

Assessment of the socio-economic value of aquaculture and sport angling for wild salmonids in northwestern Europe

Implications for treatments for sea lice infestation

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Norwegian Institute for Nature Research

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Abstract

Whelan, B., Aas, Ø., Uglem, I., Curtis, J. & Dervo, B. 2006. Assessment of the socio-economic value of aquaculture and sport angling for wild salmonids in northwestern Europe. Implications for treatments for sea lice infestation. NINA Report no.126. 45 pp.

This report presents the overall results achieved in the socioeconomic workpackage in the EU financed project SUMBAWS; Sustainable Management of Interactions Between Aquaculture and Wild Salmonid Fish.

The specific objectives of the work package, as stated in the project proposal, were to:

- quantify the socio-economic importance of the aquaculture and game angling sectors to the individual national economies.
- determine the economic effects (benefits and costs) of mutually acceptable sea lice treatments in the aquaculture sector, including the inter-industry effects.
- provide an overall cost-benefit analysis of sea lice, including both financial and socio-economic elements.

The first chapter examines the economic significance the Atlantic salmon (*Salmo salar* L.) in three countries: Ireland, Norway and Scotland. These countries are among the most important countries for conservation and use of Atlantic salmon. The chapter begins by considering the various approaches which can be used in economic evaluation of fisheries and aquaculture, and opts in this instance to focus on the “economic impact” method. It derives broad-brush estimates for output, employment and overall economic impact for the three main sectors based on Atlantic salmon (recreational angling, commercial fishing and aquaculture) in each country. It goes on to show how these can be used to characterise the manner in which the salmon stocks are utilised in each country and concludes that the economic impact of recreational exploitation, compared to aquaculture, measured either in terms of output, employment or net impact, is more significant than is sometimes thought. Commercial fishing for salmon is insignificant compared to the two other sectors. In the final section, it enumerates a number of considerations which need to be borne in mind when using the data presented to make decisions and plans about the management, conservation and enhancement of salmon stocks, and identifies further research needs. Despite a general recognition of the huge social and economic values associated with Atlantic salmon, and the development of a substantial literature on individual regions and countries, few studies have reported and estimated the overall economic value of Atlantic salmon across a number of countries and compared the value of different types of use. There are probably a number of reasons for this dearth of work. First, as will be shown below, the term “economic value” can be defined in many ways, and therefore the studies use a wide variety of approaches and conceptual frameworks, making accurate comparison very difficult (See, for instance, Radford et al. 2001). There have also been wide variations in the methodology and data used. Furthermore, most studies are focused on elucidating policy decisions in a single country, region or locality.

The aim of the second chapter is to provide estimates of the costs associated with more effective sea lice treatment in Irish, Scottish and Norwegian salmon farms. To operationalise this concept in our models, we have chosen to estimate the costs of one additional, or marginal, prophylactic treatment. It is assumed for illustrative purposes that this additional treatment would reduce the infection level on wild fish significantly. Moreover, the reported cost estimates are compared with the overall value of salmonid production in Ireland, Scotland and Norway. The total estimated costs of one additional or marginal treatment across all salmonid fish farms correlated closely to the production volume in the three countries, with Ireland having by far the lowest cost (€0.38m.) and Norway having the highest (€11.65m.). The total cost estimate for Scotland was €3.28m. The estimated treatment costs as a proportion of the production value (Norway: 0.46%, Scotland: 0.44% and Ireland 0.36%) and the cost per kg produced fish (Norway and Scotland: €0.013 and Ireland: €0.011) were nevertheless relatively similar. The cost

estimates presented in this report are most likely maximum estimates of the cost of additional treatment against salmon lice. If an additional treatment were carried out as a mitigative action in a realistic situation it would be possible to reduce the costs since not all farming areas interact with important areas for wild salmonid migration. Furthermore, detailed knowledge on migration patterns and habitat use might enable a pinpointed treatment in cases where the areas overlap and it might be unnecessary to intensify the treatment in areas with a naturally low infestation level. Finally, optimization of the current treatment schedules might also reduce the need of increased treatment.

Chapter four focuses on what can be learned for the purposes of the present project from the collapse in sea trout populations in the West of Ireland since the late 1980s. It documents and quantifies the resulting decline in angler numbers and estimates the consequential drop in tourist expenditure in the region. By utilising some of the results and experience gained in Workpackage 7 of the SUMBAWS project, which is also based in the West of Ireland region, cost estimates for the preventative treatment of wild smolts are produced. The paper shows that the feasibility of widespread use of preventative treatment is questionable and that, even if feasible, very substantial costs would be involved.

The fifth chapter develops a theoretical model of the key stages in the assumed causal chain between enhanced lice treatment, through better smolt survival and improved returns to the coast to economic and social benefits in the form of greater income and employment in the commercial and angling sectors. The model incorporates data from the earlier chapters on economic impact and the marginal costs of an extra nationwide treatment in each country. The main output from the model is a series of Cost/Benefit ratios aimed at summarising the economic impacts from treatments with varying levels of effectiveness. A number of plausible scenarios are simulated to illustrate how these ratios vary with changes in the assumptions.

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Foreword

This report summarises the results from Workpackage 1 on the EU financed SUMBAWS project. It represents the joint work of scientists from Ireland and Norway during a three-year period, with major inputs from research colleagues, managers and fish farmers from Scotland.

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1 Introduction

1.1 Background

The Atlantic salmon (*Salmo salar* L.) is probably the best known and most valuable freshwater fish species around the North Atlantic coast (Mills, 1991). It is one of the world's most prized game fish, attractive in fish markets, and, during the last decades, it has become a major aquaculture species. In short, the Atlantic salmon makes a valuable contribution to the economies of several countries in the North Atlantic. The species has, however, been under pressure for many years due to a variety of environmental and anthropogenic factors, including habitat damage and over-exploitation. It has also long been the subject of conflict between the various users of the resource – essentially different categories of commercial fishermen and sport anglers, along with the industries that depend on them (accommodation provision, tackle dealers etc.). These pressures have intensified in recent years and the species is now believed to be under serious threat (Atlantic Salmon Federation 1998).

An important new source of pressure is the salmon aquaculture industry which has been established and has grown rapidly the last twenty years. The main causes of negative interactions between wild salmon fisheries and aquaculture relates to (a) possible genetic damage from inter-breeding of fish-farm escapees with wild fish and (b) the effects of parasites and diseases spreading from aquaculture to wild fish. The SUMBAWS project focuses on one important parasite, the sea louse, and its possible effect on wild stocks. These effects have consequences for the human activities which depend on, and benefit from, the wild stocks of salmon, as well as for the aquaculture industry.

In this context, the present report provides a socio-economic evaluation of the interactions between the various salmon-based businesses (aquaculture, commercial fishing and angling) in three countries Ireland, Norway and Scotland. It compiles up-to-date, comparable figures for the value of the various sectors, examines in detail the costs involved in lice reduction and devises a methodology for estimating and comparing the costs and benefits involved.

1.2 Objectives

The specific objectives of the workpackage, as stated in the project proposal, were to:

- Quantify the socio-economic importance of the aquaculture and game angling sectors to the individual national economies.
- Determine the economic effects (benefits and costs) of mutually acceptable sea lice treatments in the aquaculture sector, including the inter-industry effects.
- Provide an overall cost-benefit analysis of sea lice, including both financial and socio-economic elements.

It is important to emphasise two dimensions which are excluded from this evaluation. First, it is aimed at assessing the costs and benefits accruing to the participants in the salmon-based industries and to examining how these would change under different lice control regimes. It does not attempt to assign responsibility for who should pay or compensate for any negative effects arising. For this reason, it does not discuss in any detail the application of the principles underlying the EU Habitats Directive to salmon. This Directive “aims to anticipate, prevent and attack the causes of significant reduction or loss of biodiversity at the source” (European Commission 1998) and implies that policy should aim to prevent damage to wild stocks occurring on any substantial scale. Its effect is similar to the “polluter pays” principle which requires the person or organisation causing the damage to pay for its alleviation. In deciding on policy, these principles would have to be taken into consideration along with the economic costs and benefits described below.

Secondly, the evaluation is based on a static “as is” situation. It does not take account of the fact that stocks of wild salmon in most countries are today well below their historic, long-run (and hence potential) levels. This means that runs could be substantially and sustainably improved if the spawning stocks are increased. Thus, if improved lice control led to better runs this would ultimately increase *future* stocks and hence yield benefits over and above the current short-run benefits as estimated in this report.

1.3 Approach adopted

The basic approaches used included the following.

- Literature search: Gather all existing documentation from government, industry and academic sources relating to the production and economics of the aquaculture and game angling businesses.
- Review literature to develop country specific aquaculture models that relate inputs (costs and quantities) to output levels (value and quantities).
- Review literature on the economic and social benefits of game angling to develop indicators which relate game angling expenditure, dependent employment, and incomes to fishing quality and wild population levels.
- Incorporate results from WPs 2,4-7, on the biological effects on wild stocks, and the cost to the aquaculture industry of the sea lice treatments into the economic models to estimate the economic implications for both the aquaculture and game angling sectors.
- Meet with key government and industry personnel to (a) review the models developed for the aquaculture and game angling sectors, (b) elicit opinions on how the models might be adjusted for improvement, (c) discuss model results with respect to the socio-economic implications of the sea lice treatments, (d) elicit comments on how the analysis might be improved based on the key personnel’s knowledge of the sectors.

1.4 Structure of the Report

The remainder of this report is divided into 5 further chapters as follows. Chapters 2-5 are laid as conventional scientific papers and Chapter 6 draws conclusions.

Chapter 2 is entitled *Economic Evaluation of the Salmon-Based Businesses*. Building on the review of methodology and results from the literature on economic evaluation of the three salmon-based industries (angling, commercial fishing and fishing farming), this chapter presents a comparative economic analysis across the three countries Ireland, Norway and Scotland.

Chapter 3, *Costs of Sea Lice Treatment on Farms*, is based on published data, where this was available, and also and on interviews and contacts with industry participants, veterinary experts and specialists from state agencies. It presents detailed estimates of the patterns and costs of sea lice treatments in the three countries. These costs include medication, labour, oxygen etc. As a way of operationalising these cost data for our models, we derive an illustrative estimate of the cost of an extra or “marginal” treatment on all farms. This figure is input into the cost/benefit analysis described in Chapter 5 below.

The fourth chapter, *Consequences of Stock Collapse and Costs of Preventative Treatment*, assembles information on the Irish sea trout collapse and provides unique empirical data on the economic consequences of that collapse arising from reduced angling. Based on the experience of colleagues engaged on Workpackage 7 in the SUMBAWS project, it also presents estimates of the cost of trapping and treating wild smolts on a preventative basis.

