area was 4900 fish - 48% of the Scottish total.**

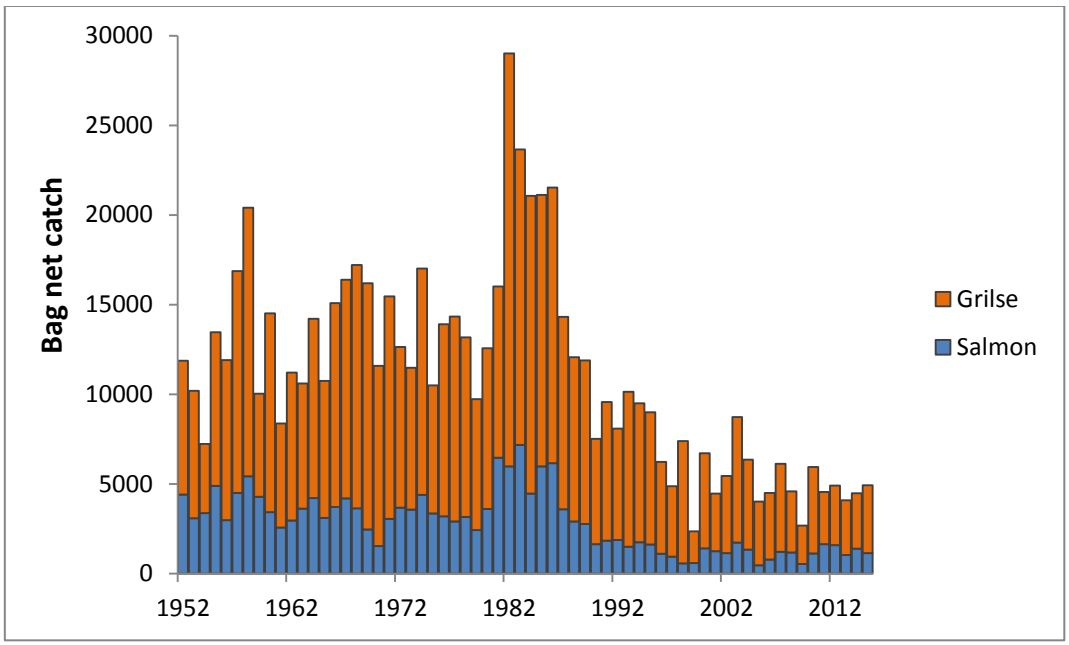

Figure 12 [13]. Bag-net catches in FCFMO coastal waters. Catches of salmon and grilse are shown separately.

Major fisheries in the estuaries of some of the FCFMO rivers were pursued up to the mid-1980s. Reported catches peaked at around 15,000 fish between 1964 and 1978 (Fig. 13). Subsequently, the fishery fell away as fishing effort reduced and, by 2005, catches in the estuary nets had declined to the trivial values characteristic of recent years.

[12] http://www.gov.scot/Publications/2015/04/6918
[13] Based on the Marine Scotland record of reported catches of salmon and sea trout.

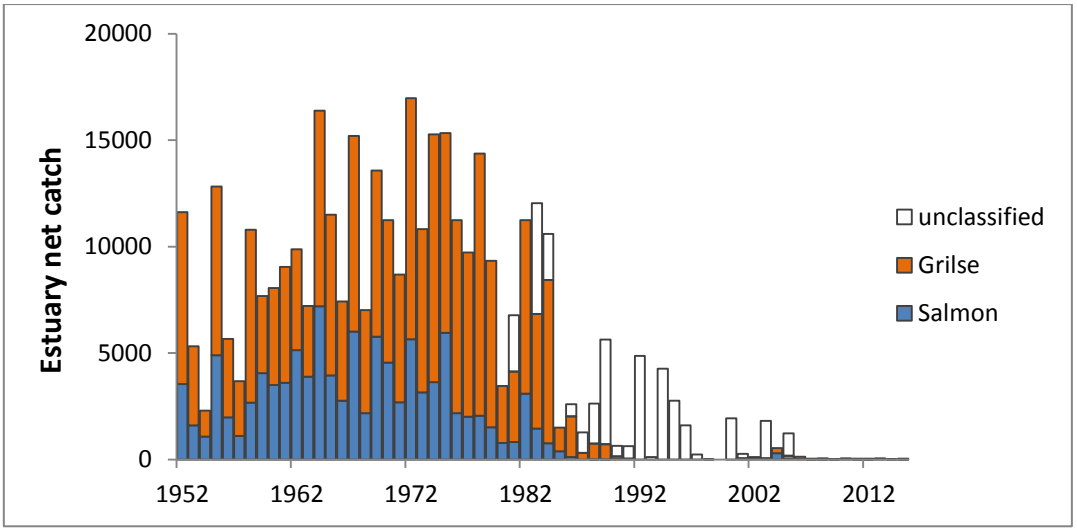

Figure 13 [14] *Catches by estuary nets in the FCFMO rivers. Declared catches of salmon and grilse are shown separately. One of the fisheries did not classify fish as salmon or grilse in some years and, for these cases, the unclassified total is indicated.*

It is not possible to fully disentangle the effects of the changing abundance of fish, the effects of competing fisheries on one another, or the effects of changing patterns of fishing effort or changes in gear technology. However, the raw figures for the net fisheries clearly show that, **at times, the coastal waters of the FCFMO area were host to a very large number of fish. This is probably still the case, albeit to a lesser extent given reported decreases in marine survival rates in recent decades.**

5.1.2. Rod catches. The rod catch record also extends back to 1952. Before the early 1990s catch-and-release was restricted to the late-season when coloured fish were often returned; otherwise most fish were killed on capture. Since then, the practice of catch-and-release has increased to reach the high levels (more than 80%) reported for recent years. Fish retained or released by the rods have been recorded and reported separately since 1994.

Catch-and- release makes the interpretation of rod catch data more difficult because, tagging studies have shown that in some rod fisheries released fish are recaptured later in the same season, thereby swelling catch numbers. Where it has been examined, the overall effect of recaptures on reported catches is not large - 5-10% might be taken as an indicative value. Recapture in a subsequent year is not a significant complication because, in Scottish conditions, most fish die after their first spawning. Very few fish survive (generally less than 2%[15]) to return to their rivers for a second time.

In future, the FCFMO Science Plan detailed below will aim to improve the value of the rod catch data by quantifying the recapture rate of released fish (see Section 8.3.3, below). In

[14] Based on the Marine Scotland record of reported catches of salmon and sea trout.

[15] I.A. Malcolm, J. Godfrey and A.F Youngson (2010). Scottish Marine and Freshwater Science. Vol.1, No 14.

the meantime, despite the possibility of multiple reporting of the same individuals, the sum of retained and released fish is considered to be the most accurate indication of the abundance of fish in rivers and this approach is adopted in what follows.

There are a number of other reasons why the reported rod catch is not likely to be a consistently reliable index of the abundance of fish in rivers. For example, catches are prone to be affected by periods of low rainfall and reduced river level, as is well-known. It follows that in an unusually dry fishing season the rod catch is likely to be less than in a uniformly wet season - even if the final abundance of fish is the same in both years. For reasons like these, interpretation of differences between pairs of catch-years, for example, should be treated with the appropriate degree of caution. On the other hand, the effects of factors like weather tend to even out over time and trends emerging over longer periods can therefore be considered with greater confidence.

Even then, trends emerging over very long periods are affected by different kinds of uncertainty. Catch data are available back to 1952 but the general arrangements governing the rod fisheries have changed markedly over the long intervening period. For example, the wider availability of transport has improved access and uptake by fishers; new rod and line technologies will have improved their effectiveness. Over time, factors like these will have gradually affected the relationship between fish abundance and rod catches and it is possible that a greater proportion of the fish present in rivers is currently caught than, for example, in the 1950s.

It is necessary to reflect on all these issues when viewing the rod catch figures. In particular, it is necessary to avoid over-interpretation of the data based on unrealistic comparisons between or across years.

Bearing all this in mind, the records show that the total reported rod catch of the FCFMO rivers has increased irregularly over the period of record (Fig. 14) with the greatest values reported for 2010, 2011 and 2012.

In the earlier years, the rod catch values will have partly reflected the prior removal of fish by the various commercial fisheries. However, it is impossible to disentangle the interactions of the three types of competing fishery within the FCFMO area because many bag-net fisheries elsewhere caught fish destined for the FCFMO rivers and because estuary-nets catch fish from more than the host river. The number of fish removed by the FCFMO estuary nets fell from 1985 onwards (see Figure 13) and there is some evidence that the rod catch increased thereafter. The fish caught by the FCFMO bag-nets were certainly not all destined for the FCFMO rivers but tagging studies have shown that many were. The bag-net catch dropped markedly around 1990 (see Figure 12). Despite this rod catches showed an

irregular decline in the following years before staging a resurgence much later (from about 2004 onwards).

