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THE MANAGEMENT AND CONSERVATION OF ATLANTIC SALMON AND ITS HABITAT IN THE RIVER MOY, IRELAND

A GESTÃO E CONSERVAÇÃO DO SALMÃO DO ATLÂNTICO E DO SEU HABITAT NO RIO MOY, NA IRLANDA.

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Abstract

The stocks of Atlantic salmon (*Salmo salar*) are declining internationally and increased attention is being given to the conservation of the fish. Similar concerns are present in Ireland where the salmon is an emblematic species. Traditionally, the River Moy in western Ireland is one of Ireland's most productive salmon angling rivers. However, the stocks of salmon have become depleted in recent years, due to a range of natural and human factors which impinge on the fish and its habitat in the river and at sea where it spends part of its lifecycle. This chapter adopts an actor-centred approach as a method of gaining insight into these factors. The research is based on critical analysis of an extensive range of scientific publications and reports.

Keywords: Salmon, conservation, River Moy, Ireland

Resumo

Os stocks de salmão do Atlântico (Salmo salar) estão a diminuir internacionalmente e é dada cada vez mais atenção à conservação do peixe. Preocupações semelhantes estão presentes na Irlanda, onde o salmão é uma espécie emblemática. Tradicionalmente, o rio Moy, no oeste da Irlanda, é um dos rios mais produtivos para a pesca de salmão no país. No entanto, os stocks de salmão têm vindo a esgotar-se nos últimos anos, devido a uma série de factores naturais e humanos que afectam o peixe e o seu habitat no rio e no mar, onde passa parte do seu ciclo de vida. Este capítulo adota uma abordagem centrada no ator como método para obter insights sobre estes fatores. A investigação baseia-se na análise crítica de uma vasta gama de publicações e relatórios científicos.

Palavras-chave: Salmão, conservação, Rio Moy, Irlanda

1- Introduction

This chapter addresses the subject of natural resource conservation in the context of the Atlantic salmon (*Salmo salar*). Salmon is a diadromous species that begins its life cycle in fresh water, migrates to sea, at about two years of age, and returns to spawn one or more years later. A widespread decline in the numbers of Atlantic salmon has been noted internationally in recent decades to which solutions are sought (ICES, 2022). Atlantic salmon is an Annex II species under the 1992 European Habitats Directive and member states are required to conserve its habitat and protect the stock status (O'Keeffe & Dromey, 2004). The measures taken for the protection of the salmon involve interaction between the fish and a wide range of other entities, many of which also interact with each other in the context of the salmon. These relationships may be viewed usefully as an actor-network as a method of describing

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their structure and interactions (Massey et al., 2021), an approach adopted in the research reported in this paper.

In Ireland, the Atlantic salmon is an iconic species, a valuable ecological link in the aquatic food chain, an indicator of high quality water and a source of revenue (Dalton et al., 2014; Grilli et al., 2018). The number of salmon returning to Irish rivers declined from about 1,760,000 in 1975 to 171,700 in 2022, resulting in reduced reproduction of the fish and reduced income for the state (IFI, 2024). Recreational angling with rod and line is an important source of revenue regionally and locally, equalling €280 per day (excluding travel) for non-local anglers, in 2016, on the River Moy, Ireland's most prolific salmon river (Grilli et al., 2018). There are, therefore, several reasons for increased attention being given to reversing the factors contributing to the reduction in salmon numbers returning to Irish rivers.

This chapter focuses on the threats to the Atlantic salmon and the measures taken for its protection in the River Moy (referred to hereafter as the Moy) in western Ireland. The aims are: (i) to identify the network of actors focused on the management and conservation of salmon and its habitat in the Moy catchment; (ii) to identify key threats to the salmon in the catchment and the actions taken to offset those threats; and (iii) to examine how an actor-centred approach can provide insight into the challenges associated with conserving the fish stocks. The evidence is based on documentary research. The chapter proceeds by discussing the actor-centred approach used in the study, outlining the methodology, describing the life course of the salmon, presenting the findings, followed by a brief summary and conclusion.