Chapter 5, *Modelling the Economic Effects of Sea Lice Treatment*, develops a computer-based model of the lice treatment process and its probable economic effects in the three countries. This model can be used to simulate the effects of different assumptions about the magnitudes

and responsiveness of the variables in question (costs, catches, angling participation rates etc.), to derive estimates of the economic benefits arising and to show how these benefits relate to the costs of treatment. A number of plausible sets of assumptions are examined. A simulation is also carried out of a regional situation where wild rather than farmed fish are treated.

Chapter 6 summarises the overall results and indicates the conclusions which can be drawn for management and policy.

2 Economic Evaluation of the Salmon Based Businesses

2.1 Conceptual Approaches

Overall, the literature on economic evaluation of fisheries utilises two basic frameworks of analysis which differ fundamentally in their objectives, data requirements and policy focus. Pollock et al.(1994) label these the “net value” and “economic impact” approaches. Each of these approaches yields a value expressed in monetary terms, but they differ sharply in what they are valuing and to whom this value accrues.

2.1.1 Net Economic Value

This approach attempts to quantify the benefit received by an individual or group from a resource, product, service or experience, having allowed for the cost involved in obtaining it. The benefits can be monetary (e.g. net income of commercial fishermen) or non-monetary (e.g. the satisfaction an angler gets from a trip to a particular fishery). Costs can also include non-monetary factors such as time or inconvenience.

Net economic value¹ can include both consumptive and non-consumptive (non-depleting) uses of the resource. The main categories of non-consumptive value are:

Existence value: the value placed by society on sustaining a resource for its own sake

Bequest value: the value placed by society on passing on the stock in healthy condition to posterity

Option value: the value placed by non-users on retaining the possibility of using the stock in the future. These values have been estimated as very substantial e.g. a UK study of the value of restoring/keeping salmon in the Thames gave a figure of EUR 18 m (Spurgeon et al 2001)

The main consumptive use values of a fish resource relate to the net incomes (and producer surplus if any) that commercial fishermen derive from the fishery, along with the satisfaction that anglers derive from using the fishery. The latter can be estimated by assessing their “net willingness to pay” or total consumer surplus. Net economic value is derived by subtracting the “opportunity cost” of the resources used in producing the angling experience. In open access (unpriced) fisheries such as are almost universal in the USA, a variety of survey techniques have been developed to measure anglers’ consumer surplus. These include:

- The Travel Cost Method (e.g. Clawson and Knetch 1966)
- Hedonic Pricing (e.g. Gillen 1982)
- Contingent Valuation (e.g. Pollock et al. 1994 Section 16.5)

With private ownership of recreational fishing rights, owners of these rights can charge anglers for access to the fishery. Thus much of the anglers’ consumer surplus that would exist in an open access fishery is converted to an income flow for fishery owners. The market price or capital value of the fishery is capitalisation of the annual income flow (Radford et al 1991). In these circumstances, the net economic (use) value comprises anglers’ consumer surplus and the owners’ income flow. In short, the net economic value approach attempts to assess the overall value to society of the net benefits arising from a resource such as a fishery whether or not these benefits actually give rise to a monetary transaction.

¹ In the literature there is neither a standard classification of the components of Net Economic Value nor a uniform terminology.

2.1.2 Economic Impact Studies

This approach focuses mainly on statistics of turnover, expenditure and related variables. The principal aim is to assess the impact of expenditure on income generation, jobs and overall economic activity in a region. In the case of angling, the key assumption is usually that anglers' expenditure is bringing under- (or un-)utilised resources into productive use. In assessing the effect of angling expenditure, it is vital to focus on the extent of "displacement", i.e. to consider what would happen to the expenditure if the resource were to disappear or become inaccessible. Only those expenditures that would disappear if the resource became unavailable can be counted as part of its economic impact. However, the economic interconnection between angling, commercial fishing and aquaculture is well established. Commercial fishing and recreational fishing compete for the same fish; farmed fish compete in the fish market with netted wild fish; and farming can cause harm to wild stocks, and thereby both to angling and commercial fishing by the spreading of sea lice and by escapees with the potential to have a long-term genetic impact on the stocks (McGinnity et al 2003). To make good overall management assessments of the whole economic sector related to Atlantic salmon, it is important to take into account the overall economic benefits arising from the presence of Atlantic salmon as a resource. To be able to do this, a better understanding of the economic impact on different countries and different uses of this species is needed.

Given existing literature and data sources, and in light of the ownership structure of salmon fisheries in Europe, it is considered that the economic impact approach is likely to be the most relevant for the present study. This approach is likely to yield values which are conceptually comparable with the estimated incomes and costs in the aquaculture sector.

2.1.3 Objective

Ireland, Norway and Scotland are all among the major countries for Atlantic salmon in the eastern part of the North Atlantic (ICES working group on Atlantic salmon report 2004). This paper summarises and updates existing data on the economic value of angling, commercial fishing and farming of Atlantic salmon in the three countries. On this basis, major similarities and differences between the businesses and the three countries are identified and discussed. Identified differences can be used to improve the economic value in different regions and sectors. Lastly, further research needs are identified.

2.2 Materials and Methods

As indicated above, there is a variety of studies in the different countries based on different years, having different conceptual and methodological approaches and covering different geographic areas. These were reviewed in order to identify those most suitable for our present purpose in terms of recency, comparability and coverage. In Scotland, a recent study (Radford et al. 2004) assesses the economic impacts of angling. In Ireland, a national study on the wild salmon sector (angling and commercial) was published in 2003 (Indecon 2003). In Norway, no recent national study of angling or commercial fishing impacts was available, so different statistics and numbers were combined to provide the best overall estimate. In order to examine the impacts from commercial fishing and aquaculture, official catch and production statistics were used in all three countries. A lot of the data used, especially for Norway, were found in so-called grey literature (Colette 1990).

We endeavoured to make the information as comparable as possible by choice of reference year (2002 where possible, 2001 otherwise) and translated monetary amounts into Euro at the exchange rate prevailing in mid 2002 (€1 = STG£0.65 and NOK 9.0, as indicated by data from the European Central Bank).

Table 1.2.1 gives an overview of data sources and the reference years for each country.

Table 1.2.1. Data sources (year published and **reference years**) for information on the economic impact of Atlantic salmon in Ireland, Scotland and Norway.

	Ireland	Scotland	Norway
Number of anglers	Indecon 2003 2001	Radford et al 2004 2002	Dervo & Knutsen 2004/Aas 1997 2002
Number of fishing days	Indecon2003 2001	Radford et al 2004 2002	Fiske & Aas 2001 2001
Angling expenditures	Indecon 2003 2001	Radford et al 2004 2002	Fiske & Aas 2001 2002
Angling - employment	Indecon 2003 2001	Radford et al 2004 2002	N.A.
Commercial fishing – catches	CFB 2003 2002	Fisheries research Services 2003 2002	Mørkved & Krokan 1997/Norway official statistics 2004 2002
Commercial fishing – gross value	Indecon 2003 2001	Fisheries research Services 2003 2002	Mørkved & Krokan 1997/Norway official statistics 2004 2002
Commercial fishing – employment	Indecon 2003 2001	Fisheries research Services 2003 2002	N.A.
Aquaculture production	Bord las- caigh Mhara 2003 2002	Fisheries research Services 2003 2002	FHL Aquaculture 2004 2002
Aquaculture production – turnover	Bord las- caigh Mhara 2003	Fisheries research Services 2003 2002	FHL Aquaculture 2004

2.3 Results

The results, based on these sources, are set out in Table 1.2.2

Ireland – angling

Based on the number of salmon licences issued, Ireland has approximately 33,000 salmon anglers. These anglers consist of one third foreign anglers and two thirds domestic. In total, they catch around 29,000 salmon (78 tonnes). Their combined expenditure is estimated at €80m. and generates employment of about 1,300 full-time job equivalents (FTE).

Ireland - commercial fishing

There are two main commercial salmon fisheries in Ireland – drift and draft net fisheries. They catch a total of 227,000 salmon (604 tonnes), with a gross value of about €4.8m. The drift net fishery accounts for approximately 80 – 85 % of the catches. The employment effect is estimated at 301 FTE.

Ireland farming

Salmon aquaculture in Ireland totalled 21,400 tonnes in 2002. The gross value of the production was estimated at €78m with a total employment effect of 300 FTE.

Scotland angling

There were 33,878 salmon and grilse caught and retained and a further 24,042 caught and released in the Scottish angling fishery in 2002 (Fisheries Research Services, 2003). There are no comprehensive data on the numbers of people who fish for salmon in Scotland, but a rough estimate is considered to be 60,000 anglers. Their overall expenditure is estimated at €113m. The employment effect was estimated at 2,200 FTE.

Scotland commercial fishing

There are two main remaining Scottish commercial salmon fisheries. These are the net and coble fishery and the fixed engine fishery. The fixed engine includes stationary bag nets, stake nets and jumper nets. The net and coble are beach seine operations in estuaries and lower parts of rivers. They were reported catching 24,000 salmon with a gross value of about €0.6m. representing a job effect of 10 – 15 FTE.

Scotland farming

The Scottish aquaculture sector produced 159,000 tonnes of salmon in 2002, with a gross value of about €460m. The employment effect was estimated at 5,000 FTE.

Norway angling

Norwegian angling-based catches of Atlantic salmon have been around 110,000 fish per year during the last three year period. There is no comprehensive, recent study of number of salmon anglers, and their expenditures and valuation of salmon and sea-trout fishing in Norway.

Every salmon angler in Norway is supposed to pay a national salmon angling licence fee, but there is evidence that many fish without paying this fee (Aas 1997). The number of anglers paying the fee have during the last 15 years varied between 150,000 and 75,000, with approximately 90 000 anglers paying the licence in recent years. When asking a sample of the Norwegian population about their participation in hunting and fishing, far higher numbers of salmon anglers occur (Aas 1997), but this method generally overestimates participation rates. Taking these different figures together, we assess the number of salmon anglers in Norway to be approximately 150,000, of which 35,000 are visiting anglers from abroad (Derivo & Knutsen 2004). Overall expenditures are estimated at €160m. There are no available calculations on jobs generated, but assuming a similar ratio of expenditure/jobs as in Ireland and Scotland, (approximately €55,000 per job) an estimate of about 2,900 FTE can be derived.

Norway commercial fishing

The remaining commercial salmon fisheries in Norway consist of two types of fixed net fisheries; the bag net fishery and the bend net fishery. These fisheries take a total of approximately 125,000 salmon, with a gross value of €3m. No figures are available for jobs generated, but studies show they are small. Table 1.2.2 shows an estimated figure of 150 FTE derived by dividing the total catch value by the average catch value per job in Scotland and Ireland (about €20,000 per job).

Norway farming

Norway has an overall salmon aquaculture production of 470,000 tonnes representing a gross value of 1 billion Euro. The FTE for the business is estimated at 10,000 jobs.

Table 1.2.2. Overview of the value of fresh-water game angling, commercial net fishing and aquaculture production of Atlantic salmon in Ireland, Scotland and Norway.