In the earlier years of the record, catches were dominated by MSW fish but the proportion of grilse and their numbers increased gradually before accelerating from the mid-1980s. Catches of MSW fish declined from about the same time but have increased again in recent years. Currently, catches of MSW fish are broadly in line with the historical average and catches of grilse are greater than ever before. **In 2015, the total rod catch for the FCFMO rivers was 7800 fish, about 14% of the Scottish total; the rate of catch-and-release was 84%.**

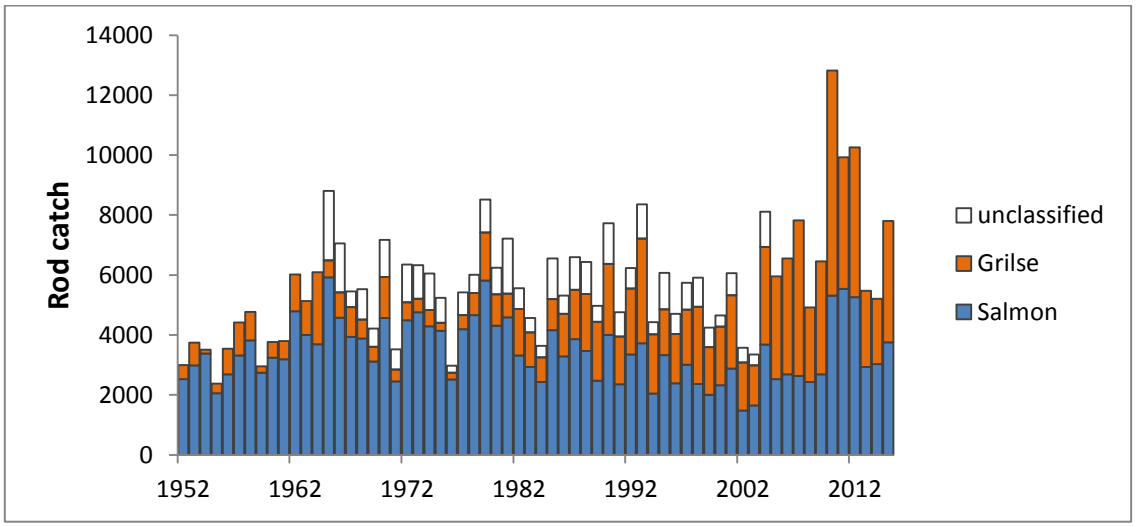

Figure 14. [16] *Total rod catch in the FCFMO rivers. Declared catches of salmon and grilse are shown separately. One of the river fisheries did not classify fish as salmon or grilse in some years and, for these cases, the unclassified total is shown separately.*

In summary, **the rod catch values suggest that in recent years there have been as many, and probably more, fish in the FCFMO rivers than previously – say, since 1990. Given the high levels of catch-and-release also now being practised, it is likely that the populations of the FCFMO rivers at spawning time have also been greater. The seemingly good status of adult spawning populations in recent years can be supported by evidence from electric-fishing surveys of juvenile populations. Uniform survey coverage across the FCFMO area is not available at present. However, recent analysis of juvenile salmon populations in the Caithness rivers**[17] **indicated that, judged by any of a range of criteria, the majority of sites were fully-charged with fry and parr over the period 2013 – 2015 (see also below).**

[16] Based on the Marine Scotland record of reported catches of salmon and sea trout.

[17] http://caithness.dsfb.org.uk/publications/

5.1.3. Genetic considerations. Many studies have shown that salmon (and trout) populations differ genetically between, and even within, river-systems. These differences arise from homing behaviour and geographical isolation which tend to keep groups of breeding fish separate from one another. Genetic measurements are often highly technical and far removed from the experience of managers. However, fish populations also differ in ways that are both obvious and important from a fishery perspective, again due to the genes that the fish inherit from their parents.

Run-timing in salmon - the date on which adults return from the sea – is one such case. Run-timing is genetically controlled and it is heritable[18]. Early-running (or spring) salmon originate in the upper parts of catchments and they return there to spawn. Early-running grilse behave in an equivalent way. Later-running salmon and later-running grilse tend to belong to the lower parts of catchments. The links between location, timing and genetics indicate that the various run-timing groups should be considered separately when possible.

This position is recognised by current national policy on conserving spring salmon which are known to be at low abundance over much of their range. The response has been to introduce advisory and statutory conservation measures centred on catch-and-release in the early months of the fishing season.This policy tacitly acknowledges that the various run-timing groups are somewhat distinct and that the early-running fish produce early-running progeny. Conserving early-running spawners through, for example, catch-and-release aims to foster rapid recovery among their progeny when marine conditions become more favourable.

This matter is important because **early-running salmon constitute a biodiversity resource that is not widely represented elsewhere in the species' range. They also have a particularly high economic value because they support extended seasonal fisheries that are no longer widely available outside Scotland and Ireland**.

5.1.4. Early-running MSW salmon (or springers). There is no formal definition of spring salmon but, in what follows, the "spring" period has been defined as running from January when the first rod fisheries open until the end of May.

Rod catches of spring fish in the FCFMO rivers (Fig. 15) declined sharply from 1980 onwards but recovered irregularly thereafter. In some recent years, rod catches of spring salmon have returned to levels at, or near to, those of the 1950s and 1960s.

[18] http://www.nrcresearchpress.com/doi/abs/10.1139/f02-011#.V2FCfKIwBOI

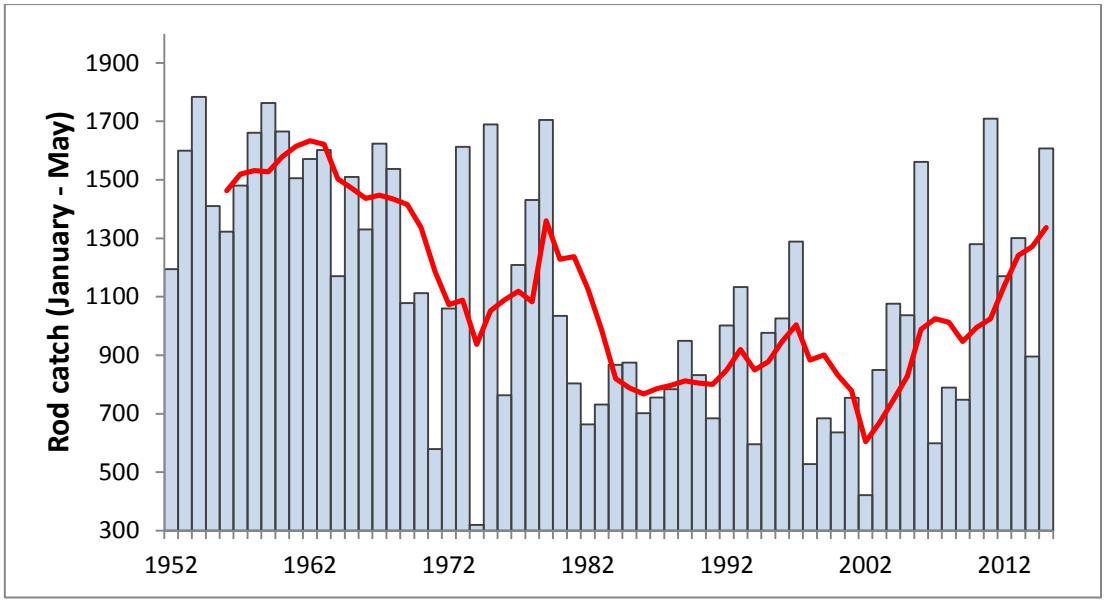

Figure 15 [19]. Rod catches of "spring" salmon (January – May) in the FCFMO rivers. The 5-year running mean value is indicated in red.

Rod catches of spring salmon will probably have been held down in the earlier part of the catch record by the very large catches sometimes made by bag-nets deployed in April and May. This pressure eased in the middle part of the record when the bag-net fisheries were gradually shifting effort towards the summer fisheries when greater catches could be made with less risk to gear from poor sea conditions. The bag-net catch declined markedly after 1990. It is likely that the increase in the rod catch of spring salmon from 1980 partly reflects reductions in netting effort over the same period. **In 2015, about 1600 salmon were caught in the FCFMO rivers before the end of May. This was about 16% of the Scottish total.**

The early part of the spring rod fishery (January to March) was never affected to any great extent by competing bag-nets due to the difficulties of operating nets on the coast in late winter. **Rod catches of spring fish over the January to March period (Fig. 16) show an irregular decline over the period of record which has continued through to recent years.**

Although the numbers of very early fish are relatively small, they are of disproportionate importance because they support prized fisheries over the first two or three months of the angling season.

[19] Based on the Marine Scotland record of reported catches of salmon and sea trout.

