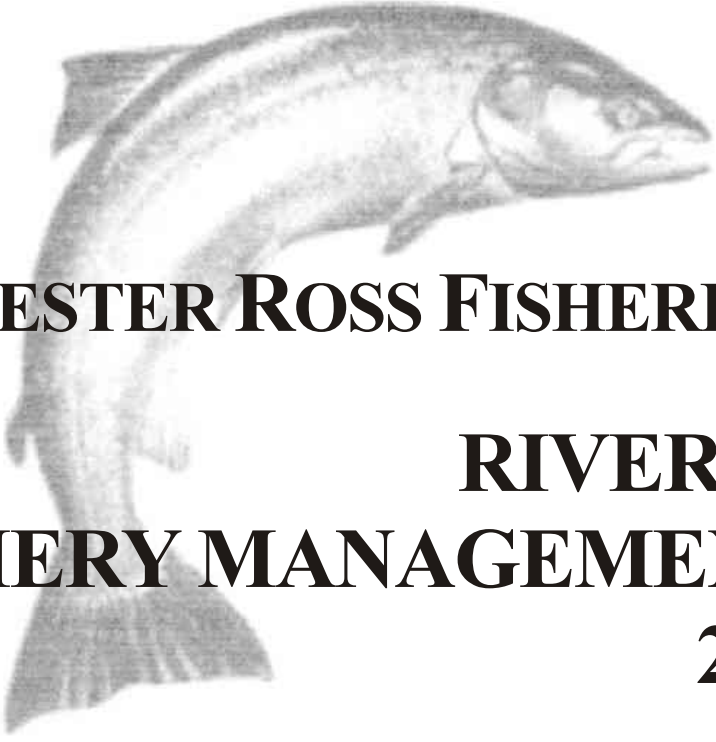




WESTER ROSS FISHERIES TRUST

RIVER BROOM

FISHERY MANAGEMENT PLAN

2002–2006





WESTER ROSS FISHERIES TRUST

Registered Charity number SCO24787

RIVER BROOM FISHERY MANAGEMENT PLAN 2002–2006

by
Peter Cunningham

July 2003

Part-funded by



**The
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Comhairle na
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Summary

- **Introduction:** The River Broom Fishery Management Plan 2002–2006 presents work carried out in 1997–2002 to assess salmon and sea trout stocks and identify factors limiting their abundance, and suggests actions to restore and develop the natural potential of the river as a fishery for salmon and sea trout. Recommendations are aimed primarily at maximising the freshwater production of juvenile fish, since this is largely within the control of riparian owners.
- **Broom catchment:** The River Broom is a typical west-coast spate stream, which rises and falls rapidly according to rainfall. The catchment has an area of 141km², and drains mountainous terrain, with peaks of up to 1,110m (Sgurr Mor). The rocks underlying the catchment comprise an assortment of generally base poor granulite, schists and gneisses. There are two main tributaries: the Abhainn Cuileig flows from the southwest for 7 km from Loch a' Bhraoin, descending 150 m into Strath More; the Abhainn Droma flows from the southeast, descending steeply over the Falls of Measach in Corrieshalloch Gorge to join the Abhainn Cuileig. From the confluence, the River Broom flows for 7 km through Strath More to the tidal limit. The predominant vegetation type is heather moor (mainly 250–500m altitude), followed by 'other mosaics' of grasses, sedges, mosses and lichens on ground above 500m. Areas of rough grassland flank the western side of Strath More (below 250m). Human habitation is confined to Strath More. The principal land uses are wild deer management, nature conservation, sheep farming and forestry. There are hydropower developments on both tributaries, and water is diverted from Loch Droma into Loch Glascarnoch in the Conon catchment area. Much of the catchment is within the Beinn Dearg SSI (Site of Special Scientific Interest), SPA (Special Protection Area), cSAC (candidate Special Area of Conservation) or Fannich Hills SSSIs.
- **Important species and habitats:** Atlantic salmon (*Salmo salar*), Brown trout (*Salmo trutta*), European eel (*Anguilla anguilla*), and Flounder (*Platichthys flesus*) were identified within the catchment area. At least 14 habitats and species that are listed by the EU Habitats and Species directive as 'threatened' occur within the Broom catchment, including alder woodland, otter, red-throated diver and black-throated diver which would benefit directly from action to conserve the catchment's fish stocks and riverine habitats.
- **Salmon and sea trout status:** Recorded catches of salmon and sea trout have fluctuated widely. Sea trout catches were highest during the 1960s, and salmon catches were highest during the early 1970s. Rod catches of both species fell, from over 150 salmon and 200 sea trout per year before 1975, to their lowest levels during the 1990s with a combined total in some years of fewer than 20 fish. The decline in sea trout from the late 1960s is most likely to be related to changes in conditions within coastal areas and to the UDN outbreak in the early 1970s. After a brief period when salmon catches recovered in the late 1970s, the collapse of both species during the late 1980s and 1990s tallies with the expansion of salmon farming within the area. Sea lice epizootics emanating from salmon farms may have affected sea trout to a greater extent than salmon. The native salmon population may have also experienced genetic introgression via hybridisation with escaped farm salmon and can be categorised as vulnerable or endangered in accordance with WWF criteria.
- **Salmon and sea trout life history:** Most Broom salmon go to sea after two years in freshwater and return to spawn after one winter at sea. Most Broom sea trout probably go to sea initially after 3 or 4 years in freshwater, although further investigations are required to confirm this. Most salmon and sea trout enter the Broom in June–September (inclusive) although salmon have been caught in the river in March.
- **Freshwater habitat:** By area, 76% of the available in-stream habitat for juvenile salmon and sea trout and 90% of the available spawning habitat is within the mainstem River Broom. Water quality remains good. The Broom has been altered by hydro-power developments, forestry, grazing pressure, muir-burn, drainage from roads, farms and houses and by confinement between artificial embankments. Nevertheless, the area accessible to salmon and sea trout comprising 156,360 m² of riverine habitat remains in a healthy state. Spawning areas within the Broom may be subject to redd-washout during peak flows in late winter with bedload transportation of coarse sediment. A correlation between years with March spates exceeding 80 cubic metres/s and low fry densities has been suggested. This 'redd-washout' problem may be exacerbated by movement of sediment from several of the tributary streams in Strath More. Bankside habitat is also good with extensive riparian woodlands of alder and other native trees. The spread of *Rhododendron ponticum* within the catchment may be of concern because of the toxins associated with *Rhododendron* leaf litter and woody debris.
- **Salmon and sea trout production:** Electro-fishing surveys indicated that stocks of juvenile salmon in the Broom have

RIVER BROOM FISHERY MANAGEMENT PLAN, 2002–2006

Summary of recommendations forming the River Broom Fishery Management Plan, 2002–2006

Priority	Recommendation	Aim	Action	Possible support	Approximate costs
high	Maintain catch and release policy for wild fish until stocks recover to levels in excess of management targets.	Higher production of juvenile fish.	Broom DSFB, WRFT	Local Angling Club	Loss of revenue
high	Maintain netting closures in Loch Broom until stocks recover substantially.	Higher production of juvenile fish.	Broom DSFB	via TWG or Broom DSFB?	Loss of revenue
high	Form marine partnership with other local stakeholders to foster improved monitoring and management of inshore waters.	Improved growth and survival of sea trout and salmon.	Broom DSFB	Highland Council, SNH	Unknown
high	• Support Area Management Agreement process. • Monitor sea lice abundance on farm and wild fish. • Take action to prevent lice epizootics in Loch Broom	Improved marine survival and growth of sea trout and salmon.	Broom DSFB, WRFT	TWG, WRFT, Highlands and Islands Enterprise	Various. Sea lice monitoring at mouth of Broom/Lael for <£1500 / year
high	Monitor erosion and sediment discharge at different locations within the river system, and take action to reduce erosion and sediment discharge.	More stable spawning areas and habitat for juvenile fish. Less frequent need for bank revetment.	Estate, FE, SSE, NTS coordinate action to identify priorities.	SSE, Forestry Commission, NTS, SNH, SLF, Deer Commission, MLURI	Unknown. Cost of 1 year studentship, about £10,000.
medium–low	Restore, enhance and create new spawning habitats at strategic locations within the mainstem, side channels and side streams (refer to Table 7.2 for site specific details.	(Returns for investment will relate to rates of marine survival.)	Estates : Broom DSFB	Consents may be required from SNH, SEPA, etc.	Various. From >£100 to <£1000 per project
medium–low	• Coppice riparian alders and birches to reduce shading – especially along smaller tributaries. • Enhance riparian habitat for biodiversity.	(Returns for investment will relate to rates of marine survival.)	Estates	Broom DSFB, WRFT, SNH, Highland Council	From <£200 / year (eg Foich roadside ditch) to have real benefit
medium	Control the spread of alien plants within the Broom catchment, especially <i>Rhododendron ponticum</i> and Japanese knotweed.	Prevent gradual reduction in production of juvenile fish.	Estates, SNH, NTS	?Forestry Commission, SNH, Highland Council	> £10,000 to eradicate rhododendron and Japanese knotweed
medium	Set up holding facility & small hatchery for strategic supplementary stocking of salmon and sea trout fry.	Increased production of juvenile fish.	Estates, SSE, WRFT	Broom DSFB, SSE. Need SEPA consent	£4000 / year to produce 100,000 fry
medium	Review hydropower operations within the Broom catchment and consider alternative abstraction scenarios.	Potential for increased production of juvenile fish.	SSE	SSE & WRFT	Cost-benefit reappraisal required

varied considerably during the period 1991–2001. Juvenile salmon were found throughout the mainstem, with the highest fry densities in the lower part of the accessible area. In contrast to salmon, densities of trout fry and parr were high in the accessible parts of small tributary streams in Strath More. Trout were much less common in the mainstem during surveys. The maximum salmon smolt out put is estimated to be 6,914 based on a target egg deposition of 406,510 eggs. This translates to a spawning target of about 250 adult salmon to deposit sufficient eggs. Since 1990, this target may not have been exceeded except in 1992 and 1997. Hence, during the period 1991–2000, fry densities and smolt production may have been limited by both inadequate egg deposition and by ‘redd washout’.

- Fishery Management Plan: To conserve remaining stocks of salmon and sea trout and to restore fisheries to a more productive state, 10 recommendations are proposed. These are outlined in the table below.

Part 1

Introduction

1.1 Aims of the Fishery Management Plan

Atlantic salmon and trout populations in Wester Ross are an invaluable renewable resource. Rod fisheries based on these fish represent an important source of tourism revenue for the local economy, while both salmon and trout are key species in the area's ecology. In addition, the Atlantic salmon is listed in Annex II of the European Union Habitats and Species Directive, and has therefore been identified as a threatened species requiring conservation action. The potential economic and ecological value of salmon and trout populations can only be reached, and then maintained, through careful and sustainable fisheries management.

The Wester Ross Fisheries Trust (WRFT) is a charity formed by river owners, angling clubs and salmon farmers in 1996. Its aim is to '*conserve, restore and develop sustainable salmon, sea trout and brown trout fisheries in Wester Ross*'. This was to be achieved with a fisheries research programme, the objectives of which are to:

- **Conduct exploratory work to establish baseline information on the status and potential of stocks in the WRFT area**
- **Monitor and identify trends in stocks and possible factors affecting them**
- **Produce a Fishery Management Plan for each river system in the WRFT area aimed at achieving the fishery's potential**

This report presents the conclusions of the WRFT's work on the River Broom 1997–2002. This includes a juvenile survey, habitat survey, acidification and redd washout studies and adult stock assessments. The estimated costs of this work are shown in Table 1.1.

Based on these findings a Fishery Management Plan has been formulated, with a time scale of 5 years. The suggested actions are aimed at attaining the natural production of juvenile salmon and trout from the freshwater habitat, and if successful other species listed by the Habitats and Species Directive will also benefit. Since the freshwater environment is largely controlled by the land owners concerned, the plan is designed specifically for them. If required, the WRFT intends to assist in the implementation of the Plan and to review its progress in 2007, when new targets and recommendations will be put forward.

To obtain the best quality of information, the work contained in the Plan has been carried out with the guidance of the Scottish Executive agencies, including the Fisheries Research Services (FRS), Scottish Natural Heritage (SNH) and the Scottish Environment Protection Agency (SEPA). The WRFT acknowledges financial assistance provided by SNH and the Highland Council's Landfill Tax Credit Scheme for the production of this Plan.

Table 1.1 Estimated costs of producing the River Broom Fishery Management Plan

Juvenile surveys, 1997–2002	£3,000
Habitat survey, 1998, 2002	£2,500
Redd Washout Project, 2000–2001	£800
Catch records analysis	£1,000
Plan preparation and production	£3,000
Total	£10,300

1.2 The Scottish Fisheries Coordination Centre

The WRFT is one of 15 similar fisheries research and management organisations established throughout Scotland. To ensure the highest quality of fisheries data collected, and the comparability of that data, a Scottish Fisheries Coordination Centre (SFCC) was established in 1997 at the FRS Freshwater Fisheries Laboratory, Pitlochry. The SFCC has developed standard procedures for the surveying of juvenile salmon and trout and their freshwater habitat, and a computer-based Geographical Information System to map this and other fisheries information. All of the information presented in this Plan was collected according to the SFCC's standardised methods. □

Part 2

Salmon and Trout Ecology

by James Butler

2.1 Introduction

Fisheries are usually based on catches of adult salmon and trout. However, adult fish represent only one stage of each species' life cycle. The effective management of fisheries requires an understanding of the entire life cycle of the fish concerned. This section summarises the ecology of west coast salmon and trout, and the factors affecting their abundance.

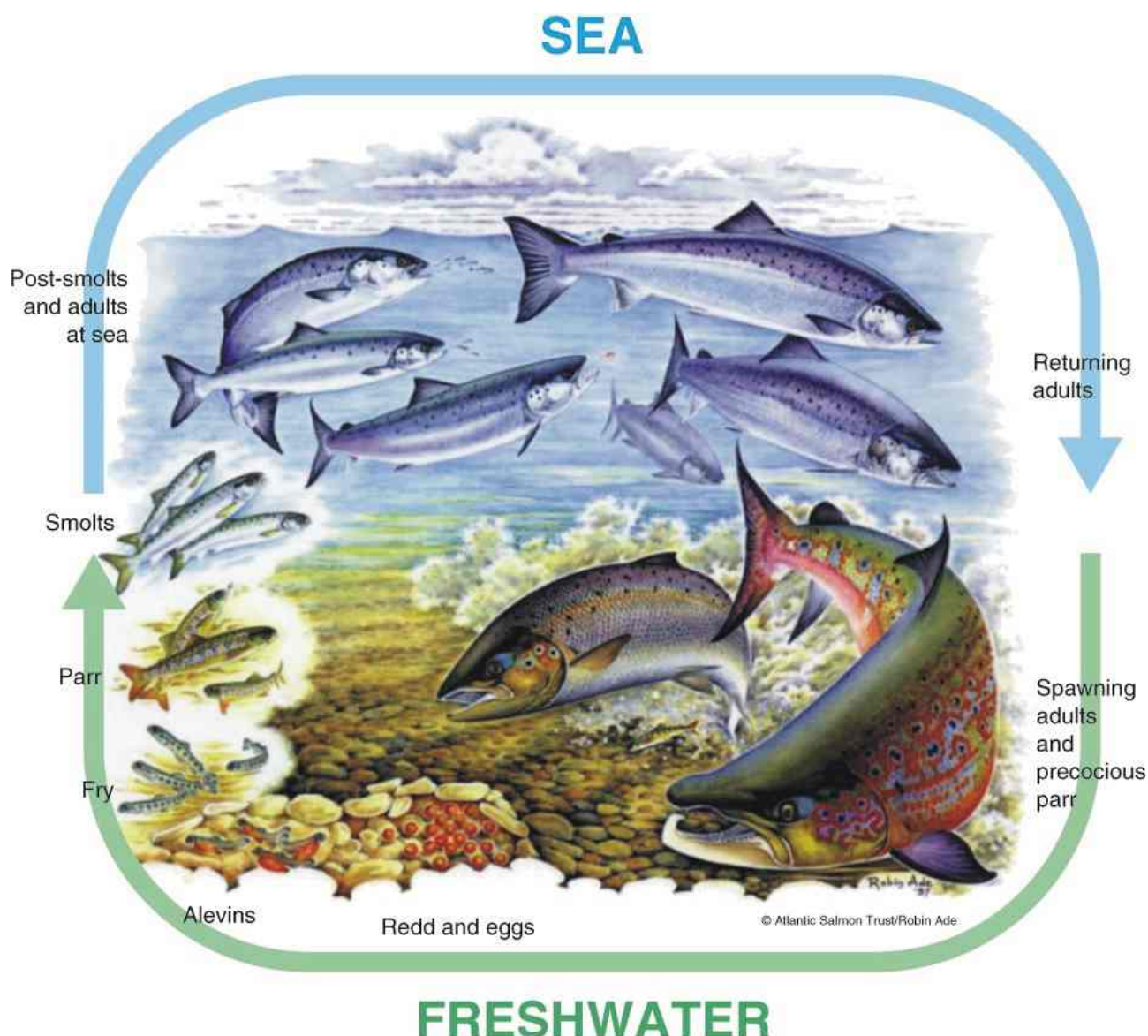
2.2 Atlantic salmon ecology

2.2.1 Life cycle

The life cycle of the Atlantic salmon is now well understood, and is summarised in Figure 2.1. The key stages are as follows:

- **Redd and eggs:** A 6 lb hen salmon will lay approximately 4,800 eggs in several nests or 'redds', usually in November. Salmon spawn in runs and glides with a gravel or cobble bed. Up to 95% of eggs can hatch successfully.
- **Alevins:** Surviving eggs hatch into alevins in early spring, and they remain in the redd until their yolk sacks have been absorbed.
- **Fry:** Once the surviving alevins have begun feeding they are known as fry. These fish disperse from the spawning area and set up feeding territories. Salmon fry favour shallow, faster flowing areas of the river, and competition for space in a well-stocked river will be fierce, resulting in high mortality during their first summer.
- **Parr:** Once the fry have grown for a year they are known as parr. Being larger in size they require more cover to hide from predators than fry, and consequently parr favour faster flowing areas with boulders, cobbles and bankside cover. They feed on insects drifting on the current. Much of this food may fall into the water from bankside vegetation. Salmon parr will also inhabit lochs.
- **Smolts:** Having reached approximately 12 cm in length the parr will begin to smolt, turning silver and migrating downstream to the sea during April and May. The further north the river, the shorter the growing season, and therefore the longer parr take to reach smolt size. In Wester Ross most juvenile salmon require three years to smolt, with a minority smolting after two or four years. Salmon smolts leave their estuaries quickly, with most heading into the open sea within two or three days.
- **Post-smolts and adults at sea:** Smolts migrate northwards feeding near the surface on crustaceans and juvenile sandeels, capelin and herring. During this stage they are known as post-smolts. Little is known of the specific feeding grounds of west coast salmon, but most British salmon feed off the Faroe Islands. Salmon which mature in their first year at sea are known as grilse, and these probably migrate no further before turning back to the Scottish coast. Fish which mature in their second or third year (Multi Sea Winter salmon) migrate further north to feed off Greenland and in the Norwegian Sea.
- **Returning adults:** As salmon mature they return southwards towards the Scottish coast, using the Earth's electromagnetic field to navigate. On reaching the coast they locate their natal rivers by smell, and will usually run into the river during high flows after rain. Once in the river the fish darken and take shelter in deep pools or lochs. They stop feeding and rely on their fat reserves for survival and further sexual development.
- **Spawning adults and precocious parr:** As autumn approaches the adult salmon home in on the area or tributary of the river where they were born. The hen selects a suitable place for spawning and digs a series of redds, in which she lays her eggs. These are simultaneously fertilised by the cock salmon, and often mature 'precocious' parr as well. The hen then covers the eggs with a mound of gravel. Having spawned, salmon are known as 'kelts', and these gradually turn silver and drop back into the sea over the winter. A few survive to return and spawn a year later.

Figure 2.1 The life cycle of the Atlantic salmon



2.2.2 Freshwater problems

Factors limiting the abundance of salmon in the freshwater phase of their life cycle are:

- **Redd washout:** During severe winter spates in which the river bed moves, redds can be washed away. Newly-hatched alevins are most vulnerable. This is further discussed in Part 5 and Appendix 2.
- **Acidification:** Acidification caused by atmospheric pollution can kill salmon eggs and alevins, and if particularly severe will also kill fry. Parr are more resistant to acid events. Coniferous forestry can exacerbate acidity.
- **Pollution:** Contamination of rivers by industrial and agricultural waste (e.g. sheep dip) can kill fish of all sizes.
- **Siltation:** The accumulation of silt in a stream can choke gravel beds, reducing the flow of oxygen to eggs and killing them. Siltation usually stems from run-off during the harvesting of forestry, or severe erosion of agricultural land.
- **Disease and parasites:** Although wild salmon carry many diseases their symptoms are not usually seen until the fish are stressed, for example by high water temperatures. Infectious Salmon Anaemia has become a recent problem in salmon farms, but it probably does not affect wild fish, although they can carry the virus. Of greater concern is the parasite *Gyrodactylus salaris* which has spread to many parts of Europe from Sweden. Although Swedish salmon are adapted to survive the parasite, foreign salmon stocks are not, resulting in very high mortalities of fry and parr. So far *Gyrodactylus* has not reached the UK.

- **Predation:** Fry, parr and smolts are eaten by a wide range of piscivorous birds in freshwater. The most prevalent predators are mergansers, goosanders and cormorants. Feral mink can also be serious predators of juvenile salmon, but only rarely occur in Wester Ross. Humans and otters are the main predators of adult salmon in freshwater.

2.2.3 Marine problems

- **Feeding:** Fish traps run by the WRFT at Tournaig (Loch Ewe), and the FRS Shildaig Sea Trout Project (Loch Torridon) indicate that as few as 3% of west coast salmon smolts survive to return to their natal rivers. In the 1960s and 1970s marine survival was as high as 30%. The main cause of this decline is thought to have been climate change in the North Atlantic, which is restricting the availability of food for post-smolts. As a consequence, more smolts die, and the surviving post-smolts and adults grow to smaller sizes than in the past. Furthermore, because Multi Sea Winter salmon remain longer in the sea, they are even less likely to survive and have become more scarce than grilse.
- **Commercial netting:** High seas netting has been vastly reduced in recent years owing to buy-outs by the North Atlantic Salmon Fund (NASF), and quota management by the North Atlantic Salmon Conservation Organisation (NASCO). Drift nets off the west coast of Ireland and Northumberland are of concern to Scottish east coast rivers, but do not directly affect west coast salmon. The greatest netting threat to Scottish west coast salmon are coastal bag and sweep nets, but with the recent local declines in stocks most netting stations have become unviable.
- **Industrial fisheries:** Recent research has shown that salmon post-smolts feed near mackerel and herring shoals, and are accidentally taken as a by-catch by industrial trawlers. The full extent of this problem is not yet known.
- **Seal predation:** In the 1990s, the Scottish grey seal population was estimated to be growing by 8% per annum, and there were fears that predation on returning adult salmon may have been increasing. However, the extent of seal predation has never been quantified.
- **Sea lice infestations:** Recent studies of salmon post-smolts in Norway have shown that fish leaving fjords with salmon farms have been infested with lethal levels of sea lice, most likely produced by the farms.
- **Escaped farm salmon:** This problem may occur in either fresh or saltwater, since juvenile salmon are produced in hatcheries and cages in freshwater, and in cages at sea. Escaped salmon will breed with wild salmon, and if this occurs consistently over a number of years, Canadian and Irish research has shown that the wild stock will suffer a cumulative loss of genetic fitness. The level of genetic dilution will be minimal if the wild population is healthy, but the effect is disastrous if the wild stock is depleted. A hybrid

population will be more vulnerable to marine mortality and any sudden changes in the freshwater environment, leading to possible extinction. See also Box 4.1.

Scottish Executive rod catch records for the north-west statistical region indicate that since 1952 catches have varied widely between years, but have generally increased gradually (Figure 2.2). However, in the mid-1990s stocks fell suddenly to record low levels, and this has coincided with the rapid expansion of the salmon farming industry on the west coast. However, it is likely that this regional collapse has been caused by the combined effects of many of the factors listed above, rather than the expansion of the salmon farming industry alone.

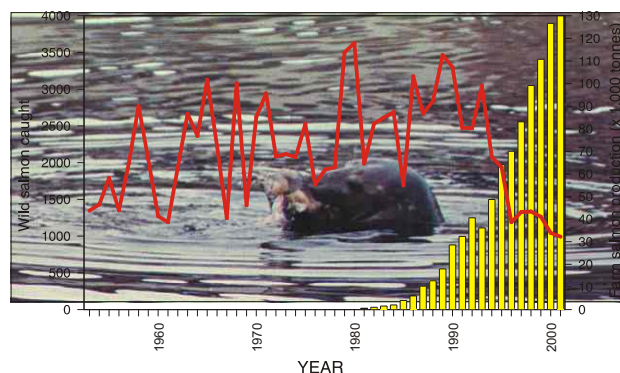


Figure 2.2 Total rod catches of wild salmon for the Scottish Executive's north-west region, compared to Scottish salmon farm production, 1952–2001

2.3 Sea trout and brown trout ecology

2.3.1 Life cycle

Unlike the Atlantic salmon, the ecology of sea trout and brown trout is not well understood. This is primarily because the brown trout is very adaptable, and can take many forms. Of principle interest to west coast fisheries is the sea trout, and its relationship with brown trout.

As for salmon, the juvenile stages of the trout's life cycle are confined to freshwater (Figure 2.3). However, there are a few minor differences. First, trout eggs are smaller and their redds are shallower than those of salmon because adult trout are generally smaller than adult salmon. Second, trout begin spawning a few weeks earlier than salmon.

On reaching smolt size young trout can either become sea trout or remain in freshwater as brown trout. In general, most females become sea trout, and most males remain as brown trout (Figure 2.3). Sea trout smolts leave the rivers at the same time as salmon smolts, in April and May. Unlike salmon smolts, however, they remain in the sea lochs for their first summer. At this stage they are termed post-smolts, and by late



The WRFT Tournai trap (top) and FRS Shildaig Sea Trout Project trap (bottom) (J Butler)

summer are known as finnock. Some finnock re-enter their river in late summer, although it is not understood why, since the majority are immature. Other finnock remain in the sea lochs for one or two years until they mature and return to their native river to spawn.

Mature sea trout run into their native rivers in the summer and autumn. Female sea trout then pair with male brown trout in October and November and spawn. Sea trout kelts return to the sea, and may run their river annually to spawn up to 12 times, growing to sizes of more than 10 lb in weight. As a consequence, most of the trout eggs produced in a healthy sea trout river are laid by larger female sea trout.

Research on brown trout has shown that there may be several races of trout in a river or loch system, of which sea trout may be only one. Other forms of trout include 'slob' trout, which are resident in estuaries and also feed on marine organisms, but do not migrate any further than their natal river mouth. 'Ferox' trout are long-lived brown trout which grow large enough to become successful predators of other fish, and Arctic charr in particular.