Freshwater Angling	Ireland	Scotland	Norway	Total
Salmon Catch*	29.000	57.900	110.000	196.900
Number of anglers (approx)	33.000	60.000	150.000	243.000
<i>of which out-of-state anglers</i>	<i>10.000</i>	<i>28.000</i>	<i>35.000</i>	<i>73.000</i>
Overall expenditure (€m.)	80.0	113.0	160.0	353.0
Employment (full time equivalents)	1.300	2.200	2900**	6.400
Marine/estuarine Commercial fishing				
Harvested salmon in net fisheries	227.400	23.700	125.000	376.100
Gross value(€m.)	4.9	0.600	3.0	9
Employment (FTE)	300	12	150***	462
Aquaculture				
Production (2002-tonnes)	21	146	470	637
Gross value (€m.)	78.0	460.0	1.000.0	1.538.0
Employment (FTE)	300	5.000	10.000	15.300

* Includes both caught and retained and caught and released fish

** Estimate by the authors based on expenditure/job in Ireland and Scotland

*** Estimate by the authors based on gross value per job in Ireland and Scotland

2.3.1 Economic Impact

The studies on angling in Ireland and Scotland (Indecon 2003 and Radford et al. 2004) estimated the overall economic impact of salmon angling by making three adjustments.

- First, they allowed for the import content of anglers' expenditure. If an angler spends on, say, petrol in a region this does not generate activity in the region to the extent of the wholesale cost of the fuel because this had to be imported. Both studies make allowance for this "import leakage", the Irish study by assuming an overall import content figure of about 40% and the Scottish one by taking each of 14 categories of angler expenditure and examining their impact individually using known import contents for each category.
- Next, they make allowance for "displacement" i.e. the extent to which the angler's expenditure would still occur in the region even if the fishery were to disappear or become inaccessible. It is commonly assumed, for instance, that local anglers will continue to spend in the area (on different products or services) even in the absence of the fishery. In contrast, it is usually assumed that foreign anglers will not visit the region if the fishery is not there. The Indecon study in Ireland assumed a displacement of 85% for Irish anglers while the Scottish study assumed that all the purely local expenditure, and half of the "intra Scotland" trips would represent displacement.
- Thirdly, they took account of the "multiplier effects" of spending i.e. the economic impact attributable to rounds of spending subsequent to the first one. The magnitude of this effect was about 1.2 in both studies, but they used different approaches to arrive at it. The Irish study made an overall assumption based on previous results from input/output tables while the Scottish study modelled the inter-sectoral transactions explicitly. When these two adjustments have been made, the resulting estimate represents the economic impact on output, income and employment.

In the case of the commercial and aquaculture sectors, the economic impact is easier to calculate since it is only necessary to take account of import content and the multiplier effect. Little firm information is available on the import content of the commercial netting sector. It is likely to be relatively small and a figure of 20 per cent is assumed. Aquaculture, being more capital intensive and having high feed costs, is likely to have much higher import content and 40 per cent is assumed.

These calculations and assumptions allow us to derive the figures for overall economic impact shown in Table 1.2.3 and Figure 1.2.1. The huge size of Norway's aquaculture industry is evident, as is the significant contribution made by angling in Scotland.

Table 1.2.3. Overall Economic Impact for fresh-water game angling, commercial net fishing and aquaculture in Ireland, Scotland and Norway

	Ireland	Scotland	Norway*	Total
	€m.			
Freshwater Angling	15.6	124.6	65	205
Commercial fishing	4.7	0.6	2.9	8
Aquaculture	56	331	720	1.107

* The angling figure for Norway is an estimate by the authors assuming foreign anglers in Norway spend 50% more than domestic anglers, and that 85% of local angler's expenditure can be considered "displaced"

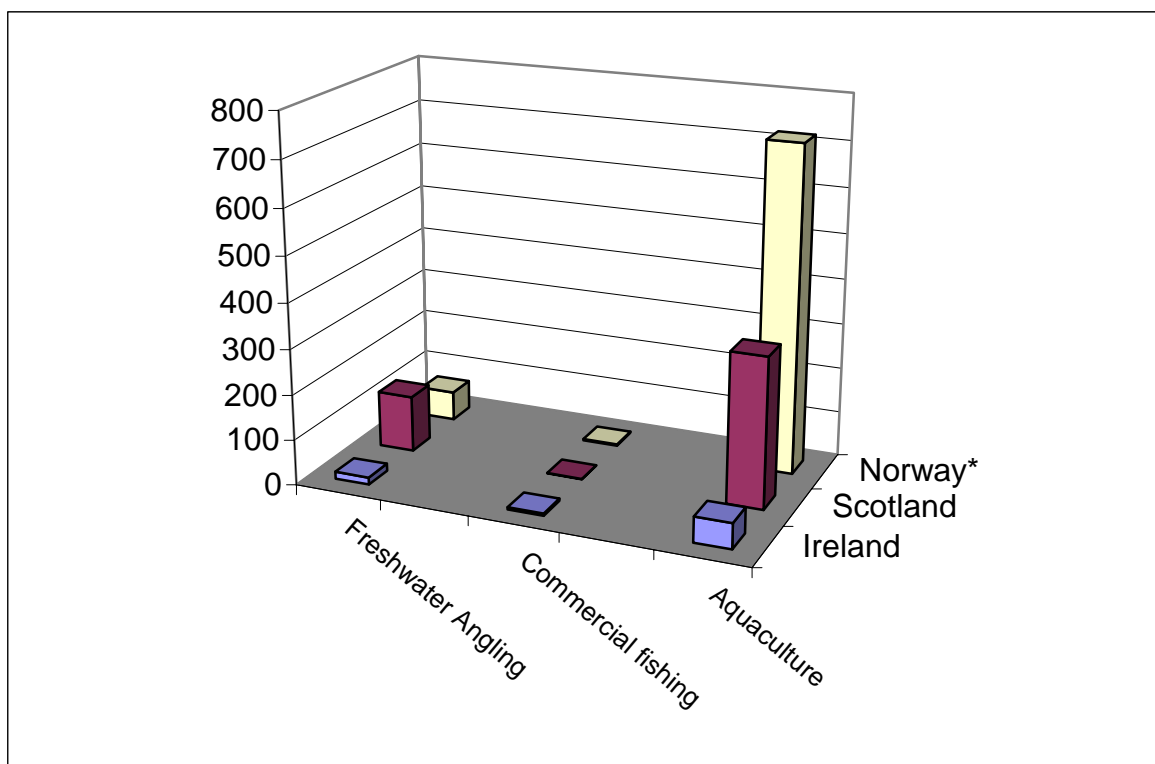


Fig. 1.2.1: Economic Impact by Business Sector and Country (Source : Table 1.2.3 above)

2.4 Discussion

The data presented above are derived from a very wide variety of sources of varying methodological and statistical quality. Furthermore, as can be seen from the notes to the tables, assumptions (sometimes quite heroic ones) were needed to remedy the absence of data for certain cells. The figures should therefore be interpreted as at best broad orders of magnitude serving to point up the similarities and differences between the countries and the sectors. This being said, we feel that the estimates for each country and sector are credible and will be of use for further studies in the field.

Despite these deficiencies, the figures illustrate that the Atlantic salmon as a species is of substantial economic significance to countries in the North-East Atlantic. A very crude estimate of gross (unadjusted) value can be obtained by aggregating expenditure on angling, the value of commercial landings and the gross value of aquaculture production, which yields a figure in excess of €1.8 billion across the three countries. Total associated employment is estimated to exceed 20,000 Full Time Equivalents.

These figures also contain several striking and interesting differences. First, the values associated with commercial fishing are very small compared to those of angling and fish farming. Only in Ireland is the preponderance of the wild catch devoted to the commercial fishing sector. The proportions of the total wild catch caught by the commercial sector in each country are:

Ireland: 88.7 per cent
 Scotland: 29.0 per cent
 Norway: 56.0 percent

Second, the value of angling, especially when measured in terms of associated employment, is higher than the general impression among businessmen and decision makers. The proportions of total employment in the three sectors accounted for by angling are as follows:

Ireland: 68.4 per cent
 Scotland: 30.5 per cent
 Norway: 22.2 per cent

It is clear that the angling sector, with its predominance of service-type jobs, is much more labour-intensive than aquaculture. This can be illustrated by relating employment to the size of the angling catch to derive the employment per 100 salmon caught (including caught and released) in the angling sector. The figures for the different countries are:

Ireland: 4.5 jobs per 100 fish
 Scotland: 3.8 jobs per 100 fish
 Norway: 3.3 jobs per 100 fish

Table 1.2.3 above showed the estimated economic impact of each of the three sectors in each of the countries, when account is taken of the import content of the output of each sector and of the "displacement effect" described above. Commercial fishing accounts for a very low proportion of total economic impact even in Ireland where it generates an estimated impact of only €4.7m despite the fact that 88 per cent of the total wild catch is devoted to this sector. The international trend is strongly towards a reduction in the commercial catch in favour of increased exploitation by angling (cf Indecon 2003). The economic impact as shown in Table 1.2.3 emphasises the current significance of aquaculture whose overall economic impact is estimated to be in excess of €1.1 billion, largely accounted for by the huge Norwegian farming industry.

Key decisions in fishery management relate to how the resources are utilised and how interactions and competition between the sectors are regulated. Gargan et al. (1998) present a modelling methodology for estimating the effect of changing the balance between commercial and angling exploitation. They emphasise the need to focus on the *marginal* quantum of extra fish and show that the biological and economic outcome of the change in exploitation policy will depend on who will catch these fish (local anglers, visiting anglers, not caught) and the responsiveness of tourist anglers to an improvement in the perceived probability of angling success. They also stress that this model depends on the assumption that the extra fish are over and above the number required to reach the optimum spawning escapement for each river system. If escapement is below the optimum level, increased escapement will benefit not just the angling sector in the season in question, but, since anglers are likely to catch only a minority of the extra fish, the remainder will be available to boost spawning and hence to increase overall

stocks in future years. These considerations apply to evaluating the costs and benefits of any salmon management policy, whether it being the choice between angling versus commercial exploitation or balancing the costs and benefits of eliminating negative interactions between aquaculture and angling. In utilising the figures derived above to value improvements in the stocks available to the angling sector, these considerations must be borne carefully in mind.

These crude figures could hopefully also serve as a starting point for further research in the area of economic values and impacts of the *Salmo salar*. As indicated, more precise data is needed to verify these estimates. Even more important, however, is the need to focus new studies on how changes in management, allocation of resources, and conservation measures in each of these interconnected sectors can increase the overall value of Atlantic salmon.