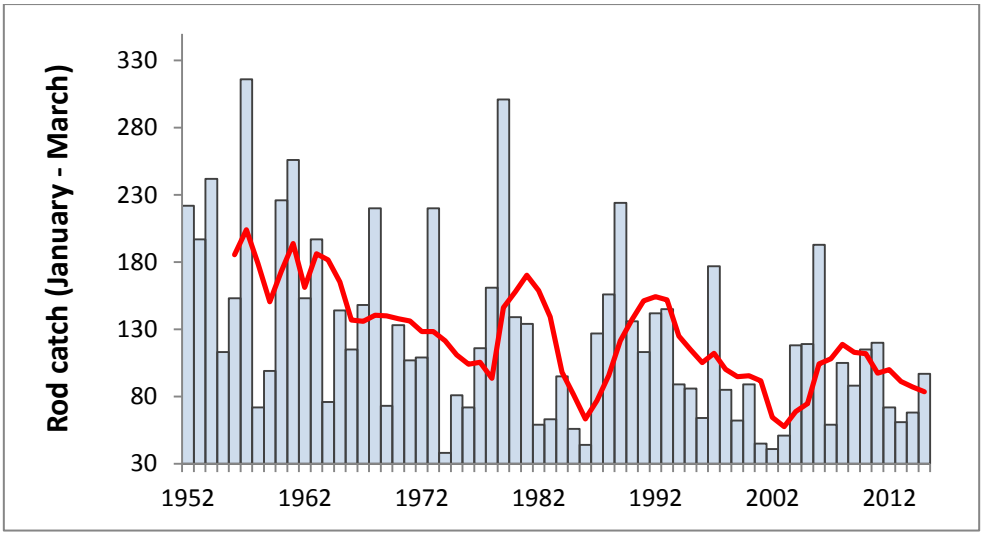

Figure 16 [20]. Rod catches of "spring" salmon (January – March) in the FCFMO rivers. The 5-year running mean value is indicated in red.

In summary, **the FCFMO rivers have a high proven capacity to support spring (January – May) fisheries. Spring rod catches have returned towards historical values, following a period of low catches from 1980 onwards and a gradual resurgence from around 2000. However, the earliest-running (January to March) component of the spring rod catch has declined irregularly over the entire period of record and shows little recent evidence of recovery.**

5.1.5. Sea-trout. Reported catches of sea trout in the FCFMO area (Fig. 17) have shifted markedly over the period of record from the nets towards the rods. By 1990, net catches (coastal and estuary) had declined to trivial values in line with reduced fishing effort. In 2015, the latest year for which data are available, the rod catch was about 600 fish - around 3% of the Scottish total. **The FCFMO sea trout resource is therefore tangible but small relative to the FCFMO area.** In 2015, 54% of rod-caught sea trout were released.

There is no evidence that the overall abundance of sea trout has declined as it has in other parts of Scotland. Over the last decade, river catches have consistently been among the greatest in the time series. **Judged by the catch records, therefore, the current status of the FCFMO sea-trout resource is to be regarded as good and it may still be improving.** Confirmatory evidence of good status is lacking because sea trout juveniles cannot be distinguished from river-residents during routine survey work.

[20] Based on the Marine Scotland record of reported catches of salmon and sea trout.

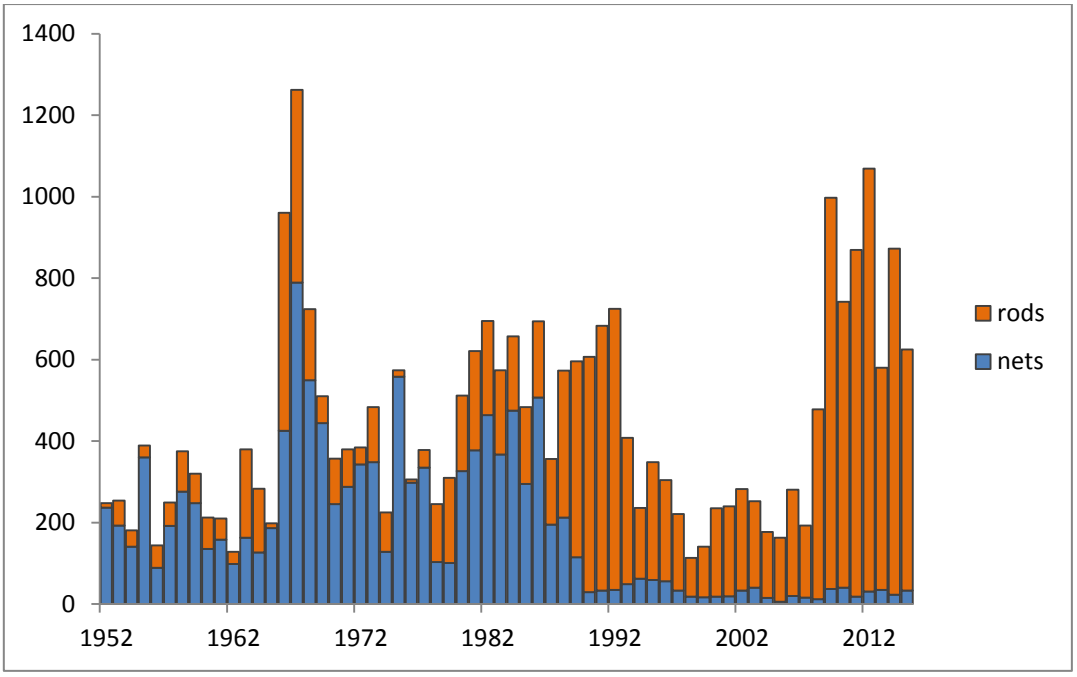

Figure 17 [21]. Catches of sea-trout in the FCFMO area.

5.1.6. Resident trout populations. As above, sea-trout are relatively unremarked in the FCFMO area but still a substantial by-catch in the salmon fishery. The relationship between sea trout and non-anadromous resident trout is unclear but the two groups are inter-linked to some extent. Females are predominant among sea-trout and they tend to breed with river-resident males.

In general, electric-fishing surveys of salmon on northern rivers fail to discover substantial trout populations. This is probably partly because trout tend to use smaller, head-water streams for spawning and nursery habitat and this type of stream is not generally targeted for salmon survey work. **In general, river populations of trout are probably relatively small (as the sea-trout catch data indicates) and no dedicated fisheries for non-anadromous river trout have developed in the FCFMO area.**

Instead, the trout fisheries of the FCFMO area are centred on its many lochs. Numerous lochs are easily and cheaply available to local and visiting anglers through any of a variety of arrangements. For example, the long-established Dounreay Fly Fishing Association has access to 10 lochs distributed throughout the north-eastern part of the FCFMO area and the more recently established Forsinard Flyfishers' Club provides access to 30 lochs around Strath Halladale. Many additional locations are freely available to trout anglers by various other arrangements handled privately or by hotels, estates or local stores.

[21] Based on the Marine Scotland record of reported catches of salmon and sea trout.

None of the trout fisheries in the FCFMO area has been fully documented in the past. Catch records are available for some fisheries but these are probably subject to variable and low levels of reporting.

As is often the case elsewhere, many of the lochs are reputed to have been stocked – usually with the legendary "Loch Leven" strain. None of this work is documented, none has been of proven effect and none has been undertaken in recent years. **All the loch fisheries must, therefore, be regarded as being on wild fish. In general, the lochs are only lightly-exploited and they have no obvious requirement for management at present.**

However, some of the FCFMO lochs are host to the few remaining British breeding pairs of the common scoter (*Melanitta nigra*). A recent proposal for cross-sectional management by RSPB has suggested that greater exploitation of wild brown trout in the scoters' breeding lochs could mitigate the adverse effects of trout on ducks by reducing competition for invertebrate prey[22]. A collaborative, experimental project is probably feasible and the possible outcome might well be of interest to fishery as well as conservation interests if reducing fish numbers increases average size.

5.2. Juvenile salmonid populations.

In 2013 the Caithness DSFB reviewed its policy on data collection and reinstated its electric fishing programme. A set of representative monitoring sites was set up to provide uniform spatial coverage. Particular emphasis was placed on obtaining high quality information on juvenile salmon populations although all fish species were recorded.

Annual surveys have been carried out since 2013. A core set of 20 sites was examined in every survey year and others were added or omitted according to strategy. In all, 26 sites were examined in one or more survey years.

Data for each annual survey was collated and analysed and the resulting reports were made publically available. In addition, in 2016 a consolidated report was produced covering all three of the survey years 2013-2015[23].