2.3.2 Freshwater problems

Many of the problems that affect salmon in freshwater also affect trout. However, there are some minor differences:

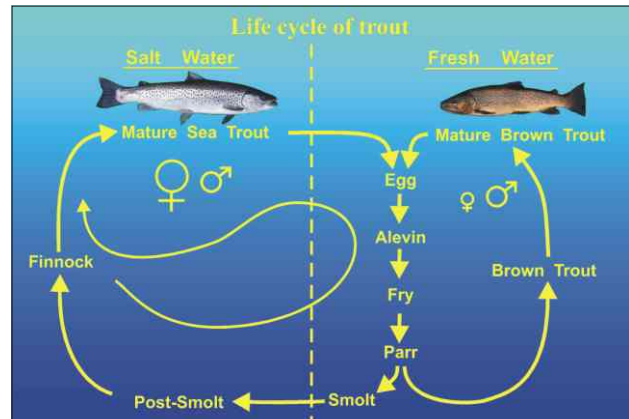


Figure 2.3 The life cycle of Scottish west coast sea trout (© FRS Freshwater Laboratory)

- **Redd washout:** Being smaller fish, trout lay their eggs in shallower redds, and therefore may be more prone to washout.
- **Acidification:** Trout are less sensitive to acidity than salmon.
- **Nutrient enrichment:** Sea trout are thought to have evolved as a result of lack of food, causing females to migrate downstream to the sea, and over time this behaviour has become genetically imprinted. However, if more food becomes available to trout in freshwater, either as a result of a lack of competitors or nutrient enrichment, the fish will lose the physical trigger to migrate to sea. Consequently severe declines in trout numbers may reduce competition for food and encourage sea trout to stay in freshwater as brown trout. The enriching effect of effluent from freshwater fish cages or agricultural fertiliser can have the same result.

2.3.3 Marine problems

Although sea trout are affected by the same marine problems as salmon, their coastal habits leave them more vulnerable to local influences:

- **Sea lice infestations:** Catch statistics show that sea trout stocks in the north west have been declining slowly since 1952, but the decline accelerated with the rapid growth of the salmon farming industry (Figure 2.4). It is highly likely that sea lice emanating from salmon farms have been the major cause of the recent collapse, as lethal levels of sea lice have been found on sea trout post-smolts in salmon farming areas, but not in areas without salmon farming. WRFT lice monitoring also shows that in fallow years lice infestations on sea trout fall, and then increase in years when production restarts in the sea loch.

Unlike salmon, sea trout react to heavy lice burdens by returning prematurely to freshwater, where the lice die. While in freshwater the sea trout stop feeding, and therefore lose growth and condition. Skin damage from the sea lice also causes secondary infection, and combined with the stress of transfer from sea to freshwater, many die. The result is that

lice-infested sea trout grow more slowly in the marine phase of their life cycle, and their life expectancy also falls.

Consequently the average size of sea trout declines, as shown by the Scottish Executive statistics. Between 1952 and 1988 the average weight remained between 1½ lb and 2 lb, but in 1989 declined rapidly, coinciding with the growth of the salmon farming industry. The FRS Shildaig Sea Trout Project shows that currently less than 1% of sea trout smolts survive to maturity, whereas in the past up to 11% did. In contrast, sea



Sea trout (top) may remain in freshwater as brown trout (bottom) if their food supply improves (J Butler)

trout in the Solway region, outside the salmon farming zone, have maintained their average weight (Figure 2.5).

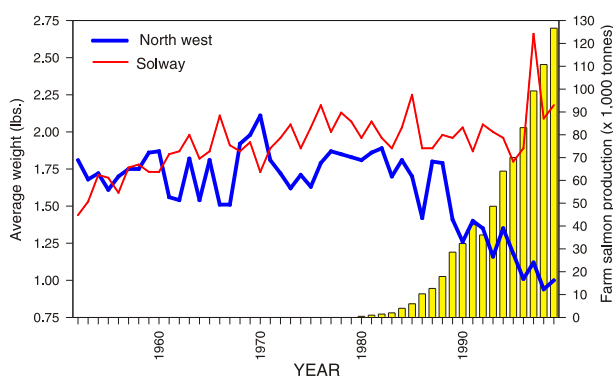


Figure 2.5 Average weight of rod caught sea trout for the north-west and Solway regions, compared to Scottish salmon farm production, 1952–1999

- Coastal feeding:** The long-term decline of sea trout prior to salmon farming clearly suggests that another factor has been involved. Although numbers of sea trout were dropping, their average size remained consistent until 1988 (see Figure 2.5). One possible explanation for the long-term decline prior to the establishment of salmon farming is the decline in stocks of sea fish. Herring and sprats spawn in west coast sea lochs, and their young form an important component of the sea trout diet. Herring stocks were severely over-fished in the post-war years, and collapsed in the 1970s. The abandonment of the

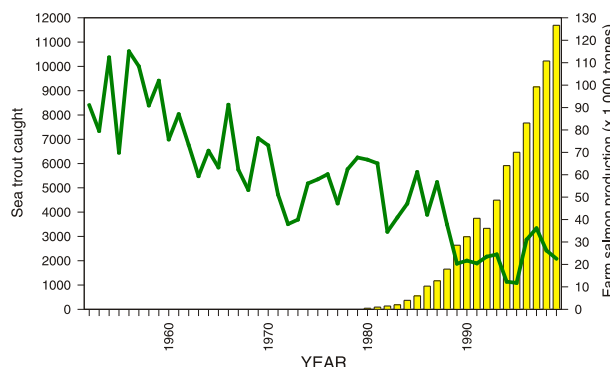


Figure 2.4 Total rod catches of sea trout for the Scottish Executive's north-west region, compared to west coast salmon farm production, 1952–1999

three-mile limit may also have allowed over-fishing of other coastal white fish by industrial vessels, exacerbating the problem.

2.4 Competition between juvenile salmon and trout

Juvenile salmon and trout living in the same rivers tend to live in separate types of habitat, reducing the competition for space. Salmon are better adapted to faster, shallower water, while trout favour deeper, slower-flowing water, and consequently prefer to live in lochs. While salmon favour well-lit areas, trout prefer shade and cover provided by bankside vegetation. However, if the trout's preferred habitat is over-populated they will aggressively colonise the more open areas, out-competing the salmon. In the context of the Broom, this is further considered in Part 4. □



Sea lice damage to the dorsal fin of a sea trout post-smolt (S Northcott)



Sea trout feed on juvenile sea fish in west coast sea lochs
(J Butler)

Part 3

The River Broom

3.1 Location, inshore fisheries, salmon netting and aquaculture

3.1.1 Loch Broom

The River Broom enters the sea at the head of Loch Broom, initially a long narrow sea loch 15 km in length and 1–1.5 km wide, that opens out into the Minch, 3 km north west of Ullapool (Figure 3.1).

3.1.2 Inshore Fisheries

Loch Broom was an important spawning area for sprats and herring. Herring and sprats are important prey items for sea trout. In 1788, the town of Ullapool was developed by the

British Fisheries Society to provide a base from which to exploit herring. By the middle of the 19th century, the inshore fishery had virtually been abandoned. Although there were periods of recovery after then, the herring fishery was temporarily closed in the late 1970s following a period of sustained over-fishing to allow stocks to recover.

Stocks of haddock and cod have declined greatly within the area within living memory. The local spawning status of cod and other white fishes requires further investigation. Mackerel move into inshore waters to feed on sprats, sandeels and juvenile herring in summer. During the 1980s and early 1990s large quantities of mackerel were landed or processed on East European ‘klondyker’ factory ships anchored in Loch Broom.



Loch Broom, with River Broom estuary in foreground and Ullapool in the distance. Corry salmon farm cages can be seen near the narrows (Ullapool Museum)

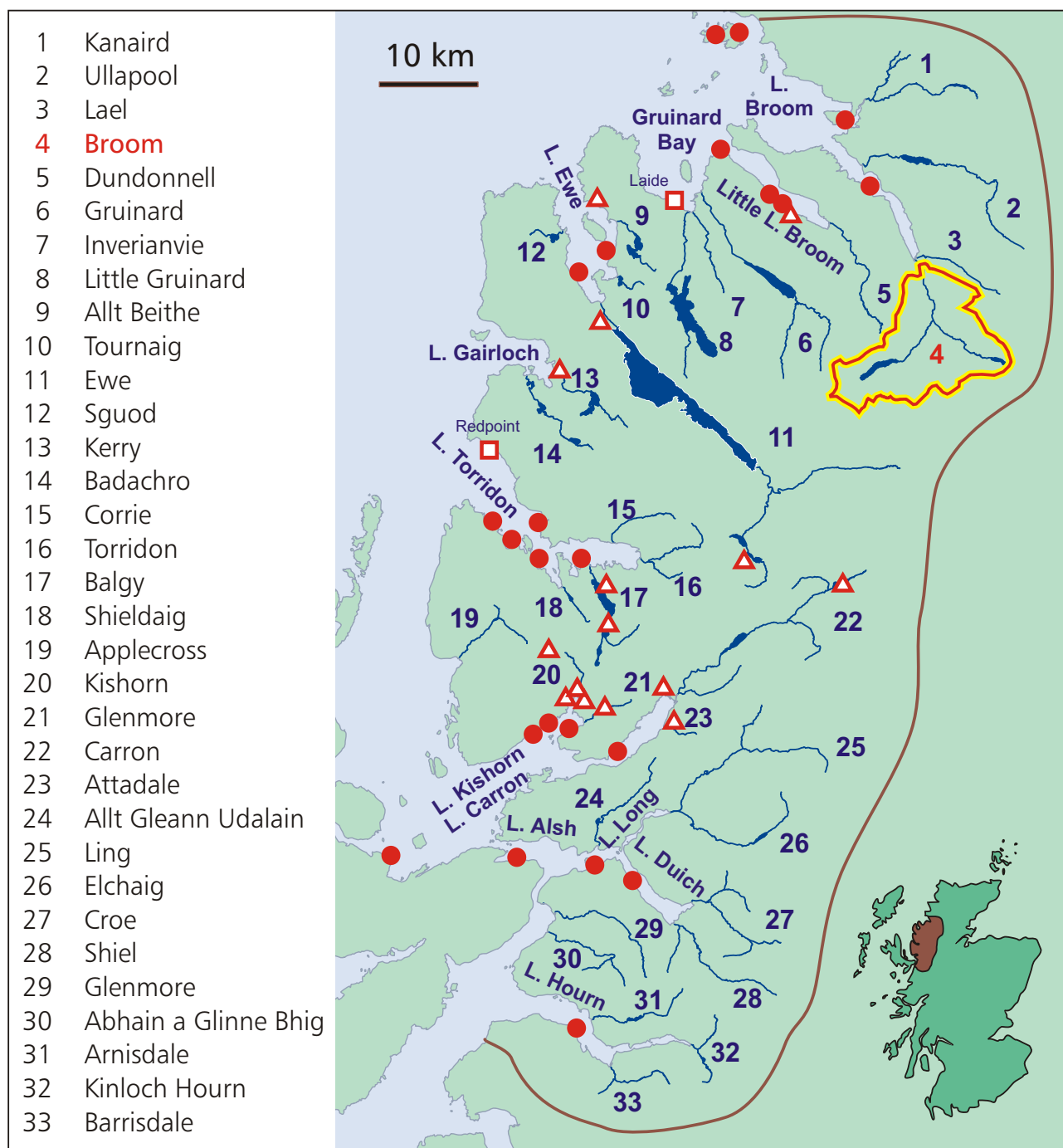


Figure 3.1 The River Broom catchment relative to the WRFT area, and marine (●) and freshwater (△) salmon farm sites, and salmon netting stations (□)

Prawns (*Nephrops norvegicus*) are taken both by creel fishermen and by trawlers from inshore waters around Wester Ross. Lobsters have declined within the inner loch over many years. A few lobsters are still taken by creel fishermen farther out. Scallops are taken by dredgers and by SCUBA divers. Mussels, horse mussels and winkles are collected by hand at low tide, primarily for local consumption. Cockle beds at the head of Loch Broom were also formerly harvested.

- During the 1970s, trawl surveys were carried out by the Scottish Marine Laboratory (now Fisheries Research

Services, FRS) to investigate the local abundance of juvenile herring and sprats. Annual surveys of juvenile fishes are important to establish population trends in coastal areas.

- The potential for restoration of productive inshore fish and shellfish fisheries may be considerable. Effective integrated coastal zone management measures (possibly including Marine Conservation Zones) are needed to restore yields of many species within Loch Broom and surrounding inshore waters. The restoration of healthy coastal fisheries will also

ensure an abundance of many of the varied prey items on which salmon and sea trout feed.

3.1.3 Neighbouring salmon rivers

The Lael River joins the Broom in the inter-tidal area. The Lael may still support a few salmon – WRFT recorded one parr during electro-fishing surveys in 1999. The Ullapool River enters the sea near the mouth of the inner loch, 10 km from the Broom estuary. The estuary of the Kanaid River is a further 5 km to the north. To the west, the nearest salmon rivers are the Dundonnell at the head of Little Loch Broom (45 km by sea), and the Gruinard and Little Gruinard (37 km and 38 km by sea respectively).

Rod catches of salmon and sea trout in all five rivers fell during the late 1980s and/or early 1990s. Salmon populations in the Gruinard and Little Gruinard Rivers remain relatively healthy. WRFT Fishery Management Plans for the Kanaid, Dundonnell, and Gruinard Rivers provide further details.

- **The genetic variability of wild salmon and trout populations in the west of Scotland is currently being investigated by FRS. These studies aim to identify integral ‘populations’ and their origins. The occurrence of non-native genes (for example, from stocked fish or escaped farm salmon) within wild populations may also become apparent.**

3.1.4 Salmon netting around Loch Broom

There are netting rights for salmon at Leckmelm (Leckmelm Estate), Lochbroom Glebe (Church of Scotland General Trustees) and Inverlael (Inverlael Estate). Net and cobble fisheries have not been operated since 1987. The salmon and sea trout taken by nets in Loch Broom are likely to have originated from a number of local rivers in addition to the River Broom.

Illegal netting remains a potentially serious threat to the recovery of salmon and sea trout fisheries in the west of



Yair Fish trap, by mouth of River Broom. These traps were designed to trap fish on the falling tide. In some parts of Wester Ross they were operated as recently as 1970s. Mackerel, sea trout, flounder and other fish were taken (see also aerial photo) (J Butler)



Bag-net fishermen, Loch Broom 1960. There has been no known netting for salmon and sea trout in Loch Broom since 1987 (Ullapool Museum)

Scotland, especially if legal netting interests are not fully respected.

- **If people from local communities are able to share the benefits of healthy salmon and sea trout fisheries, they are more likely to actively support restoration programmes.**

3.1.5 Intensive aquaculture

The closest active marine salmon-farming site is situated within Loch Broom south of Corry Point, about 7 km from the river mouth. The site is owned by Wester Ross Salmon Ltd, and has operated since the early 1980s. The biomass consent for this site is currently set at 1050 tonnes. The site is currently operated as a single year class site. Wester Ross Salmon also has sites in Loch Kanaid, 16 km from the river mouth.

Other ‘active’ salmon farms within the Loch Broom/ Little Loch Broom area are Scottish Sea Farms by the Summer Isles and Ardesie Salmon Ltd in Little Loch Broom. Marine Harvest Scotland has a sea-bed lease at the mouth of Little Loch Broom near Stattic Point, and at the time of writing (March 2003) has plans to stock a 1400-tonne biomass salmon farm in October 2003. There are also plans to develop a 1900-tonne biomass salmon farm (subsequently cod and haddock) at Annat Bay.

Problems for wild salmon and sea trout associated with salmon farming are discussed in Part 2.

- **In line with the Tripartite Working Group concordat chaired by the Scottish Executive (2000), discussions have taken place between river owners, fish farms and WRFT to set up an Area Management Agreement (AMA) within an area encompassing the ‘Two Brooms’ (Loch Broom and Little Loch Broom). The proposed AMA has the overall aim of improving the health of both farmed and wild fish stocks.**

3.1.6 Estuary

The River Broom flows for 3 km from the upper tidal limit to its Low Spring Tide point of entry into the sea. An intertidal expanse of sands and mudflats of 1.4 km² is exposed at low

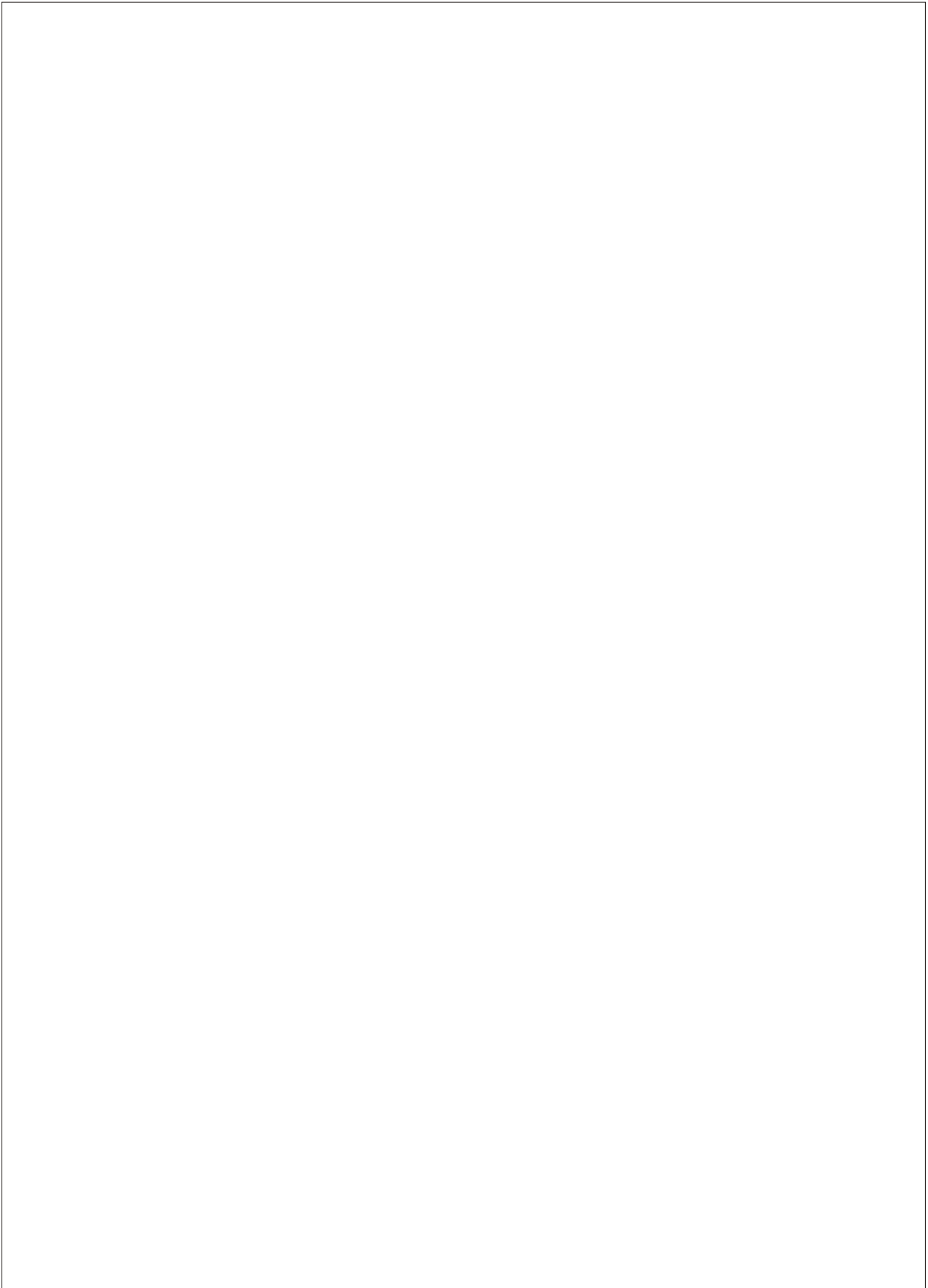


Figure 3.2 The River Broom catchment, showing locations of hydro-power schemes (Crown Copyright)

tide. This area supports a large population of worms, bivalves and other invertebrates, and provides rich feeding for many fish and birds.

Fish-eating birds include gulls, divers, cormorant, shag, red-breasted merganser, heron and kingfisher (in 2002).. Common and grey seals inhabit inshore waters, and otters live around the coasts and along the rivers. Although salmon and sea trout can form a significant part of the diet of these animals in local situations, other predators and pests of salmon are also taken (e.g. eels, sea lampreys, pollack). Predation may be a problem when stocks are already severely depleted for other reasons, or where the health of salmon and sea trout smolts is compromised (e.g. sea lice infestations).

- **Long-term monitoring of predator occurrence (v. time) within Loch Broom may help to establish any changes that impact upon levels of predation of juvenile and adult salmon and trout.**

3.2 Characteristics of the catchment

3.2.1 The Broom catchment

The River Broom has a catchment area of 141.4 km² (Figure 3.2). The catchment drains mountainous terrain, with peaks of up to 1,110 m (Sgurr Mor). There are two main tributaries. The Abhainn Cuileig flows from the southwest for 7 km from Loch a Bhraoin, descending 150 m through Cuileig Gorge into Strath More. The Abhainn Droma flows from the southeast, descending steeply over the Falls of Measach in Corrieshalloch Gorge to join the Abhainn Cuileig. From the confluence, the River Broom flows for 7 km through Strath More to the tidal limit. The river habitat is described in more detail in Part 5.

3.2.2 Geology

The Broom catchment lies to the east of the Moine thrust zone. The rocks underlying the catchment comprise a complex assortment of hard, generally base-poor metamorphic rocks, predominately granulite, schists and gneisses of the Moine Series. The landscape and 'lochscape' reflect their glacial origin. Within the catchment are fine examples of glacial features including corrie lochs and the U-shaped valley of Strath More. Soils are generally nutrient poor. Peat deposits are thicker between 250m and 550 m altitude.

The fluvio-glacial alluvium of the Strath More flood plain (less than 3 km² in total) provides the only relatively fertile agricultural land within the catchment area.

Excessive movements of boulders and cobbles particularly within Strath More have caused stream-bank and stream-bed destabilisation, and may have led to the destruction of salmon redds and emerging fry (see Part 5 and Appendix 2). Coarse sediment has accumulated within the mainstem of the river,

raising the level of the stream bed above that of surrounding farmland.

- **An assessment should be made of rates and causes of soil erosion within the catchment area. A primary objective should be to identify the areas of highest sediment discharge into the river system.**

3.2.3 Climate and rainfall

Wester Ross has a moist maritime climate. Weather patterns are dominated by a westerly Atlantic air-stream. Meteorological records from the National Trust for Scotland's Inverewe Garden, Poolewe, show a 20-year average annual maximum temperature of 12.1°C, and average rainfall of 1,734 mm (max 2,315; min 1,430 mm).

3.2.4 Vegetation

The predominant vegetation type is heather moor (mainly 250–500 m altitude), followed by 'other mosaics': mainly of grasses, sedges, mosses and lichens on ground above 500 m (Figure 3.3). Areas of rough grassland flank the western side of Strath More below 250 m.

Conifer plantations comprise 10 km² of the catchment area. Lael Forest belonging to the Forestry Commission is the largest forest unit (8 km²) and extends along the entire eastern side of Strath More from the valley floor to altitudes of 200–300 m. Trails guide visitors through a 6 ha woodland garden planted with trees and shrubs from many parts of the world. Prominent trees in the garden and along the roadside include mature North American firs and Giant redwood.

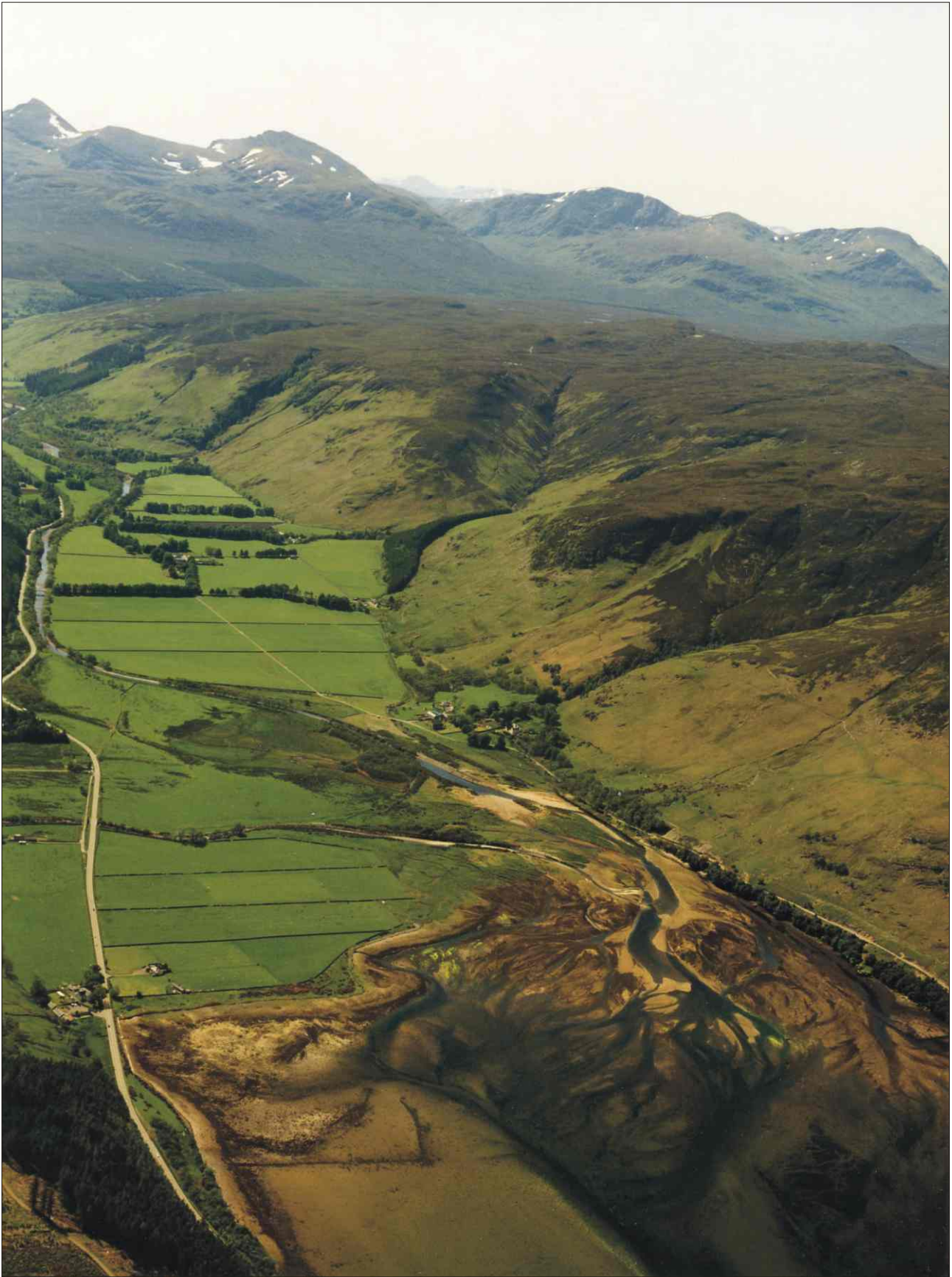
Six listed ancient, long-established or semi-natural woodlands are located within the Broom catchment. Three woodland fragments are located on the open hillsides of Leitir Fhearna south of Loch a' Bhraoin. These woodlands are unfenced, are subject to deer grazing, and are not presently regenerating.