3 Costs of Sea Lice Treatment on Farms

3.1 Introduction

There is growing acceptance in the industries and among management agencies in the North Atlantic, as well as a growing number of scientific studies, that supports the theory that the problem of sea-lice infection on wild salmonids is related to salmonid farming. It is believed that salmonid aquaculture affects wild salmonid stocks negatively by drastically increasing the number of hosts for salmon lice in coastal areas where both wild and farmed salmonid smolts meet the marine environment for the first time (Gravil 1996; O'Donoghue et al. 1998; Bjørn et al. 2001; Heuch & Mo 2001; Holst et al. 2003; McKibben & Hay 2004; Penston et al. 2004; Heuch et al. 2005). For instance, Tully and Whelan (1993) and Butler (2002) estimated that > 95% of salmon lice eggs and larvae produced on the west coasts of Ireland and Scotland, respectively, were of farm origin. In addition, infective lice stages may also derive from escaped farmed salmon (Heuch & Mo 2001).

Intensified treatment against salmon lice in fish farms might increase the number of wild fish returning to rivers, and as such increase the economic returns from tourism fishing based on wild anadromous salmonids. In this context, it is of interest to estimate the economic costs of reducing sea-lice levels in farms to a level that would cause no damage or that will significantly reduce the negative effects on wild stocks.

In this chapter the objective was to estimate costs of intensified treatment. Such data is essential in cost/benefit analyses on the economic gain of precautionary treatments, in terms of increased economic returns from recreational exploitation of wild salmonid stocks. It is, however, complicated to calculate the costs of the treatment required to eliminate completely the negative effects on wild stocks of sea lice originating from aquaculture. Firstly, few studies have looked at the overall costs associated with sea-lice treatment in salmon farms. Secondly, there is no knowledge regarding the extent and quality of treatment needed to completely eliminate the problems imposed on wild stocks by salmonid aquaculture. Thirdly, infection rates, treatment pattern and costs of treatments vary significantly between farms, regions and countries. There are variations both on a larger spatial/geographical scale, on a smaller spatial scale and variation over time. In addition, some of the costs related to sea-lice are not those related to treatment or lack of treatment, but to those of feeding efficiency and food costs, which are affected, by both sea-lice infections themselves, and the stress imposed on the fish from bath treatments.

The problems with sea lice vary between southern and northern farm locations, and between locations depending on freshwater influence. In Norway, sea lice problems have been generally limited in northernmost farming districts and in areas with a good freshwater influence and larger in southern locations with higher salinity. Local oceanic conditions such as current patterns and freshwater influence also create huge local differences in sea lice problems, sometimes over short distances. In addition, variation in sea temperatures and freshwater runoff cause temporal variations. High freshwater runoff, very low or very high temperatures all reduce sea lice population growth.

The treatment strategies also vary between countries. Generally, treatment against sea lice has three main measures; oral medicaments, varying bath treatments and use of biological control through using wrasse in the pens as cleaner fish. Normally, smaller fish are treated with oral medicaments. Wrasse is also used for controlling lice levels on smaller fish (mostly in Norway south of Troms). On larger fish, bath treatments are most common, but oral treatment is widespread on larger fish in Scotland and Ireland. Oral treatment is also becoming more common on larger fish in Norway. Strategies for treatment differ somewhat between the three countries, partly because of differences in traditions, because of different regulations relating to drugs, and partly due to differences in how the aquaculture industry experiences the lice prob-

lem. Nevertheless, it is possible to assess some of the costs of treatments at a large scale across a majority of farms in all three countries, in order to indicate the range for such costs.

The aim of this chapter was to estimate the costs of a more intensive sea lice treatment effort in the farms, and as an example, we have estimated the costs associated with one additional, prophylactic treatment at national level. This additional, or marginal, treatment is envisaged as acting as a precautionary action to supplement the existing treatment schedule. We do not have evidence that a treatment regime of this kind would be the most appropriate or effective in practice. However, for illustrative purposes, it seems reasonable to assume that such a treatment would have a significant effect on the overall lice infestation levels in the fish farms and thus probably also on the infestation levels in wild salmonid stocks. Theoretically, this could produce an economical benefit for recreational fisheries based on wild salmonids. However, it is speculative to link one additional treatment to a specific reduction in lice infestation level on farmed fish (for instance zero level of female ovigerous lice) to a given increase in wild fish survival and/or returns. More research is needed to quantify this link more precisely.

Furthermore, the costs of intensified treatment were compared to the overall value of salmon production in Ireland, Scotland and Norway. The reported cost estimates will subsequently be used for modelling the relationship between costs and benefits under different hypothetical scenarios, which represent qualified judgments of the effects of sea lice on salmonid returns to the fjords and rivers, and the economic effects of this on tourism businesses and landowners (see Chapter 5 below).

3.2 Material and Methods

3.2.1 Data sources

Ireland: We began by estimating the typical pattern and costs of sea lice treatment on salmon farms in Ireland. Data are not available in Ireland for total stocks in each month or for the exact national pattern of harvesting. The approach adopted was, therefore, to set out a simplified picture for 2004 of on-farm stocks, using assumed mortality, growth and biomass levels based on known patterns as described by local experts and industry participants. These data are then combined with information on medicine and treatment costs to obtain an approximate estimate of the total national annual costs of treatment. It is emphasized that this approach provides a means for estimating overall national costs. It should not be interpreted as giving an empirically valid description of all aspects of the Irish salmon farming industry. We are grateful to the following who provided advice and data: Dr Hamish Rodger of Atlantic Veterinary Services Galway, Mr R. Flynn of the Irish Salmon Growers Association and Dr D. Jackson of the Marine Institute.

Scotland: Detailed estimates for the overall costs of treatment in the Scottish industry were provided to us by Mr Chris Wallace and his colleagues of Marine Harvest Ltd. As in Ireland, national data on the total monthly biomass in the sea are not available and the approach adopted was to build up estimates based on informed assumptions about stocks, mortality, growth and biomass based on known patterns derived from detailed discussions with local experts and industry participants. These data are then combined with information on medicine and treatment costs to obtain the desired figures.

Norway: Monthly data on the total biomass in the sea is available for Norway and this was utilized in our work. The data used for the calculations were obtained from the statistics of the Norwegian Seafood Federation (J. Grøttum, FHL), from the Norwegian Directorate for Fisheries (B. Halsteinsen & K. Johnsen, NDF), from recent literature (Øvretveit 2004, Josefsen 2004) and from aquaculture companies (Skretting & Ewos). The data used for the calculations comes from 2004.

3.3 Calculation of costs

The calculation methods vary somewhat between the countries. This is mainly a result of varying availability and level of details of information and source data (see above). In general the calculations for Ireland and Scotland were performed in a somewhat simpler way than for Norway. However, when the same method as was used for Ireland and Scotland was applied to the data for Norway the results were relatively similar to those presented in the report.

3.3.1 Costs for Ireland and Scotland

The costs for Ireland and Scotland were estimated following a three-step modelling approach. First, the number of smolts needed to produce the actual amount of slaughtered biomass fish from one batch of smolts released into the sea was estimated from the assumed mortality over the period from release to slaughter (Ireland: 7 mill smolts, Scotland: 39.5 mill smolts). Secondly, the biomass, originating from one smolt batch, which was in the sea per month, was calculated on basis of standard growth and mortality models. These models were based on country specific data.

In Ireland it was assumed that one batch of smolt was released per year, while it was assumed that two batches per year was put in the sea in Scotland. In addition, the fact that the biomass in the sea at any actual point of time originates from batches put in the sea over several years was taken into account, i.e. the total amount of salmon that is in the sea at a specific date might originate from one or two smolt releases in the same year and in addition from smolt put into the sea in earlier years. This is important since a marginal treatment has to be carried out for the entire biomass in the sea at a given time.

The assumed treatment strategies over a year (2004) also varied between the two countries. For Scotland it was assumed that two Excis (bath), two Salmosan (bath), and two slice (oral) treatments were carried out in one year. For Ireland two Slice and one Excis was assumed to be carried out for smolt batch 1 (put into sea in 2003) and one Slice treatment for smolt batch 2 (put into sea in 2004). The costs for Slice treatment was calculated as cost of the required amount of Slice feed needed to complete a seven day cure for the estimated biomass at the relevant times. The costs of bath treatment were the sum of the costs for chemicals, labour, oxygen and loss of biomass due to mortality and growth reduction following bath treatment. These costs were calculated as described in **Table 1.3.1**.

Table 1.3.1. Methods for calculation of costs associated with bath treatment

Costs	Formulas
Chemicals	$(\text{Biomass} / \text{treated biomass per m}^3) * \text{chemical costs per m}^3 \text{ treated}$
Labour	Labour cost per treatment * number of treatments
Oxygen	Cost per treated ton fish
Mortality	Number of fish * 0.004 * average price per kg salmon
Growth reduction	Biomass * 0.00075 x average price per kg salmon

The cost of one additional treatment was calculated as the average of the assumed costs for all treatments in Scotland since all smolt batches were assumed to be treated simultaneously. In Ireland the cost of one additional treatment was calculated as the average of the treatment costs for smolt batch 1 plus the costs of one oral treatment for smolt batch 2. These costs were calculated in local currencies and the Scottish figure translated into Euros using the appropriate conversion ratio for 2004. The costs of one additional treatment were then expressed as the proportions of the value of the total production in each country and as the treatment cost per kg of fish produced.

3.3.2 Costs for Norway

The calculations for Norway are based on actual production data for different regions and months in 2004. These data includes reported numbers and sizes of fish in the sea at the end of each month. Thus, the calculation method differs from the calculations for Ireland and Scotland since modelling of the monthly biomass and fish number was not required. In addition, oral treatment was assumed to be the only treatment used for fish below or equal to 1 kg, while bath treatment only was applied for fish larger than 1 kg. As in the other countries local costs of chemicals, oxygen and labour were used in the calculations. Two types of medicines are used for bath treatment in Norway, Alpha Max™ and BetaMax™, and the average price of these was used in the calculations. Apart from this, costs for one single treatment were calculated in the same way as for Ireland and Scotland (Table 1.3.1). One difference was that the availability of monthly data on the biomass in the sea enabled calculation of the costs for each month during the year. The average cost of one additional treatment was thus calculated as the average of the monthly costs. Moreover, the treatment cost per kg slaughtered fish was estimated on basis of the total reported numbers of fish in culture at the end of each month in 2004 for different regions. The total fish number was corrected for an assumed average survival from treatment to slaughter (91%) and the resulting number of fish was multiplied with the mean slaughter weight for each month. Mean weight at slaughter was defined on basis of data for 2004. This enabled the cost of one additional treatment as a proportion of the value of the production and the cost per kg of fish produced to be estimated as for Scotland and Ireland.

3.4 Results

3.4.1 Costs for each country

The estimated costs for one additional treatment across all farms in Ireland would amount to about €0.38m. in 2004 (Table 1.3.2). The cost for Scotland was about €3.28m. when converted from £STG (Table 1.3.3.). Furthermore, the results showed that the total cost for one additional treatment for Norway as a whole was €11.65m (Table 1.3.4.).