2- An actor-centred approach

Discussion of an actor-centred approach calls actor network theory (ANT) to mind. ANT is well documented and is introduced only briefly here to explain why only certain elements are applicable to the study of the conservation of the salmon stocks and the protection of their habitat in the Moy catchment. ANT may be described as a form of social analysis that permits the relationships between stakeholders in a particular network to be studied in a dynamic way (Callon, 1999; Law, 1993). The actions between the members of the network assume importance, not just the actors per se. ANT has its origins in science and technology studies and the sociology of scientific studies in the early 1980s (Jöhannesson & Bærenholdt, 2009). Some of its principal proponents are John Law (1993), Michel Callon (1999) and Bruno Latour (2007) who drew on ideas proposed by the French philosophers Michel Foucault, Michel Serres, Gilles DeluzE and Felix Guttari. The emphasis is on 'practices' or actions. ANT is based on the methodological principle of material relationalism which proposes that "researchers should refute not only all pre-given distinctions between the natural and the cultural but all distinctions which essentialise actors, in favour of the processes, the translations by which networks (do) *work"* (Eden et al., 2000, 262). The concept of translation, inherent in ANT, means that the outcomes of the actions taken should be identifiable; for example, the extent to which the salmon has responded to the actions adopted for its conservation. Because the conservation actions are ongoing on the Moy, it is not possible to reach definitive conclusions about the extent to which the salmon has responded. Thus, although the focus on actions as well as actors and the recognition of the agency of non-human entities

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as well as humans inform the research, ANT as such is not used. For critical discussion of ANT see, for example, Woods (1997) and Bosco (2006).

An actor-focused approach enables the salmon to be placed at the centre of the network of the other actors and actions that impinge on its welfare (Massey et al., 2021). These include the natural aquatic environment in the river, its sources of food, the temperature of the water, sources of pollution that can threaten its survival, a range of institutional actors at local, regional, national and international levels that serve to protect the fish or whose activities impinge negatively on it and its environment, owners and managers of angling waters and anglers who present threats whilst also affording protection in certain ways. The relationships and actions between the salmon and the other actors are not static. They change over the fish's lifecycle and its geographical progress in a dynamic way as the salmon migrates between freshwater and the sea.

3- Methodology

The research is based on 152 publications, including academic papers, reports by international scientific bodies, publications of Inland Fisheries Ireland (IFI), the agency responsible for managing and protecting salmon stocks, and other agencies and organisations that support the welfare of the fish and its habitat. For reasons of space, only some sources are cited in this chapter. Some of the actors were known from previous research (Cawley, 2018) and others were identified from the reviewed literature. The academic papers and scientific bodies' publications were sourced through searches on the Web of Science and Google Scholar, for years since 2000, using the terms 'Atlantic salmon Ireland' first and then refining the results with reference to 'River Moy', 'life cycle', 'habitat', 'protection', 'threats', 'nutrients', 'sedimentation', 'predator', 'remediation' and the different terms applied to the fish at different stages in its life cycle. Fifty-four sources consulted on the IFI web site consist of: legislation relating to salmon angling in Ireland; annual reports on salmon and sea trout angling, 2010-2023, and reports on salmon monitoring programmes; reports relating to the application of the EU Habitats and Water Framework (WF) Directives for various years; reports on the fish stocks in individual lakes in the Moy catchment; 20 annual Research Newsletters; and other reports specific to the study.

Other organisations of particular importance in protecting the salmon stocks directly or indirectly whose publications and web sites were consulted are: the government Department of Food, Agriculture and the Marine (DAFM); the research-based Marine Institute (MI); the Environmental Protection Agency (EPA) and the county councils which have responsibility for implementing the EU Water Framework (WF) Directive; the Office of Public Works (OPW) which is responsible for the maintenance of river drainage; the National Parks and Wildlife Service (NPWS) and its parent, the Department of Housing, Local Government and Heritage (DHLGH), which are responsible for ensuring compliance with the EU Habitats Directive, under which the Moy catchment is designated as a Special Area of Conservation (SAC) and the salmon is protected; Uisce Éireann which provides water services; Teagasc, the Agriculture and Food Development Authority, which advises farmers on land use practices; the River Moy Trust (RMT), a voluntary organisation, which promotes community care of the river; the international North Atlantic Salmon Conservation Organisation (NASCO), whose mission is to support

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and promote actions for protection, conservation and restoration of wild Atlantic salmon throughout the species' range; annual conference reports and posts of Salmon Watch Ireland (SWI), a membership organisation dedicated to restoring wild Atlantic salmon and sea trout; and publications of AFLOAT, a marine journalism source.