On the east of Strath More there are several areas of ancient or long-established woodlands within the Lael Forest. On the west side of Strath More in Coill a' Ghille are degraded woodlands of mature alder and hazel (formerly coppiced). These woodlands are to be enclosed within a Woodland Grant Scheme (WGS) project area, designed to foster natural regeneration.

The river embankments and back channels of the River Broom support mature riparian woodlands of alder, gorse, birch, willow, ash and Japanese knotweed.

Enclosed improved grasslands and arable land are confined to the valley bottom of Strath More.

Rhododendron ponticum and other exotic plant species are spreading within the catchment area. Rhododendrons create dense shade, and toxins (phenols) from their leaves and roots



Aerial photograph of western part of Broom catchment, facing south. Heather peatlands cover much of the area, with grasslands on the lower slopes and higher montane areas. A relic ancient woodland patch, Coille a' Ghille, (alder and hazel mainly) can be seen on the slopes of Strath More (upper left) in front of a conifer plantation (since felled). The highest mountains from right to left are: Sgurr Mor (1,110 m), Sgurr nan Clach (1,093 m), Sgurr Breac (995 m), A' Chailleach (997 m) (Ullapool Museum)

build up within the soil, preventing growth of other plants for 10 years or more following removal of the living plant. The most extensive areas of rhododendrons are in the Braemore area.

Other self-regenerating exotic species include Japanese knotweed (especially along river banks), laurel, cotoneaster, and several North American conifers. The National Trust for Scotland has a rigorous control programme to remove exotic plants from Corrieshalloch Gorge. However, large numbers of rhododendron seeds are produced within adjoining areas and settle on cleared areas.

3.2.5 Hydrology

The River Broom is a typical west-coast spate stream, which rises and falls rapidly according to rainfall. This is illustrated in Figure 3.4, which shows the discharge of the Broom in 2001, as measured at the SEPA gauging station at Croftown by Inverbroom.

Spates usually lasted for only a few days, with discharges thereafter returning to levels below 5 m³/sec (unless rainfall is sustained). Peak flows were recorded during the autumn and early winter, and lowest flows in the spring and summer.



Exotic alien plants are spreading within the Broom catchment. *Rhododendron ponticum* (above) is particularly abundant around Braemore; Japanese knotweed (below) grows along the river bank in Strath More (K Starr; A Gray)

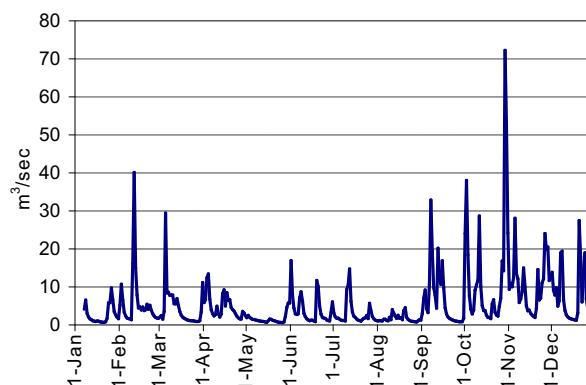


Figure 3.4 Discharge of River Broom at SEPA Croftown Gauging station, Inverbroom in 2001

During spring–summer 2001, there were spates in excess of 5 m³/sec in June and July, but none in May and August. Although the discharge at which salmon enter the river is unknown, their timing of entry is likely to relate closely to water levels and to vary from year to year accordingly.

3.3 Human activities and impacts within the Broom catchment

3.3.1. Human population

Human settlement is largely restricted to Strath More. The principle settlements are Braemore, Auchindrean, Glackour, Foich, Auchlunachan, Croftown, and Clachan at the head of the estuary. There are approximately 100 residents within the catchment area, almost all within Strath More. However, the population increases during the summer with many tourists passing through or staying within the area. Tourist attractions include Corrieshalloch Gorge (owned by the National Trust for Scotland), Lael Forest Garden (owned by Forest Enterprise) and the nearby Woodturning Centre.

The A835 (trunk road) Ullapool–Garve road passes through Strath More and alongside the Abhainn Droma. The A832 from Gairloch crosses the Abhainn Cuileig above the Cuileig Gorge and joins the A835 at Braemore Junction.

3.3.2 Land ownership

Land ownership within the catchment is divided between Inverbroom Estate, Inverlael Estate, Forestry Commission (Lael Forest), Foich Estate, Braemore, the National Trust for Scotland (Corrieshalloch Gorge), and smaller house holdings.

3.3.3 Land use

The principal land uses are wild deer management, nature conservation, sheep farming and forestry.

Sporting estates

Deer stalking takes place between August and February inclusive. Red deer are found mainly on the open hill at densities high enough to prevent the regeneration of native trees and various other plant species. Sika deer and roe deer occur primarily along the riparian corridor and other wooded areas at lower densities (especially in terms of ecological impact).

Protected areas

Large parts of the Broom catchment are managed with regard to their 'Special' conservation status. Further details are provided in Section 3.5.2.

Agriculture

Sheep are grazed within and along the western side of Strath More. Small numbers of cattle are also grazed within Strath More.

Muir-burn

Areas of heather moor are burnt most years – particularly in early April with the aim of promoting new growth of vegetation for grazing animals. The long-term impacts of muir-burn on soil fertility and the biological productivity in the wet west of Scotland are not fully understood. From the fisheries perspective, wind-blown insects from moorland areas can form a substantial part of the diet of trout and juvenile salmon at certain times of year. Muir-burn may affect the diversity and abundance of insects.

Forestry and Woodland Grant Schemes

Lael Forest is managed by Forest Enterprise for timber production, for wildlife conservation and for public amenity, with woodland trails through mature stands of specimen native and non-native conifers.

On the west of Strath More a new Woodland Grant Scheme has been designed to incorporate and allow regeneration of ancient alder-hazel woodland remnants.

- **An integrated land-use management plan of the Broom catchment area might focus upon how to enhance the value of natural resources within the area and minimise adverse impacts to the river. Priority issues might include: an assessment of grazing pressures and of muir-burn, the development of productive moorland and grassland, the regeneration of native woodlands, the control of undesirable alien plants, and the protection of special native plant communities (see section 3.5.2). Collaborative actions that reduce surface water run-off and soil erosion, and subsequent downstream damage to river banks (requiring costly river engineering works), should be highlighted.**



Hillside near Gairloch, nine months after being burnt (P Cunningham)

3.3.4 Hydro-electricity

There are two hydro-electricity-related schemes within the River Broom catchment area.

Droma

The Hydro-electric Development (Scotland) Act of 1943 led to the development of large-scale hydro-power projects within Ross-shire. As part of the North of Scotland Hydro-Electric Board's Constructional Scheme No 16: Glascarnoch Luichart-Torr Achilty Project, waters from parts of the upper Droma catchment were diverted across the watershed from the Broom catchment into Loch Glascarnoch in the Connon catchment.

The Droma project was built around 1950 and is operated by Scottish and Southern Energy PLC (S&SE). When flows in the upper Droma rise above about 2 million gallons per day (0.105 m³/sec), water from the Allt Leacachain and Allt a'Mhadaidh over-spills into diversion pipes which transfer a proportion of the flow into Loch Droma reservoir and eastwards into Loch Glascarnoch.

Flows from approximately 21 km² of the River Droma catchment (total area about 44 km²) are impacted by the scheme. Flows in the lower Droma below the Falls of Measach may be reduced by as much as 40% at certain times. With respect to the mainstem Broom (downstream), normal spring and summer levels may be reduced by around 10%. Because of the limited flow capacity of the transfer pipes, the impact of the scheme on very large winter spates is relatively small.

There is a relatively small area of habitat accessible to salmon and sea trout within the lower River Droma below the Falls of Measach (see Part 5). Primarily because of this, the overall impact of the scheme upon juvenile salmon and trout production from the Broom catchment may be in the order of a 5–10% reduction in potential smolt output.

Cuileig

In 2002, S&SE completed work on the construction of the Cuileig gorge hydro-power scheme. In contrast to the Droma



Pipeline diverting water from Allt a' Mhadaidh to Loch Droma. Much of the water from a substantial part of the Droma catchment is directed to Loch Glascarnoch (P Cunningham)

project, this 'run of the river' hydro-power scheme does not involve the transfer of any water away from the Broom catchment; nor is the flow below the generating station changed – except, perhaps, in terms of certain water quality parameters (e.g. temperature, dissolved gas concentrations).

Above the Linn falls by the power station is a 1,500 m length of river extending to impassable falls in Cuileig Gorge that may have formerly supported production of juvenile salmon. In the past, a few salmon are said to have been able to ascend the Linn falls. The compensation flow below the intake is 0.31 m³/sec. Water is drawn into the power station only when flows exceed 0.81m³/sec because the minimum operating flow is 0.5 m³/sec. At full operation, the power station draws 3 m³/sec. Production of juvenile trout and salmon is unlikely to be altered significantly by the Cuileig Scheme.

- **Water entering the lower Linn pool from the power station should be monitored for levels of dissolved gasses and other parameters that may affect salmon. Salmon behaviour within and below this pool should also be monitored.**
- **Further analysis of the economics of developing alternative flow management regimes to enhance the productivity of Broom fisheries without loss of value to hydro-electricity generation (e.g. diversion, storage and removal of a larger proportion of autumn and winter flood water, release of higher summer compensation flows) may be worthwhile. There may be viable options for restricting the discharge of peak flows from Loch a'Bhraoin and Loch Droma (see Part 7).**

3.4 Water Quality

3.4.1 Freshwater Fish Directive

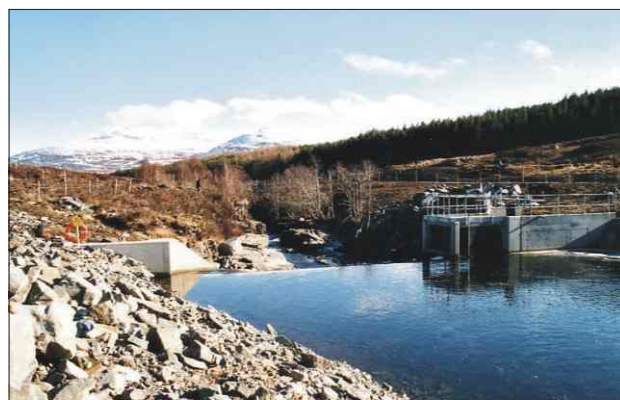
In 1976 the European Economic Community (now the European Union) introduced the Freshwater Fish Directive,

which aimed to establish 'quality requirements for waters capable of supporting freshwater fish'. Rivers were divided into salmonid or cyprinid water, and water quality standards were set for each using certain criteria (e.g. pH, temperature, pollutants). In Scotland, SEPA is responsible for monitoring water quality and for assessing whether rivers are attaining the standards set; if they are not, they must identify and rectify the pollution problem.

The River Broom was designated as a salmonid water under the Directive in 1977. An automatic gauging station is located by Inverbroom Bridge near Croftown which records river flow. Water samples are taken at monthly intervals and analysed by the Scottish Environment Protection Agency.

3.4.2 Scottish River Classification Scheme

In 1996 SEPA established a further water quality assessment, the Scottish River Classification Scheme. This takes into account invertebrate and water chemistry information to classify rivers from A to D, with rivers that are graded C and D requiring government action to improve water quality. The Broom was classified grade A, indicating that the catchment has no major pollution problems.



Power station intake above Cuileig gorge (P Cunningham)



Cuileig Power station. Loose sediment from below the power house was washed downstream into the Junction pool (P Cunningham, February 2002)

3.4.3 Nutrient status

There has been a gradual increase in recorded total phosphorus levels in the River Broom at Croftown during the past five years (Figure 3.5). This may relate to septic tank discharges from toilet facilities in Corrieshalloch Gorge and houses and farms situated within Strath More.

- **Further investigations may be required to explain the observed rise in Total phosphorus within the Broom, and whether there are any associated impacts (positive or negative) on production of juvenile trout and salmon.**

3.4.4 Water Frameworks Directive

At the time of writing, discussions are ongoing regarding future monitoring under the EU Water Frameworks Directive. After 2005, routine monitoring by the Scottish Environment Protection Agency (SEPA) is likely to include distributions and densities of both aquatic plants and aquatic animals in river systems and coastal waters.

3.5 Important species and habitats in the Broom catchment

3.5.1 Habitats Directive species

In 1992 the European Union set out to satisfy the requirements of the Biodiversity Convention signed at the Rio Earth Summit by introducing the Habitats & Species Directive. The prime purpose of the Directive was to establish Special Areas of Conservation (SACs) and Special Protected Areas (SPAs) for rare and endangered habitats or species. SNH are charged with establishing SACs and SPAs in Scotland, but also to promote the sensitive management of all listed species and habitats outside these conservation areas.

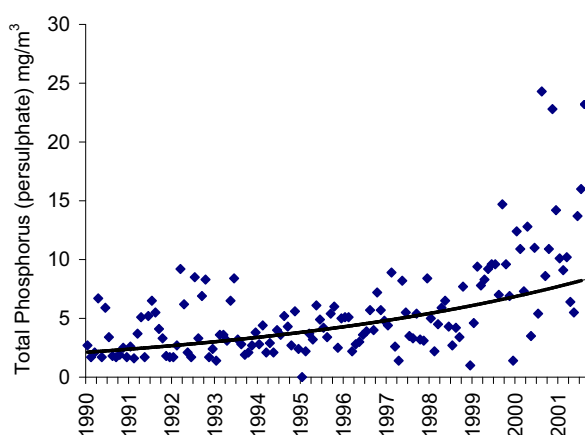


Figure 3.5 Phosphate levels in the Lower Broom have

At least 14 listed habitats and species occur within the Broom catchment, including the Atlantic salmon (Table 3.3). Four of these, alder woodland, otters, red-throated divers and black-throated divers would benefit directly from action to conserve the catchment's fish stocks and riverine habitats. Conversely, salmon and trout populations will benefit from many of the actions to conserve other listed habitats and species, especially those aimed at maintaining the natural fertility and productivity of the catchment area.

Table 3.3 Annex I habitats and Annex II species designated by the 1992 EU Habitats and Birds Directive that occur in the River Broom catchment

Annex I	Annex II
• Alpine pioneer formations of the <i>Caricion bicoloris-atrofuscae</i> • Blanket bogs • Caledonian forest • Species-rich <i>Nardus</i> grassland, on siliceous substrates in mountain areas (and submontane areas in continental Europe) • Alder woodland on flood plain	• Eurasian otter • Atlantic salmon • Red-throated diver • Black-throated diver • Golden eagle • Merlin • Peregrine • Dotterel • Golden plover

3.5.2 Protected Areas

Abbreviations

SSSI: Site of Special Scientific Interest (for sites of UK importance)

SAC: Special Area of Conservation (for sites of European importance, excluding birds)

SPA: Special Protection Area (for sites of European importance for birds)

c: candidate

The two largest protected areas partly within the Broom catchment (Figure 3.6) are Beinn Dearg (SSSI, SPA, and cSAC), and the Fannich Hills (SSSI).

Beinn Dearg is botanically the most outstanding mountain system in the Northern Highlands, and the third most diverse mountain system in Britain. The mountain supports a wide selection of special plant communities, and provides important habitat for other special wildlife. The Fannich Hills SSSI has close affinities with Beinn Dearg, but is slightly less varied with fewer calcium-loving plants.

Corrieshalloch Gorge SSSI has been described as the most outstanding gorge in the NW Highlands. The gorge supports important native flora, notably unusual Atlantic bryophytes. Nationally-rare invertebrates have also been found, of which some may be enjoyed by the more discerning trout or salmon

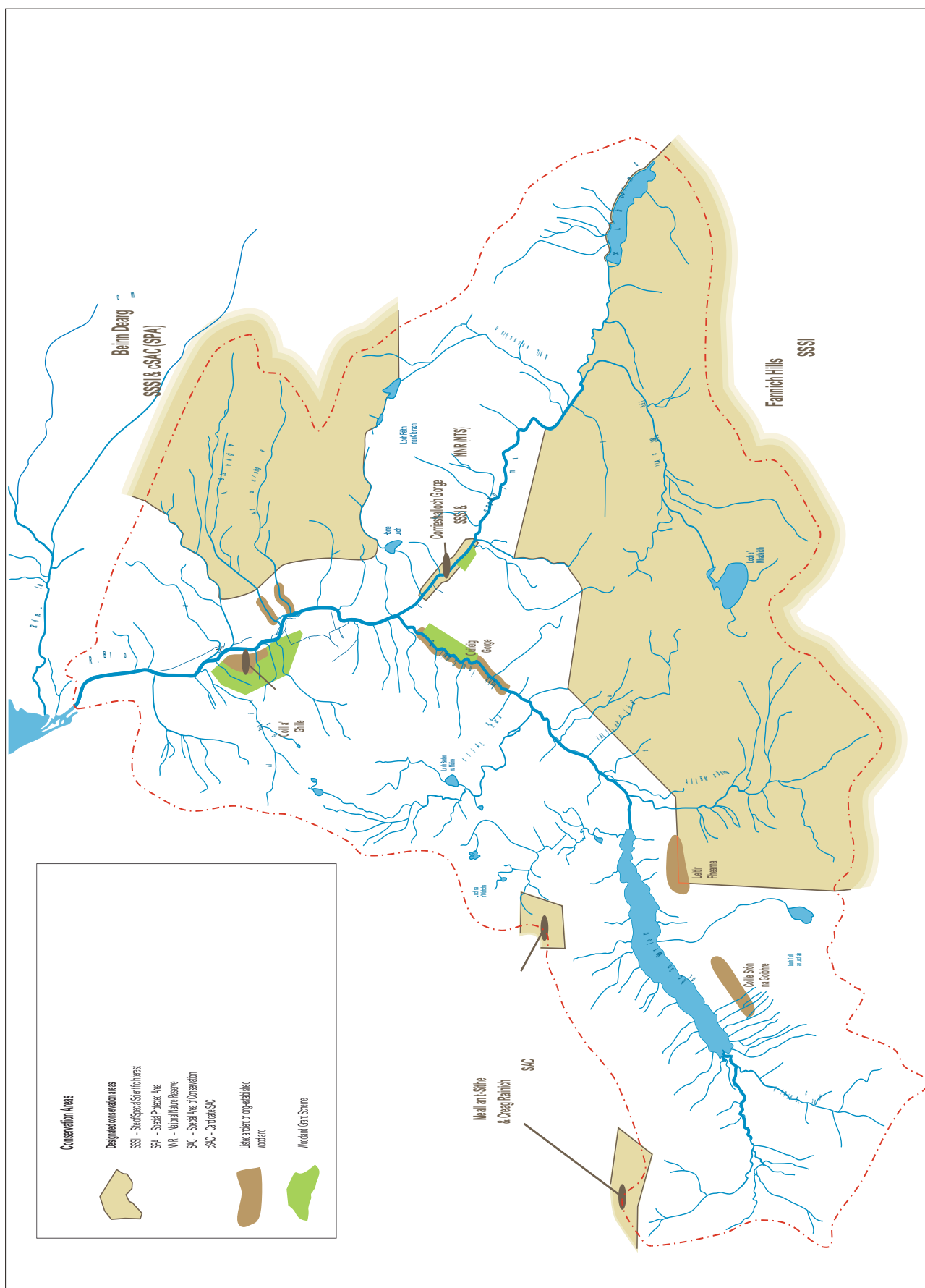


Figure 3.6 Large areas within the Broom Catchment are designated as protected areas. The conservation of upland plant communities and montane soils can help to imitigate against problems associated with rapid run-off of rain water, including acid flushes (Crown Copyright)

parr in the river below. The site was declared as a National Nature Reserve (NNR) in 1951.

Meall an t-Sithe has been designated as an SAC primarily for its geological interest.

3.5.3 Fish species

During the course of the surveys of juveniles carried out by the WRFT, four indigenous fish species were identified within the River Broom catchment: Atlantic salmon (*Salmo salar*), brown trout (*Salmo trutta*), European eel (*Anguilla anguilla*), and flounder (*Platichthys flesus*).

Salmon and sea trout (sea-going populations of brown trout) occur within the River Broom and accessible sections of tributary streams (see Part 5). Resident populations of brown trout exist throughout the catchment, including the hill lochs. European eels were found throughout Strath More during juvenile fish surveys, and were more common in the lower reaches.

Further details of salmon, trout and eel distributions are given in Part 6.

European Eel (*Anguilla anguilla*)

There is growing concern that eel numbers are declining in some parts of their range. In many respects, the life cycle of the eel is the opposite of that of the salmon. Eels spawn in the Sargasso Sea and *enter* freshwater at the age of 2 as elvers. They may remain and grow in fresh water for ten or twenty years before returning to the sea as mature adults. Although eels eat trout eggs, trout fry and parr, and large salmon parr eat small eels!

Many eels were found in the Broom during surveys. The size–frequency distribution of recorded eels from the August 2000 electro-fishing survey is shown in Figure 3.7. Eels were returned alive to the river and were not aged.

Small eels (less than 10 cm length) were recorded only from within the lowest 3 km of the river. Medium-sized eels (10–20 cm length) were most abundant within the middle reaches of Strath More. Larger eels (over 20 cm) were distributed throughout the length of the River Broom.

Elvers ascend rivers in the spring. The survey suggests that many of them remain within the lower part of the River Broom during their first spring/summer.

- **Further investigations are required to more fully understand the movements and habitat requirements of eels. Relationships between eels and trout, salmon and other species (e.g. predation, competition for food) also require further study.**

Brown trout (and Arctic charr, *Salvelinus alpinus*)



In autumn, silver eels migrate to the sea and begin their journeys to the Sargasso sea. Large eels may eat salmon eggs, fry and parr. However, trout may eat small eels (below) (J Butler; K Starr)



Loch a' Bhraoin is the largest loch within the Broom catchment and supports a population of land-locked brown trout of up to 500 g (1 lb+), with a few much larger fish. A fishing lodge on the shores of Loch a' Bhraoin formerly provided accommodation for two ghillies during the summer months. The fishing on Loch a' Bhraoin belongs to Inverbroom Estate. Large trout of over 4 kg have been taken from other hill lochs within the catchment area.

Scottish populations of land-locked charr originate from sea going charr populations at the end of the last period of glaciation. Although charr are present within many of the lochs to the north and south of the Broom catchment, they are not recorded within any of the apparently suitable lochs in the Broom catchment. Charr may have been unable to colonise

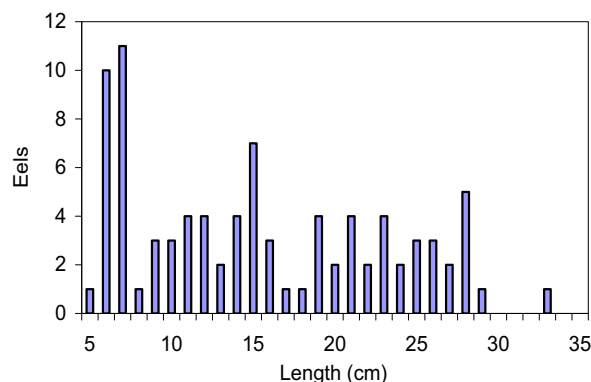


Figure 3.7 Size frequency of eels recorded during electro-fishing surveys along the Broom in August 2000

Lochs Bhraoin and Droma because of high impassable falls on the Cuileig and Droma rivers.

- **Further investigations are required to confirm that charr are absent from lochs within the Broom catchment. If their absence is confirmed, possible explanations could be included within an overall assessment of charr distribution within North-West Scotland.**

3.5.4 Other species

Birds

Dippers are resident along the Broom. Common sandpipers and grey wagtails are summer visitors; numbers of snipe and woodcock increase in the autumn.

These birds feed on invertebrates; aquatic insects are likely to be a major item in their diet.

- **Records of birds such as Dipper within the Broom catchment at different times of year provide an indication of aquatic insect abundance.**

Aquatic invertebrates

Most of the stream systems within Wester Ross are naturally oligotrophic (deficient in nutrients). Production of plants and animals tends to be limited by the availability of phosphorus. Aquatic invertebrates represent a major part of the diet of juvenile salmonids. Growth rates and production of juvenile salmon and trout within the River Broom are likely to relate to food availability.

- **WRFT has long-term plans to gather and collate data describing the distributions, densities and relative importance of aquatic insects within Wester Ross river catchments. Such data may be presented within a second**

generation of 5-year Fisheries Management Plans for Wester Ross river systems.

3.6 Salmon rod fishing rights

Rod fishings for migratory fish are divided between Inverbroom Estate (River Cuileig; River Broom left bank from Junction Pool to the March Pool), Church of Scotland (left bank, March Pool to the sea), Braemore Fishings (River Broom right bank Junction Pool to Auchindrean), Foich Estate (River Broom right bank from Auchindrean to Kennel Burn) and Inverlael Estate (River Broom right bank Kennel Burn to the sea).

The salmon and sea trout fisheries of the Broom are described in the next section.



Loch a' Bhraoin Lodge, with the fragmented woodlands of Leitir Fhearna on the slopes above the loch (P Cunningham)

Part 4

Salmon and Sea Trout Fisheries and Stocks

4.1 Introduction

Catch records provide an indication of changes in the abundance of both salmon and sea trout within the River Broom and Loch Broom over the past 50 years. They can also provide valuable information relating to the timing of fish runs into the river and of fish sizes, and provide a basis for adult stock assessments.

Salmon and sea trout are considered together in this section. This is for several reasons:

- The timings of changes in abundance of the two species can be compared.
- Some of the factors relating to changes in abundance may be common for both species.
- Interactions between trout and salmon may influence respective abundance (e.g. competition for spawning habitat, for juvenile habitat and for food).

Catch records have very kindly been provided by Inverbroom Estate (1995–2002), Braemore (1994–2001), Foich Estate (1963–2001) and Inverlael Estate (1968–2002) and by the Broom District Salmon Fishery Board. Unfortunately both estate and official records are somewhat patchy for certain periods. Fishing effort and record keeping (especially for catches of smaller sea trout) have clearly varied over the years. During the period 1997–2002, fishing effort appears to have been much reduced on some sections of the river. Therefore trends in catches may not have always closely followed those of the fish populations.

Both rod and net catches are considered. In some years the net catch was relatively high but the rod catch was low or vice versa, perhaps because of weather conditions, or changes in fishing effort. Some of the net-caught fish may have been destined for other rivers. Although records indicate that there have been several periods of relative abundance and relative scarcity for both sea trout and salmon during the past 50 years, catches of both salmon and sea trout in the Broom appear to have declined to their lowest levels during the 1990s. This apparent decline tallies with that of many of the other rivers within the area.

4.2 Salmon catches

Wild salmon

During the 1950s the combined (rod and net) recorded catches of salmon from the Broom district were between 50 and 150 fish per year (Figure 4.1). In most years, more fish were recorded in rod catches than in net catches. Recorded catches increased in 1960s and remained high until the late 1970s, when the net catch began to decline.

During the 1960s, 1970s and 1980s, the River Broom regularly provided in excess of 100 rod-caught salmon per year, with catches of 196 salmon to rods in 1963 and 163 in 1974. Recorded catches declined during the 1990s and have not exceeded 30 wild fish since 1997 (Figure 4.2).