Table 1.3.2. Costs of one additional treatment in Ireland in mill €

Treatment 2004	Chemicals	Labor	Oxygen	Mortality	Growth reduction	Sum
Slice, February, Smolt batch 1	0.22					0.22
Slice, September Smolt batch 1	0.12					0.12
Slice, December Smolt batch 2	0.18					0.18
Excis, May Smolt batch 1	0.09	0.06	0.04	0.03	0.06	0.28
Cost for one marginal treatment as the average of batch 1 plus batch 2, €m.						0.38

Table 1.3.3. Costs of one additional treatment in Scotland in £m.

Treatment 2004	Chemicals	Oxygen/ Labor	Mortality	Growth reduc- tion	Sum
Slice, February	2.19				2.19
Slice, May	2.58				2.58
Salmosan, July	0.72	0.29	0.13	0.60	1.74
Excis, August	1.61	0.30	0.13	0.56	2.60
Salmosan, September	0.64	0.31	0.14	0.53	1.62
Excis, October	1.43	0.31	0.14	0.50	2.39
Average costs in £m.					2.19
Average costs in €m.					3.28

Table 1.3.4. Costs of one additional treatment in Norway, amounts in mill NOK unless other is specified.

Treatment 2004	Chemicals	Labor	Oxygen	Mortality	Growth reduction	Sum
Slice costs, average for 12 months, fish =< 1 kg	14.2					14.2
Bath costs, average for 12 months, fish > 1 kg	24.7	35.7	6.2	5.6	10.8	82.9
Cost in mill NOK						97.15
Costs in €m.						11.65

3.4.2 Comparison across the three countries

Table 1.3.5 below shows the estimates of the cost of a marginal or extra treatment in each of the countries as derived from the available calculations. As can be seen, the cost of treatment varies with national variation in production and ranges from €11.65m. in Norway to €0.38m. in Ireland. When expressed as a proportion of the value of national output, the cost is highest in Norway and Scotland and lowest in Ireland. The cost of a marginal treatment varies from 0.36 % of the total slaughter value of the year's production in Ireland to 0.46 % in Norway. The costs per kg produced fish are relatively low and vary from €0.011 in Ireland to €0.013 in Scotland and Norway. Thus, treatment in Ireland can be considered the cheapest on a per unit basis, while the costs for Norway and Scotland are slightly higher than Ireland.

Table 1.3.5. Summary of the costs of one additional treatment in each country

	Currency (mill)	Cost of a marginal treatment	Cost in €m	Total value of production m€	Costs as % of total production	Costs per kg produced fish €
Norway	NOK	97.15	11.65	2513	0.46	0.013
Scotland	£STG	2.19	3.28	752	0.44	0.013
Ireland	€	0.38	0.38	106	0.36	0.011

3.5 Discussion

Not surprisingly, the total estimated costs of one additional or marginal treatment across all salmonid fish farms correlated closely and positively with the production volume in the three countries, with Ireland having by far the lowest cost and Norway having the highest. The costs as a proportion of the production and as the actual cost per kg of fish produced were nevertheless relatively similar, with the proportional cost being somewhat lower for Ireland than the two other countries. This implies that the two different approaches for modelling the costs of one additional treatment produced comparable results.

The results also showed that the cost of an intensified treatment per kg fish was low in all three countries. However, since the profit margins in salmonid culture are relatively small an increased cost in terms of one additional treatment against salmon lice might be significant for the profitability of salmonid aquaculture, especially in periods with low prices. Nevertheless, the stakeholders, according to the polluter-pay principle, might argue that any sea lice infestation level harming wild fish should be treated, even if this is not "profitable".

The cost estimates presented in this report are mainly designed to increase understanding of the cost range which would be associated with a more intensive and successful sea lice treatment on salmon farms. As such, these estimates are likely to be maximum estimates of the costs of a better and more intensive sea lice treatment strategy. If an additional treatment were being carried out as a mitigative action in a realistic situation, there are several strategies by which it would be possible to reduce the costs connected with the treatment. First, the areas where salmonid farming is carried out do not always correspond with the most important areas for the wild salmonid migration. This is, for example, the case in Scotland where most of the salmon farming is carried out on the west coast, while the most important areas for the wild salmonid stocks are on the east coast. In such cases, an additional treatment might have only a limited effect on the wild stocks. Secondly, in cases where the farming areas and the important areas for wild stocks overlap the extent of an additional treatment might be reduced if the migration routes or the most used areas for wild salmonids are known. An additional treatment

would obviously be of relatively low importance in farms that are located far away from these areas. Thus, an additional treatment might for instance be carried out only in farms placed in particularly vulnerable areas. Thirdly, some farm sites have a naturally low infestation level and an additional treatment might also have a low effect in such locations. This might, for instance, be the case in northern Norway, where problems with lice infestations are considerably less than further south in Norway. Finally, optimization of the current treatment schedules (and thus reductions in the current costs associated with this treatment) might also lead to a reduction in the infestation levels in the farms. It might actually be possible that an optimized treatment schedule would be more effective than an additional treatment. For instance, the efforts made in Norway to synchronize the treatments within regions have proved to be very successful. Moreover, improvements of the treatment methodology might also reduce the infestation levels substantially without increased costs. The use of wrasse is for instance regarded as being a less costly, but still an effective, approach for reducing infestation levels compared to some chemical treatments in appropriate locations.

The cost estimates presented in this report are necessary inputs to the models that are developed in Chapter 5 below to explore the relationship between the costs of a better treatment against salmon lice and the possible economic benefits, in terms of improvement of the recreational fishery, for the tourism businesses and the landowners. However, this cost/benefit analysis is greatly hampered by the lack of precise knowledge regarding the degree of improvement of the salmonid stock following an increased treatment. Even though it is very likely that an additional treatment against salmon lice in the fish farms will have a certain positive effect on the infestation levels it will be quite speculative to predict how much it will reduce the infestation level and how much it will subsequently improve the wild stocks. Nevertheless, the reported cost estimates are useful in cost/benefit analyses under a range of hypothetical scenarios, which represent qualified judgments of the positive effect on the infestation levels in the farms and the subsequent increase in salmonid returns to the fjords and rivers (see chapter 5 below).

4 Consequences of Stock Collapse and Costs of Preventative Treatment – the Case of Irish Sea-Trout

4.1 Introduction: The Irish Sea Trout Collapse

A considerable literature now exists on the collapse of sea trout fisheries in the West of Ireland which occurred in the late eighties and early nineties and whose effects persist up to the present time. An important part of this literature has focussed on the role of sea lice infestation in this collapse and on the origin of such infestation. For the purposes of the present project, this literature can illustrate: (a) the economic consequences arising from a stock collapse in a migratory salmonid species which had been popular with anglers and (b) the cost and feasibility of rehabilitating these fisheries, with a view to either restoring stocks to their pre-collapse levels or sustaining a minimal number of spawners sufficient to maintain the genetic integrity of the stock. We begin with a brief general account of the sea trout collapse based mainly on Whelan and Poole (1996).

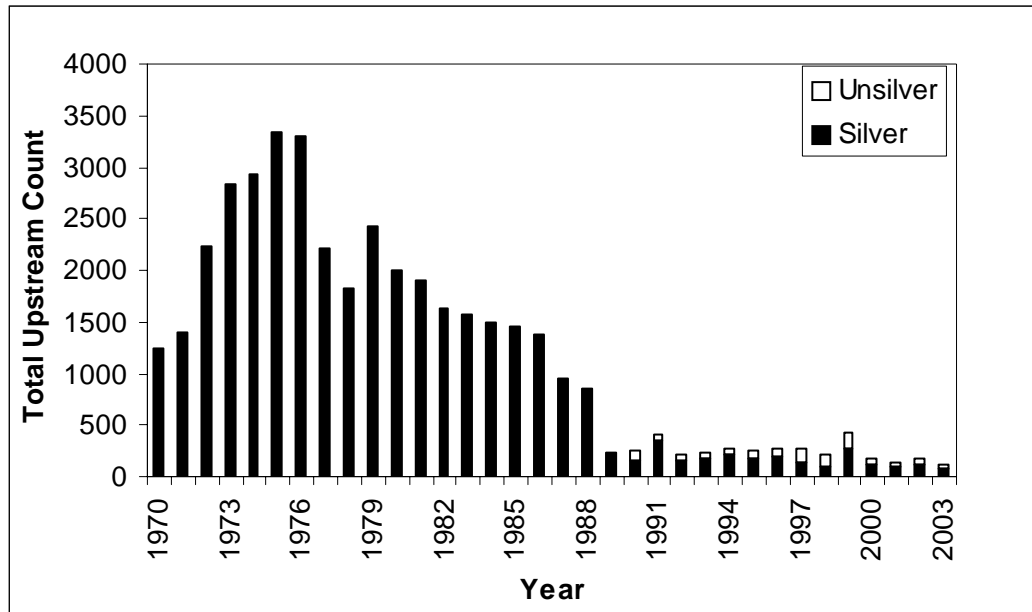
Irish west coast sea trout are relatively slow-growing and long-lived compared to salmon. They remain in freshwater for two to four years before migrating to the sea as smolts and often return three or more times to spawn in freshwater. Over the last thirty or forty years there has been a slow secular decline in abundance which has been attributed to a variety of factors including poaching, excessive commercial exploitation, field and arterial drainage and subsequent maintenance, fertilisation of the surrounding land, deforestation and erosion due to over-grazing by sheep. A sharper and more serious decline has been documented beginning in 1986 which had by 1989 resulted in a population collapse in most fisheries between Galway Bay in the south and Clew Bay in the north (Whelan 1991, 1992, 1993). The precipitate and enduring nature of the collapse can be illustrated by the comprehensive data from the Burrishoole system which is systematically monitored as an index river system (See Table 1.4.1 and Fig. 1.4.1 from Poole et al. 2004). Broadly similar patterns of escapement prevail in most of the other systems in the affected area (Anon 2002)

TABLE 1.4.1. Mean upstream migration in five year periods for silvered and unsilvered trout, including the proportion of 0+ sea age and the spawning escapement

Migration Years	Total Silver	No. of Finnock	%0+ Age	Sea Un-silvered	%0+ Age	Sea Total Migration	Spawning escapement	Es-
1970-'74	2130	1065	50			2130	1812	
1975-'79	2624	868	31.6			2624	2369	
1980-'84	1719	740	43.5			1719	1622	
1985-'89	978	455	42.6			978	906	
1990-'94	206	124	60	74	73.4	280	279	
1995-'99	177	111	62	112	75.3	289	289	
2000-'03	98	57	63.5	56	71.6	155	155	

Source: Poole and Whelan (2004)

Fig. 1.4.1. Annual numbers of upstream migrating sea trout through the Burrishoole fish traps for 1970-2003, showing silvered and unsilvered migrants separately since 1990 (Source: Poole and Whelan 2004)



A number of official and unofficial bodies and groups investigated the collapse including the Sea Trout Action Group (Anon 1992) and the Sea Trout Working Group (Anon 1991-1994). As many as eighteen different hypotheses were advanced and investigated to account for the collapse including an outbreak of an unknown disease, loss of fodder fish such as sand eels, increased predation by sea fish such as pollack on concentrations of sea trout in the vicinity of salmon cages, acidification etc. Some of these factors appeared likely to have had a gradual long term negative effect on sea trout stocks but most could not account for the sudden very substantial collapse in the late 1980s. Whelan and Poole (1996) conclude that “the only consistent factors, therefore, to emerge from the research carried out to date are the premature return of both smolts and kelts to estuaries in late May and the presence of abnormal numbers of juvenile lice.” Detailed further research on the sea lice (Tully and Whelan 1993; Tully et al 1993a and Tully et al 1993b) showed that :

- in the region studied some 95 per cent of the total nauplius larval production of *Lepeophtheirus salmonis* was from farmed salmon;
- that the morphological and physiological impact of the lice on the sea trout was significant and sufficient to cause mortality;
- that, in a number of cases, lice infestation levels rose and fell in response to the presence or absence of salmon cages.