Survey sites were assessed by comparing both numerical and biomass densities. An example is shown in Figure 18. It describes the salmon populations for the survey site at Lythmore on the River Forss in September each year. The panel on the left of the figure shows that the numerical densities of the various age classes varied widely between years. By contrast, however, the right hand panel shows that the total weight of young fish at the same site stayed more or less the same from year to year

[22] https://www.rspb.org.uk/whatwedo/projects/details/239777-causes-of-common-scoter-decline
[23] http://caithness.dsfb.org.uk/publications/

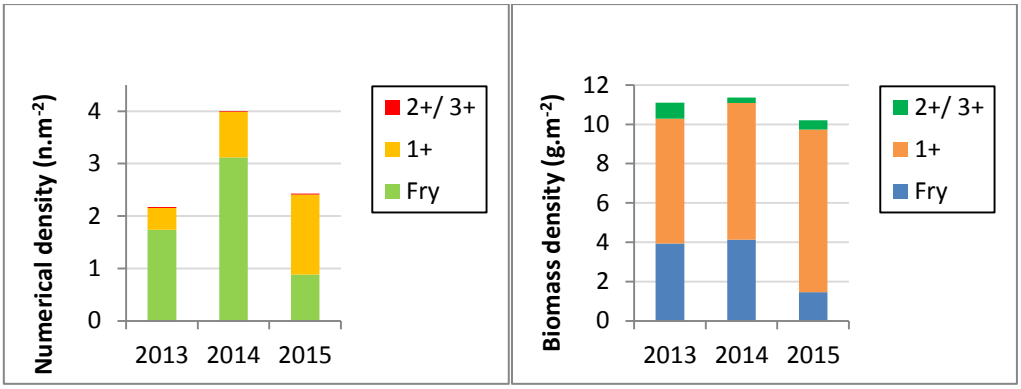

Figure 18. Comparison of numerical density and biomass density for the survey site at Lythmore on the River Forss. Values for fry, 1+ parr and older parr are shown separately.

Therefore, at the standard September survey date, the Lythmore site has a natural limit, not on fish numbers, but on the biomass of fish it supports. For Lythmore, the limit is around 11 grams of fish weight per square metre as measured in September. The average size of fish varies because they grow larger when competition is low and remain smaller when competition is intense. The limit to biomass can therefore be achieved by any of a multiplicity of combinations of fry and parr of varying number and size. Because of this, the numerical status of fry or parr cannot be fully assessed without first considering the size of individuals in both groups and their combined biomass.

Lythmore consistently supports a high biomass density of young salmon. Sites in many other locations showed lower natural limits, reflecting the lower quality of the habitat they contain. Some sites like Lythmore reached close to their natural biomass limit every year but, for others, the patterns were less consistent.

Overall, according to conventional criteria, the Caithness DSFB surveys indicated that populations of juvenile salmon were at high numerical status at many sites in 2013, 2014 and 2015. Consideration of biomass density confirmed this judgement, extended it to cover most sites and added to the confidence that can be placed in its validity.

The high status of juvenile populations in the Caithness rivers is consistent with the high rod catches reported for these rivers in recent years and the high rates of catch and release being practised. Both these factors are mirrored in the other FCFMO rivers suggesting that, although explicit evidence for these rivers is presently lacking, juvenile salmon populations are probably mostly robust across the entire FCFMO area.

6. Integrated management.

Fish and fish populations cannot be effectively managed in isolation because of the wide range of non-fishery factors that impact, or potentially impact, on the freshwater

environment and the habitat it provides. There are a large number of public and private agencies whose activities will impinge on the FCFMO's remit including, for example, local authority road and planning departments and ranging to national agencies such as SEPA and SNH.

SEPA has an established remit to monitor and manage the water environment and this is highly complementary to fishery management, as detailed above.

SNH designates, monitors and manages habitats and species under a range of national and international arrangements. There are several levels of designation and Figure 19 shows only the features of the Flow Country designated as Special Areas of Conservation (SACs).

From the fisheries point of view, the most important of the SACs lying within the proposed FCFMO area are the Rivers Borgie, Naver, Thurso and Berriedale/ Langwell which are all designated solely or secondarily for their salmon populations; there are only 17 such designations in Scotland. Lochs Watten and Wester have more general designations for their unusual ecologies. The vast area of the Caithness and Sutherlands Peatlands SAC dominates much of the FCFMO area.

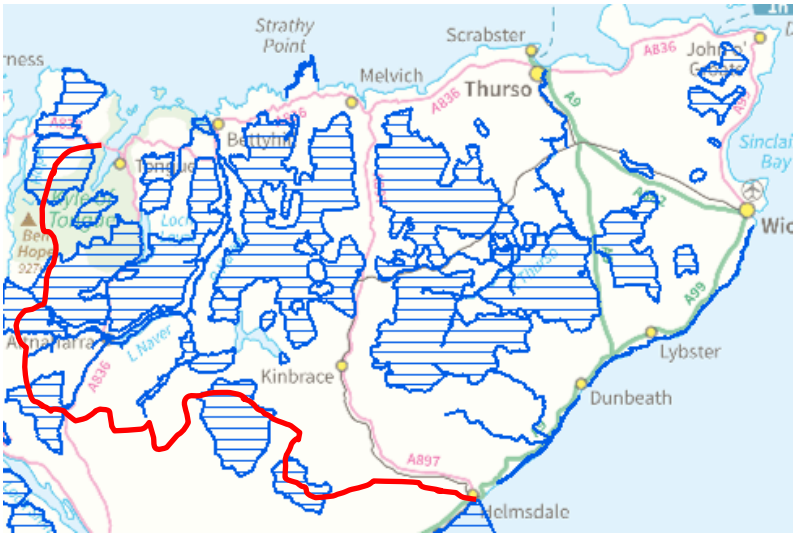

Figure 19. Features within the FCFMO area designated as Special Areas of Conservation[24]

Many of the activities of SEPA and SNH are complementary to those of the proposed FCFMO. Equally, some of the activities of the FMO could be used to enhance those of SEPA and, in particular, of SNH given a shared interest in the SAC rivers. As a more specific example, SNH, SEPA and the current DSFBs independently obtain juvenile electric-fishing data for related purposes but using different protocols and techniques. Duplication and lack of standardisation could be addressed by deploying the specialist skills of the FCFMO in the service of all three bodies.

[24] http://gateway.snh.gov.uk/sitelink/searchmap.jsp

7. Recent Track Record of Scientific Management.

7.1. Caithness DSFB.

7.1.1 Electric-fishing survey methods. As above, the Board's work has shown that the biomass density of juvenile salmon offers a novel and potentially informative index of the natural productive capacity of particular sites, and also of the site's actual performance relative to its potential. The biomass approach to assessment requires field-work of high quality but, otherwise, few additional resources. The biomass approach will be further investigated (see below) but, because of its low additional cost and high additional power, it will be a cornerstone of monitoring work in the FCFMO area.

The Board's survey work has shown that the River Wester is the sole exception to good status among the Caithness rivers and consistently anomalous in all survey years. The single survey site on this small river carried only very low numerical densities of exceptionally large fry and parr. Despite their large size, the biomass densities of the fish were much lower than expected based on habitat assessment. This indicates that spawning and recruitment are consistently inadequate at the Wester survey site.

In the light of these findings, the Wester catchment is to be investigated in more detail (see below). The aims will be to discover the extent and the cause of the factor limiting production and to identify management options for restoring the river towards its full natural potential.

Although electric-fishing cannot quantitatively characterise any of the non-salmonid fish species likely to be encountered during survey work, all captured species are recorded and the distribution of eels, for example, is known and documented in the Board's annual survey reports.

7.1.2. Documentation of electric-fishing sites. All the CDSFB electric fishing sites have been permanently documented[25]. Photographs and bank measurements have been compiled in order to facilitate exact relocation of sites in future survey work. Additional measurements of stream channel width and stream depth have been archived in order to identify any changes in the conformation of sites that may affect their capacity to support juvenile fish in future survey years.

7.1.3. Scotland River Temperature Monitoring Network [26]. Stream temperatures much above 20^{o}C are potentially adverse for salmonids. The spate rivers of the FCFMO area are particularly susceptible to warming in summer during extended periods of low flow.

[25] http://caithness.dsfb.org.uk/publications/
[26] http://www.gov.scot/Topics/marine/Salmon-Trout-Coarse/Freshwater/Monitoring/temperature

Many of the scale samples collected from parr for age determination during the CDSFB electric-fishing survey of September 2013 showed atypical "summer growth checks" possibly caused by high water temperatures in July that year - although measurements of water temperature were not available at that time.

Since 2014, CDSFB has participated in the Scotland River Temperature Monitoring Network organised by MSS. The Board services data loggers that continuously record water temperature at a set of 11 sites distributed throughout the River Thurso catchment. Summer growth checks have not been present on fish scales during the period since the data loggers were installed - and nor have temperatures much in excess of 20^{o}C.

The data loggers will remain in place over the term of the MSS project. Thereafter, the FCFMO will consider making unilateral arrangements to continue collecting temperature data in order to monitor variation over a longer period.

7.1.4. Photographs to estimate re-exploitation rate, exploitation rate and sex. Coded fish-tags can be used to estimate the re-exploitation rate of salmon – ie. the proportion of the fish that are caught again after being released. This is important because catching the same fish more than once inflates catch numbers and due allowance must be made for this when catch trends are used to infer trends in the abundance of spawners. Tagging is also a well-known means of estimating the size of fish populations using the so-called mark-recapture design.