In reading the various sources, information was recorded under the headings of 'actors' and 'actions' posing threats to the welfare of the salmon and those serving to offset those threats, according to the various stages of its lifecycle. This information is discussed in the results section and summarised under the headings used in Table 1.

4- The life cycle of the Atlantic Salmon (*salmo salar*): requirements and threats

The Atlantic salmon has different requirements at different stages in its life cycle. Adult female salmon usually return to their river of origin in late summer and autumn, having spent one or more years at sea, and lay their eggs in gravel beds ('redds'), generally in the upper reaches of a river. The eggs are fertilised by one or more males and covered by the female with gravel by her tail to several centimetres in depth to protect them from detritus and predators. Suitable supplies of well-oxygenated gravel, free of sediment, on the river bed are essential for the successful laying and hatching of salmon eggs and for the longer-term survival of the fish stocks (Cooke, 2022).

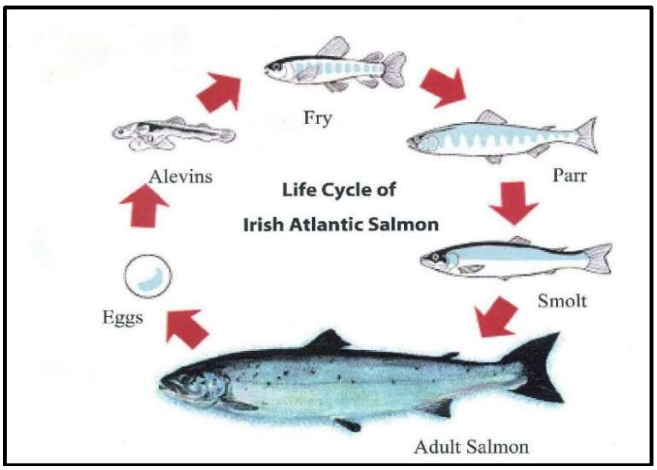


Figure 1. Life cycle of Irish Atlantic Salmon
Source: www.marine.ie

When salmon fry ('alevins') hatch, usually in April and May, they are sustained initially by the yoke sac which they retain (Figure 1). After three or four weeks, they begin to swim up to the surface of the water to fill their swim bladder with air and gain neutral buoyancy, making it easier to swim against the current in fast flowing streams. This critical period exposes the alevins to predators such as cormorants (*Phalacrocorax carbo*), eel (*Anguilla Anguilla*) and trout (*Salmo trutta*). When the alevins begin to swim freely they are called 'fry'. Their food consists of microscopic invertebrates, such as the larvae of caddisfly (*Trichoptera*), mayfly (*Ephemeroptera*) and stonefly (*Plecoptera*), and their

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abundance is regulated by temperature, predation, pollution and competition for food with other fry and other species of fish. A temperature of 15:9_C has been identified as optimum for salmon growth (Elliott & Hurley, 1997) and thermal stress may occur at temperatures above 20_C from reduced water levels and reduced oxygen in the water. Over the autumn the salmon fry develop into 'parr' which have vertical stripes and spots that provide camouflage. They continue to feed on freshwater invertebrates and continue to grow for one to three years while maintaining their territory in the stream.

Climate-driven increases in freshwater temperatures directly affect the numbers, growth and later survival at sea of juvenile salmon (MOBLEY et al., 2021; Thorstad et al., 2021). River bank vegetation plays a central role in providing food, shade, protection from predators and controlling water temperatures (Cooke, 2022; Kelly & Kelly, 2024). Suspended sediments serve to reduce visibility and the capacity to avoid predators (Kelly & Kelly, 2024; Suttle et al., 2003). Excess organic nutrients (nitrates and phosphates) reduce oxygen in the water and can cause fish kills (Dalton et al., 2014). Competitors for food include the offspring of inter-breeding between farmed salmon and wild salmon, which mature more quickly (McGinnity, et al., 2009), and the Pacific salmon (*Oncorhynchus gorbuscha*), a recent arrival in Irish rivers, which has a two-year life cycle (IFI, 2023a; Millane et al., 2019).