On the basis of this evidence, the hypothesis that sea lice infestation attributable to salmon farming played a key role in the sea trout collapse appears plausible.

4.2 Materials and Methods

The material presented in this paper is derived from two main sources: (a) a study by Fingleton (1990) based on a sample survey of accommodation owners in the Connemara (west Galway/Mayo) region which attempted to quantify the scale of business lost due to the collapse in sea stocks and (b) information based on personal communications from our partner the Irish Central Fisheries Board in connection with Workpackage 7 of the SUMBAWS project.

4.3 Results

4.3.1 The Economic Effects of the Collapse

The sample used in the Fingleton (1990) study was very small and various assumptions and simplifications were needed in order to arrive at an estimate of the loss, but the results are of interest since we are not aware of any comparable studies in the literature. The figures, though necessarily crude and tentative, illustrate how angler numbers react to a serious decline in stocks and indicate the type of decline in business experienced by the region in question. Fingleton's principal results are shown in Table 1.4.2. He estimates that demand for bednights by anglers has fallen by just over 50 per cent, with a fall of the same magnitude in total expenditure. Updating the value of the loss to current (2004) values by the Consumer Price Index, the loss of IR£721,00 in 1990 would amount to €1.4m in present day values.

Table 1.4.2: Estimated Angler Bednights and Expenditure in the Connemara Region before and after the Sea Trout Collapse

No. of hotel/guesthouse angling bed nights	Prior to 1987 11,778		In 1990 5,498		Loss 6,280	
	Irish 34%	Foreign 66%	Irish 34%	Foreign 66%	Irish 34%	Foreign 66%
Origin of anglers						
Hotel/guesthouse bed nights by origin	4,005	7,773	1,869	3,629	2,135	4,145
Percentage of anglers using above accommodation type	37.50%	66.10%	37.50%	66.10%	37.50%	66.10%
No. of anglers bed nights at all accommodation types	10,680	11,759	4,984	5,490	5,693	6,271
No. of anglers bed nights from all origins at all accommodation types	22,439		10,474		11,964	
Average expenditure per bed night (IR£)	38.76	79.74	38.76	79.74	38.76	79.74
Total expenditure, all origins (IR£)	1,352,000		631,000		721,000	

4.3.2 The Cost and Feasibility of Stock Restoration

As stated above, this section relies heavily on the work of our partner the Irish Central Fisheries Board in connection with Work Package 7 of the SUMBAWS project to whom we express our sincere thanks. The details of how smolt capture and treatment is organised are given by the CFB in their description of Workpackage 7. Here we concentrate on the cost and feasibility issues in order to reach a preliminary judgement about the practicality and economics of using a treatment such as substance EX in the treatment of wild fish.

A key issue is the objective. If one wishes to treat all or most of the descending smolts (and kelts), then large fixed traps will be required and these may not be feasible at all in larger systems. If the objective is just to treat a proportion of the run (say a number large enough to maintain the genetic integrity of the stock) then it may be feasible to use devices such as rotary screw traps which would have a lower capital cost. However, the numbers of fish involved would not be sufficient to restore the stock to a level that could provide attractive angling.

Consideration also has to be given to the likely cost in terms of mortality from trapping and treating. In heavy floods it is probable that some of the smolts could get crushed in the traps and all handling of wild fish for treatment purposes poses risks. Estimates of the likely mortality rate are not available.

Costs will also be affected by whether one uses a food-based treatment like Slice or a bath treatment like substance EX. The former involves retaining the smolts in captivity for longer and ensuring that they habituate to feeding in this environment. This will make the feed-based option much more expensive.

We attempted to make a minimum cost estimate by assuming that a fixed trap was feasible (i.e. that it was a small system) and that a bath treatment such as EX could be used. It was further assumed that the objective is only to treat, so that tagging and re-capture of the returning smolts are not required. As shown in Table 1.4.3 below, the total cost, making these minimising assumptions, is estimated at about €27,000 per trap (river) in year 1 and €16,800 per annum thereafter (ignoring depreciation/maintenance costs).

Table 1.4.3: Estimated cost per Trap per annum

	€
Capital cost of trap	10.000
Tanks, pumps, oxygen, nets, medicaments	2.500
Mileage= 300 per week @€1 per mile	3.900
Staff = 1 person per trap @ €800 per week	10.400
Total Cost in year 1	26.800
Annual operating costs thereafter	16.800
<u>Assumes: No tagging: Small system; Bath Treatment</u>	

If it was desired to treat all the sea trout rivers in Connemara (the region worst affected by the collapse) then the list would be as follows:

Large Systems	Smaller systems
Costello	Furnace
Screebe	Lettermucka
Invermore	Inverbeg
Gowla	Carna
Ballynahinch	Ballinaboy
Clifden	Doohulla
Dawros	Owengarve
Erriff	Belclare
Delphi	Crumlin
Carrowniskey	Culfin
Bunowen	Ardbear
Newport	
Burrishoole	

Even if it was feasible to operate fixed traps on the larger systems (which is quite doubtful), the total annual cost of treating all these systems would be of the order of €0.64m. (24 systems @ €26.8 K per system) in year 1 and €0.40m thereafter. This compares with an estimated total annual expenditure by visiting (i.e. non-local) sea trout anglers in pre-collapse conditions (at present day money values) of €2.8 m. (=IR£1.35m from Table 1.4.2 above, increased by the growth in the Consumer Price index between 1987 and 2004, and expressed in €)

4.4 Discussion

The experience of the sea trout collapse in the West of Ireland shows that angling activity, angler numbers and spending by tourist anglers are highly responsive to a sustained deterioration in the probability of success. The estimated economic effects given in Table 1.4.2 are based only on expenditure by non-local anglers i.e. those who, in the main, spend an overnight in the region when angling. They do not include any provision for reduction in expenditure by local anglers or for any increased cost incurred by these anglers by having to switch species or travel further for their fishing. It is, however, likely that these impacts would be less than those caused by the decline in angling by non-locals.

It must also be borne in mind that the approach adopted, as discussed in Chapter 2 above, is an economic impact approach. Thus, it excludes any estimate of the existence, option or bequest values of the sea trout stocks. No data is available to estimate these types of value but they are undoubtedly positive and could be substantial.

From an economic point of view, two major issues arise in relation to the preventative treatment of wild smolts. First, the practicality of such treatment is in doubt. As described above, the feasibility of treatment depends on the size of the system, the type of trap, the prevailing water conditions and numerous other factors. Mortalities are likely to occur and could be serious, especially in a heavily depleted stock where each smolt is of critical importance to the survival and maintenance of the genetic integrity of the stock. Secondly, even if trapping for treatment is judged feasible, substantial costs would be involved.

5 Modelling the Economic Effects of Sea Lice Treatment

5.1 Introduction

We now attempt to integrate all of material developed in Chapters 2 to 4 by developing a simple computer model of the lice treatment process and its economic effects in the three countries, in terms of Costs and Benefits (C/B). The conceptual foundation for the model is based in knowledge, assumptions and hypotheses established in the overall SUMBAWS project, supplemented by general literature on linkages between wild and farmed fish stocks, recreational fisheries, and how they are each valued. The model is built up in stages starting with money spent on sea lice treatment, leading through the hypothesised improvements in smolt survival, likely improved adult returns, improved catches and, from this, increased economic impacts in the wild fish businesses. The strength of the computer model is that it can be used to simulate the effects of different assumptions about the magnitudes of the variables in question and to derive estimates of economic benefits and how these benefits relate to the costs of treatment. Given the uncertainties about the magnitudes of the variables used, the model can only provide indicative answers about the consequences of the assumed changes. However, we believe that it does capture some of the key relationships and that its results will be of use as a guide to policy. A number of plausible sets of assumptions are examined. A simulation is also carried out of a regional situation where wild rather than farmed fish are treated.

The cost data used refer to our illustrative case of a nationwide, marginal treatment. As was emphasised in Chapter 3 above, this additional, or marginal, treatment is envisaged as acting as a precautionary action to supplement the existing treatment schedule. We do not have evidence that a treatment regime of this kind would be the most appropriate or effective in practice. However, for illustrative purposes, this treatment regime is utilised in order to operationalise our model.

5.2 Data and Methods

The best way of explaining how the model is derived and how it can be used is to work through an example. Table 1.5.1 shows, both diagrammatically and arithmetically, a realisation of the model for a particular set of assumptions. The first line shows the cost, in millions of euro, of a marginal lice treatment in each country. These figures are derived from Table 1.2.4 above. The following lines show the effects of different factors on smolt survival. These are:

- a. The (smolt) "survival improvement factor" i.e. the percentage change (increase) in the number of smolts surviving past the coast after treatment (The biological dimensions of the overall SUMBAWS project should shed some light on this).
- b. The "smolt/adult conversion factor" i.e. a factor allowing for the possibility that the extra surviving smolts have a different survival rate to adult than the pre-treatment fish. In most cases, we have assumed this =1.0
- c. The "commercial catch improvement factor" i.e. the ratio of the change (increase) in the commercial catch to the change in the number of returning adult fish. A value of 1 indicates that the commercial catch increases proportionately with the increase in the adult returns. If, say, the commercial catch were limited by quota to its pre-treatment level then this factor would be set to zero.
- d. The "angling catch improvement factor" i.e. the ratio of the change (increase) in the angling catch to the change in the number of returning adult fish. A value of 1 indicates that the angling catch increases proportionately with the increase in the adult returns. If, say, anglers catches rose less than proportionately than to the size of the run because of the timing of spates, then this factor would be less than one.
- e. The "angler response factor". This factor is the "elasticity of angler expenditure with respect to catch" i.e. the proportionate increase in angling expenditure due to a unit increase in overall angling catch. It summarises the combined effect of a number of

processes. The basic rationale is that salmon runs increase, angling success improves, angling activity increases (days fished per angler rise and/or the number of anglers increases) and expenditure rises. Note that there is no necessary proportionality between these processes. Because more fish are present it does not mean that expenditure will rise proportionately.