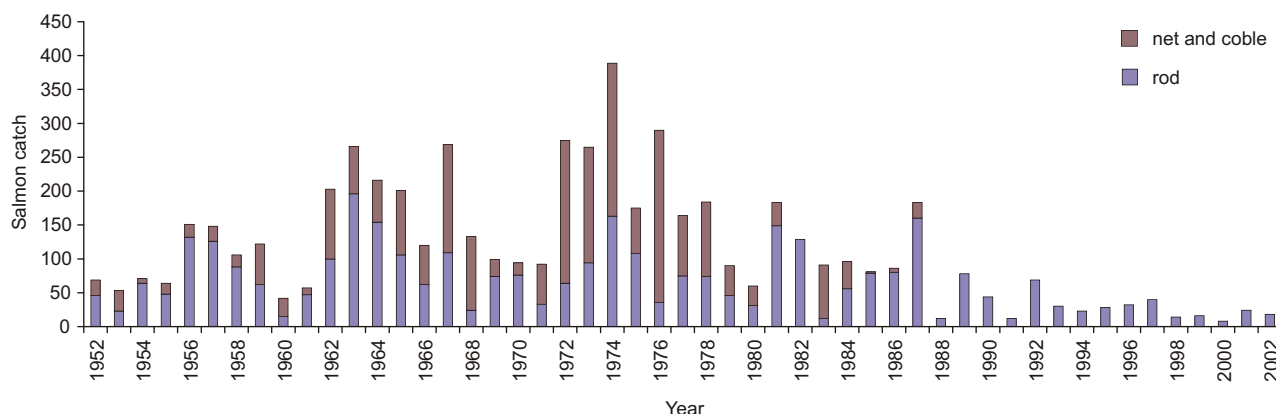


Figure 4.1 Recorded catches of 'wild' salmon in the River Broom and Loch Broom, 1952–2002

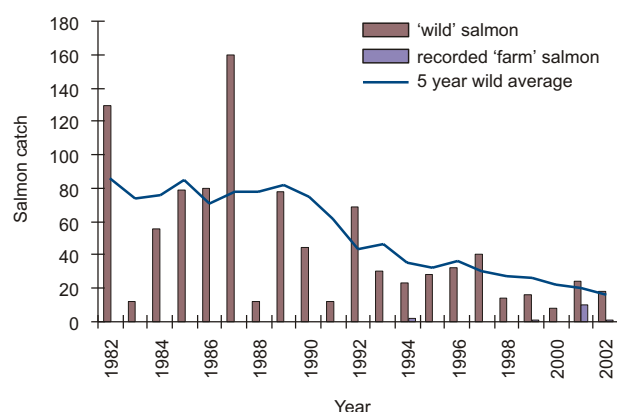


Figure 4.2 The total annual rod catch of salmon from the River Broom, 1973–2002. Catches of recorded 'farm' salmon are shown as a separate column. The five-year average is also shown. Based on Broom DSFB data

Escaped farm salmon

One escaped farm salmon was recorded in 1999 in the Broom rod catches, 10 were recorded in 2001 (Figure 4.2). Catch records for the River Broom for most years do not distinguish 'wild' from 'farmed' salmon. Therefore the overall extent to which farm salmon have occurred within the Broom over the past 20 years is largely unknown.

4.3 Freshwater (smolt) ages of Broom salmon



In 2001, over 30% of the Broom salmon catch was of escaped farm salmon (J Butler)

Scales collected during juvenile surveys suggests that the majority of Broom salmon spend two or three years in freshwater before going to sea as smolts (see Part 6). The two scales of adult Broom salmon examined were of grilse (1 Sea Winter salmon) that had gone to sea having spent two years in freshwater (i.e. 2 year old smolts).

- **To learn more about smolt and sea ages of Broom salmon, more scales of adult salmon should be collected. Escaped farm salmon can also be identified by scale reading. Scale packets can be provided by WRFT biologists**

Box 4.1: Escaped farm salmon

Farm salmon are selectively bred to perform well in captivity. They have been developed over several generations from a mixture of native salmon from British and Scandinavian rivers or from other origins. Escapes may occur during the freshwater or marine stage of the farm production cycle as a result of accidents or criminal damage. Escaped farm salmon are not always easily recognised and tend to be under-recorded in rod catches. Scale analysis may be required to confirm a farmed origin of rod-caught fish, especially if the salmon escaped as a parr or smolt.

Escaped farm salmon can spawn successfully in the wild. However, studies have shown that the rates of survival to adulthood of the progeny of farm salmon and of native x farm salmon hybrids can be much lower than for native wild fish. Escaped farm salmon that spawn in the wild may compromise the genetic integrity and fitness of native populations, and can reduce the productivity of salmon rivers.

- Whenever possible, anglers should try to differentiate between wild and escaped farm salmon. Guidance leaflets are available from WRFT. Identified farm salmon should not be returned to the water. Any scales that are displaced during capture or handling should be collected (scale packets are available from WRFT biologists); these can help to confirm the status of captured fish.

4.4 Salmon stock components and run timing

Two of the most detailed catch records for the Broom are those of Inverlael Estate and Foich Estate. During the period 1968–86 (inclusive), the lower part of the river was fished consistently by Mr Andy Bremner, Dr John Anthony, Dr Barrie Evans and Mr Morgan Whitteridge. From 1963, Mr A. MacKenzie and a succession of enthusiastic proprietors, their families and guests fished the middle section of the river.

The distribution of weights of wild salmon caught during the period 1977–1986 (Figure 4.3) suggests that the majority (60–70%) of Broom salmon had spent 1 winter at sea (i.e. 'grilse') and a minority (30–40%) had spent 2 or more winters at sea (i.e. 'salmon'). Catch records suggest that numbers and median sizes of Broom salmon have fallen over the past 30 years (Figure 4.4).

Scale samples from other nearby rivers show that the size cut-off between 'grilse' and 'salmon' is usually about 7.5 lb (3.4 kg). However, the average sizes of grilse tend to increase

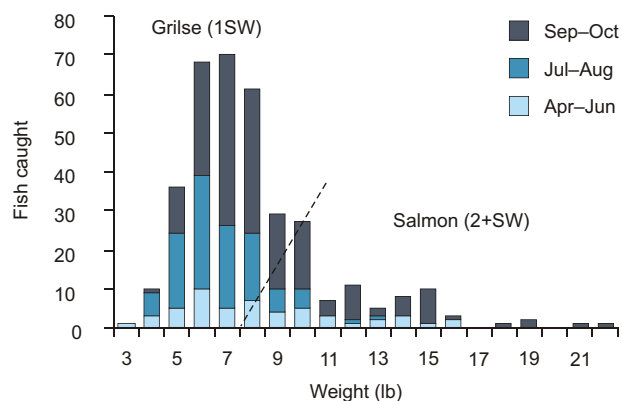


Figure 4.3 The weight distribution of salmon caught in the lower River Broom, lower river, right bank, 1970–2001

toward the autumn. Autumn grilse can be 9 lb or more in weight, having grown rapidly during the spring and summer prior to river entry. Autumn grilse are often as large as early running 2SW salmon that enter freshwater before the end of June.

A small proportion of Broom salmon enter the river before the end of May. In 1973, 16 out of the annual total of 30 salmon

taken by Inverlael rods were caught before the end of May, the earliest on 7 March. However, this appears to have been an exceptional year. More recently relatively few early fish have been taken. The largest catches of salmon are usually taken from July onwards. The largest fish are generally taken in September and October, and several fish of over 20 lb have been recorded during this period within the past decade. A cock fish of 25 lb from the Broom is recorded in the *Daily Record* of 23 June 1989. During the period 1867–1897, a salmon of 33 lb is recorded as having been taken.

4.4 Average size of River Broom salmon

The average weight of rod-caught Broom salmon declined from 3.5 kg or above (1960s–1980s) to nearer 3 kg in the 1990s. This may reflect changes in growth rates at sea, or simply changes in the relative proportions of 2SW fish to 1SW fish (Figure 4.5).

Box 4.2 Genetic basis for run timing?

The variability in apparent run timing of Broom salmon raises some interesting questions. Scientists remain uncertain of the extent to which, for Scottish west-coast rivers, run timing is predetermined by genetic factors. For some of the larger east-coast river systems, studies have shown that ‘early’ returning salmon and ‘late’ returning salmon represent distinct populations. For example, ‘spring’ salmon in the Aberdeenshire Dee head for the upper reaches of the river and spawn towards the end of October. ‘Autumn’ Dee salmon may spawn within 10km of the tide near Aberdeen in December or even early into the New Year. Eggs of spring salmon from the Dee and North Esk have been shown to be significantly larger than eggs from autumn salmon of similar size.

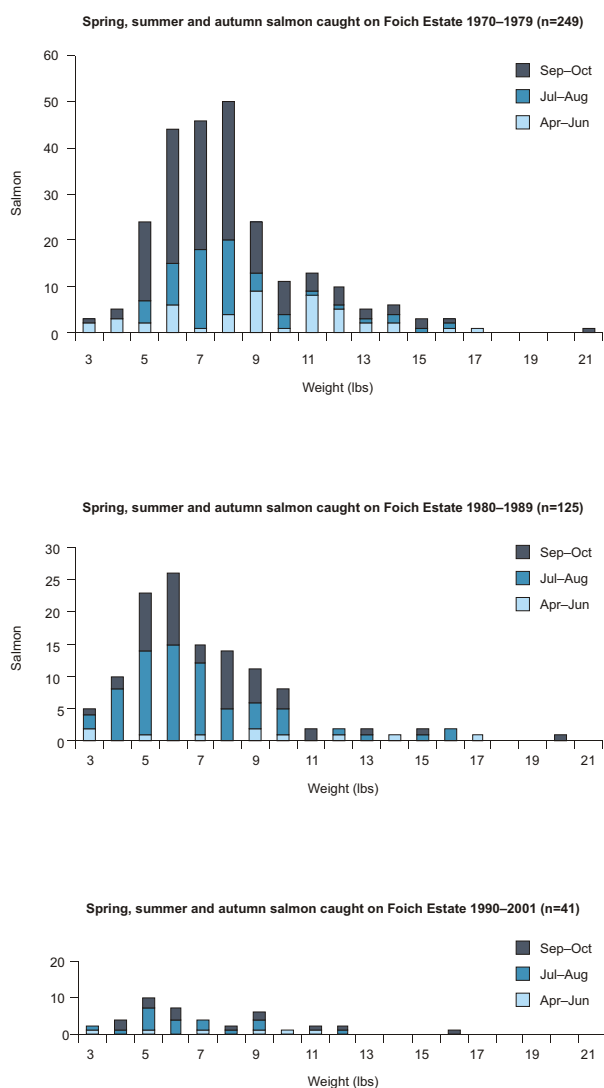
Could the same be true of Broom salmon? Are ‘early’ returning fish genetically distinct from ‘late’ returning fish? Perhaps less so than for the Dee, for the following reasons:

Firstly, the Broom is a spate river, and the timing of spates may vary considerably from year to year. At the population level, a more flexible strategy may be more successful in a less predictable environment. It may be advantageous for the progeny of a single family of fish to return over a range of

times during the season (rather than all at once). That way, at least some of the returning adults may arrive at the river mouth at the most opportune moment.

Secondly, because the Broom is such a short salmon river, a single male salmon may be able to fertilise eggs of both early and late running female entrants anywhere between the highest and lowest spawning areas. The level of genetic differentiation between early and late entering Broom fish is therefore likely to be somewhat less than for respective Dee or North Esk fish.

However, from the perspective of population restoration, it may still be safest to assume that like will tend to produce like. In other words, use early fish as broodstock to produce early fish, and late fish to produce late fish. Further research is required to find out more about whether run timing of Broom and other west-coast salmon is determined primarily by genes carried by the female, by the male, or by both parents – or indeed whether environmental cues play a major role.



Numbers of multi-sea-winter salmon may have declined disproportionately since the late 1980s (K Starr)

4.5 Sea trout catch

The combined (rod and net) recorded catches of sea trout from the River Broom and Loch Broom were usually of between 150 and 400 fish per year from the early 1950s until the early 1970s, when numbers declined (Figure 4.6). From the late 1950s to the early 1970s, proportions of recorded fish taken by rods and by nets were generally similar. From the early 1970s, the proportion of recorded fish taken by rods was larger. Netting ceased in the late 1980s.

Recorded catches of Broom sea trout were lower than at any time previously in 1978–80. Rod catches of sea trout recovered during the early 1980s, but then collapsed during the early 1990s to their lowest levels (Figure 4.7).

Figure 4.4 Catch records suggest that numbers and median sizes of River Broom salmon have fallen over the past 30 years (based on Foich catch records)

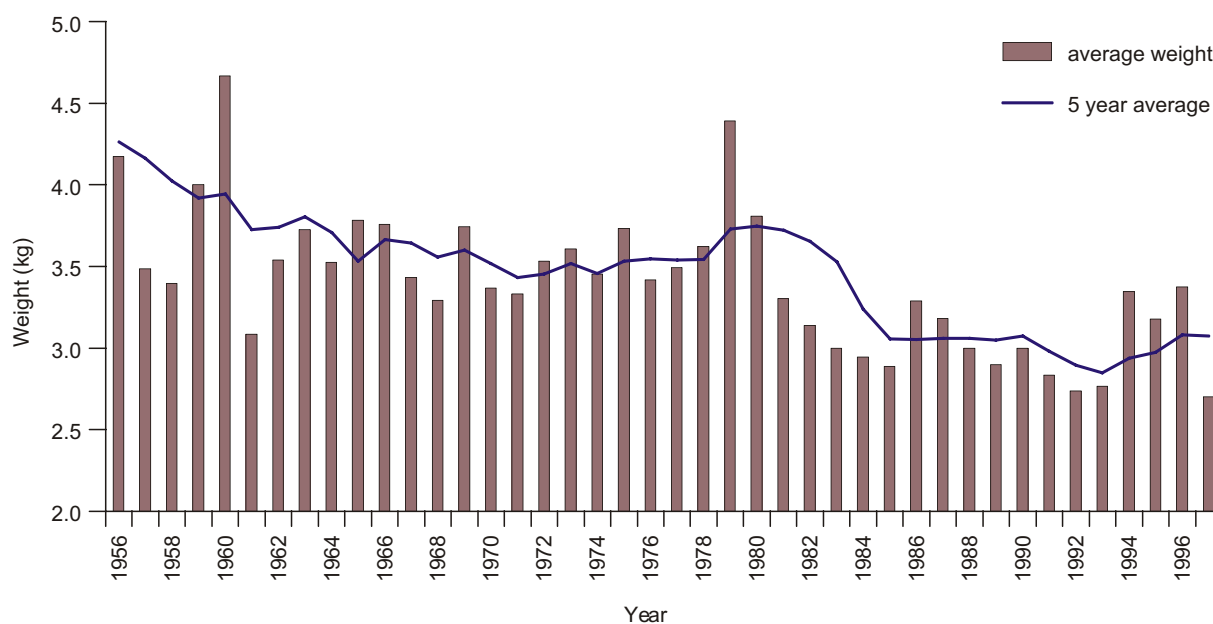


Figure 4.5 The average weight of rod-caught salmon and grilse, 1950–1997 (from SEERAD data)

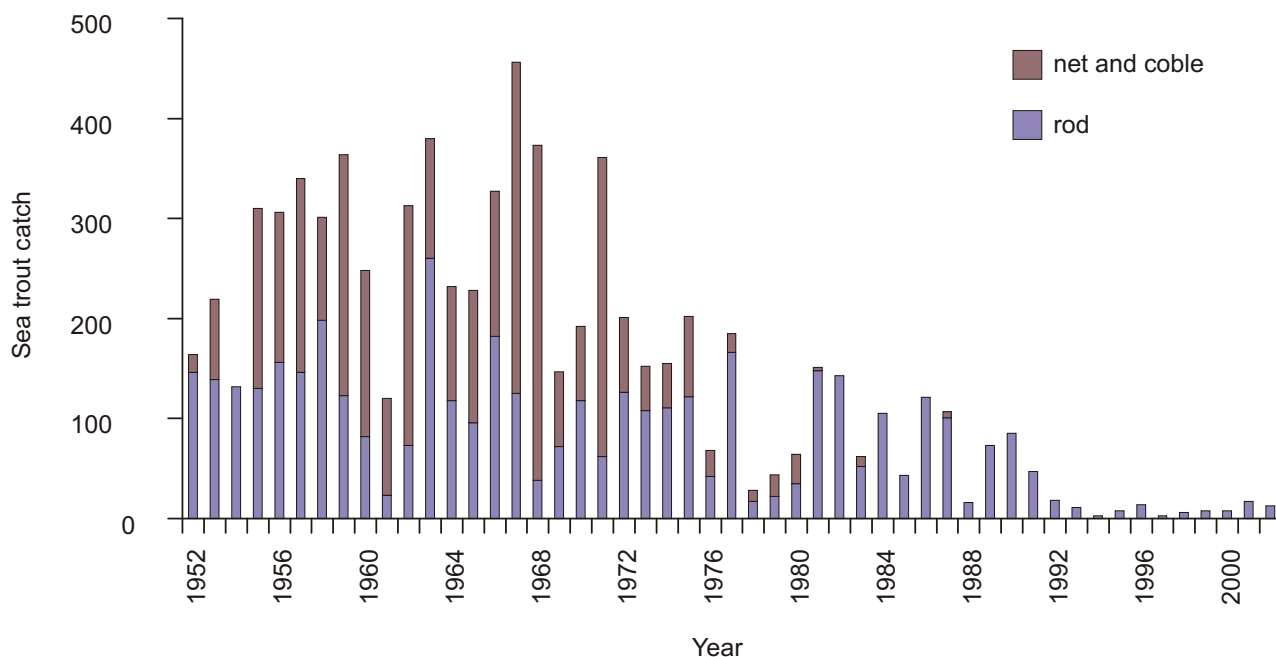


Figure 4.6 Recorded sea trout catches in the River Broom and Loch Broom, 1952–2002

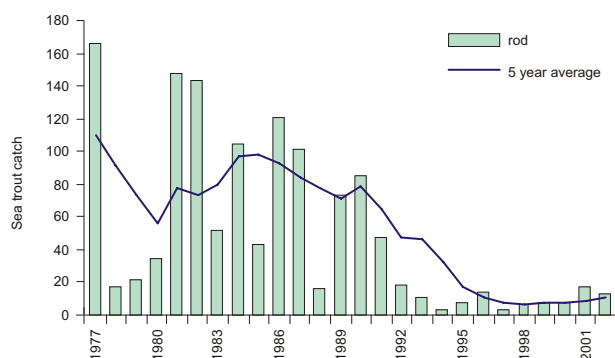


Figure 4.7 Recorded sea trout rod catches in the River Broom, 1977–2002

4.6 Sea trout run timing

During the period 1968–1986, sea trout were taken by rods fishing the lower River Broom from May to October. The largest number of sea trout were taken in September (Figure 4.8). This may partly be a reflection of fishing effort, targeted primarily at salmon. However it is also possible that maturing sea trout feed for a longer period during the summer prior to spawning.



The sea trout catch fell dramatically in the late 1970s, recovered partially during the 1980s, then collapsed in the early 1990s

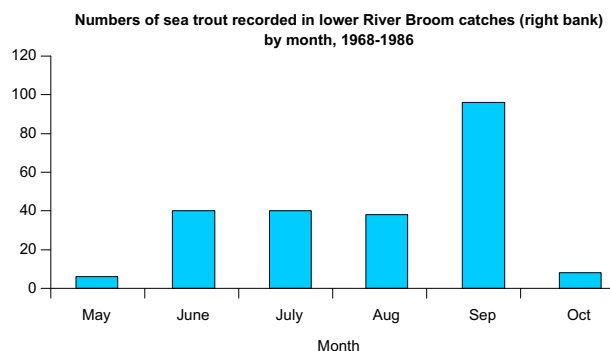


Figure 4.8 More sea trout were taken from the Broom by rods in September than in other months

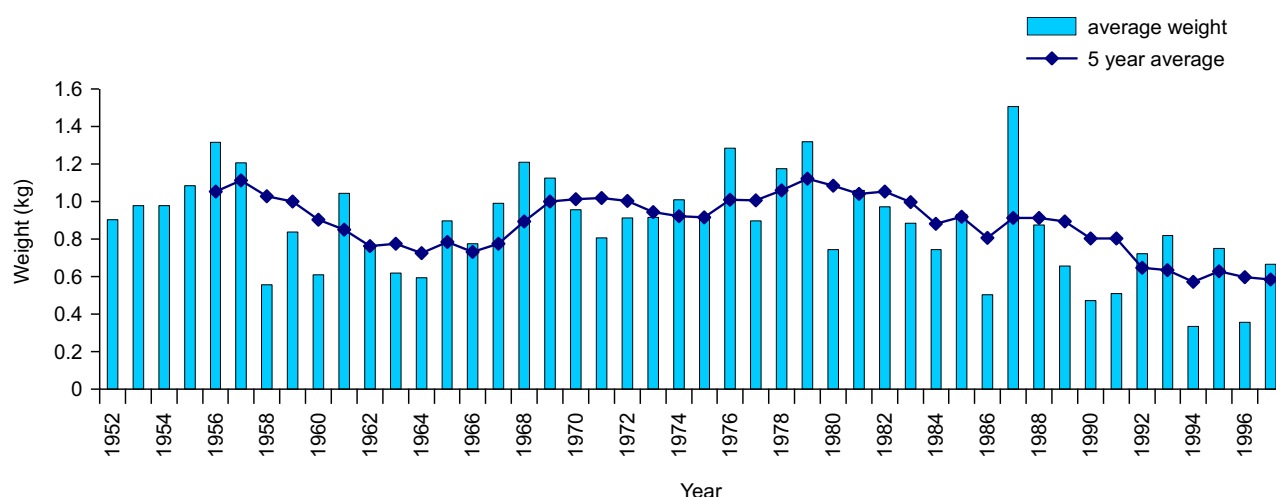


Figure 4.9 The average weight of rod-caught sea trout, 1952–1997 (from SEERAD data)

4.7 Sizes of Broom sea trout

The average weight of recorded rod-caught sea trout varied considerably during the period 1952–1997 (Figure 4.9). However, for some years during the 1990s average weights were lower than for any previous year. Assuming that fishing selectivity has been relatively constant over the years 1952–1997 (i.e. the same likelihood of capture of fish of different sizes during different periods), this decline probably corresponds to a reduction in the average size of adult sea trout returning to the river.

A similar decline has been observed elsewhere in Wester Ross, including Loch Maree catches. It has been explained in terms of reduced growth rates at sea and lower rates of survival (i.e. shorter average life span).

4.8 The decline of sea trout and salmon stocks in the Broom

Records suggest that during the past 50 years the catch of sea trout relative to salmon has changed (Figures 4.10 and 4.11). During the 1950s and 1960s, more sea trout than salmon were recorded in the combined net and rod catches from Loch Broom and the River Broom. However, from the early 1970s, the relative proportion of salmon was usually higher.

This may simply relate to changes in record keeping. Records of sea trout may be more complete for some periods than for other periods. Rod-caught sea trout of under 2 lb may have been returned by some anglers without being recorded. However, in *both* rod and net catch statistics from the early 1970s, a decline in the numbers of sea trout and relative increase in the numbers of salmon appears. An alternative explanation is that from the 1970s the Broom salmon population became more successful than the sea trout population.

A 6 lb (2.5 kg) Broom sea trout is likely to have already spawned 3 or 4 times and be 5 to 8 years old. In contrast, a 6 lb (2.5 kg) Broom grilse is likely to be only 3 years old. Sea trout may have been particularly vulnerable to legal (recorded) and illegal (unrecorded) coastal netting because of their relative longevity and tendency to remain within inshore waters. Peak sea trout catches recorded towards the end of the 1960s prior to the decline in the early 70s may also be an indication of over-exploitation of local sea trout stocks within the area at that time.

Ulcerative Dermal Necrosis (UDN) affected many west coast rivers particularly in the early 1970s. This may have also contributed to a disproportionate reduction in the biomass of spawning sea trout and sea trout egg deposition over subsequent years, as fewer sea trout survived to spawn a second or third time. More recently, the contrasting success of sea trout and salmon is likely to relate to further changes within the marine environment. Salmon migrate to distant feeding areas within the open ocean. By remaining within coastal waters, sea trout are more likely to be affected by changes in the abundance of inshore prey species, inshore predator abundance and, since the mid-1980s, by sea lice epizootics associated with salmon farming. On the other hand, salmon may be more vulnerable to capture as by-catch, for example in the Norwegian Sea mackerel fishery, and to genetic intro- gression via hybridisation with escaped farm salmon.

Large adult sea trout and salmon have partially overlapping spawning habitat requirements. Within the Broom they may have spawned in the same areas. Compared to other rivers, the Broom is rather unusual in that over 80% of the accessible spawning habitat is within the main river, much of it suitable only for larger fish, normally salmon. When older sea trout were common, trout egg deposition within the main river may have been higher, with many trout eggs being buried relatively deeply by larger female sea trout.

Investigations by WRFT indicated that spawning habitat in the Broom may be vulnerable to redd washout as a result of more

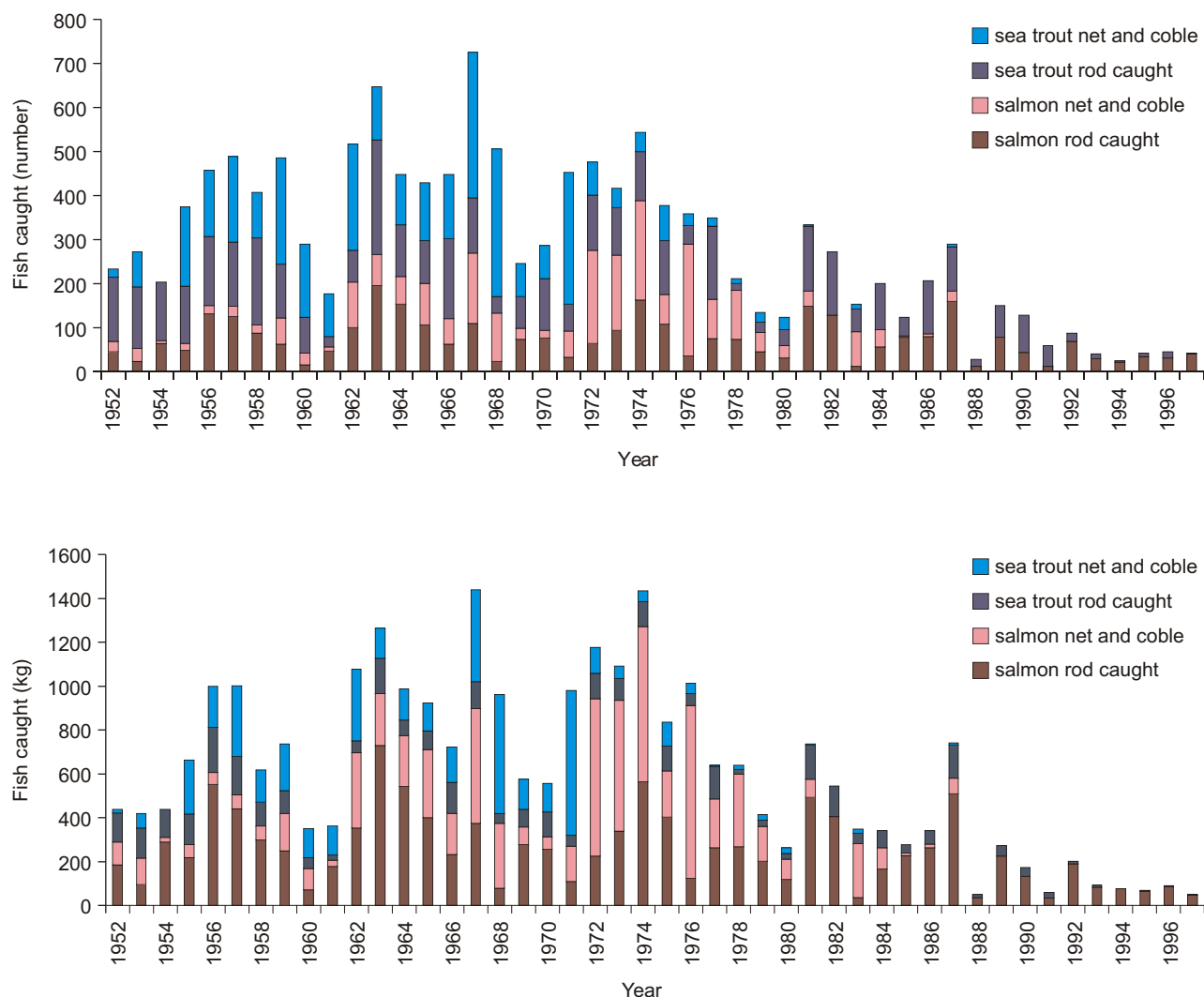


Figure 4.10 Catches of salmon and sea trout in the River Broom and Loch Broom, 1952–1997 (all methods), by number (above) and biomass (below). The biomass of adult salmonid returning to the river system may have fallen from over 1 tonne per year to less than 100 kg per year. Although trout eggs are slightly smaller than salmon eggs, changes in the relative numbers of eggs deposited annually within the system are likely to most closely correlate to the biomass (rather than numbers) of adults of respective species returning to the system

intensive spate events associated with climatic change (see Part 5 and Appendix 2). This may also have impacted disproportionately upon sea trout recruitment. Trout bury eggs less deeply and in gravel of smaller clast diameter than salmon because of their smaller size. Trout redds would therefore be more vulnerable to redd washout.