Caithness DSFB has carried out preliminary studies to determine whether a different approach can be used to estimate exploitation rate and re-exploitation rate. Thus, the facial spotting patterns of salmon parr have previously been shown to be unique to individuals[27]. Natural markings are used to identify individuals in studies of a wide range of non-fish species - for example, whales, seals and cheetahs. With this in mind, the Board has examined facial spotting patterns in adult fish. Although the adult patterns are simpler than those evident in parr, they also are unique to individuals and they persist unchanged even in fish becoming coloured near spawning time.

Recording facial constellations in salmon could be used to supplant coded physical tags which are in any case prone to failure and misreading. Instead, a facial photograph taken before release could be used to pinpoint recapture of the same individual among fish caught and photographed at a later date in the same season.

As above, knowing exploitation and re-exploitation rates is crucial for being able to deduce the abundance of spawners through knowing the proportion of fish caught by the rods. Equally, knowing the sex ratio of the spawners, as well as their numbers, is crucial for

[27] http://onlinelibrary.wiley.com/doi/10.1111/j.0022-1112.2005.00730.x/full

inferring egg deposition - for example, in relation to Conservation Limits. Preliminary investigation by the CDSFB indicates that sex can also be identified from facial measurements derived from the same planar images used to record facial spotting patterns. On this basis, it will be possible to estimate spawner numbers separately for the sexes.

7.2. Northern DSFB.

7.2.1. Tagging to estimate re-exploitation rate. Each year since 2000, River Naver staff have tagged a sample of rod-caught fish before release in order to estimate re-exploitation rate. Around 300 fish are tagged annually using numbered Floy tags; date and location are recorded. Tag numbers are recorded on any subsequent recapture, along with recapture location and date. The Naver data await formal analysis but this should be carried out in order to take stock of the information now available since a previous analysis of a similar data set for the River Spey proved informative[28]. The Naver work should continue as part of a wider trial along the lines indicated in Section 8.3.3, below.

7.2.2. Electric fishing survey work. The Naver carries out an annual electric fishing survey on a permanently marked set of around 70 index sites dispersed throughout the catchment. Around one third of the sites are fished annually in a rolling programme designed to provide extensive spatial coverage. Likewise, the Halladale has a survey programme based on nine index sites. In both cases, the three-pass depletion method, allied with stop-nets, is used to produce fish density estimates of a high standard. The age of parr is determined by scale reading.

This work should continue and it will be incorporated into the wider FCFMO programme described at 8.3.1, below.

7.3. Helmsdale DSFB.

7.3.1. Fish counter. The River Helmsdale is equipped with a fish counter at Torrish, about 7 km from the sea. The counter is of the resistivity type and it is continuously maintained and periodically validated by Board staff. The Torrish counter is the only such installation on in the FCFMO area.

7.3.2. Electric fishing survey work. The Helmsdale DSFB team carries out electric-fishing surveys of the same set of 30-40 sites each year. The site boundaries are fixed and all exceed 100m^2. Three-pass depletion methods are used and stop nets are deployed to produce accurate estimates of juvenile density. Data sets are available for the past 10 years or more. This work should continue and, as for the Northern and Caithness Boards' work, it should be incorporated into a wider FCFMO programme as described at 8.3.1, below.

[28] http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2400.2007.00540.x/abstract

7.4. Flow Country Rivers Trust (FCRT)[29].

The Trust is a charity registered in Scotland. It was formed in 2014 with the purpose of promoting and supporting initiatives, including research and education, to further the conservation of freshwater species of fish and associated flora and fauna within the Flow Country. Despite its recent formation, the Trust has already participated in several on-going projects and is planning others.

7.4.1. River Wester restoration. As described above, the River Wester in eastern Caithness was a consistent anomaly in the CDSFB's annual electric-fishing surveys in showing unexpectedly low densities of salmonids. The Wester was formerly a renowned sea-trout fishery but it has declined over recent decades. The few fry and parr present at survey were very large suggesting that habitat quality is not limiting but, instead, that recruitment at the egg/ fry stage is sub-optimal. The Trust is presently seeking support for a scoping study that will (1) aim to expand the range of the electric-fishing survey sites in the river to gauge the wider picture, (2) identify any impediments to spawning and, if necessary, (3) consider appropriate management options for restoration of this small river's salmonid populations.

7.4.2. Saturation stocking. Recent electric-fishing surveys by CDSFB have centred on determining the biomass density of juvenile salmonids. Based on comparisons over three survey years, sites appear to have a fixed ceiling on their capacity to support a total biomass of fish rather than any particular ceiling on fish numbers. The ceiling value appears to vary between sites, as would be expected given their variable habitat quality. In order to determine whether the biomass values observed to result from natural spawning are maximal values, one site on each of two rivers in the Board area with hatcheries was saturated with unfed fry in April, 2016. Each stocked site has been paired with an untreated control site nearby. All four sites will be electric-fished in the usual way and pair-wise comparisons will be used to test whether stocking raises biomass values above the putative ceiling values that appear to result from natural spawning.

7.4.3. Fishermen's knowledge project. The Pentland Firth on the northern Caithness coast is a centre for marine renewable energy development. Tagging studies have shown that the Firth and its environs is also a hub for adult salmon returning from the ocean not only to local rivers but to rivers much further afield. The likely effects of renewables development on migrating salmon are unknown. However, the range of potential effects is likely to be limited by the proximity of migrating fish to development sites. The routes that salmon take through the Firth are unknown and cannot be easy discovered using conventional approaches because of the extreme hostility of the Firth's environment. The Trust has received support from The Fishmongers' Company to evaluate an alternative approach to understanding salmon behaviour based on the physical, documentary and oral legacy of the salmon fishermen who have worked the Firth's waters for more than 100 years.

[29] http://www.fcrt.org/

7.4.4. Wick smolt tracking project. Although little is known of the routes that returning salmon take to reach their rivers, even less is known about the outwards routes that smolts take when they leave for the ocean. The Trust has provided financial support for a smolt tracking project carried out by the Environmental Research Institute (see below). In addition, the Trust has provided substantial logistic and practical support and invaluable volunteer effort for the project, bringing with it expert knowledge of the study river and the coastal environment nearby.

7.5. Environmental Research Institute.

ERI[30] is actively involved in salmon research. It also researches other areas with substantial synergies with the fisheries area, for example, peatland restoration, environmental management of the Flow Country, and the coastal hydrography of the Pentland Firth and its surrounding area.

7.5.1. The Pentland Salmon Initiative. In 2013, ERI established the Pentland Salmon Initiative[31] with the aim of fostering a partnership of stakeholders - including academics, fishery boards, planners and developers – with interests in marine renewables and salmon migration in the special context of the new developments along the Caithness and Sutherland coasts. The PSI has since served as a thematic link for a number of research projects, and for formal and informal discussions among stakeholders representing interests from Caithness and Sutherland and beyond.

7.5.2. Hydrodynamic Models to Understand Salmon Migration in Scotland. In 2014, ERI completed a major report[32], funded by The Crown Estate, on the coastal migration of salmon and particularly on the potential use of computer-based particle-tracking models to generate hypotheses for testing by experiment. The report also raised a number of themes that are now being investigated under collaborations supported by the PSI. For example, the ERI's Wick Smolt Tracking Project (see below) and the FCRT's Fishermens' Knowledge project (see above) stem from the report. In addition, historical data generated over the past 100 years or so by tagging salmon captured in the coastal netting fisheries was compiled in the report and will be interrogated by ERI as part of FCRT's Fishermens' Knowledge project.

7.5.3. Workshop on Monitoring Migratory Salmonids in the Moray Firth Rivers. In 2014, ERI hosted a workshop under the auspices of the PSI to consider arrangements for the

[30] http://www.eri.ac.uk/

[31] http://tethys.pnnl.gov/sites/default/files/attachments/984_Guerin_The%20Pentland%20Salmon%20Initiative%20a%20new%20research%20partnership%20exploring%20the%20potential%20interactions%20between%20migratory%20fish%20and%20marine%20renewables.pdf

[32] https://www.researchgate.net/publication/261874209_Marine_Research_Report_Hydrodynamic_models_to_understand_salmon_migration_in_Scotland

gathering of assessment data for salmon and sea-trout in the Moray Firth rivers. The workshop was prompted by queries arising as a result of the drive for marine renewable energy in the Moray Firth. The workshop was attended by a wide range of stakeholders from the industry, government, academic and fisheries sectors. Elements of the main discussion paper are embedded in the draft fishery management plan, below.

7.5.4. Wick smolt tracking project. There is an almost total lack of information on the timings and routes taken by smolts leaving their rivers for the sea and this lack of knowledge constrains options for coastal management. The need for information for the FCFMO rivers, in particular, has become pressing in the context of the major developments in marine renewables and related infrastructure taking place in the Moray Firth and along the northern coast. There is a particular requirement to understand the use of the Pentland Firth as a route by smolts in transit from the FCFMO rivers to the north Atlantic.