To illustrate how the model works, let us consider the first column of numbers which refers to Norway. Table 1.2.4 in Chapter 2 above showed that the cost of a marginal treatment in Norway was €11.65m. The assumed survival improvement factor is 1.1, giving a 10 per cent increase in smolt numbers. The smolt/adult conversion factor is 1 i.e. the extra surviving smolts have the same probability of returning as the pre-treatment smolts once they leave the coast. The commercial and angling catch factors are each assumed to be 1 i.e. both angling and commercial catch rise proportionately with adult returns. Angler response is assumed to be 0.5 because of a general assumption of diminishing returns and the likelihood that as catch per angler rises, expenditure per angler does not rise proportionately.

The combined effect of all these factors is applied to the current commercial catch (€3m) and to the current value of angling expenditure (€160m) giving increased value of €0.30m and €3m respectively. The "total economic benefit" is the sum of these two quantities €3.30m. The Cost/Benefit ratio is then about 1.40, showing that the increase in costs exceeds the increased value of the increase in economic activity. Note that the C/B ratios are below one for both Scotland and Ireland. In Scotland, costs are about sixty per cent of benefits, while in Ireland the C/B ratio is 0.08, indicating that benefits dramatically exceed costs by a factor of about twelve to one.

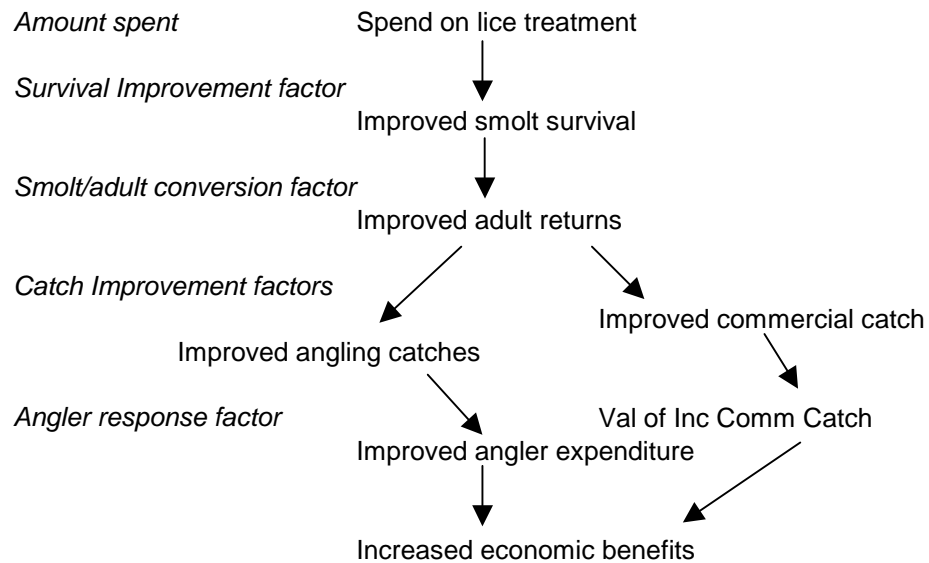
5.3 Results: Other Scenarios

Tables 1.5.2-1.5.5 illustrate what happens when one changes the assumptions. Table 1.5.2 shows the implications of an even lower smolt survival, five per cent improvement in smolt survival. In this case, costs exceed benefits in both Norway and Scotland while benefits still exceed costs in Ireland. Table 1.5.3 illustrates the effect of a 20 per cent improvement in survival here, benefits clearly exceed costs in all three countries. Table 1.5.4 shows a negative situation: 5 per cent survival combined with poor angling catch improvement and the angler response factor set at 0.5. Here costs exceed benefits in both Norway and Scotland but benefits still exceed costs in Ireland. On reflection, it is clear that these general patterns are influenced by a number of considerations: (a) the large size of the Norwegian fish farming industry and thus the high cost of treatment (b) the high expenditure per fish caught by anglers in Ireland and (c) the low cost of treatment in Ireland (primarily due to the relatively small size of the Irish fish-farming industry). A reasonable inference, especially for Norway, would be that focusing treatment on areas with a particularly good return (plentiful runs of salmon or low costs of treatment) would be a better strategy than a nationwide treatment.

Table 1.5.5 shows a realisation of the model relating to the treatment of wild sea trout in the Connemara area as discussed in stage (c) above. Assuming a 10 per cent overall improvement in survival and an angler response of 0.5, it shows a Cost/Benefit ratio of 2.9 i.e. costs exceed benefits by almost three to one. This emphasises the high costs and limited feasibility of trapping and treating wild smolts.

Economic Effects of Improved Salmon Survival from Lice Treatment

Table 1.5.1: Survival Improvement = 10% Angler Response= 0.5 All other factors proportionate



	Norway	Scotland	Ireland
Units			
€m	11.65	3.28	0.38
% change	10%	10%	10%
% change	10%	10%	10%
% change	10%	10%	10%
% change	10%	10%	10%
€m	0.30	0.06	0.49
€m	8.00	5.65	4.00
€m	8.30	5.71	4.49
C/B Ratio	1.40	0.57	0.08

Total current value of commercial catch €m
Total current value of angling expenditure €m

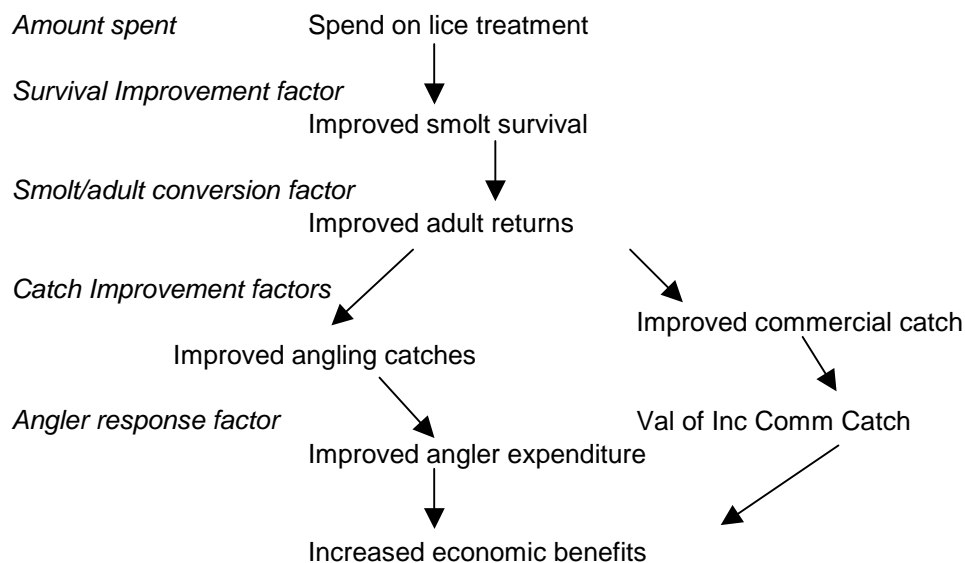
3.0 0.6 4.9
160.0 113.0 80.0

Modelling Factors

- Survival Improvement 1.1 (= ratio of improved smolt survival to pre-treatment survival)
- Change in smolt/adult conversion 1 (=ratio of improved adult survival to pre-treatment adult survival)
- Commercial catch improvement 1 (=ratio of improved comm.catch to pre-treatment commercial catch)
- Angling catch improvement 1 (=ratio of improved angler catch to pre-treatment angler catch)
- Angler response 0.5 (= elasticity of angler expenditure with respect to angling catch)

Economic Effects of Improved Salmon Survival from Lice Treatment

Table 1.5.2: Survival Improvement = 5% Angler Response= 0.5 All other factors proportionate



	Norway	Scotland	Ireland
Units			
€m	11.65	3.28	0.38
% change	5%	5%	5%
% change	5%	5%	5%
% change	5%	5%	5%
% change	5%	5%	5%
€m	0.15	0.03	0.25
€m	4.00	2.83	2.00
€m	4.15	2.86	2.25
C/B Ratio	2.81	1.15	0.17

Total current value of commercial catch €m

3.0 0.6 4.9

Total current value of angling expenditure €m

160.0 113.0 80.0

Modelling Factors

Survival Improvement

1.05 (= ratio of improved smolt survival to pre-treatment survival)

Change in smolt/adult conversion

1 (=ratio of improved adult survival to pre-treatment adult survival)

Commercial catch improvement

1 (=ratio of improved comm.catch to pre-treatment commercial catch)

Angling catch improvement

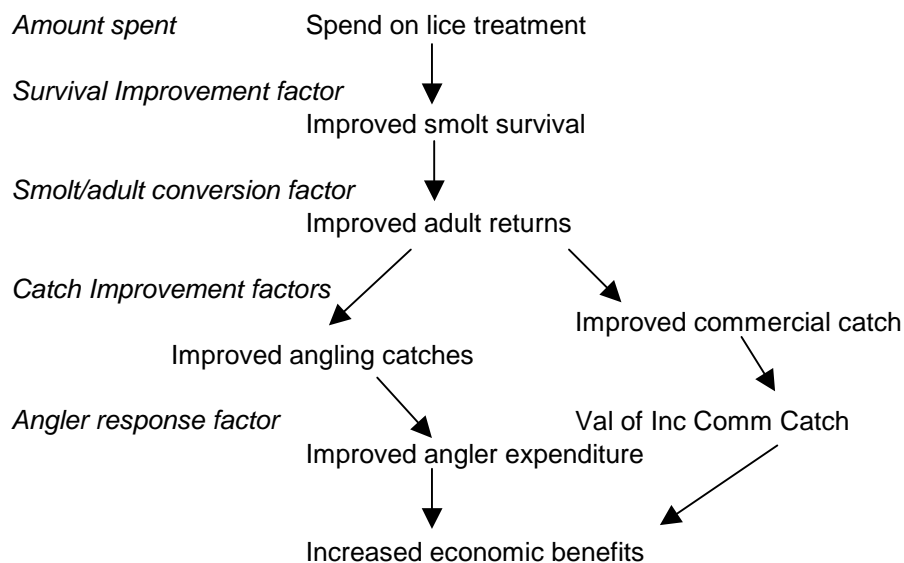
1 (=ratio of improved angler catch to pre-treatment angler catch)

Angler response

0.5 (= elasticity of angler expenditure with respect to angling catch)

Economic Effects of Improved Salmon Survival from Lice Treatment

Table 1.5.3 Survival Improvement= 20% Angler Response= 0.5 Angling Catch Improvement= 1
All other factors proportionate