The decline in sea trout from the early 1970s would have led to a reduction in trout egg deposition relative to salmon egg deposition. In turn, the reduction in sea trout egg deposition within the main river may have led to increased habitat availability and food supply for juvenile salmon. To an extent, juvenile salmon and trout compete for territory and for food. Where both species are present, trout tend to be more aggressive and to dominate where the current is slower (juvenile salmon and trout production are considered in Part

6). It is therefore possible that the production of juvenile salmon subsequently increased as a response to reduced competition from progeny of sea trout.

- **Records of observation of spawning salmon and sea trout can provide information from which spawning areas and spawning requirements (in terms of flow, gravel characteristic, water temperature, etc.) of each species within the system can be defined.**

4.9 Restocking

WRFT has obtained few details of past restocking.

In February 1998, a meeting was held between Wester Ross Fisheries Trust, Wester Ross Salmon (WRS) and riparian

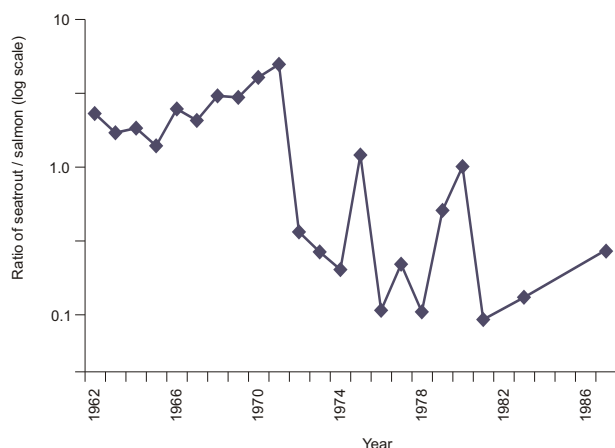


Figure 4.11 Ratio of sea trout to salmon in recorded net catches for Loch Broom

owners or their representatives for the Ullapool and Broom Rivers to investigate possibilities of setting up a hatchery and captive broodstock facilities for the two rivers. In 2002 WRS again offered to help set up a hatchery facility if asked to do so. Following resolution of some of the problems relating to poor marine survival (e.g. sea lice epizootics), restocking programs may help to speed up the recovery particularly of the sea trout population.

FRS Marine Cultivation unit at Aultbea has also helped with restocking work. Early in 2002 approximately 20,000 Broom eggs were being incubated at the facility.

4.10 Catch and release

Studies in other river systems have shown that, of the total number of adult salmon that enter a river, the proportion taken by rod and line may vary between 5% and about 50%. Fish that enter the river earlier in the season tend to be more vulnerable than those that enter later in the year. In one study on the Welsh River Dee, 40% of salmon that entered from the sea before the end of May were taken by rods.

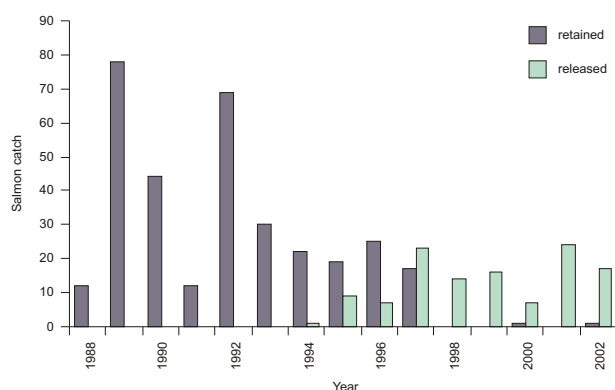


Figure 4.12 Retained and released salmon caught by rod on the River Broom



The return of rod-caught salmon and sea trout, especially females, will hasten recovery of respective populations (J Butler)

Radio-tracking studies have shown that more than 50% of rod-caught salmon, if handled correctly following capture and carefully released back into the river, can survive to spawn. 'Catch and release' is recommended by NASCO (North Atlantic Salmon Conservation Organisation). Over the past few years anglers fishing the Broom have been encouraged to release all salmon and sea trout except escaped farm fish, and most salmon are now released (Figure 4.12). This policy should be continued until stocks have recovered.

4.11 Conclusions

- During the period 1952–2000 recorded rod and net catches of salmon and sea trout have fluctuated widely. Catches (combined net and rod) of sea trout were highest during the 1960s, and catches of salmon were at their highest during the early 1970s. Although there were good rod catches of both salmon and sea trout for some years during the 1980s, catches of both species fell to their lowest levels during the 1990s.

- It is likely that the majority of Broom salmon go to sea after two years in freshwater (S2 smolts) and a minority after three or more years. Rod catches suggest that a majority of Broom salmon return as 'grilse', after spending one winter at sea (1SW salmon). Although most Broom salmon enter freshwater between July and September (inclusive), fish may enter the river from as early as March to as late as October.
- Rod catches indicate that most sea trout enter the Broom in June–September (inclusive). The average recorded size of sea trout has generally varied from between 0.7 kg and 1.7 kg. In the late 1990s, the average recorded sea trout weight of about 0.5 kg in some years, was less than at any other time since the 1950s. This suggests that few sea trout were surviving to spawn a second time.
- The decline in sea trout from the late 1960s is most likely to be related to changes in conditions within coastal areas and to the UDN outbreak in the early 1970s. Juvenile salmon may have been able to occupy some of the habitat and to exploit some of the food resources formerly taken by juvenile trout, and this may partly explain the increase in the proportion of salmon relative to sea trout caught during the mid-1970s.
- The collapse of both species during the late 1980s and 1990s tallies with the expansion of salmon farming within the area. Sea lice epizootics emanating from salmon farms are likely to have affected sea trout to a greater extent than salmon. The salmon population would have been particularly vulnerable to genetic introgression via hybridisation with escaped farm salmon owing to the small size of the population and the relatively confined and easily accessible area for salmon within the River Broom.
- Until stocks recover, the policy of catch and release of salmon and sea trout should be continued wherever possible. Wild fisheries interests should work together with other stakeholders to restore more favourable conditions for wild fish within coastal areas.

Part 5

The Freshwater Habitat

5.1 Introduction

The main objective of the Fishery Management Plan is to maximise the natural output of juvenile salmon and trout from the river. This part of the fishes' life cycle is within the riparian owners' control, whereas marine factors largely are not. This approach is also justified by the fact that the number of returning adults will generally depend upon the number of smolts produced by the river, which in turn is governed by the numbers of parr the river can support. This section assesses the characteristics of the River Broom in terms of current and potential freshwater production. In doing so, factors that may limit juvenile production are identified.

5.2 Accessible area

A primary aim of the habitat survey was to identify the area of water accessible to salmon and sea trout. This involved the mapping of obstacles such as natural falls and man-made



Salmon and sea trout in the River Broom are confined by water falls to Strath More, shown above (Ullapool Museum)



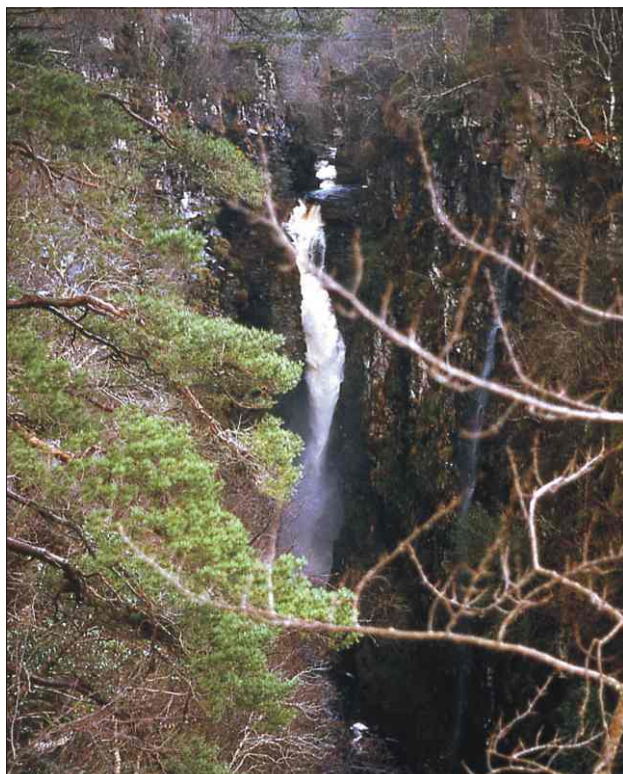
The 'Linn' Abhainn Cuileig. Salmon are said to sometimes be able to ascend the falls and continue upstream to an impassable fall in Cuileig Gorge (WRFT)

obstructions. Electro-fishing surveys were sometimes carried out above obstacles to determine whether or not juvenile salmon were present. If not, it was assumed that the obstacle was probably impassable to both salmon and trout migrating upstream.

The River Broom is accessible all the way up to the confluence of the Abhainn Cuileig and the Abhainn Droma by Braemore (Figure 5.1). However, the Abhainn Cuileig is normally passable to adult salmon for only 400 m above the junction pool to the Linn Pool. A few salmon are said to negotiate the 3 m "Linn" at high flows, continuing as far as an 8 m fall in Cuileig Gorge, a further 1,500 m upstream. The Abhainn Droma is accessible to the 35 m high Falls of



Falls in Cuileig Gorge are impassable to salmon and sea trout (WRFT)



The Falls of Measach, Corrieshalloch Gorge. The gorge supports important native plant and insect species. Efforts by the National Trust for Scotland are ongoing to control non-native plants within the gorge (J Butler; Ross Gardiner)

Measach in Corrieshalloch Gorge, 1,500 m above the Junction Pool. For salmon and sea trout, most of the tributary streams that join the River Broom in Strath More are accessible for only a few hundred metres from the river, to natural waterfalls. However, an unnamed drainage ditch by the side of the A 835 (T) and the Auchlunachan burn may be passable to adult salmon and sea trout for more than 1 km during high flows.

The accessible area of the catchment is shown in Table 5.1. All of this is riverine habitat, of which the River Broom mainstem constitutes 77%. The most important tributaries by area are the Abhainn Droma and Abhainn Cuileig.

Table 5.1 River and loch area naturally accessible to salmon and sea trout in the Broom catchment

Water body	Accessible (m ²)	Proportion (%)
River Broom mainstem	120,210	76.8
Abhainn Droma	14,350	9.2
Abhainn Cuileig	13,850	8.9
L'Foich' ditch by A935	2,575	1.6
Allt Ach'-Ghlaineachain	2,050	1.3
Other tributaries	3,325	2.1
Total	156,360	

Note: Allt Glac Odhar, Allt a' Gharbhain and Allt Cuil an Droighinn dry up in summer so not included.

5.3 Salmon and sea trout habitat

5.3.1 Habitat origin

An important feature of the accessible part of the Broom system is that much of the course of the main river and many of the burns in Strath More have been altered by man.

Until the 19th century, the channel of the Broom periodically shifted across the floodplain. During the late 19th century, Sir John Fowler (designer of the Forth Bridge) reclaimed large parts of Strath More for farming by constructing a network of drains, ditches and embankments. A series of 1–3 m high cobble embankments protect farmland from flooding and confine the River Broom within its present channel. River banks are protected from erosion by rock armoring (typically of large limestone boulders from Ullapool Quarry).

Tributary burns and drainage ditches have also been routed to limit flooding and waterlogging of soils. When the A835 (T) was built by the Department of Transport, tributaries entering the Broom valley from the east were rerouted. One of these, the Allt Glac Odhar (Glackour Burn), has been channeled over

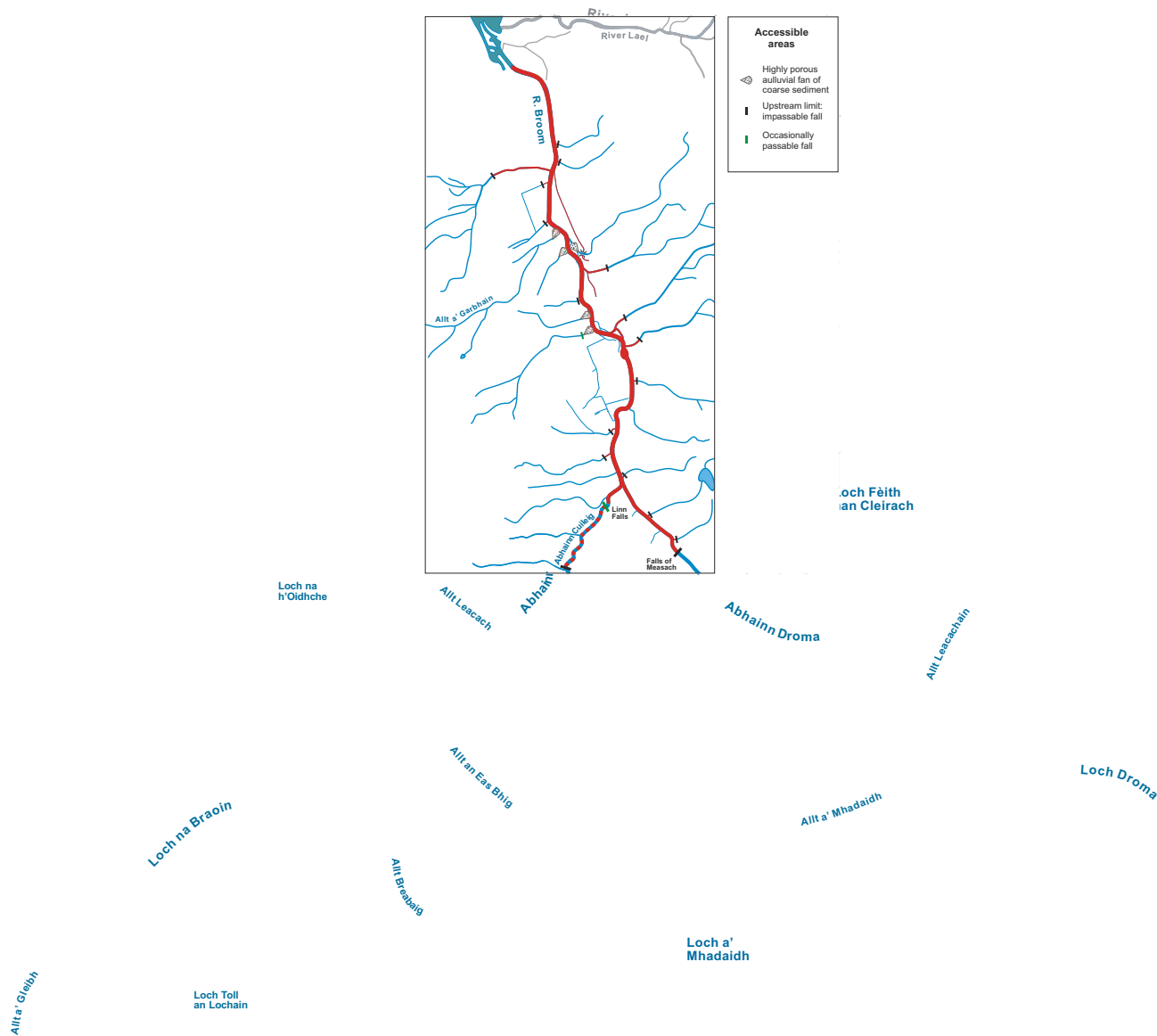


Figure 5.1 Areas accessible to salmon and sea trout within the River Broom system (Crown Copyright)



Auchindrean Bridge, built by Sir John Fowler. The river here provides good habitat for salmon parr, and has been electro-fished most years since 1993 by Ross Gardiner of Fisheries Research Services (J Butler)

the unnamed drainage ditch that runs alongside the A935 (T) by 'Foich'. Much of the water in the Allt Glac Odhar appears to filter into this drainage ditch.

5.3.2 Stream characteristics

The gradient of the River Broom varies from 1 in 70 to 1 in 100 in the upper reaches around Braemore to 1 in 250 in the lower reaches around Inverbroom. The channel width varies from 8–22m, becoming wider on average towards the sea. Current speeds therefore tend to be greatest toward the top of the river. Around Braemore, the river bed is mainly composed of irregular, poorly rounded pebbles, cobbles and boulders (diameter 6–40 cm); towards the river mouth most of the streambed is of finer particles (diameter 2–10 cm).

Tributary streams (particularly Allt a' Braighe, Allt Cuil an Droighinn and Allt Glac Odhar) drop steeply into Strath More from valley sides discharging large quantities of poorly sorted sediment, originating from hillside erosion. Much of this material settles within the channel of the Broom. In some places, this may be raising the level of the river bed above that of surrounding farmland land.



Allt Glac Odhar 'aquaduct' over Foich roadside ditch. During dry periods, most of the water in the Glac Odhar burn percolates through the stream bed into the Foich ditch (P Cunningham)

- Reducing erosion within the catchment is a key requirement towards river bed stabilisation and higher levels of fisheries productivity (see 'Redd washout', section 5.5.2 below).

5.4 Juvenile salmon and trout habitat

The accessible area of the Broom is entirely riverine habitat and is therefore better suited to juvenile salmon than to trout. Some 71% of the overall accessible area consists of riffles, runs and glides over boulders or cobbles, and is therefore ideal for salmon parr. There are few deep pools to provide shelter for adult fish in low flows and for parr and pre-smolts in winter. Burn mouths and flooded backwaters may provide alternative winter refuge for parr. However, the extent to which parr utilise such areas in winter, rather than trying to seek cover in the river bed under stones, is not known.

Most trout inhabit smaller tributaries and deeper pools. The 'Foich' roadside ditch is potentially the most important tributary because of its length, gentle gradient and relatively even flow. Other drains and backwaters may provide habitat for trout parr; and for salmon parr during periods of high flow in the winter.

5.5 Spawning habitat and redd washout

5.5.1 Spawning habitat

The principle salmon and trout spawning areas within the accessible area of the catchment are shown in Figure 5.2. A feature of the Broom is that most (90%) of the spawning habitat within the accessible area is within the mainstem and limited to the lower part of the main river. With the exception of small areas below the junction pool and in the Abhainn Droma, the upper 3 km of the accessible area has no spawning habitat. There are small areas of spawning gravel in some of the tributaries but, like the mainstem, these are mostly highly unstable and prone to bed movement during spates (Table 5.2). The habitat survey, carried out in 1998, concluded that 89% of the accessible river bed was extremely unstable.



The Junction Pool, confluence of Abhainn Droma and Abhainn Cuileig. Densities of salmon and trout fry at sites above this pool are consistently low. However, higher densities of salmon parr suggest that some juvenile salmon may move upstream to colonise these areas as they grow (P Cunningham)



Much of the stream bed of the Upper Broom is composed of cobbles and boulders: excellent salmon parr habitat, but largely unsuitable for spawning fish (P Cunningham)

5.5.2 Redd washout

Weather patterns may be changing on the west coast of Scotland. Compared with the 1970s, winters are becoming wetter, with more frequent and larger spates. Long-term SEPA flow data from the River Ewe confirms that the trend is occurring in Wester Ross, and the 1999–2000 winter was the wettest on record. By comparison, however, the 2000–2001 winter was one of the driest (Figure 5.3).

As a result of the greater frequency and size of spates, ‘redd washout’ has become a problem in the more unstable rivers. Detailed studies in collaboration with FRS and SEPA on the River Broom suggest that the greatest damage occurs in March, when eggs are hatching. Any spate larger than 80 cumecs in this month is likely to cause river bed movement

(bedload sediment transportation) capable of killing the emerging alyns, and limiting the number of smolts produced. Despite the unstable nature of the river, and the evidence of erosion and bank collapse, siltation is not a major problem

by that year class. Spates of this magnitude occurred in March 1990, 1999 and 2000 and corresponded with relatively low fry densities. Fry, parr and pre-smolts may also be vulnerable to being washed out of the river at very high turbid winter flows.

Redd washout may be one of the main factors limiting the production of juvenile salmon and sea trout within the River Broom system. For this reason, a series of management actions are suggested in Part 7 to address this problem.

Further details of this study are provided in Appendix 2 (the Redd washout study report).

within the accessible part of the Broom. This is largely a result of the highly mobile nature of the streambed: silt and sand



The Foich roadside ditch is potentially an important spawning and nursery tributary for trout. Where alders have been cut back from the water's edge, more light reaches the stream, and growth of algae (a food source for mayfly larvae) is higher (P Cunningham)



Extensive areas of gravel suitable for salmon spawning are located below the mouth of the Allt a Bhraighe. However, movements of gravel in large spates may limit production of fry in some years (P Cunningham)

Figure 5.2 Location of principle spawning areas within the Broom system (Crown Copyright)

Table 5.2 The distribution of spawning habitat in the accessible area of the Broom catchment, listed in order of the tributary's importance. Also given is the proportion of spawning in each section considered to be unstable.

Section	Spawning habitat (m ²)				Proportion unstable
	Trout (gravel)	Salmon/trout (pebbles)	Salmon (pebbles/cobbles)	Total	
River Broom	112	1110	1907	3129	100%
Allt 'Mhuilin	2	100	22	124	0%
'Foich' roadside ditch	30	85	0	115	0%
Allt na h-Ighine	5	23	30	58	100%
Allt A'Bhraige	20	6	2	28	53%
Ach-Ghlaineachain	3	0	4	7	100%
Abhainn Cuileig	2	0	0	2	77%
Abhainn Droma	0	0	2	2	26%
TOTAL AREA:	174	1324	1967	3465	89%

Note: Allt Glac Odhar, Allt a' Gharbhain and Allt Cuil an Droighinn dry up in summer, and are not included

particles are winnowed out by winter spates. However, potentially suitable spawning areas along some of the quieter backwaters and the Foich roadside ditch are prone to siltation. On the east side of Strath More, great care needs to be taken to ensure that forestry operations in the Lael Forest do not lead to the discharge of excessive amounts of silt. 'Puddling' by cattle on the west side of Strath More may also increase the discharge of silt in some places.

Recommendations aimed at addressing these issues are outlined in Part 7.

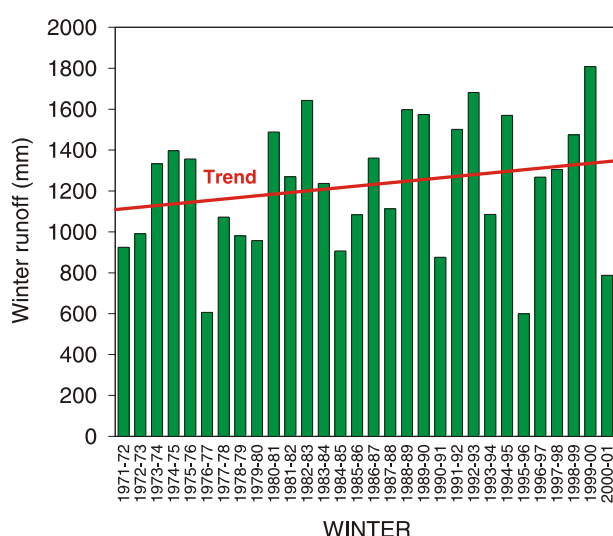


Figure 5.3 Total winter runoff (November–March inclusive) in the River Ewe catchment, 1971–1972 to 2000–2001. Data kindly provided by SEPA

5.6 Pollution and acidification

5.6.1 Pollution

SEPA's EU Freshwater Fisheries Directive sampling record no major problems with pollution within the catchment. However, anecdotal information indicates that in the past there may have been problems associated with the discharge of cattle slurry and sheep dip residues. Suffice is to say that great care should always be taken to ensure that residues from farming operations do not enter water courses, either directly or in run-off following heavy rain fall.

There is recollection locally of a cyanide poisoning incident within the River Broom during the 1970s which is said to have caused the mortality of large numbers of salmon and trout. The nearby Ullapool River is also said to have been targeted in this way at the same time.

- All pollution incidents should be initially reported to SEPA as quickly as possible to ensure that appropriate precautions can be taken and a full report prepared. WRFT may be able to assist with the recovery of any salmon and sea trout.

5.6.2 Acidification

The majority of the Broom catchment's geology is mildly acidic. Although water flowing off such rock is also naturally acidic, it does not harm the fish because of the buffering effect of dissolved organic matter carried in the water. However, the amount of organic matter naturally decreases in winter months, and becomes even more diluted during spates. Consequently if a burn has a high acidity (i.e. low pH), it will pose a threat to fish during winter spates. Eggs are the most prone to mortality from acidity, and salmon are more vulnerable than trout.

Burns that are potentially sensitive to winter acidification are those that drain high ground with little vegetation and a naturally acidic geology. Those downstream from large lochs tend to be protected from high acidity because still water acts as a natural 'sink' for acid events. In the winter of 1997–98, water samples were taken from three sites within the Broom catchment and a fourth site in the River Lael and tested for their acid sensitivity. Although pH levels dropped and the water became more acidic as the flows increased, none of the sites were considered to be acid sensitive.

5.7 Bankside Vegetation

5.7.1 Native trees and shrubs

Bankside vegetation has several important functions in the freshwater production of juvenile salmon and trout. Deciduous leaf litter fertilises the stream, providing vital organic input which in turn enhances aquatic insect life, and thus food for young fish. Terrestrial insects falling onto the water from bankside vegetation also provide an additional food source for fish, particularly during the latter part of the summer. Alders and some willows are generally regarded as being particularly valuable for riparian areas. Their roots and limbs provide shade and cover for parr, and also reinforce banks and limit erosion and collapse.