It is not feasible to directly address this question because the extreme environmental conditions of the Firth severely limit the power of conventional techniques. Instead, as part of an indirect approach, tagged salmon smolts are being tracked as they leave the Wick River, 20km to the south of the entrance to the Firth. The aims of the project are two-fold – (1) to explore the capabilities of the acoustic tagging technology in the local coastal environment in relation to possible future work and (2) to test hypotheses on the initial marine trajectories of smolts. The work is funded by the European Union and the FCRT and supported by BOWL, the developer of a windfarm to be located off the Caithness coast.

8. Draft Fishery Management Plan.

The proposed FCFMO area is large. It includes 13 river networks if the Berriedale and Langwell are considered separate for management purposes. As above, the networks share many features because of their common origins in the Flow Country but each has distinctive features determined by local aspects of the landscape. Even if the networks' fish populations respond similarly to regional influences, they will also vary independently in response to local factors. Any differences between populations will be reinforced by homing and homing also dictates that, in general, the effects of management exercised in one location will not extend to others. **It is appropriate, therefore, that each river network should be managed separately.**

At present, the networks are managed according to a variety of established fishery and DSFB arrangements. **The current high status of the rivers and fish populations indicates that these local arrangements have been effective.** Those aspects of the current management system that have proved robust should therefore be retained and incorporated in the new management approach.

On this basis, the FCFMO will conduct high-level management activities to maintain and improve fish and fishery resources in its area, within the legal and policy framework set by SG. Day-to-day management will remain a local responsibility of fishery owners and other stakeholders– eg. tenants, lease-holders, RSBP, SNH, SEPA and forestry, farming, fishing and other commercial interests. Once again, the non-fisheries aspect to coastal and freshwater management emphasises the need for a cross-sectional approach to setting the fisheries management agenda and getting buy-in from all those involved.

The FCFMO management plan will therefore centre on the assessment, protection and improvement of the existing natural resources of the area, anticipating and addressing approaching changes that may have adverse effects. In order to achieve its objectives, the FCFMO will collaborate and engage widely with regional and government bodies and with local interests, too. River-specific sub-plans will be defined later in the FMO process when the FCFMO remit has been agreed and fully defined.

8.1. Natural resources available to the proposed FCFMO.

All the factors considered in the preceding sections of this document suggest that the environmental and fisheries resources of the proposed FCFMO area are currently in a robust condition. Relative to other parts of Scotland, there are presently very few adverse issues to be addressed. In summary -

1. The freshwater and coastal environment is relatively pristine. There is no substantial legacy from industrial activity associated with river use. Most of the lochs are not impacted by human activity. Agricultural land-use is localised and relatively non-intensive. As far as is known, Canadian pondweed, *Elodea canadiensis*, is the only invasive, non-native aquatic species present in the FCFMO area; it has a restricted presence in Loch Watten and the associated lower catchment of the Wick River. Fish-farming is absent from both rivers and coastal waters.

Only the wind-farm and forestry sectors are more prevalent than in other potential FMAs. There is no evidence that wind-farm development has resulted in major, permanent or widespread effects on the freshwater environment. Forestry on the peatlands will contract because many areas felled during the current cycle will not be re-planted. In the interim, however, local problems with the effects of some forestry works on streams and rivers have become evident and these will require to be addressed, together with the relevant public agencies, in order to maintain the high status of the affected catchments.

2. The great majority of fish populations are at high status. Judged by rod catches, there have been more salmon and sea-trout in the FCFMO rivers in recent years than for many years previously. Given the high current level of catch and release, the number of salmon and sea-trout present at spawning time is probably also rather greater now than before. Juvenile salmon populations are in a generally robust condition. Populations of resident trout in all the FCFMO lochs are to be regarded as pristine. There are few non-salmonid

species in the FCFMO area and, as far as is known, there are no local risks to their status. No introduced fish species are reported.

8.2. Strategy for scientific management.

Given the few species present in the FCFMO area, strategy will centre on managing salmonids and especially salmon and sea-trout. Given the existing high status of salmonid populations the primary aim will be to ensure that this situation persists or improves. The main objectives of the management plan will be to (1) define the state of salmonid resources, (2) identify any changes, (3) identify true targets for management action, (4) set realistic expectations for outcomes and (5) test whether the outcomes are achieved.

In order to meet these objectives monitoring data will be coupled with a consideration of biological mechanisms, including natural variation, and this has determined the necessary scope and design of an effective monitoring plan.

Beyond monitoring, there are a number of broader issues that will be continuously addressed because they have the potential to reduce the status of the FCFMO's natural resources. In some cases, a watching brief will be sufficient but in others data collection or research may be required. The aim will be to address adverse issues unilaterally according to the evidence, or to make representations to others, on the same basis, in support of the FCFMO's duties or responsibilities.

8.3. Core scientific activities.

As above, the principal activity of the FMO will be to monitor fish populations using the established mainstays of assessment – juvenile survey work and catch analysis. The first priority will be to harmonise methods, approach and standards across the FCFMO area taking account of any additional requirements that may be set by SG. From the FCFMO perspective, the particular purpose of harmonisation is to gain greater interpretative power by being able to make multiple comparisons of equivalent data of uniformly high quality across a wider spatial scale than at present.

8.3.1 Juvenile electric-fishing surveys. Juvenile fish production sets the starting point for everything that follows in the life-cycle. Juvenile survey work therefore lies at the very core of assessment and it will form the major part of FCFMO scientific field activities.

The FCFMO will use monitoring information to define the current status of fish populations, to detect emerging trends and to detect and manage the impacts of any of a range of unforeseeable events. The aim, therefore, is to build up an annual series of assessments that will define the resource and describe natural temporal and spatial variations in its status.

At present, information of the necessary calibre is lacking for some of the FCFMO rivers and its acquisition is considered a high priority. On the one hand, the field programme must be

sufficient for its purpose but, on the other, it must be financially sustainable. The initial strategy, therefore, will be to acquire information where it is lacking in order to tailor a long-term monitoring programme to the picture as it emerges. This approach has proved successful within the CDSFB area.

Monitoring data of high quality will be essential both for the conservation and economic fisheries aspects of the FCFMO's duties. In the latter context, investment in gathering data will provide a return by supporting targeted management action in a timely and proportionate way. Good data will also increase business confidence in relation to such matters as sustainable exploitation and the prediction of future fisheries.

The FCFMO will set up a core set of 50 index sites distributed throughout its area to provide approximately uniform spatial coverage. The new set of sites will be biased to include sites already being routinely surveyed in order to secure the value of existing long-term data sets. All the sites will be on streams greater than 4m in width, all will have an area greater than 120m^2, each site will be permanently identified and its habitat will be characterised. The sites will be surveyed by 3-pass electric-fishing in a rolling programme conducted annually between late August and early October each year. The aim will be to construct an extended time series based on the repeat survey of a set of key index sites using standardised methods. The time-series will permit assessment of variation between years.

The survey schedule will be adapted within year, or year on year, in response to feedback becoming available from completed work. The survey data will be formally analysed and the results used to generate values for both numerical density and biomass density, separately for each age-class, and also an index for predicted smolt numbers in the following year. The results will be reported annually.

As above, juvenile production (and ultimately smolt production) is the most stringent measure of management effectiveness. Many of the remaining core tasks described below are designed to obtain information related to factors that may limit juvenile production.

8.3.2. Catch analysis. Catch data are used to assess whether the number of adults remaining after the fisheries is sufficient to fully replenish freshwater habitat with eggs and therefore fry. The catch analysis presented above is based on the standardised data sets prepared by MSS each year for each Fishery District. The MSS database is an extremely valuable account of the fisheries and the FCMO will continue to rely on its availability. However, the MSS database cannot be used to support real-time management because it is not updated until several months after the fisheries in question terminate and when the next year's fishery is already well underway.

There are additional weaknesses in the MSS procedure that arise from the initial set-up of a data collection system designed to provide a record of economic activity rather than a means of fisheries assessment. Thus, the data are aggregated by month which is sub-

optimal for rod fisheries on spate rivers like those of the Flow Country that are particularly prone to the effects of random periods of low flow, or other weather-related events. Monthly aggregation also means that the database does not support a capacity to factor-out the effect of variables like river height on daily catches, thereby reducing the potential precision of assessment.

The Thurso River has a web-site that is updated daily to give catches by beat. This facility will be replicated to cover the other larger rivers of the area in order to gain greater spatial coverage of catches in real-time over a wider set of rivers. The Thurso web-site contains daily information on river height but an updated system could be matched with additional parameters that are likely to influence catches in order to facilitate accurate real-time assessment. These parameters can be observed and recorded by river managers or, in some cases, gleaned from existing web resources. The River Halladale already maintains an exemplary electronic game-book which might be used as a web-based model for the other FCFMO rivers. The Thurso website is open to the public but access to any other web-pages will be at the discretion of proprietors.