Once the parr have grown to 10cm-25cm in length, they pre-adapt physiologically to life in seawater by a process known as smolting. Their salt-regulating mechanisms change, they become more silver in colour and swim with the current instead of against it. In spring, large numbers of one-to-three-year-old smolts swim downstream to the river estuaries. On reaching the sea they migrate along the North Atlantic Drift, and into the rich feeding grounds of the Norwegian Sea and the wider North Atlantic Ocean (THE MARINE INSTITUTE, undated).

The smolts encounter biotic (predation) and abiotic (water flow and water temperature) threats to their survival on the journey to the ocean (Barry et al.. 2024). Smolts grow quickly in the sea but can be affected by infestation by sea lice (*Lepeophtheirus salmonis*), which can be exacerbated by ocean warming (Shephard & Gargan, 2021). Salmon post-smolts are also subject to capture as by-catches by pelagic fishing vessels in international extra-territorial waters (Gibney et al., 2021). It is difficult to identify with precision the factors that affect the survival of salmon at sea. However, "rising ocean temperatures and acidity and concurrent changes in ocean circulation, stratification, nutrient input and oxygen content" are impacting on food web dynamics and other ocean processes with implications for salmon (Thorstad et al., 2021, 2657).

Salmon that reach maturity after one year at sea ('grilse') may return in summer weighing 0.8kg-4kg. If it takes two or more years at sea to mature, the salmon will return in spring as larger fish (3kg to 15kg), much prized by fishermen. A high proportion of salmon return to their river of origin. On return they may face a series of challenges before reaching the upstream spawning areas, including poachers, pollution from anthropogenic and other sources and physical obstacles in their paths (IFI, 2024). Angling by rod and line is not considered a threat; it is strictly regulated in terms of the angling season and the numbers of fish that can be taken from the water and is monitored closely by IFI and private fisheries

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(Cawley, 2018). Mortality can be significant after spawning but some salmon survive, return to the sea and return to their rivers of origin again (THE MARINE INSTITUTE, undated).

5- Results: conserving the Atlantic Salmon and its habitat in the River Moy, an actor-centred analysis

The River Moy rises in the Ox Mountains of County Sligo and flows through the adjoining County Mayo for most of its 100 km length, draining a catchment of over 2000 km^2 (Figure 2). The system includes two large lakes, Lough Conn and Lough Cullin, and many small lakes and streams. For much of its course, the Moy flows through lowland pasture and is fed by streams from the surrounding mountains. The Moy records the highest Irish catches of salmon by rod and line but catches fell from an estimated 9500 in 2010 to some 4800 in 2022, reflecting declining returning numbers of fish (IFI, 2010-2023). A recent report identified the main threats to the survival of salmon in the Moy catchment as draining/channel modification, agricultural enrichment, afforestation, inadequate sewerage treatment and industrial discharge (Nasco, 2020, 23). These threats and counteracting them involve many actors and actions, as the analysis of the literature illustrates.

Threats to the returning salmon include poaching (illegal netting), increased water temperatures, removal of shade, and obstacles that interrupt movement upstream (Table 1). Fishing with nets for salmon ceased in Irish rivers in 2007 (Greene, 2006). Occasional poaching occurs on the Moy and the offenders are prosecuted in the courts. River bank shade helps to regulate the water temperature for adult as well as young fish and IFI and landowners undertake appropriate pruning and replace vegetation that has been removed. Angling is suspended when the thermal stress limit of 20º_C is exceeded, which occurred on the Moy between the 8th and the 21st of September 2023 (Afloat, 2023; IFI, 2023c). Obstacles in the path of salmon as they swim upriver to spawn include high weirs, the pediments of bridges and inappropriate culverts, that may become more difficult to surmount as water levels fall (IFI, 2024). IFI has established a Barrier Mitigation Division (IFI, 2024) and, in collaboration with the OPW, removed 14 weirs from the River Glore, a tributary of the Moy, in 2024 (Wroc, 2025).

An adequate supply of well aerated gravel is essential for successful spawning and egg hatching. The supply of gravel in several areas of the Moy catchment was depleted during the 1960s during two arterial drainage schemes which deepened the river (EPA, 2018). A decline in spawning and fish production followed. Gravel refurbishment and associated downriver boulder placement, to reduce gravel erosion, is in progress in 2024 with the OPW, in 38 sites on the Moy and five of its tributaries (Figure 2; Walsh & Partners, 2022). The EU WF Directive is supportive in promoting the restoration and maintenance of high status hydrological conditions (EPA, 2024).