However, excessive shading can restrict the growth of aquatic algae and other plants upon which some mayfly larvae and other species of aquatic invertebrate feed. Therefore, a mixture of open (especially riffles) and shaded (especially pools) areas is usually considered to provide the best combination of habitats for production of juvenile salmon and trout.



The highest densities of salmon fry are usually recorded in the lower part of the river at Inverbroom Bridge (P Cunningham)

5.7.2 Non-native plants

Japanese knotweed is well established in many places along river banks and stream ditches in Strath More. *Rhododendron ponticum* is widespread within the catchment and grows along river banks in several places. These plants can create dense shade and prevent the growth of more desirable plant species within the water and in the riparian zone. Leaves of rhododendrons contain toxic phenols, and may adversely impact upon biological productivity if allowed to spread.

5.8 Freshwater and estuary predation of juvenile salmon and trout

Juvenile salmon, trout and eels are a natural part of the diet of red-breasted merganser, goosander, cormorant and heron. So long as densities of juvenile salmonids are near the carrying capacity of the system, the impact of bird predation on smolt production is likely to be minimal. A river can support only a finite number of fish. Under normal conditions, the growth of juvenile fish exceeds the available food supply and habitat space within the river. Surpluses of fry and parr are produced as weaker individuals are out-competed by faster-growing stronger individuals. Weaker fish are displaced from areas of prime habitat – providing food for predators.

However, where the carrying capacity of the system has not been reached, predation may be a problem. Furthermore, studies on the River Dee have indicated that migrating smolts may be particularly vulnerable to predation by mergansers as they head towards the sea. Although it is again likely that the smaller, weaker smolts are most vulnerable, the full extent of predation has been difficult to judge.

The RSPB can advise on protocols for monitoring numbers of fish-eating birds. Licences to shoot mergansers may be obtained from the Scottish Executive by salmon fishery boards if there is good reason to believe a problem exists. Where predation by seals is considered to be a problem, a variation on the employees' firearms licence may be obtained to enable seals to be shot in season.

5.9 Conclusions

- **The Broom river system has been altered by hydro-power developments, forestry, grazing pressures, muir-burn and within Strath More by drainage from roads, farms and houses and by confinement between artificial embankments. Nevertheless the accessible area to salmon and sea trout, comprising 156,360 m² of riverine habitat, provides prime habitat for trout and particularly for juvenile salmon and remains in a healthy state.**
- **By area, 76% of the available in-stream habitat for juvenile salmon and sea trout and 90% of the available spawning**

Table 5.4 Accessible parts of Broom system with overhanging trees (1998)

Watercourse	Accessible area (m ²)	Area covered (m ²)	%
River Broom mainstem	120,210	> 12,000	>10%
Abhainn Droma	14,350	4,475	42%
Abhainn Cuileig	13,850	936	9%
Unnamed ditch* by A935 at Foich	2,575	2,550	99%
Allt Ach'-Ghlaineachain	2,050	946	46%
Other tributaries	3,325		
TOTAL	156,360	12,835	68%

* parts of this ditch have been cleared since the habitat survey

habitat is within the mainstem River Broom. Some of the tributary streams entering the Broom in Strath More are subject to drying out in summer. Spawning habitat within the Broom system is mostly suitable only for larger fish (salmon rather than small sea trout).

- Spawning areas within the Broom may be subject to redd-washout during peak flows in late winter with bedload transportation of large amounts of sediment. A correlation between years with March spates exceeding 80 m³/sec and low fry densities has been demonstrated (see Appendix ??). The redd-washout problem may be exacerbated by discharges of sediment into the Broom from several of the tributary streams in Strath More (e.g. Garavan Burn, Auchlunachan Burn). Measures aimed at addressing the redd washout problem and for enhancing natural production of fry are outlined in Part 7.
- Water quality remains good. Bankside habitat is also good, with extensive riparian woodlands of alder and other native trees. The spread of Japanese knotweed along river banks should be monitored, but probably does not represent a threat to the productivity of the river (although it is an inconvenience to anglers). The spread of *Rhododendron ponticum* within the catchment may be of greater concern because of the toxins associated with *Rhododendron* leaf litter and woody debris.
- Given the present depleted state of salmon and sea trout stocks, numbers of mergansers, cormorants and seals should be monitored by river owners (with support from RSPB) if a problem is suspected. Observations of predator damage on rod-caught fish should also be recorded.

Part 6:

Freshwater Production of Juvenile Salmon and Trout

6.1 Methods

To assess the status of the Broom's juvenile salmon and, to a lesser degree, trout stocks, electro-fishing surveys have been carried out every year since 1990 (except for 1992 and 1995) by Fisheries Research Services (FRS) scientist Ross Gardiner. In addition, since 1997, WRFT has carried out additional surveys throughout the catchment.

Two forms of survey have been used: quantitative and semi-quantitative (timed). Quantitative electro-fishing involves delineating an area (FRS sites) or closing off a section of typical juvenile habitat with nets (WRFT sites – following SFCC protocol) and removing the fish within that section. For FRS sites, a bank-side generator and power unit is used to deliver the current via a cable to a hand-held anode. For WRFT sites, backpack electro-fishing equipment with a self-contained, battery-supplied, power unit is used. Having measured the area of water, an estimate of the density of fish is made based on numbers of fish recorded.

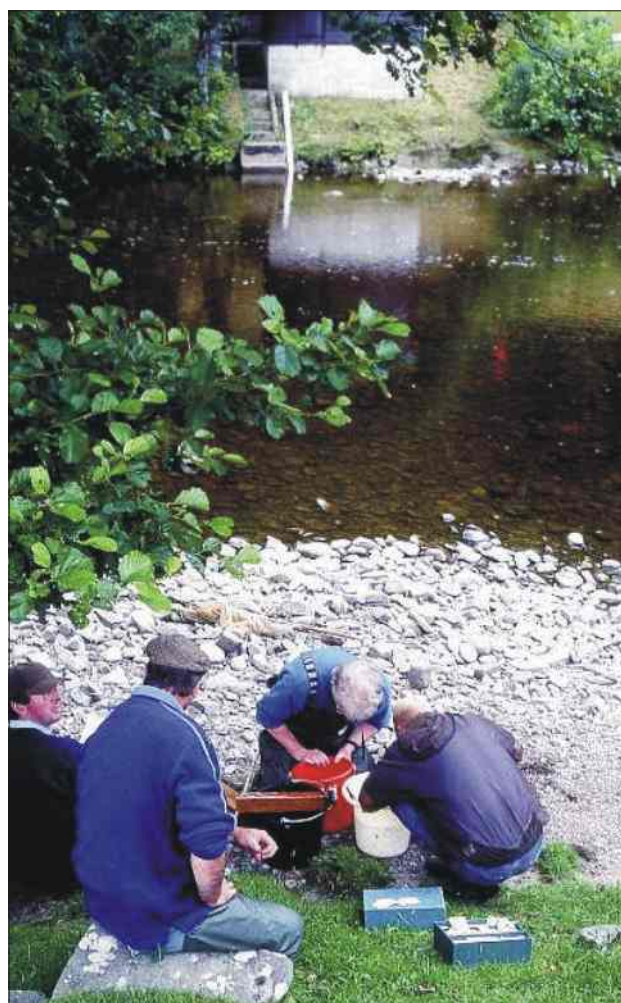
In larger rivers such as the Broom, both forms of survey are more suitable for sampling juvenile salmon populations than juvenile trout populations. Water deeper than about 30 cm cannot easily be fished without more expensive and complex equipment. Pools and deeper glides tend to be favoured by trout, and trout abundance may have been underestimated in some parts of the river.



Quantitative electro-fishing the Cuileig River above the Junction pool. This site has been fished most years since 1991 by Ross Gardiner (right) (P Cunningham)

Semi-quantitative or timed electro-fishing involves fishing for a set period of time at a large number of sites. The results do not provide accurate estimates of fish densities, but provide an index of the distribution and relative abundance of fish over a wider area.

Four quantitative FRS sites were established in the accessible area of the Broom in 1990, and to compliment these, two more were established by WRFT in 1997 (see Appendix 1). These sites have been fished regularly and provide an indication of changes in juvenile fish densities within the river during this



Recorded salmon fry densities have usually been highest at the FRS site by the SEPA monitoring station near Inverbroom bridge (A McGilivray)

period. In 1998, a further 17 semi-quantitative (timed) sites were surveyed to investigate the distribution of juvenile fish within the area of the catchment thought to be accessible, including three on tributaries.

No juvenile salmon were found at the site above the Linn Falls in 1998, indicating that salmon probably had not spawned above the falls in recent years, and the site has not subsequently been resurveyed. A further semi-quantitative site was surveyed above a road culvert on the Allt na h-Ighine in 2000. No juvenile salmon were found at this site either, indicating that the culvert is probably impassable.

For the fully quantitative sites, results were compared with a 'Wester Ross average' calculated from collated data from 13 unstocked rivers in the WRFT area (including the Broom) surveyed in 1999.

6.2 Distribution of juvenile fish

Details of electro-fishing survey results are given in Appendix 1.

Figure 6.1 shows the distributions of juvenile trout, salmon and eels from the survey in July 2000. This survey focused on shallow 'riffle habitat' favoured by salmon, so the proportions of other fishes within the Broom mainstem may slightly underestimate their true relative abundance within the river. Note however, that the proportion of eels vs. juvenile salmon decreased away from the lower reaches, and that trout were much more abundant within the tributaries than in the main river.

6.2.1 Salmon

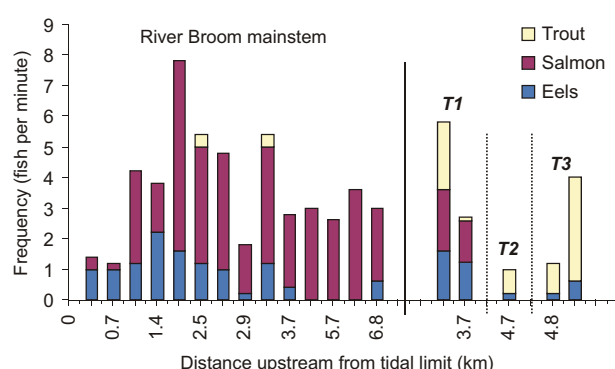


Figure 6.1 An overview of juvenile fish distribution in the River Broom, from the electro-fishing survey in July 2000. Both quantitative (2) and semi-quantitative sites (17) are included. Numbers of fry and parr have been added together for trout and salmon. (Tributaries: T1 Sawmill Burn; T2 Allt a' Braighe; T3 Allt na Ighne)

Figure 6.2 shows the distribution and relative abundance of salmon fry in 2000. Fry occurrence indicated where successful

spawning had occurred the previous autumn. Distribution was good, with fry found at 88% of sites. However, the numbers of fry found were only moderate at most sites. The highest numbers were found in the region of the confluence with the Garvan Burn (3.6 fry per minute), and at the mouth of the Foich roadside ditch (5 fry per minute).

Figure 6.3 shows the distribution and relative abundance of salmon parr in 2000. In comparison to salmon fry distribution, parr tended to be found at relatively higher densities towards the upper part of the accessible area.

Overall, the great majority of juvenile salmon were found at main river sites, highlighting the primary importance of the mainstem River Broom to salmon production within the system.

6.2.2 Trout

In contrast to salmon, very few trout fry were found at any of the sites on the main river (Figure 6.4). However, trout fry and parr were present in all the tributaries at relatively high densities.

6.3 Densities of juvenile salmon and trout

Using the FRS data, densities of respective age classes have been compared from one year to the next (Figure 6.5, page 43). To some extent, years with high fry densities appear to be followed by years with high 1+ parr densities (e.g. 1996 fry - 1997 1+ parr; 1998 fry - 1999 1+ parr). 1+ parr densities have never been higher than fry densities the preceding year.

The variation in average densities of fry suggests fluctuation in spawning success from year to year. This could be due to variations in the numbers of successfully spawning returning adults. However, it has been suggested that fluctuations are also partially due to redd-washout during wet winters (see Appendix 2) or to a combination of this and other factors.

Using pooled data from all six quantitative sites (including the two WRFT sites on tributaries), average densities of juvenile salmon and trout from surveys in 1997 to 2001 have been obtained and are shown in Table 6.1 (see Appendix 1 for data).

Over the period 1997–2001, the average density of salmon fry recorded at the six sites is consistently poor compared with the Wester Ross average. However, recorded average densities of salmon parr were slightly higher than Wester Ross averages.

Part of this apparent discrepancy between salmon fry and parr densities relative to WRFT averages may be related to

Table 6.1 The average densities (fish/100m²) of juvenile salmon and trout fry and parr recorded during quantitative electro-fishing sites (FRS and WRFT pooled) in the Broom catchment from 1997 to 2001. For comparison, the average densities are given for a group of 13 unstocked Wester Ross rivers (including the Broom) surveyed in 1999.

	Broom					Wester Ross average*
	1997	1998	1999	2000	2001	1999
Salmon fry	8.7	20.2	13.5	13.4	17.4	26
Salmon parr	13.8	12.5	13.8	9.4	10	10
Trout fry	2.5	9.5	15.5	1.5	8.8	16
Trout parr	7.8	4.7	6.8	9.7	5.5	4

*Kanaird, Ullapool, Lael, Broom, Dundonnell, Gruinard, Inveranvie, Little Gruinard, Allt Beithe, Tournai, Loch Sguod, Kerry and Balgy

Figure 6.2 Distribution and abundance of salmon fry within the accessible area of the Broom in 2000 at WRFT sites (quantitative and timed)

Figure 6.3 Distribution and abundance of salmon parr within the accessible area of the Broom in 2000 at WRFT sites (quantitative and timed)

sampling inadequacy. The two WRFT sites are in small tributary burns into which salmon may have migrated in their second year (see below). Salmon fry tend to be most abundant in shallow riffle-run areas with mainly pebble substrate near where salmon have spawned. Additional sites may be required to fully understand overall variation in fry densities. For example, there is a 1000+m section of main river below Achindrean bridge that has yet to be surveyed. The WRFT habitat survey (see Part 5) indicates that this section may be of some importance as a spawning area within the middle section of the river.

As they grow, juvenile salmon tend to occupy progressively deeper, faster habitat, with coarser cobble substrate. Within the Broom there is an abundance of this sort of higher-energy habitat relative to stable spawning habitat. Relative to other rivers in WRFT, the survival of fry to the parr stage and beyond appears to be good.

An analysis of the individual site results, particularly in the tributaries, suggests that juvenile salmon migrate between different parts of the accessible area according to the availability of suitable habitat as they grow. Salmon fry were absent or present at very low densities at the Allt Bhraighe and Sawmill Burn (Figure 6.6) sites. The occurrence of higher salmon parr densities suggests movement. Average densities (fish/100 m²) of juvenile trout fry and parr found at 28 quantitative electro-fishing sites in the Ewe system in 1997, 1999 and 2001, compared with average densities for 13 other unstocked Wester Ross rivers surveyed in 1999 (see Appendix I for data).

In contrast to salmon, few trout were found, except within the tributaries. Trout fry densities averaged for all electro-fishing sites tended to be low, except in 1999.

It is possible that densities and production of juvenile trout within the main river would have been substantially higher during periods when sea trout catches were much higher (e.g. pre-1970s). This is one of the intriguing puzzles: to what extent were (and are) juvenile salmon and juvenile trout competing for the same habitat? During the 1950s and 1960s, the abundance of older, larger sea trout probably meant that there was much higher deposition of trout eggs. During this period juvenile trout may have been more abundant overall, with more competition between juvenile trout and salmon – especially in the main river. The catch data analyses in Part 4 suggested some increase in salmon abundance following the decline of sea trout stocks in the early 1970s.

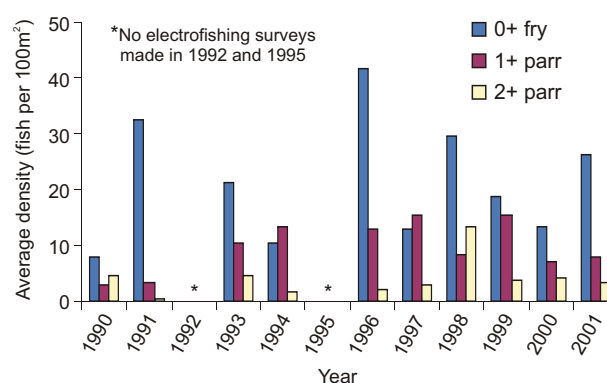


Figure 6.4 Distribution and abundance of trout fry within the accessible area of the Broom in 2000 at WRFT sites (quantitative and timed)

Figure 6.5 Juvenile salmon age class comparison for the 4 FRS sites on the mainstem River Broom from 1990–2001 (there were no surveys in 1992 or 1995)

6.4 Age structure of juvenile salmon and trout

6.4.1 Salmon

It has been possible to examine the age structure of the juvenile salmon population by reading scales taken from fish caught during electro-fishing surveys.

Figure 6.7 shows the frequency of juvenile salmon in different length groups recorded at WRFT sites in 1998 and 1999. Comparisons between the years should be made with caution because the survey in 1998 was one month earlier than in 1999.

However, in neither year were 3+ year old salmon parr recorded. This suggests that nearly all Broom salmon in recent years appear to have gone to sea as either two or three year old smolts. Scales from only two adult salmon from the Broom were read; both were from fish that went to sea as two-year old smolts. Where possible (bearing in mind the recommendation to return wild fish to the river after capture as quickly and with as little stress as possible until stocks have recovered), additional scales of adult Broom salmon should be collected for further analyses of the population.

6.4.2 Trout

Trout of one, two, three and four years old were recorded (Figure 6.8), some of which may have been progeny of sea trout. Some of these may have subsequently gone to sea; others may have remained within freshwater as brown trout. Larger trout tend to inhabit the deeper water by preference, and are therefore seldom recorded during back-pack electro-fishing surveys. Data collected at the WRFT Tournai trap indicated that trout smolts tend to be in the size range 150–210 mm, on average larger and older than salmon smolts.

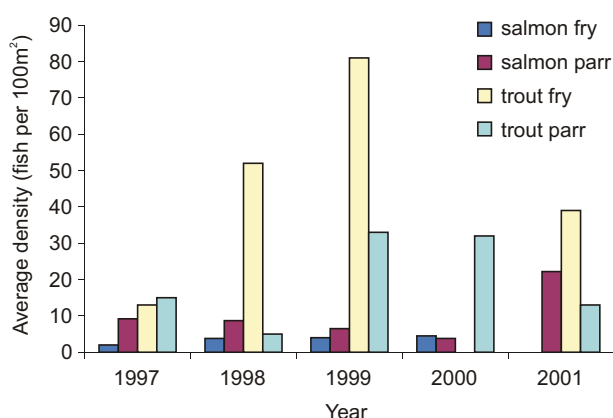


Figure 6.6 Juvenile fish densities in the Sawmill Burn. Note how trout were much more abundant than salmon. Juvenile salmon may have moved into this tributary from downstream

6.5 Spawning targets for salmon

Long-term research into the Atlantic salmon has led to the development of new management techniques. One of these is the setting of spawning targets. Every river has a natural carrying capacity for juveniles, based on the accessible area available to spawning adults. By calculating the minimum number of salmon eggs required to saturate the accessible area with parr, and therefore maximise the output of smolts, it is possible to assess from runs of adult fish whether the river is reaching its natural potential. The result of this assessment can then be used to guide fisheries management decisions. Spawning targets are now being recommended by NASCO as a simple method for managing salmon populations on a river-by-river basis, and are currently used in England and Wales, Canada and the USA.

The calculation of spawning target begins by estimating the minimum number of eggs ('egg target') required to produce the carrying capacity of fry, parr and smolts in the accessible river habitat (see Appendix 3). For the Broom, at least 406,510 eggs are needed to saturate the accessible area of 156,360 m² (Table 6.2). Using typical egg-smolt mortality rates it can be estimated that, if the egg target has been reached, the river should produce a maximum of approximately 6,914 salmon smolts. Overall, 76% of these should be produced by the mainstem of the river.

The egg target can then be translated into the number of female salmon needed to lay the required quantity of eggs. A female salmon produces approximately 1250 eggs per kg. If the average weight of Broom salmon is 3 kg (6lb 9oz), then one salmon produces approximately 3750 eggs. Thus, a run of at least 110 hens is required to reach the egg target of 406,510, plus a further 110 males to fertilise them, giving a minimum spawning target of approximately 220 salmon.

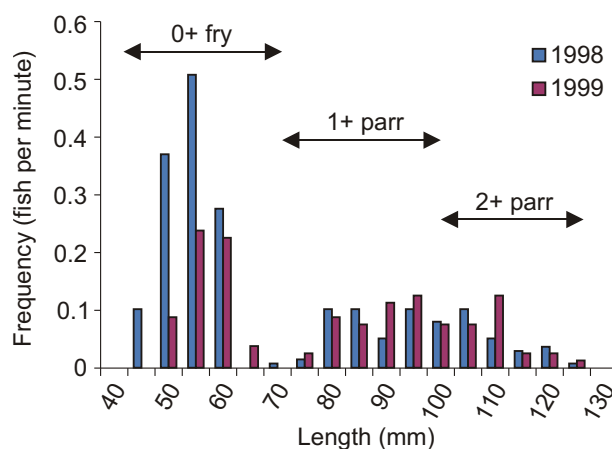


Figure 6.7 Length-frequency data for juvenile salmon caught in the Broom during WRFT electro-fishing surveys in 1998 (27 August) and 1999 (27 September)



In the Ewe, most sea trout smolts (above) go to sea after 3 years in freshwater and most salmon smolts (below) go to sea after 2 years. Additional scales from Broom sea trout (including finnock) and salmon are required to determine smolt ages for Broom fish (J Butler)

This minimum level is termed the Minimum Biological Acceptable Limit (MBAL), and is effectively the carrying capacity of the river. To allow for losses of adults from disease and predation, or egg loss due to redd washout, an overestimate is made of the number of adults required, thus creating a safety margin (see Appendix 3). FRS use a safety margin of 15% to give a Management Level (ML). For the Broom, the ML is therefore 253. Given the possible problems with redd washout in some years, it would be judicious to use this or a higher target instead of the MBAL.

Without a fish counter it is impossible to measure the annual run of salmon into the Broom. However, extensive research on rivers in England and Wales with fish counters has shown that on average 15% of salmon are caught on rod and line. The same average figure has been calculated for the River Awe (Argyll) using a counter. Taking this figure, the annual Broom

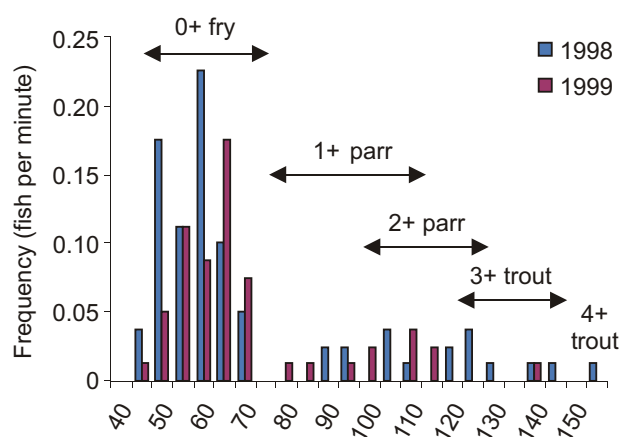


Figure 6.8 Length–frequency data for juvenile trout caught in the Broom during WRFT electro-fishing surveys in 1998 (27 August) and 1999 (27 September). The relative scarcity of larger trout is most likely primarily related to sampling method

Table 6.2 Calculation of the minimum target of salmon eggs required to maximise the smolt output from the accessible area of the Broom catchment

Water body	Accessible (m ²)	¹ Min egg target	² No of salmon	³ Max smolts
River Broom mainstem	120,210	312546	167	5315
Abhainn Droma	14,350	37310	20	635
⁴ Abhainn Cuileig	13,850	36010	20	612
L'Foich' ditch by A935	2,575	6695	4	114
Allt Ach'-Ghlaineachain	2,050	5330	4	91
Other tributaries	3,325	8645	5	147
Total	156,360	406,510	220	6914

Notes:

- 1 2.6 eggs/m²;
- 2 3750 eggs per spawning pair;
- 3 one smolt per 58.8 eggs;
- 4 includes the occasionally-accessible area above 'Linn'

rod catch of wild salmon has been translated into a crude estimate of the total run for each year from 1970 to 2001. Having deducted fish caught and killed, the annual wild escapement (i.e. fish that survived to spawn) can be calculated and compared with the MBAL and ML spawning targets (Figure 6.9).

Rod catches suggest that, from 1970 to 1979 and from 1980 to 1989, both the spawning targets were attained or exceeded in seven years per decade. However, from 1990 to 1999 both spawning targets were exceeded in only two years, 1992 and 1997. Neither spawning target appears to have been exceeded since 1997. However, the 2001 catch suggested that the spawning stock was again close to the lower target and that egg deposition may have been close to the estimated carrying capacity.

This interpretation should be treated with caution especially if fishing effort has varied greatly from year to year. Mean fry densities in 1999 and 2000 indicate that salmon spawned successfully in 1998 and 1999 – when rod catches were 0 and 1 salmon respectively. Furthermore, particularly in dry years, it is possible that substantial numbers of salmon do not run the river until after the main fishing period (i.e. October).

Given the above precautions, from the above analyses the size of the spawning population appears to have been highly variable throughout the period. Corresponding production of juvenile fish from the river may have been limited in some years by a shortage of spawning adults as well as by 'redd washout'.

A similar decline has been recorded in fisheries in neighbouring rivers. Although the primary problems for salmon are understood to relate to changes in marine survival, other factors that are common to several watersheds within the area may have also affected production. SEPA data indicates that the intensity of spates has increased (see Appendix 2). The frequency of washout of redds, fry and invertebrate larvae (food for fry and parr) from the river bed may have also increased. The increasing frequency of large spates may be associated with climatic change. This may have been exacerbated by rapid run-off from land that is less able to soak up rainwater. In turn, it has been suggested that increasing numbers of grazing animals (sheep and deer primarily) during the latter part of the 20th century may have reduced the ability of land to retain and hold back rainwater. Some of the most productive salmon habitats in Wester Ross are river sections downstream of lochs (e.g. Gruinard, Little Gruinard, Ewe, Kerry, etc.) where flows tend to fluctuate less widely and stream beds are more stable.

6.6 Conclusions

- **Electro-fishing surveys (1991–2002) indicated that salmon were dominant within the mainstem River Broom (except in the lowest section, where eels were more abundant) whereas tributaries were dominated by trout. Juvenile salmon were distributed throughout the accessible part of the mainstem. The distribution of salmon parr was more even in space (from site to site) and time (from year to year) than that of fry. This may reflect the patchiness of spawning habitat and the vulnerability of salmon redds in some areas to ‘redd washout’, where eggs and alevins are swept away by large winter spates.**
- **In contrast to salmon, very few juvenile trout were found within the mainstem Broom in any of the years. However, densities of trout fry and parr were high in the accessible parts of most of the small tributary streams in Strath More.**

This suggests that trout were either unable to spawn successfully within the mainstem, or that they preferred to spawn in the tributaries.