The aim will be to build up a capability for real-time management such that legal exploitation, for example, can be managed in response to current trends in local abundance.

8.3.3. Exploitation rate and sex ratio. As above, the utility of raw fishery data is reduced by the uncertain nature of the link between the numbers of fish available to be caught and the catches actually achieved. Exploitation rate (the fraction of the river entrant fish that is caught by the rods) is the concept that makes the link. Exploitation rate also links the catch to the number of spawners that remain to replenish the river with eggs.

If an accurate fish-counter is available, exploitation rate can be determined by comparing the catch with the number of fish entering the river, and the number of fish remaining to spawn can be estimated by deducting the number of retained fish from the number counted entering the river.

Among the FCFMO rivers, only the Helmsdale is equipped with a fish counter. However, even in the absence of a counter, exploitation rate can still be estimated by using a different approach. In this case, a sample of river entrants is trapped, the fish are tagged before being released, and the proportion of tagged fish is determined among all the fish that are subsequently caught by the rods. This procedure is based on the so-called “mark-recapture” design.

Fortuitously, the advent of catch-and-release removes the need for a separate trapping operation and, instead, fish captured by the rods can be tagged before their release. Taking advantage of catch-and-release, the mark-recapture approach to assessment has been previously deployed in a small number of Scottish rivers including the River Naver.

However, tagging is invasive, tag loss may occur and accurately reading tag numbers on recaptured fish is problematic in field conditions. Therefore, a novel alternative to tagging is proposed that utilises unique facial markings (Figs. 20 and 21) to "tag" individuals. Individuals captured and photographed can be identified if and when they are captured again. The method requires only a photograph of modest quality, standardised on one side of the fishes' face and taken at right-angles to the facial plane.

Figure 20. Casual record shot taken at approximately right-angles to the facial plane.

Figure 21. Expanded view showing unique facial constellation (in this case comprising 6-spots).

Potentially, therefore, tagging fish or recording the unique natural markings of individuals, can generate estimates of the number of river entrants, the fraction of released fish that are caught for a second (or third) time and the number of fish that remain to spawn, making due allowance for the number of fish that are retained.

However, using natural markings, rather than tagging, to track individuals potentially offers an additional advantage. Preliminary investigation indicates that the sex of individuals can be determined, even at an early stage of sexual development, from facial measurements made from the photographs used to record facial spotting patterns. For example, based on preliminary study, the fish shown in Figure 20/ 21 has a facial index that shows it to be female. The illustration is a routine, record shot sampled from the web; the fish was captured in May.

If the fraction of females in the rod catch is known, estimates of the estimated number of spawners can be adjusted to give a value for female spawners only. Furthermore, egg number in females is linked to body size, so if photographs are accompanied by a measure of body weight or length measurement, the number of eggs available from each female can also be estimated. Body weight for fish to be released can be accurately measured using a net incorporating a balance. Otherwise, a measurement of body length made using a flexible seamstress' tape is much more accurate than a visual estimate of body weight.

The number of eggs available to rivers is one of the two key factors (the other is wetted area) used for setting Conservation Limits – a process already being undertaken by MSS based on guestimates for both exploitation rate and sex ratio.

The FCFMO will train ghillies, who are accustomed to handling large numbers of fish, and mount a field trial of the photographic method. This will discover whether, in practice, a large enough number of adequate images and accompanying measurements of body length can be obtained for individual rivers to support a workable assessment method. The aims will be to estimate the number of river entrants independently of the catch data and to estimate the number of eggs deposited each year.

8.3.4. Integrated field programme for assessment.

All the field-based assessment operations (**1-5**) will be carried out during the freshwater phase as per Figure 21.

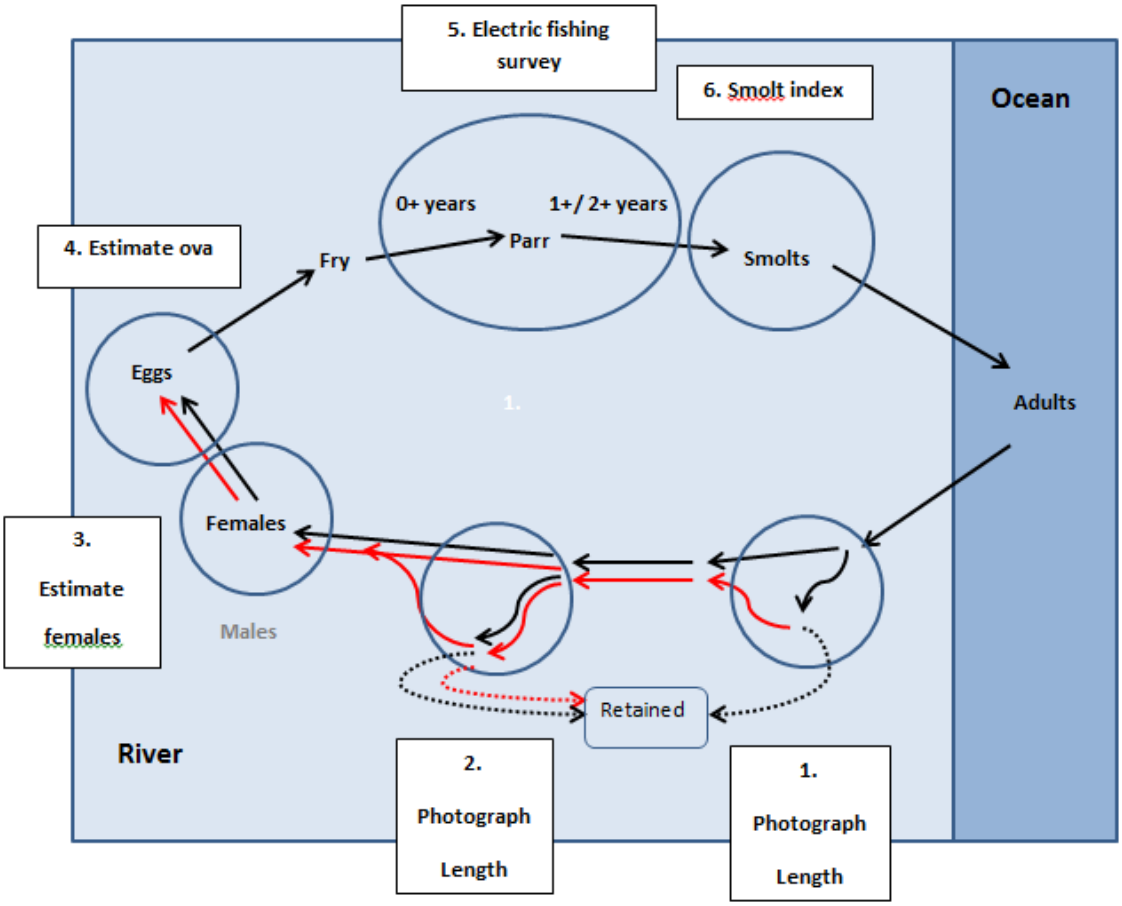

Figure 21. Schematic of proposed field programme for assessment.

(**1**) Adults captured by the rods on any specified date and at any specified location are photographed, weighed or lengthed and categorised as returned (in red) or retained; any fish that cannot be photographed or measured are counted and categorised. (**2**) The process is exactly repeated.

From **1** and **2**, the number of river entrants is estimated using the mark-recapture approach; the number of fish remaining after the rod fishery is estimated by subtracting the retained catch from the estimated number of river entrants.

(**3**) The number of females remaining after the fishery is estimated from the observed sex ratio. (**4**) The number of eggs they contain is estimated from their body size.

(**5**) The numerical and biomass densities of 0+ (6 months old), 1+ (1.5 years old) and any remaining 2+ (2.5 years old) juveniles are determined in September each year by electric-fishing survey. (**6**) The electric fishing data are used to generate an index of the numbers

and sizes of fish that are potentially available to participate in the smolt run the following May. This value is an index only, because an unknown proportion of pre-smolts will die between September and May and the fish that survive will grow larger by an amount that will not be known.

8.3.5. Non-quantitative electric fishing. As above, routine monitoring of juvenile fish populations will use fully quantitative electric fishing methods because this approach is cost-effective and it provides the best basis for accurate assessment. If appropriate and when necessary, however, the range of the network of monitored sites will be extended using qualitative electric-fishing to explore local, query-driven issues.

8.3.6. Environmental monitoring. Water temperature is one of the key variables affecting freshwater resources since it profoundly affects all ecological processes and salmonids, too. Salmonids are cold water species and susceptible to adverse effects on growth and survival at temperatures near the upper limit of what is probably the present summer range on the northern rivers. Until recently there were no temperature records for any of these rivers although the Thurso is now part of the MSS temperature monitoring project.