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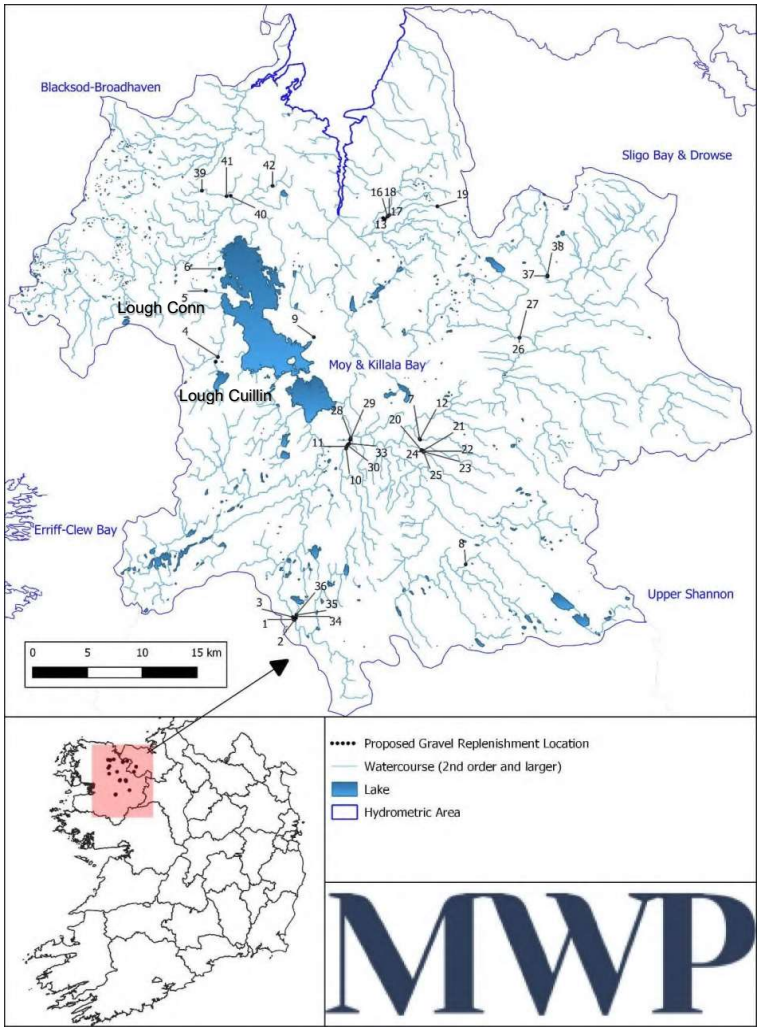


Figure 2. The River Moy
Source: WALSH & PARTNERS (2022)

Sediment from the erosion of river and stream banks at livestock watering points impacts on salmon spawning and egg development in gravel and, when in suspension, reduces the capacity of the salmon fry to escape predators (WILD TROUT TRUST, 2022). The IFI has introduced fencing along watercourse banks to reduce this problem and farmers who have derogation from the EU Nitrates Directive are required to install fencing 1.5 metres from a waterway (DFAM, 2024). Teagasc provides advice to farmers about the fencing of riparian areas

Sedimentation and acidification of water from the felling of coniferous forests take place in a number of areas, including along the headwaters of the River Deel in the northwest of the catchment (Dhlgh, 2020). The timing of felling involves discussion between IFI and the state forestry company, Coillte, to minimise the negative impacts. In a positive development, conifers are being replaced with native deciduous tree species in the environs of Lough Conn and Lough Cullin (Dhlgh, 2020). Sediment release from two quarries in the south of the catchment placed water quality at risk, in 2024, and required remedial action (EPA, 2024).