- **Surveys indicate that the stocks of juvenile salmon in the Broom have varied considerably during the past ten years. This may be because of reduced egg deposition in some years, because of ‘redd-washout’ (see Appendix 2), or a combination of these and other factors.**
- **The maximum salmon smolt output is estimated to be 6,914 based on a target egg deposition of 406,510 eggs. This translates to a Minimum Biologically Acceptable Spawning Limit spawning target of 220 adult salmon, and a Management Level of 253.**
- **Catch records suggest that salmon spawning targets were exceeded in seven years per decade during the 1970s and 1980s. However, since 1990, the spawning targets may not have been exceeded except in 1992 and 1997. It is therefore likely that fry densities have also been limited by inadequate egg deposition in recent years. Note that the catch data upon which this interpretation is based should be treated with caution because of variations in fishing effort and fishing conditions from year to year**

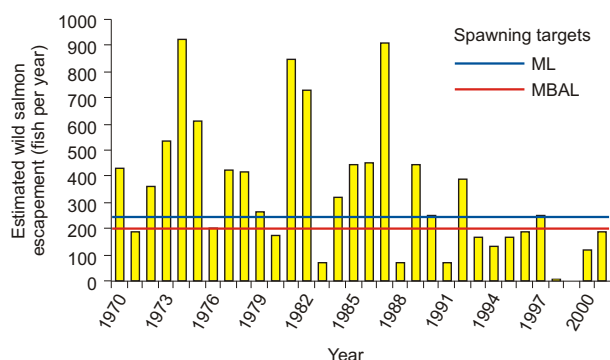


Figure 6.9 Estimated annual run of Broom wild salmon based on rod catches, 1970–2001, relative to the Minimum Biological Acceptable Limit (MBAL) and recommended Management Level (ML) spawning targets to ensure adequate egg deposition

Part 7

The Fishery Management Plan, 2002–2006

7.1 Introduction

So far this report has described the Broom catchment and its accessible area, and has assessed stocks of salmon and sea trout and the factors limiting salmonid productivity.

This part of the plan also puts forward recommendations to rectify problems and to optimise fisheries production within the control of land and river owners. If successful, the measures taken will contribute towards SNH's obligations to conserve the Atlantic salmon under the EU Habitats Directive, plus some of the other listed species within the riverine area and Loch Broom. Together, these proposals form the Broom Fisheries Management Plan, designed to be carried out over the next five years. The WRFT will assist in the implementation of the plan, monitor its progress by continuing to survey fish stocks, and then evaluate progress in 2007. Recommendations are summarised in Table 7.1.

The restoration of a prolific fishery in the Broom for sea trout may be somewhat easier than for salmon. There are two reasons for this:

- The genetic integrity of Broom trout is likely to be partly retained within the non-migratory population. In contrast, if the salmon population has experienced genetic introgression via hybridisation with fish of farm origin, it may take several salmon generations for the population to re-adapt and regain former whole-life-cycle levels of fitness.
- Sea trout feed in inshore waters where local stakeholders can influence survival and growth (sea lice, food abundance, predation). Salmon migrate to distant sea areas: local stakeholders have less influence over what happens in and en route to and from the Norwegian Sea.

7.2 Summary of preceding action points

Many points and suggestions for further investigations to address fisheries problems have already been highlighted within the context of the foregoing. These are as follows:

7.2.1 Inshore fisheries, fish farming and wise diplomacy

Salmon and especially sea trout will benefit from good management of inshore waters.

- The potential for restoration of inshore fin-fish and shellfish fisheries within Loch Broom and surrounding inshore waters may be considerable. Healthy coastal fisheries will ensure an abundance of many of the varied prey items upon which salmon and sea trout feed. More effective integrated management measures may be needed to generate and sustain high yields of many species, including the designation of 'conservation areas' to protect valuable spawning grounds and nursery habitats, and to provide sanctuary for important brood fish.
- Local stakeholders, especially those who harvest from or discharge into the marine environment, should be given encouragement and support by local authorities to form a partnership or forum within which initiatives to restore or enhance the natural biodiversity and productivity of inshore waters can be fostered and implemented.
- Annual monitoring of juvenile sea fishes and important fish and shellfish habitats in coastal areas can help to establish changes from year to year. During the 1970s, trawl surveys were carried out by the Scottish Executive's Marine Laboratory to investigate the local abundance of juvenile herring and sprats. Inshore fishermen, divers and fish farm workers may also be able to gather useful information based on their observations.
- In line with the Tripartite Working Group concordat chaired by the Scottish Executive (2000), discussions have taken place between river owners, fish farms and WRFT to set up an Area Management Agreement (AMA) within an area encompassing the 'Two Brooms' (Loch Broom, Little Loch Broom and Gruinard Bay). The proposed AMA has the overall aim of improving the health of both farmed and wild salmonid stocks, focusing initially on improved control of sea lice (*Lepeophtheirus salmonis*) in fish farms and the elimination of associated problems for wild salmon and sea trout.
- It is likely that there has been genetic introgression of the native Broom salmon population via hybridisation with escaped farm salmon. However, the extent and significance of this in terms of the productivity of the fishery is still

unknown. Studies are underway to investigate genetic variation of wild salmon and trout in the west of Scotland. These studies aim to describe integral fish ‘populations’ and their origins. The occurrence of non-native genes (i.e. genes derived from stocked or escaped farm salmon) within the wild population may also be recorded.

- To reduce any incentives for illegal fishing, it may be prudent to ensure that local communities are able to share the benefits derived from the restoration of healthy salmonid fisheries. By providing public access via the local angling club, some river owners in other parts of Wester Ross have been able to

strengthen local interest and active support for management measures aimed at restoring healthy and productive fisheries. Examples of successful partnerships can be provided on request.

7.2.2 Integrated catchment management

The quality and productivity of the freshwater habitat is affected by management practices higher up within the catchment area.

Table 7.1 The main recommendations forming the Broom Fishery Management Plan, 2002–2006

Priority	Recommendation	Aim	Action	Possible support	Approximate costs
high	Maintain catch and release policy for wild fish until stocks recover to levels in excess of management targets.	Higher production of juvenile fish.	Broom DSFB, WRFT	Local Angling Club	Loss of revenue
high	Maintain netting closures in Loch Broom until stocks recover substantially.	Higher production of juvenile fish.	Broom DSFB	via TWG or Broom DSFB?	Loss of revenue
high	Form marine partnership with other local stakeholders to foster improved monitoring and management of inshore waters.	Improved growth and survival of sea trout and salmon.	Broom DSFB	Highland Council, SNH	Unknown
high	• Support Area Management Agreement process. • Monitor sea lice abundance on farm and wild fish. • Take action to prevent lice epizootics in Loch Broom	Improved marine survival and growth of sea trout and salmon.	Broom DSFB, WRFT	TWG, WRFT, Highlands and Islands Enterprise	Various. Sea lice monitoring at mouth of Broom/Lael for <£1500/year
high	Monitor erosion and sediment discharge at different locations within the river system, and take action to reduce erosion and sediment discharge.	More stable spawning areas and habitat for juvenile fish. Less frequent need for bank revetment.	Estate, FE, SSE, NTS coordinate action to identify priorities.	SSE, Forestry Commission, NTS, SNH, SLF, Deer Commission, MLURI	Unknown. Cost of 1 year studentship, about £10,000.
medium–low	Restore, enhance and create new spawning habitats at strategic locations within the mainstem, side channels and side streams (refer to Table 7.2 for site specific details.	(Returns for investment will relate to rates of marine survival.)	Estates : Broom DSFB	Consents may be required from SNH, SEPA, etc.	Various. From >£100 to <£1000 per project
medium–low	• Coppice riparian alders and birches to reduce shading – especially along smaller tributaries. • Enhance riparian habitat for biodiversity.	(Returns for investment will relate to rates of marine survival.)	Estates	Broom DSFB, WRFT, SNH, Highland Council	From <£200 / year (eg Foich roadside ditch) to have real benefit
medium	Control the spread of alien plants within the Broom catchment, especially <i>Rhododendron ponticum</i> and Japanese knotweed.	Prevent gradual reduction in production of juvenile fish.	Estates, SNH, NTS	?Forestry Commission, SNH, Highland Council	>£10,000 to eradicate rhododendron and Japanese knotweed
medium	Set up holding facility & small hatchery for strategic supplementary stocking of salmon and sea trout fry.	Increased production of juvenile fish.	Estates, SSE, WRFT	Broom DSFB, SSE. Need SEPA consent	£4000/year to produce 100,000 fry
medium	Review hydropower operations within the Broom catchment and consider alternative abstraction scenarios.	Potential for increased production of juvenile fish.	SSE	SSE & WRFT	Cost-benefit reappraisal required

- To address problems such as those associated with erosion and stream bed instability, a systematic land use (vegetation and soil) management study of the Broom catchment area would be of great value. The study could aim to contrast the impacts of different land uses (e.g. forestry, sheep pasture, game) and management actions (e.g. timber extraction, muir-burn, stocking densities) upon the overall productivity, economy, biodiversity and capital value of the area. The study could be prepared in collaboration with a university or land use research institution.
- The study might focus upon how to enhance the overall value of natural resources within the area. There may be opportunities for reducing soil and nutrient wastage, and for reducing the discharge of coarse sediment (cobbles and boulders) into the Broom and consequent problems for channel management. Issues may include: the impacts of grazing pressures and muir-burn on soil fertility and run off; special native plant communities and associated wildlife (see Part 3); forest harvest; woodland regeneration; and the spread of undesirable alien plants.
- With regard to the mainstem River Broom, a primary objective should be to identify the areas of highest erosion and sediment discharge into water courses. This part of the study could form the subject matter of a postgraduate student thesis, for which financial support may be available.
- An analysis might focus on how pooled investments can most efficiently be targeted for maximum mutual benefit through collaborative action between landowners, their tenants and other people involved with land and biodiversity management within the area, including Scottish Natural Heritage and Scottish and Southern Electricity.

7.2.3 Hydropower and water quality

Hydropower developments and human habitations have affected the productivity of the river (see also 7.2.4).

- The production capacity of the Broom as a salmon and sea trout fishery may have been reduced by about 5% as a result of water abstraction via Loch Droma. It may be possible to enhance the natural productivity of Broom fisheries without loss of value to hydroelectricity generation. This could be via storage and/or abstraction of a larger proportion of autumn and winter floodwater, and/or release of higher summer compensation flows. An economic reappraisal of alternative abstraction and discharge regimes (especially the Droma) or storage– flow management regimes (esp. Cuileig–Loch a' Bhraoin – see below) may be worthwhile.
- Deep holding pools for adult salmon are important to the fish population and the fishery, and provide sanctuary from predators at low flows. The behaviour of adult salmon in the pool below the Cuileig power station should be monitored. How effective is the pool by the power station outflow for holding salmon through the summer prior to spawning? Do other pools (Linn Pool, Junction pool) provide sufficient alternative holding area prior to spawning?
- The availability of the nutrient phosphorus to primary producers (chiefly algae) is likely to limit biological productivity in the Broom. SEPA may be able to investigate why concentrations of Total phosphorus have increased over the past ten years and whether there may be associated impacts (positive or negative) on the production of juvenile salmon and trout.

7.2.4 Other fish and wildlife

Information about other species can contribute to an overall understanding of the system.

- European eels were found in parts of the Broom at relatively high densities. Investigations are required to more fully understand the movements and habitat requirements of eels within the Broom catchment area. Relationships between eels, juvenile salmon, trout and other species also require further study.
- Although Arctic charr are known to exist in many of the larger lochs within neighbouring catchment areas, records of charr within the Broom catchment have not been seen. If their absence is confirmed, possible explanations could be included within an overall assessment of charr distribution within North West Scotland.
- The numbers of bird such as dippers may relate to the abundance of aquatic invertebrates or, during the autumn, to the presence of fish spawning nearby. Records of water birds within the Broom catchment at different times of year may provide other useful information.
- Over future years, WRFT will gather information about distributions, densities and the relative importance of aquatic invertebrates as food for trout and salmon within Wester Ross river catchments. These data will be presented within a second generation of 5-year Fisheries Management Plans for Wester Ross river systems.

7.3 Recommendations for salmon and sea trout fisheries

7.3.1 Assistance from anglers

To interpret changes in the productivity of the fishery and to understand the local behaviour of salmon and trout, information recorded by anglers, estate staff and others with local knowledge and interest in the river can be of much value.

- Whenever possible, anglers should try to differentiate between wild and escaped farm salmon. Guidance leaflets are available from WRFT. Until stocks of wild fish have

recovered, WRFT recommends that all wild salmon and sea trout should be carefully released, following NASCO guidelines. Salmon identified as farm escapees should be killed.

- Any fish scales that are displaced during capture or handling should be collected. These can be read by WRFT to provide information about the growth of the fish in freshwater and in the sea. The identity of escaped farm salmon can also be confirmed by scale reading. Please contact WRFT for scale packets.
- Catches should be carefully recorded. If possible, a WRFT catch effort recording form should be filled in during or following each fishing trip. This information can be used to document changes in the numbers of salmon and sea trout returning to the river and the sizes and condition of returning fish. Please contact WRFT for catch recording forms.
- Records of observation of spawning salmon and sea trout would provide information from which the spawning areas and spawning requirements (in terms of flow, gravel characteristic, water temperature, etc) of each species within the system could be defined. Please ask WRFT for further information about recording salmon redds.

7.3.2 Restoration and maintenance of high quality salmonid habitat

The Broom has historically supported prolific salmon and sea trout fisheries, even though large parts of the accessible section of the River Broom in Strath More have been altered by man.

The main channel, up to the Droma–Cuileig junction pool, is currently confined between artificial embankments of excavated material, revetted with limestone boulders (see Part 5 for further details). The river habitat is therefore not entirely natural, nor is it ideal for salmon and sea trout. This has been highlighted by the ‘redd washout’ study (Appendix 2). In some years, poor recruitment of juvenile salmon may be partly a consequence of the artificial confinement of floodwaters within the manmade channel. Scouring of the river bed is likely to be exacerbated by ‘bed load’ transportation of unstable coarse sediment (cobbles and boulders) at peak flows.

These problems are primarily of concern to the survival of eggs and alevins, and may restrict recruitment (the number of young fish produced) during some years. Larger parr are more likely to be able to move to more stable and sheltered backwaters during periods of high spate flows. The following action points aim to address these issues (see also Figure 7.1):

- Large amounts of coarse sediment enter the main river via tributary burns in Strath More. A key objective of land management practices should be to reduce input of eroded sediment into streams. This will not only improve conditions

for juvenile salmonids; it will also increase the length of time between expensive channel protection works.

- The provision of more stable spawning and nursery habitat for salmon and sea trout has been considered. Various opportunities have been identified for improving or creating up to 6000m² (total) of salmonid spawning and nursery habitat within Strath More. These are described in detail in Table 7.2. Note that SNH or SEPA consents may be needed for some actions. The numbers given (anticipated fish production; estimated costs) are very approximate, but are intended to provide some guidance for comparing and prioritising actions. However, until more is known about the success of salmon and sea trout spawning within the main stem, or rates of marine ‘return’ are much improved (Table 7.3), the need or likely contribution to the fishery of many of the proposed actions remains speculative and probably marginal.
- Nevertheless, some of the actions proposed are relatively small scale, straightforward and inexpensive. They can be carried out and their impact monitored by estate workers or enthusiastic ‘volunteers’. Clean, well-graded gravels, and other habitat features can be developed primarily for the benefit of salmon and sea trout. Other actions may be combined into small habitat management projects with benefits for fish and other wildlife. These require more detailed design and costing. SNH may be able to part-fund projects that enhance wildlife diversity, or protect special habitats or listed species.
- A number of backchannels have been cut off by channel engineering works, reducing the available ‘wetted’ area. It may be possible to reinstate some of these with controlled flows from the main river to provide new or more extensive ‘wetted’ area for spawning, summer and/or winter juvenile trout and salmon fry habitat. Expert engineering advice should be sought prior to embarking upon any projects involving flow diversion.
- Tributary burns drop very steeply from the sides of Strath More. Most of these currently provide either poor habitat for juvenile salmonid production, or virtually no habitat at all, disappearing during low summer flows into thick porous ‘fans’ of coarse sediment. However, there are several places where controlled flows from tributary burns could be fed into drainage ditches around field margins to create more stable and extensive spawning habitat for sea trout and possibly also for salmon, protected both from excess scouring from eroding sediment, and from siltation. Expert engineering advice should be sought. The development/colonisation of spawning channels may be ‘kick-started’ via stocking of eggs or fry as part of a broader ‘extensive’ stock enhancement project (see 7.3.4).
- Actions within the riparian zone include selective coppicing of trees (especially alders and willows) to reduce shading and promote growth of in-stream plants. Regrowth from coppiced

trees can be vigorous, providing lots of leaf matter, which should ideally be provided by low bushes rather than taller, less productive trees. New livestock fencing with effective water gates may be required where grazing pressure or trampling by livestock leads to excessive erosion and silting.

Refer to Management Table 7.2. for site-specific details.

7.3.4 Hatchery/stocking programme

Please refer to Box 7.1. For the Broom, stocking *may* be justified in some years as ‘an insurance policy’. Fish native to the Broom should be used as broodstock. Especially when egg deposition has been below the carrying capacity of the system and/or during, redd-washout years, supplementary stocking of fry can, in theory, elevate overall fry densities. Eggs or fry could also be planted in tributary burns or ditches where the habitat has been enhanced, complementing rather than competing with progeny of wild fish in the main river. During years when natural spawning appears to be adequate and redd washout is not thought to be a problem, fry could be stocked above Cuileig Gorge on an experimental basis.

To have measurable impact, facilities for incubating 50–100,000 salmon eggs would be required. Secure facilities for holding approximately 20–25 female salmon and 20–25 male salmon would also be required (including precocious parr, which can be taken from the river).

The approximate estimated cost of setting up a hatchery for salmon is set out in Table 7.4.

Table 7.3 Numbers of rod caught fish per 1000 smolts produced. **Suggested recent rod exploitation rate in red.** Historic rates in blue. Excludes net catches in Loch Broom.

Marine return rate (smolt–adult river entrant)	Rod exploitation rate				
	5%	10%	15%	20%	25%
3%	1.5	3	4.5	6	7.5
5%	2.5	5	7.5	10	12.5
10%	5	10	15	20	25.0
15%	7.5	15	22.5	30	37.5

The old cattle shed at Garvan may be a suitable site for a hatchery if a reliable intake from the Garvan Burn can be established. However, this burn is unstable, and engineering expertise should be sought with regard to intake design.

Box 7.1 ‘Health Warning’

The success of a hatchery-stocking programme, in terms of benefits to the fishery, depends not only on a high level of skill, experience and dedication by those employed, but also on a clear understanding of the need for stocking prior to commencement.

The impacts to wild fisheries of stocking programmes have rarely been well monitored. In general, studies have shown that, where the river habitat is in good order, stocking is no substitute for natural production. It is often best to leave wild fish to spawn naturally without disturbance.

Compared to wild progeny, stocked fish perform poorly in terms of survival from fry to smolt and smolt to adult. This may be because of behavioural inadequacies (especially in relation to predators) and the stocked fishes’ unfamiliarity

with the river environment. Stocked fish may also compete with wild fish – ultimately to the detriment of the fishery.

Note that European legislation has recently been passed banning the use of ‘Malachite green’ – a chemical that was formerly used routinely on many hatcheries to prevent fungal infection. Control of fungus has subsequently become more problematic.

At present, WRFT is seeking clearer guidance from Fisheries Research Services regarding the restoration of small West Coast salmon populations. Please contact WRFT for the latest scientific information and advice.

Table 7.2 Options for enhancing and developing salmon and trout habitat in Strath More.

This table provides information about places where opportunities exist for the development of prime habitat for juvenile salmon and sea trout within the Broom system. For the majority of locations, the primary aim of proposed actions is the creation of stable, semi-natural, spawning and nursery (1st summer) habitat, from which naturally produced salmon and trout fry can descend to occupy vacant habitat within the mainstem River Broom. An analogy is the provision of nesting boxes for wild birds.

Proposed actions aim to supplement fry production within the main river and to insure against heavy depletion of year classes caused by ‘redd washout’ within the main river. Together, proposed actions aim to provide a ‘back up’ *natural* fry production system, capable of sustaining smolt production at optimum levels, even during years of extreme winter spates when ‘redd washout’ is likely to severely reduce fry recruitment from spawnings within the main channel (for reasons discussed in Part 5). **Estimates of maximum potential additional smolt production from the Broom as a result of proposed actions are shown in red. These figures will only be reached if there is vacant habitat for fry and parr to grow on within the main river (i.e. when the carrying capacity for juvenile trout and salmon within the main river has not been reached).** In years when spawning and egg - fry survival is adequate within the main river (i.e. for years when the carrying capacity is already exceeded), additional fry or parr descending into the main river from side channels will not lead to additional production.

However, some of the proposed spawning channel locations also provide limited opportunities for development of *in situ* parr habitat and smolt production. These locations may be able to produce small numbers of smolts *in addition to those produced from the main river* (about 500 salmon smolts in total, these numbers shown in [] brackets). Some locations may also be able to provide valuable over-winter parr habitat possibly increasing overall levels of fry-parr and parr-smolt survival within the Broom system. Some locations may also be able to produce and supply enhanced levels of natural parr food (i.e. aquatic invertebrate), enhancing the *production capacity* of the main river (i.e. more rapid growth of parr to smolts – more in 2 years rather than in years).

Note that some locations provide opportunities that appear to be more attractive (in terms of estimated cost - perceived benefit) than others. For example, the Foich roadside ditch (25) and Auchindrean drain (16) appear to offer particularly good returns for minimal investment. Some of the relatively inexpensive mainstream spawning habitat improvements may also be particularly beneficial relative to their cost, especially those towards top of accessible area where the provision of improved salmon spawning habitat may be particularly worthwhile (e.g. 4, 5, 6, 7, 8, 10).

To jump start operation of any substantial new spawning channel, stocking with eggs or fry of native origin is recommended. This could be done in conjunction with a small broodstock holding facility (for rod-caught fish) and hatchery to incubate eggs at least as far as the eyed stage. The success of the any spawning channel in terms of being able to attract wild fish to spawn within them should be monitored (c. bird nest box ...).

The total cost of the entire system over a ten year period has been estimated at £4000–5000 per year, including capital costs, maintenance costs and monitoring. The estimated total additional production from the system is 3800 sea trout smolts and 4250 salmon smolts per year. The viability of the system depends upon rates of marine survival and rod capture rates. For example, at 5% marine survival rate and 20% rod capture rate (= one rod caught fish for every 100 smolts produced), the system would sustain yields of an additional 38 rod-caught sea trout and 42 rod-caught salmon per year.

PROVISO The creation of spawning channels for salmon and sea trout has rarely been undertaken within the UK and methods remain experimental. Detailed plans and costings are required for many of the larger scale actions suggested. WRFT will be happy to discuss and to develop pending further interest.

Table 7.2 appears on the following pages.

Table 7.2 Options for enhancing and developing salmon and trout habitat in Strath More.

No.	Location	OS grid ref.	Description	Suggestion	Potential additional production per year [see note]	Initial cost estimate / life expectancy	Estates
1	Lower Linn Pool (Cuileig)	1920E 7890N	Waterfall pools Tail race from Cuileig Power Station	Monitor holding pools. Create spawning areas at tail.	Low water refuge for 50 + S adults	£	S&SE Inverbroom
2	Junction Pool	1935E 7915N	Confluence Pool of Cuileig and Droma (Top of Broom)	Monitor. Consider creating spawning areas at tail.	Low water refuge for 50 + S adults	£	Inverbroom Braemore S&SE
3	Field west of Junction pool	1925E 7920N	Old floodplain. Grasses and bracken. Sheep grazings.	Possible location for artificial spawning channel, 300m x 2 m (approx). Drains could be diverted from lower slopes of Carn Break More. Parts of channel may require fencing.	6000 T fry (80% descend into main river) 1200 [240] T parr 300 [60] T smolts 4000 S fry (100% descend into main river) 200 S smolts	£1000 / 5 years (for diversion of streams and excavation)	Inverbroom
4	Junction Pool – tail	1935N 7925E	Damp back channel on right side of 'island': stream bed stable: mossy stones: 100m x 3m	Enhance as spawning channel. Refresh salmon gravels. Coppice alders overhanging back channel to provide maximum sunlight. Monitor use by spawners and fry densities. May require stock control (new fence).	4000 S fry (90 % descend into main river) 800 [80] S parr 200 [20] S smolts	£100 / 2 years (2 man days channel excavation by hand)	Braemore
5	'Braemore' ford	1930N 7930E	Large semi-transverse ford with downstream island: Possible spawning areas on both sides of ford.	Refresh salmon gravels on left side of ford.	4000 S fry 200 S smolts	£20 / 1 year (0.5 man days channel excavation by hand)	Inverbroom
6	'Braemore' island, right side	1930N 7933E	~90% of flow across ford towards right bank, and down right side of island. Right bank eroding.	Control erosion along right bank, using rock armouring or gabions.		£	Braemore
7	'Braemore' island, left side	1930N 7933E	~10% of flow into back channel to left of island.	Enhance as spawning channel (250m x 4m) Monitor use and fry densities.	4000 S fry (75% descend into main river) 800 [200] S parr 200 [50] S smolts	£200 / 2 years (mainly hand-built vortex weirs; gravel improvements)	Inverbroom

No.	Location	OS grid ref.	Description	Suggestion	Potential additional production per year [see note]	Initial cost estimate / life expectancy	Estates
8	Arthur's Pool	1925N 7970 E	Holding pool, with options for spawning bed (s) near tail.	Location for spawning bed at tail of pool on left side.	50 S adults 2000 S fry 100 S smolts	£50 / 2 years (one man day)	Inverbroom Braemore
9	?Garden Pool						
10	Allt Creagan a' Mhuilinn / Glac a Mhuilinn back channel	1920N 7985E	Steep burn dropping into river. Damp back channel (100m x 3m) to north, on left side of River Broom	Enhance as spawning channel. Refresh salmon gravels Through part-diversion of burn via 30m x 1.5m channel into damp back channel. Protect from large spates. Coppice overhanging trees for maximum light.	4000 S fry (87% descend into main river) 800 [100] S parr 200 [25] S smolts	£100 / 2 years (materials for intake structure; hand labour)	Inverbroom
11	Bends above Auchindrean Pool	1945N 8020E	Erosion of right bank on bend above pool. Possible spawning gravels above eroding bend.	Monitor rate of erosion: may not be a serious problem. Monitor use by spawning fish and fry densities.			
12	Auchindrean Pool & down-stream to bridge.	1950N 8025E	Holding pool.	Selectively coppice sections of riparian trees to reduce shading. Consider fencing left bank from grazing during summer, to allow dense grasses & herbs to grow over edge of stream. Winter grazing may be possible.	Low water refuge for 20 S [100 S parr] [20 S smolts]	£50 / 5 years £300 / 5 years (new fence and fence repairs)	Inverbroom
13	Allt na h-Ighine	1950N 8100E	Culvert under road. Pool created on burn acts as sediment trap.	Improve culvert. Manage spawning gravel above culvert. Monitor	4000 S fry (75% descend) 800 [200] S parr 200 [50] S smolts	£	Highland Council
14	Allt a' Braighe	1940N 8120E	Lower part of burn.	Create artificial spawning channel, 350m x 4m, to enter R. Broom at NGR 1900 8145. 1. Diversion weir for controlled flow at NGR 1930 8125 2. 100m x 1m ³ channel excavation through embankments. 3. Coppice alders for maximum light. 4. Promote aquatic weed growth. 5. Monitor use and fry & parr densities	20000 S fry (90% descend to main river) 4000 [400] S parr 1000 [100] S smolts 10000 T fry (80% to main river) 2000 [400] T parr 500 [100] T smolts	£2000 / 5 years (200m ³ excavation [£1000] + diversion weir & channel intake structure [£500] + design maintenance and monitoring [£500])	Foich