The MSS temperature monitoring network (see above) may ultimately lead to the development of models of sufficient accuracy to predict temperature outside the network itself. However, validation will be necessary even if modelling proves successful. Therefore, the FCFMO will make arrangements to set up a minimal array of data loggers in order to detect the occurrence of any adverse episodes of high temperature.

8.3.7. Advisory activities. The FCFMO will develop advisory policies as the need arises particularly in the context of local conditions and practices. Initially, for example, local guidance on genetic issues, particularly in relation to hatchery practice and stocking, will be prepared. At present, hatcheries operated (or have operated recently) on the rivers Helmsdale, Borgie, Halladale, Wick and Dunbeath. As FCFMO assessments come on-stream, it will also become possible to offer more accurate advice than at present on the sustainable retention of fish - outside any legal restrictions that may be in force.

8.3.8. Support for Scottish Government. To be edited in.

8.3.9. Attitude to research activities. The FCFMO will be generally supportive of incoming research proposals, particularly those that will bear on matters related to its remit. Otherwise, depending on the skills and resources required, the FCFMO will undertake minor or preliminary investigations, initiate collaboration or contract specialist support from institutions such as ERI.

8.3.10. Data policy. All data will be consolidated, analysed, reported on and permanently archived. This is important because, in the past, the potential historical value of some data has been lost or reduced due to failures in all these areas. Future reports will therefore provide full context and interpretation in order to permanently secure their value; the

expectation will be that raw data will be made widely available and permanently accessible in the form of a first edit file.

8.3.11. Response to emergent issues. Salmon and sea-trout range widely over a large number of different habitats – freshwater, coastal and marine – before they complete their life-cycle. They are therefore potentially susceptible to a correspondingly large number of adverse effects acting at any of the many different stages of their lives. Many of the issues that might be raised – for example, global climate change, coastal and marine fisheries, predation - lie beyond the local, specialist remit of the FCFMO Science Plan and will require to be addressed at other levels – for example, by MSS or SG or by SNH or SEPA.

However, there are also issues that arise outside the FCFMO's immediate ambit but which the FCFMO can help address by making additional use of the fishery data gathered by way of the Science Plan described above. Furthermore, identification and appraisal of emergent issues will make it possible to anticipate upcoming requirements for fishery data and to consider making appropriate modifications to FCFMO data-gathering. Foresight has sometimes been lacking in the past and, consequently, consideration of some emergent issues has been hampered by the absence of appropriate baseline data.

a. Marine mortality of salmon. The marine mortality rate for salmon is reported to have increased over recent decades, particularly for rivers in the southern and central parts of the species' European range, including Scotland. For Scotland, research data are available from the River North Esk[33] where (by the mid-2000s) the size of the marine effect was sufficient to reduce the fraction of smolts returning as adults to around 10-25% of the level being achieved around 1970. No data exists for any of the FCFMO rivers but it must be assumed that they were affected in much the same way.

Unfortunately, the North Esk data set has been curtailed following the destruction by flood-water of the facility on which it was based. However, high rates of marine morality have reportedly continued to date for other rivers in Europe[34]. Paradoxically, however, recent rod catches in the FCFMO area have been rather greater than previously, as discussed above. This must mean that the high rate of marine mortality for fish belonging to the northern rivers has now eased or that smolt production has increased in recent years. In either case, it is not clear that reducing angling pressure and fishing mortality yet further on the northern rivers would result in even greater smolt production since stream populations of juveniles already appear to be in extremely good heart.

This point should be resolved by using fishery data to examine the complex relationship between the size of spawning populations and the level of smolt production (size and number). The aim will be to discover where salmon populations in the FCFMO area presently lie on the so-called stock-recruitment relationship – that is, the line that links the size of the spawning stock with the size of the ensuing smolt run.

[33] http://www.gov.scot/Topics/marine/science/Publications/TopicSheets/MarineMortality
[34] http://www.nasco.int/sas/background.htm

b. Renewable energy and associated infrastructure. Over the past decade, the FCFMO area has become a hotspot for land-based windfarm development[35]. In many cases, major construction projects have involved preliminary forest clearance on peatlands sites in close proximity to flowing water.

Despite the obvious risks to the aquatic environment, there is no evidence that the effects of development on the hydrochemistry of adjacent streams have been large or persistent. There is also no evidence that fish populations have been adversely affected although this judgement should be qualified by noting that the current approach to obtaining and analysing electric-fishing survey data provides assessments that are not particularly sensitive to change. This is an issue that the FCFMO will attempt to address in the context of any future windfarm development using the approach to electric-fishing survey work described in Section 8.3.1, above.

The coastal waters around the FCFMO area are also a current target for renewables development using a variety of techniques to harness wind, wave and tidal power. The marine energy sector is in its infancy and it is not possible to envisage how much progress will ultimately be made, which technologies will prevail or how rapidly development will proceed.

At present, however, two major projects are underway near the FCFMO rivers - the Meygen tidal turbine array in the Inner Sound of Stroma near John O' Groats and the BOWL offshore wind-farm in the northern Moray Firth. Similar projects are envisaged for adjacent locations but these are at a less-advanced planning stage. Additional projects will be brought forward in future. At this early stage, it is impossible to gauge what the combined scale of the works and overall pattern of development is likely to be in, say, 20 years' time.

It is also not known, whether any of the marine projects will impact on diadromous fish moving to and from the FCFMO rivers. This uncertainty is in part due to the uncertainties associated with commercial development. However, uncertainty is also partly due to the almost complete lack of biological knowledge regarding the ways in which local coastal waters are used by foraging sea-trout, salmon smolts migrating to the ocean feeding grounds or adults returning to their rivers.

ERI and the FCRT are already beginning to research some of the local biological issues. However, in view of the potentially large scale of local offshore development much more information will be required to identify the scale and nature of any impacts of development on the salmonid populations of the FCFMO rivers. The FCFMO will endeavour to obtain the information necessary to manage any adverse effects by way of its electric-fishing programme, by supporting the work of other organisations and by representing the specific interests of the FCFMO rivers in the wider forum.

[35] http://www.arcgis.com/apps/webappviewer/index.html?id=5ec04b13a9b049f798cadbd5055f1787

c. Land-drainage and peatland restoration. The Flow Country peatlands have been impacted by extensive deep-drainage works directed towards achieving either of two quite separate outcomes - both of which are now widely regarded as having been ill-considered or ineffective. Drainage was undertaken either to support afforestation with conifers or to improve hill grazing and game management[36].

Extensive native woodland, and especially conifer woodland, is not a natural feature of the Flow Country. However, in the late 1970s and early 1980s large tracts of the Flow Country were developed for commercial forestry. As a preliminary, the ground was deep-ploughed in order to lower the water table because the naturally saturated soils would not otherwise support conifers. Trees were planted on the elevated ridges between the open drains. In the mid-1980s, public subsidy was withdrawn in recognition of the environmental damage being caused and planting in the Flow Country declined markedly. From a specifically fisheries perspective, extensive forest development was unfavourable for the hydrology and hydrochemistry of affected catchments and the effects will be long-lasting.

The forest drains were designed to reduce the water storage capacity of the peatlands and to speed the transit of rainfall to the river networks. Even now, the extensive systems of closely-spaced, parallel drains remains substantially intact, hidden within standing forest cover or exposed on felling. The inevitable consequence of drainage is to increase peak flows in flood events and to reduce flood duration. This has the effect of amplifying the natural hydrological features (spates and droughts) that sometimes limit the fishery potential of the Flow Country rivers. As forest cover develops the original effect of drainage is modified because trees capture rainfall and return part of it directly to the atmosphere through evaporation. When the trees are felled, however, the original drainage effect again becomes dominant.

Most of the peatland forests are now becoming mature and felling has started. This will inevitably affect the hydrology of the FCFMO rivers in the predicted ways. It is also evident that some current forestry works are adversely affecting the hydrochemistry and hydrology of streams and rivers despite the wealth of published guidance on procedures and safeguards from FCS, SNH and SEPA. The FCFMO will take steps to monitor the effects of future forestry activity on aquatic ecology and fishery interests.

Some of the areas that are most favourable for forestry will be re-planted but the less favourable areas will be abandoned. Some previously drained areas are currently being managed back towards their natural condition in order to restore their wildlife interest and/ or to conserve the huge mass of carbon sequestered by ecologically intact peatland. Both objectives are dependent on re-wetting the peatlands by disrupting the drainage systems bequeathed by forestry and other land management practices. Given the importance now accorded to the ability of intact peatlands' to continuously capture and store atmospheric

[36] http://theflowcountry.org.uk/news/peatland-restoration-on-open-bog-part-1/

carbon, there may well be future support for extending the pilot projects now being developed over much larger areas.

In this regard, the FCFMO will have common purpose with RSPB, SNH, and the Peatlands Partnership because restoration of natural flow regimes will be favourable for fish populations and for fishery interests. The FCFMO will therefore encourage and support peatland restoration and monitor the response of salmonids to the changes effected.