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Table 1. The actor network focused on the Atlantic salmon during its life cycle in the River Moy catchment

Age	Lifecycle stage of salmon	Actor sources of threat	Regulatory, research and remediation actors and actions
3+ yrs	Returning salmon moving upstream	1. Poaching with nets; 2. Climate change and removal of shade; 3. In stream physical obstacles.	1. IFI angling regulations and legal system; 2. IFI and landowners replacing vegetation; 3. IFI, OPW, local authorities;
3+ yrs	Spawning and ova	1. River drainage and gravel removal; 2. Sedimentation; 3. Eutrification; 4. Removal of shade.	1. OPW, IFI, WF Directive; 2&3. IFI, EPA, local authorities, NPWS, Coillte, Teagasc; EU Directives; legal system; 4. IFI, landowners.
<1 yr 1-2 yrs	Alevin and fry Parr	1. 1-4 as for spawning and ova development; 2. Competitor for food- Pacific pink salmon.	1. 1-4 as above; 2. Monitoring by IFI and reporting by anglers; research by IFI, NASCO.
2+ yrs	Smolts	1. Predators in estuary; 2. Sea lice; 3. Death at sea.	1. IFI monitoring; 2. IFI, MI: monitoring, research and action as necessary; 3. Research by IFI, MI, NASCO.
3+ yrs	Adult fish North East Atlantic	1. Increased sea temperatures, arising from climate change, affect food supply; 2. Harvesting as by-catches; 3. Predators.	1-3.IFI monitoring and research in association with NASCO; representation by NASCO.

Source: Scientific literature and official reports

Runoff of nutrients (nitrates and phosphates) from slurry on farms and sewage works reduces the oxygen level in rivers and streams and promotes weed growth, impairing the health of the salmon throughout its life cycle. Low levels of runoff from farms in several parts of the catchment are considered by the EPA (2024) to pose a threat to water quality. Nutrient enrichment is greatest in areas of intensive agricultural production in some western areas (EPA, 2024) and contributed to fish kills in the past (Marson & Kelly, 2024). Teagasc promotes good practice among farmers in this regard. Leakage from sewage and wastewater treatment works occurs in the environs of the towns of Castlebar and Ballina and a number of smaller towns (EPA, 2024) and requires action by the local authorities and Uisce Éireann. Chemicals can be a problem and those used in the cleaning of a water treatment tank were identified as a probable cause of the death of some 500 young salmon and trout in 2021 (Meadows, 2021). IFI monitors these events and takes legal action in association with the NPWS, the local authority and the EPA, if required. This can include action against Uisce Éireann.

An absence of sediment and nutrients in the water and the presence of shade are necessary for the survival and successful growth of the salmon alevin, fry, parr and smolts (Table 1). Maintenance of river banks and their vegetation by landowners is supported by IFI to contribute to habitat diversification and to supplies of invertebrates for the juvenile salmon and provide appropriate shade from increased water temperatures (Cooke, 2022). A Pacific pink salmon, whose fry competes vigorously for food with

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Atlantic salmon fry, was caught in the Moy in late June 2023 (IFI, 2023b) and poses a new threat that is being researched by IFI and NASCO. Anglers are requested to report all sightings of the fish.

When the smolts swim downstream to the Moy estuary at about two years of age on their way to the sea they encounter new threats to their survival in cormorants (*Phalacrocorax carbo*), common seals (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) (Cronin et al., 2014). There is a reluctance to interfere with natural competition from the main predators, except in exceptional circumstances. Smolts grow quickly in the sea but can be affected by sea lice infestation (*Lepeophtheirus salmonis*) acquired from escaped farmed fish in the estuary area. IFI is vigilant in monitoring the escape of fish from fish farms which can also infect returning salmon. Internationally, NASCO monitors climate change, changing sea temperatures and their impacts on sources of food for salmon, the salmon per se and the impacts of by-catching by pelagic fishing vessels and makes representations to the appropriate bodies.

6- Summary and conclusion

The research identified: (i) the network of actors involved in protecting and conserving the salmon stocks in the Moy; (ii) the main threats to the welfare of the salmon and the measures taken to offset those threats; and (iii) the value of an actor network approach in understanding the processes at work.

It is apparent that salmon in the Moy are subject to a growing number of threats throughout their life cycle which contribute to their declining numbers.These arise from both public and private land use practices and climate change. A wide and growing number of measures have been introduced to improve the habitat for the fish which involve many agencies and organisations among which IFI plays a pivotal role in being responsible for managing and conserving salmon stocks as a public good and a source of revenue. The welfare of the Atlantic salmon depends also on global climate change and actors and actions during its life in the North East Atlantic Ocean that are not well understood and require research and collaboration at an international level.

The research does not provide solutions to the many issues that surround the welfare of the Atlantic salmon but the application of an actor-centred approach illustrates the complexity of the task involved in its conservation and that of its habitat and the need for collaborative actions.

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