No.	Location	OS grid ref.	Description	Suggestion	Potential additional production per year [see note]	Initial cost estimate / life expectancy	Estates
15	Wire Pool (Allt a' Braighe Pool)	1925N 8120E	Good spawning ford at tail of pool beneath electric wires; gravel relatively stable. Alder (?willow) and gorse growing over flood gravels.	Monitor use by salmon and fry densities.		£50 / year	
16	Auchindrean Drain	1910N 8115E	Drain enters River Broom, via 40cm pipe through embankment. Lower section of drain with thick weed growth, though grazed upper parts. Receives Auchindrean farm drainage. Spillage from drain into field at NGR 1905 8105	Develop sea trout and salmon spawning channel, 350m x 2m. 1. Increase controlled flow through channel with 40m x 20cm steel pipe / aqueduct from Allt Cuil an Droighinn. Intake weir in Allt Cuil an Droighinn. 2. Fence 250m through fields. 3. Monitor use by spawning fish and fry numbers.	10000 T fry (80% descend to main river) 2000 [400] T parr 500 [100] T smolts 5000 S fry (80% descend to main river) 1000 [200] S parr 250 [50] S smolts	£3000 / 10 years (stock fencing 250m [£1500] + intake structure and pipe [£500] + maintenance and monitoring [£100 / year])	[2]
17	Allt Cuil an Droighinn	1890N 8115E	Large discharge of coarse sediment into river.	Stabilise stream banks to minimise sediment discharge. Consider diversion to link with Auchindrean drain (see above)	See above	£ (see above also)	
18	Allt Briste	1885N 8140E	Large deposit of coarse sediment (cobbles, boulders etc.) into excavated channel below bridge.	Monitor movement of sediment. Dig test pits between bridge and Wood Pool (NGR 1880 8170) to investigate water levels and possibilities of extending stream channel [250m x 2m] to drain which enters Wood Pool (approx. 100m x 2m³). Long- term success depends upon reducing further inputs of sediment to about < 20 m³ of cobbles / boulders year. This requires upstream bank stabilisation.	5000 S fry (90% descend to main river) 1000 [100] S parr 250 [25] S smolts 5000 S fry (90% descend to main river) 1000 [100] S parr 250 [25] S smolts	£1500 / 5 years (includes 200m³ channel excavation [£1000 / 5 years])	Inverbroom
19	Allt na h-Uamhaig	1850N 8220 E	Lower channel 300m x 1.5 - 2m wide through field & alder woods. Mud, rushes and weeds.	Investigate possibilities for diverting more water through channel via regulated flow diversions of Allt a' Gharbhain and / or Allt Briste on hill at NGR 1790 8150 (400m x 2m spawning channel)	4000 S fry (80% descend to main river) 1000 [160] S parr 250 [40] S smolts 4000 T fry (50% descend to main river) 1000 [500] T parr 250 [125] T smolts	£ 2500 / 5 years (100 m³ gravel excavation [£500] + water diversion works [£1000] + 100m fencing [£600] + mainten. & mon. [£80 / year])	

No.	Location	OS grid ref.	Description	Suggestion	Potential additional production per year [see note]	Initial cost estimate / life expectancy	Estates
20	Allt a' Gharbain	1835N 8240E	Large discharge of coarse sediment. At low flows, water disappears into alluvium of cobbles and boulders 100–150m below bridge. Stream bed very unstable with frequent movements of coarse sediment.	1. diversion of part of headwaters into Allt na h-Uamhaig, for spawning channel (see above) 2. 140m x 20 cm pipeline or aqueduct to provide increased flow through road & field side ditch (see below). Robust intake weir required. 3. Pipe supply to proposed hatchery in shed at NGR 1840 8240.	1. see above 2. see below 3. see hatchery		
21	Sawmill Burn (Allt a' Mhuilín)	1895N 8200E	Over shaded lower section.	Coppice alders to provide more light. Monitor juvenile salmon and trout densities.	1000 T fry 200 T parr 50 T smolts	£50/4 years	
22	Glacgour Burn (mid)	1880N 8225E	Aqueduct over Foich roadside drain	Divert part flow via 20cm pipe into Foich roadside drain to increase flow in drain (see below)			
23	Glacgour Burn (lower)	1870N 8235E	Channel through alder woods 250m x 2.5 m (+ 100m x 2m)	Enhance as spawning channel (825m ²) 1. Excavate channel through embankment at NGR1880 8220. 2. Fit 10 m x 25cm steel perforated pipe from main river beneath rock armouring 3. Restore embankment over pipe	8000 S fry (87% to main river) 1600 [200] S parr 400 [50] S smolts	£1200/5 years (pipeline & excavation [£800] + maintenance and monitoring [£40/year])	
24	Garavan roadside ditch.	1820N 8260E to 1835N 8325E	0.5-2.0 m wide ditch by side of road (500m x 0.5 - 1m) and sheep field (350m x 2m), dropping over steep cobbled shoot. Presently inaccessible to salmon and sea trout. Shaded and heavily grazed through field	Develop 900m x 1–2.5m spawning channel for trout. 1. Create fish pass 100m x 2m wide excavated channel. 2. Increase controlled flow through channel with 140m x 20cm steel pipe / aqueduct from Allt a' Gharbhain. Intake weir / mechanism required in Allt a' Gharbhain. 3. Selectively thin trees along burn through field for maximum sunlight to burn. 4. Fence off burn from livestock through field.	10000 T fry (60% to main river) 2000 [800] T parr 500 [200] T smolts [requires ~10 kg of adult female sea trout / year] 4000 S fry (75% to main river) 800 [200] S parr 200 [50] S smolts	£5500/10 years (excavation of fish pass and channel [£1500] + pipeline [£1400] + tree management [£20/year] + 400m stock fencing [£2400])	

No.	Location	OS grid ref.	Description	Suggestion	Potential additional production per year [see note]	Initial cost estimate / life expectancy	Estates
25	Foich roadside drain	1885N 8220E to 1850N 8340E	1.5–2m wide channel. Stable stream bed, though much silt & organic debris. Flows UNDER Allt Glac Odhar (Glackour Burn). Alders growing over drain for > 70% of drain length.	Enhance as spawning channel for salmon and sea trout (1400m x 1.5 m) 1. Divert controlled flow from Glackour burn via 2m x 20cm pipe. 2. Renew spawning gravels at 50 -100m intervals along drain. 3. Coppice alders (as at 1870 8270) for maximum sunlight; remove rhododendrons. 4. Promote weed growth in pools. Monitor during spawning season and via electro-fishing.	10000 T fry (50% to main river) 2000 [1000] T parr 500 [250] T smolts 10000 S fry (90% to main river) 2000 [200] S parr 500 [50] S smolts	£2100 / 10 years (pipeline [£100] + instream spawning habitat [£100/year] + coppice alders [£100/2 years] + monitor & maintain [£50/year])	
26	Allt Ach'Ghlaine achain	1760N 8330E	Slate burn, with short steep catchment basin. Large amounts of sediment, including clay & boulders up to 60cm discharged into stream channel below Auchlunachan. Flows through beech wood to River Broom. 1000m x 2m accessible.	Stabilise sides of burn above Auchlunachan to minimise rate of erosion. Possible salmon spawning area by mouth of burn.	Stock with 2000 S fry 400 S parr 100 S smolts	£	
27	Croft town Burn	1775N 8400E to 1770N 8475E	Drainage ditch 800m x1m from Croftown to Clachan. Joins Clachan Burn (Alltan Leacach) near tidal limit and River Broom in estuary.	Enhance as sea / slob trout juvenile rearing channel. Fence off selected sections and promote growth of aquatic weeds.	4000 T fry 800 T parr 200 T smolts	£1200/10 years	
28	A'Cheapach ditch / duck ponds	1775N 8515E	Muddy ditch (500m x 1m) & ca.1ha shallow muddy duck pond(s) feeding into pipe in embankment. Outlet of pipe not located. May not be currently accessible to trout. May be subject to salt water incursion. Potential for development as juvenile sea trout (or salmon) production area.	1. Investigate access for migratory trout through pipeline and salt water incursion (sluice may require repair) Pipeline may require partial 'opening' to provide fish access. If OK: 2. Control water level April–October for maximum summer pond area. Reduce level in winter for drainage. 3. Coppice alders / cut birches to provide more sunlight for growth of aquatic weeds. 4. Option: developed as extensive trout / salmon smolt production unit with water intake spawning channel from Lael River.	If OK: 10000 T fry (with refreshed spawning area / stocking) 4000 T parr 800 T smolts ?2000+ T/S smolts / year with supplementary feeds	£2000–4000 / 5 years	Inverlael

[Note: Additional *in situ* production estimate / year,

T: Sea trout, S: Salmon, (assuming that survival rates are: fry-parr: 20%, parr-smolt: 25%)

Table 7.4 Estimated costs for a hatchery operation for the Broom

Materials	£	£
Inlet structure (e.g. on Garvan Burn)	2000	
Header tank	500	
Pipework & valves	500	
Broodstock tanks (2nd hand)	1000	
Hatchery trays @ 10,000 eggs / tray	500	
Security fence / locks and alarm	1000	
Ice alarm	500	
		6000
Construction		
20 man days @ £100 / day	2000	
		2000
Total		£8000

If the hatchery operates for 5 years, this equates to £1600/year.

Operation: 1 year	Man days	£
Annual maintenance 2 days	2	200
Brood stock capture and transfer 10 days	10	1000
Stripping eggs	4	400
Egg inspection / picking (72 hours)	3	300
Stocking fry	5	500
Total		£2400

Estimated total cost per year of hatchery operation over a 5 year period: £4,000.

Appendix I

Electro-fishing results

1 WRFT quantitative electro-fishing sites and results in 1997–2002

2 WRFT semi-quantitative (timed) electro-fishing sites and results in 1998

3 WRFT semi-quantitative (timed) electro-fishing sites and results in 1999

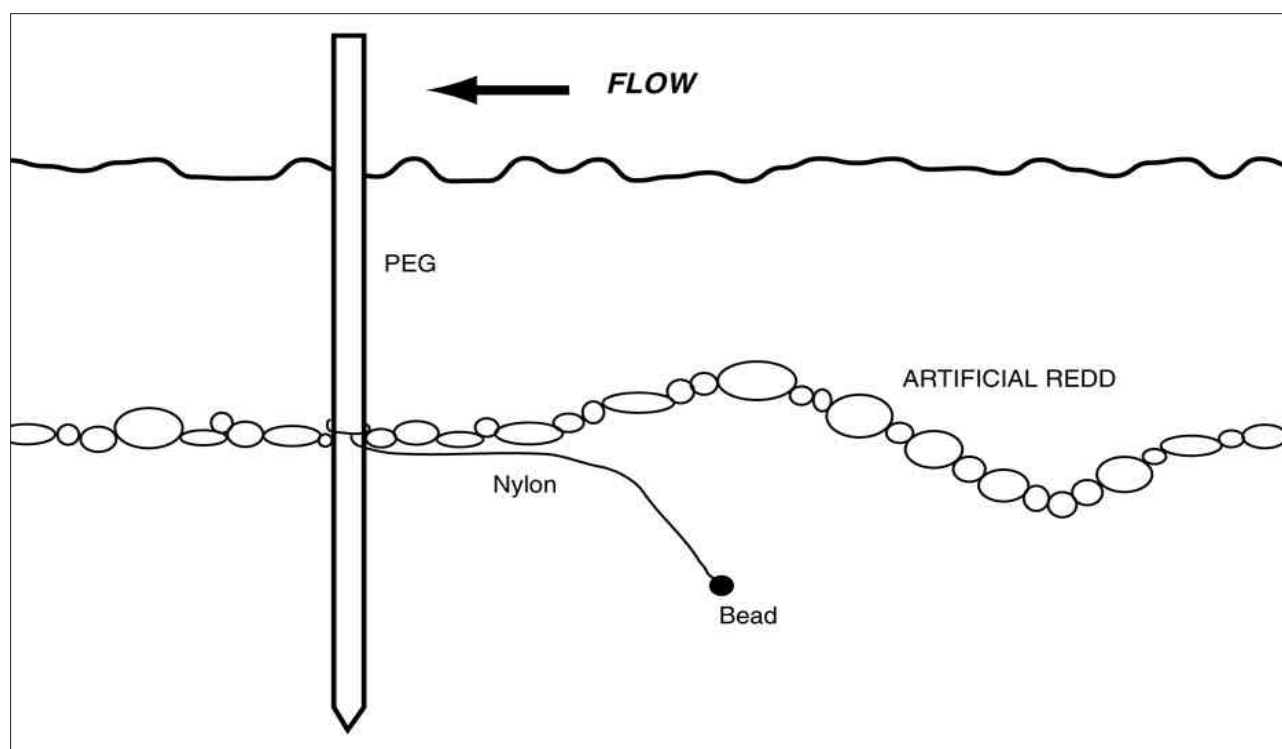
4 WRFT semi-quantitative (timed) electro-fishing sites and results in 2000

5 Locations of WRFT electro-fishing sites in the Broom catchment (Crown Copyright)

Appendix II

River Broom Redd Washout Study

Creation of artificial redd site.



James Butler (Spey District Fisheries Board) and Ross Gardiner (FRS)

Method

- Two redds created at each site, at 45° upstream and to either side of the stake.
- One salmon redd (large bead buried at 30 cm), one sea trout redd (small bead buried at 15 cm).

Site planted in November, and checked the following April. If washed out, bead found hanging on the end of the nylon, downstream from stake.

1 Introduction

Electro-fishing surveys of juvenile salmon at four fixed sites in the River Broom (Wester Ross) by Ross Gardiner (Fisheries Research Services) over 9 years since 1990 have shown wide fluctuations in densities (see Part 6).

Recent studies have demonstrated that winters are becoming wetter on the west coast. Winter spates and associated bed movements have been shown to limit hatching success of eggs and the survival of emerging salmon fry in both North America and Norway. Utilising flow data from a Scottish Environment Protection Agency (SEPA) monitoring station on the River Broom, the possibility that recent wet winters were a partial cause of the fluctuations in juvenile salmon abundance was investigated.

The relative susceptibility of different rivers in the WRFT area to winter bed disturbance was also tested in the winter of 1998/99. Bone beads were planted in a total of 79 artificial redds in 18 river systems in November 1989. Salmon egg-sized beads were buried at 30 cm, and sea trout egg-sized beads at 15 cm, which are regarded in the literature as representative depths. Beads were buried upstream of angle-iron stakes hammered into the river bed, to which they were attached using fishing nylon. If the beads were washed out they would hang downstream of the stake in the current. Redds were checked in April 1999.

2 Results

2.1 Fry density versus total winter runoff

Regression analysis was carried out on average salmon fry densities and total runoff for the previous winter (November–March inclusive). The result showed a statistically significant inverse correlation (Figure 1).

2.2 Fry density versus peak daily winter flow

Figure 1 The inverse correlation between total winter runoff (November–March inclusive) and average salmon fry densities the following summer in the River Broom over 9 years

The regression of average fry density versus the peak daily flow the previous winter was loosely, but not significantly inversely correlated ($r^2 = 0.36$, $p = 0.086$).

2.3 Fry density versus monthly winter runoff

Comparison between annual fry density and total runoff for each winter month over the 9 year period showed no significant relationship for November, December, January or February; however, the inverse correlation for March was significant (Table 1, Figure 2).

Table 1 The correlation coefficient and p value for the regressions between annual average salmon fry densities and monthly winter runoff (n = 9 years)

	Nov	Dec	Jan	Feb	Mar
r^2	0.014	0.066	0.147	0.235	0.55
p	0.764	0.505	0.308	0.186	0.022

Figure 2 The inverse correlation between total annual March runoff and average salmon fry densities the following summer in the River Broom over 9 years

2.4 Fry density versus peak daily flows in winter months

Comparison between annual fry density and peak daily flows for each winter month over the 9 year period also showed no significant relationship for November, December, January or February, but a significant inverse correlation for March (Table 2, Fig. 3).

Table 2 The correlation coefficient and p value for the regressions between annual average salmon fry densities and monthly peak daily flow (n = 9 years)

	Nov	Dec	Jan	Feb	Mar
r^2	0.129	0.111	0.1067	0.209	0.57
p	0.343	0.381	0.3501	0.216	0.019

Figure 3 The inverse correlation between peak daily flows in March and average salmon fry densities the following summer in the River Broom over 9 years

2.5 Correlation between salmon fry and 1+ parr densities

To determine whether egg or alevin losses in any year resulted in lower 1+ parr densities, fry densities were regressed against 1+ parr density for the following year. Only six pairs of consecutive years of electro-fishing data were available for this comparison. The relationship was a significant positive correlation, described by the following equation:

$$1+ \text{ parr} = 2.61 + 0.363 \text{ fry } (n = 6, r^2 = 0.77, p = 0.022)$$

2.6 Comparison between redd washout in different WRFT rivers

Of the total of 79 artificial salmon and 79 sea trout redds constructed in 18 WRFT rivers in the winter of 1998/99, 57% of salmon and 68% of sea trout redds were washed out. In the River Broom, 60% of five salmon redds and 80% of five sea trout redds were washed out, slightly above the average for all rivers. There was a highly significant difference between the proportion of salmon redds washed out in the 18 rivers ($\chi^2 = 8.492$, $df = 17$, $p < 0.001$). Similarly, there was a highly significant difference between the proportion of sea trout redds washed out ($\chi^2 = 7.610$, $df = 17$, $p < 0.001$).

3 Discussion

The analysis of Ross Gardiner's electro-fishing data, and the flow data from the Scottish Environment Protection Agency's monitoring station suggests strongly that the wide fluctuations in salmon fry densities in the Broom are due to variations in winter flows during the previous winter. In wetter winters, fry abundance declines, but in drier winters fry abundance improves. Analysis of monthly flows and peak daily flows indicates that high runoff and large spates in March are most likely to result in low fry abundance the following summer. This suggests that the mortality of fry during hatching and emergence due to excessive bed movement is the primary cause of the problem.

That summer fry densities are positively and significantly correlated with 1+ parr densities the following year demonstrates that mortality at the emergence stage is not compensated for by an abundance of fry. This may well be because the vast majority of the river suffers from bed movement when it occurs, leaving few spawning areas undisturbed. Combined with poor egg deposition due to depleted runs of adults, insufficient fry are produced in wet years to compensate for the losses. Furthermore, the positive correlation between fry and parr indicates that wetter winters, and wet periods in March in particular, limit smolt production in the Broom, and therefore adult returns from those affected cohorts.

The artificial redd experiment in the winter of 1998/99 suggests that there are significant differences between the susceptibility of different rivers in the WRFT area to redd

washout. The Broom is particularly unstable, with 89% of the accessible river bed being extremely unstable; by contrast, only 4% of the River Kanaid (a neighbouring catchment to the north) is unstable. This may account for the fact that the washout of the Broom artificial redds was worse than the WRFT average for both salmon (60% versus 57%) and sea trout (80% versus 68%). Consequently it can be concluded that not all rivers in the WRFT area are affected by emerging fry mortality to the same extent as the Broom. Therefore the west coast phenomenon of wetter winters may be limiting smolt production and runs of returning adults only in the more unstable rivers such as the Broom.

Appendix III

Calculation of wild salmon spawning targets

1. Data used to calculate wild salmon spawning targets

JUVENILE HABITAT	Maximum smolt output	Egg-smolt survival rate	Target egg deposition rate
¹ RIVERINE	0.05/m ²	0.017	2.6/m ²
² LACUSTRINE – Grade 1	20/ha	0.019	1,052/ha (0.105/m ²)
³ LACUSTRINE – Grade 2	7/ha	0.019	368/ha (0.037/m ²)

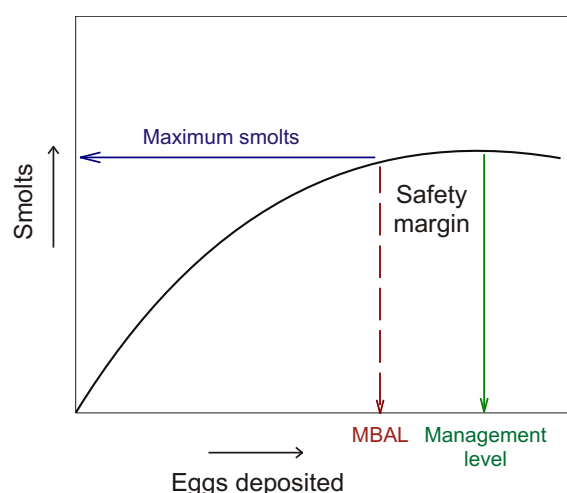
¹ **Riverine habitat** Data are used from the FRS Girnock Burn trap, River Dee. It has been calculated that the riverine area of 58,000 m² above the trap requires a minimum of 150,000 eggs to produce a maximum smolt output of 3,000 fish. This equates to an egg deposition rate of 2.6/m². However, to allow for a ‘safety limit’ the FRS have increased the target by 15% to 3.0/m².

² **Lacustrine habitat – Grade 1** Shallow lochs are more productive than deeper, oligotrophic ones. For the sake of definition, shallow lochs have been termed Grade 1. To estimate the potential smolt output of these lochs, data have been used from the WRFT Tournai trap. In 1999 the system produced a run of 703 smolts, and scale samples showed that 534 (76%) had grown in Lochs Dalthean and Loch a Chuirn¹⁷. Both lochans are small, shallow and reedy, and have a total area of 26 ha. This equates to a smolt output of 20/ha, and using the Canadian lacustrine egg-smolt survival rate (see below) of 0.019, an egg deposition target of 1,052/ha was derived. The productivity of lochs for salmon depends on the level of competition from other species. In Tournai only brown trout and eels are present, and since this is typical of most lochs in the WRFT area, this egg deposition target is probably transferable to other Grade 1 lochs.

³ **Lacustrine habitat – Grade 2** There are no data available for deeper, unproductive lochs in Scotland. Instead, information for lakes in Newfoundland, Canada, were used, where the average smolt output is 7/ha. It has been calculated for these unproductive lakes that the egg-smolt survival rate is 0.019, yielding an egg deposition target of 368/ha.³⁶

2. Biological and management spawning targets

Different forms of spawning target are used within the range of salmon-producing countries. The first is the Minimum Biological Acceptable Limit (MBAL). This egg deposition target is set at the minimum eggs required to produce the maximum number of smolts, and surplus return of adults. However, this target does not allow any contingency for unforeseen disasters (e.g. disease, redd washout, acidification) which might reduce the survival of eggs below that predicted. Consequently some rivers set a management level, that also produces the maximum number of smolts, but aims for a slight overproduction of eggs to compensate for any problems. Management levels also give a degree of security when the data used to calculate spawning targets may be inaccurate. These spawning targets are illustrated in the theoretical stock-recruitment graph opposite.



Appendix IV

Summary of the six conservation status categories standardised for Atlantic salmon by the World Wide Fund for Nature. (One generation is equal to 5 years.)

Category	Criteria (one of the following applies)
1 Extinct	• Known historical presence, but no evidence of reproduction for one generation.
2 Critical	• Less than 50 spawners annually. • Decline in population size by an order of magnitude within the last generation. • Average of less than 20% attainment of spawning targets in most recent years. • An average of more than 30% of spawners in last five years are farm escapees. • Non-native smolts constitute more than 30% of smolts annually.
3 Endangered	• Fewer than 50 spawners at least once in each generation. • Population reduced by 50% in most recent generation, or 75% over longer time period. • Average of 20–50% of spawning target attained in two most recent years. • An average of more than 10% of spawners in last five years are farm escapees. • Non-native smolts constitute more than 10% of smolts annually.
4 Vulnerable	• 50–100 spawners and no serious decline caused by human factors. • Average of 50–90% of spawning targets attained in two most recent years.
5 Healthy	• More than 500 spawners and no serious problems caused by human factors. • Average of 100% of spawning target attained in two most recent years.
6 Unknown	• Too little information available to enable categorisation.

Appendix V

Catch records

Please follow the following principles, as shown in the example below, for accurate catch recording:

- Record the date
- Record *all* fish caught, including small finnock and trout
- Record each fish individually if possible
- Record place of capture
- Record weight of fish, estimated if fish returned
- Record whether released or killed
- For salmon, record if wild or farm escapee

Note any other interesting points: sex of fish, time of day, sea lice damage, tags, put in hatchery, etc.

Sample catch records:

Date	Name	Place	FISH	Weight (lb)	Killed/Returned?	Notes (fly, pool), sea trout tag details, sea lice damage etc.
21st July 1999	Mr. Joe Bloggs	Balgy	Salmon	5 lbs.	Killed	Escaped farm fish. Grass Pool, Stoa's Tail, spate. 8 pm.
" " "	" "	"	Sea trout	8 ozs.	Returned	Finnock. Bridge Pool. Stoa's Tail. 9.30 pm. Not tagged. approx. 40 lice
25th July 1999	Mrs. Mary Bloggs	Balgy	Salmon	11 lbs.	Returned	Wild hen fish, quite stale. Thunder & Lightning, Falls Pool, dusk.
" " "	" "	"	Salmon	4 1/2 lbs.	Returned	Fresh cock fish, wild. Thunder & Lightning. Bridge Pool, 9 pm.
" " "	" "	"	Sea trout	2 lbs.	Returned	Fresh run, Bridge Pool. Zulu, 11pm. Night fishing.
" " "	" "	"	Sea trout	9 ozs.	Returned	Finnock. Bridge Pool. 11.30 pm.
" " "	" "	"	Brown trout	10 ozs.	Returned	Bridge Pool, Zulu, 12 pm. Fishing for sea trout.
1st August 1999	A.N. Other	Loch Damp	Brown trout	1 lb. 2 ozs.	Killed	Dap. 3 pm in Narrows.
" " "	" "	"	Brown trout	10 ozs.	Killed	Dap. 2.30 pm at boat house.
" " "	" "	"	Sea trout	3 lbs.	Returned	Stale hen fish. Dap in Narrows. 2.30 pm.



Wester Ross has some of the most exciting and prolific wild game fishing in Scotland. Although many of the numerous brown trout lochs can still provide outstanding sport, stocks of salmon and sea trout have declined in many river systems over the past 10–15 years.

Healthy salmon and sea trout populations are not simply of importance to fisheries. These fishes were probably of 'keystone' importance to the development of diverse and productive freshwater ecosystems. The breeding success of birds such as Black-throated diver, Osprey and White-tailed eagle may have been related to the abundance of fish. The distribution of otters and freshwater-pearl mussels may also be partly related to the abundance of trout and salmon.

Wester Ross Fisheries Trust was established in 1996 in response to the need for solutions to fisheries problems and to improve the management of wild fisheries. The Trust employs a full-time biologist and several part-time assistants. This report provides an outline of the following:

Catches of salmon and sea trout in the River Broom

Results of juvenile salmon and trout surveys within the catchment

An assessment of the freshwater habitat accessible to salmon and sea trout

Management recommendations and options to restore the natural fisheries productivity of the River Broom system

Wester Ross Fisheries Trust is a registered charity dedicated to the conservation, restoration and development of healthy and sustainable fisheries in Wester Ross.

New members are always welcome!

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