	Norway	Scotland	Ireland
Units			
€m	11.65	3.28	0.38
% change	20%	20%	20%
% change	20%	20%	20%
% change	20%	20%	20%
% change	20%	20%	20%
€m	0.60	0.12	0.98
€m	16.00	11.30	8.00
€m	16.60	11.42	8.98
C/B Ratio	0.70	0.29	0.04

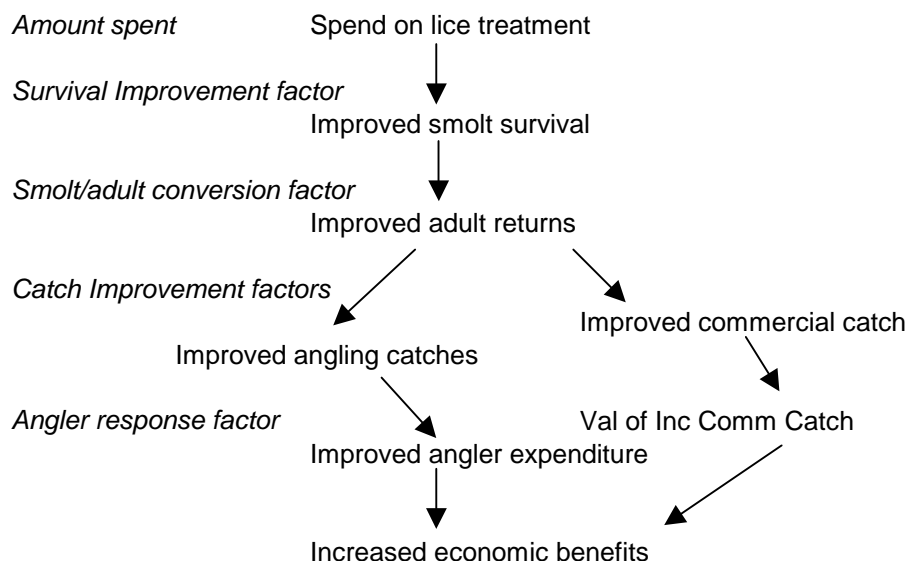
Total current value of commercial catch €m	3.0	0.6	4.9
Total current value of angling expenditure €m	160.0	113.0	80.0

Modelling Factors

Survival Improvement	1.2 (= ratio of improved smolt survival to pre-treatment survival)
Change in smolt/adult conversion	1 (=ratio of improved adult survival to pre-treatment adult survival)
Commercial catch improvement	1 (=ratio of improved comm.catch to pre-treatment commercial catch)
Angling catch improvement	1 (=ratio of improved angler catch to pre-treatment angler catch)
Angler response	0.5 (= elasticity of angler expenditure with respect to angling catch)

Economic Effects of Improved Salmon Survival from Lice Treatment

Table 1.5.4: Survival Improvement= 5% Angler Response= 0.5 Angling Catch Improvement= 0.5 All other factors proportionate



	Norway	Scotland	Ireland
Units			
€m	11.65	3.28	0.38
% change	5%	5%	5%
% change	5%	5%	5%
% change	5%	5%	5%
% change	3%	3%	3%
€m	0.15	0.03	0.25
€m	2.00	1.41	1.00
€m	2.15	1.44	1.25
C/B Ratio	5.42	2.27	0.31

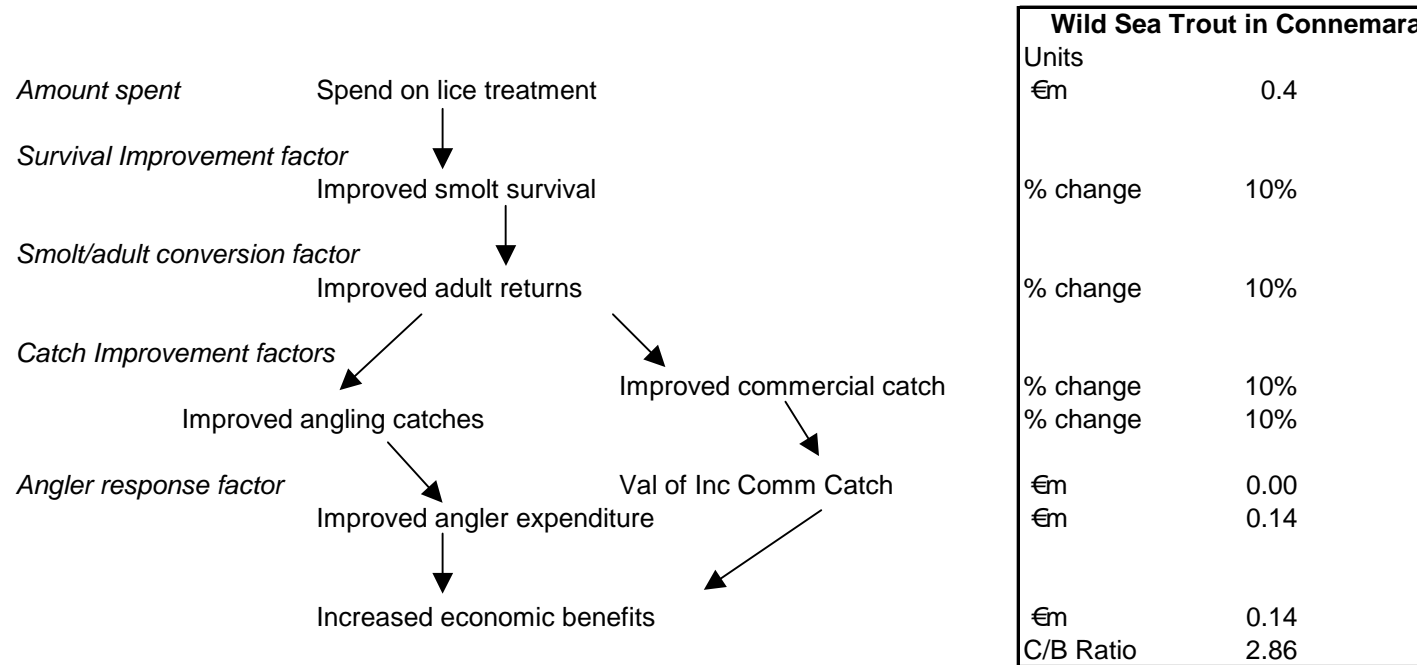
Total current value of commercial catch €m **3.0** **0.6** **4.9**
Total current value of angling expenditure €m **160.0** **113.0** **80.0**

Modelling Factors

- Survival Improvement 1.05 (= ratio of improved smolt survival to pre-treatment survival)
- Change in smolt/adult conversion 1 (=ratio of improved adult survival to pre-treatment adult survival)
- Commercial catch improvement 1 (=ratio of improved comm.catch to pre-treatment commercial catch)
- Angling catch improvement 0.5 (=ratio of improved angler catch to pre-treatment angler catch)
- Angler response 0.5 (= elasticity of angler expenditure with respect to angling catch)

Economic Effects of Improved Salmon Survival from Lice Treatment

Table 1.5.5: Survival Improvement = 10% Angler Response= 0.5 All other factors proportionate



Total current value of commercial catch €m 0.0
Total current value of angling expenditure €m 2.8

Modelling Factors

- Survival Improvement 1.1 (= ratio of improved smolt survival to pre-treatment survival)
- Change in smolt/adult conversion 1 (=ratio of improved adult survival to pre-treatment adult survival)
- Commercial catch improvement 1 (=ratio of improved comm.catch to pre-treatment commercial catch)
- Angling catch improvement 1 (=ratio of improved angler catch to pre-treatment angler catch)
- Angler response 0.5 (= elasticity of angler expenditure with respect to angling catch)

5.4 Discussion

The overall purpose of the modelling exercise is to illustrate how investments in sea lice treatment (either on farmed or wild fish) can lead to improved revenues to the wild fish sector, primarily in the recreational tourism fishing. The model is a simplified version of the assumed chain of causation linking sea lice on salmon farms with the effects on wild salmonids and the businesses dependent on them.

However, central elements in the model remain uncertain and speculative. First, while there is general acceptance that sea lice levels and sea lice treatment strategies in farms or on wild fish have the potential to influence wild fish returns, the current state of knowledge does not permit us to establish a firm “dose/response” relationship between the level or type of treatment and a quantified increase in returns to the coast. Furthermore, the assumption that improved smolt survival due to sea lice treatments will provide improved adult returns is complicated. It is well established in the literature that a range of factors affect salmon growth and survival at sea (such as availability of fodder fish, variations in predator populations etc.) and these factors might at times mask the effect of improved sea lice treatment.

While the assumption that increased adult returns normally increase catches for both the commercial and angling sectors is well established and documented, the assumption that increased catches increase expenditures may be more questionable. Furthermore, the magnitude of the increase in expenditure in response to any given improvement in (expected) catch needs to be estimated. There is, however, some evidence that this response can be sizable in the case of salmon angling. (Bell 1989). It is quite possible that this relationship is non-linear and subject to threshold effects (i.e. the increase needs to be above a certain absolute size to evoke any response) or satiation/saturation effects (e.g. due to good angling spaces/pools being limited even if runs improve). More research is needed to elucidate these issues.

The limitations of the “economic impact” approach on which all the data and modelling is based must also be borne in mind. On the one hand, as explained in Chapter 2, this approach excludes “non-consumptive” values such as existence, option or bequest values (Pollock et al. 1994). On the other hand, the figures presented in Tables 1.5.1 to 1.5.5 are based on total angling expenditure and the value of total commercial catch in each country. They do not make allowance for multiplier effects or for displacement effects in the case of angling and operating costs in the case of commercial fishing. If allowance could be made for all these factors, the Cost/Benefit ratios would change, possibly to a substantial extent.

The main value of the modelling approach is that it clearly highlights what factors are most important for the Cost/Benefit ratio and how they interact. Thus, it is clear that the cost of marginal treatment depends crucially on the size of the fish farming sector. This means, for instance, that the cost in Norway for a nationwide treatment is very high. It would be very important in this case to target and limit the intervention to particular regions or systems where the benefits are expected to be especially large such as key angling systems or areas where lice infection is especially high. The models also emphasise what types of benefit are likely to arise and to whom they will accrue. Thus, in all three countries the largest benefits from improved runs are likely to be in the angling sector rather than in the commercial fishing operations, due to the relatively small size of the latter. The modelling approach also indicates the key areas on which future economic research should focus. Improved estimates of angler response were mentioned above. It would also be important to obtain quantified biological information on the likely response in terms of improved runs to improvements in treatment and to improve our estimates of the costs involved on a national, or perhaps even more importantly, a regional or river system basis.

6 Summary and Conclusions

6.1 Objective

The present report provides a socio-economic evaluation of the interactions between the various salmon-based businesses (aquaculture, commercial fishing and angling) in three countries Ireland, Norway and Scotland with particular reference to the effects of sea lice infestations. It compiles up-to-date, comparable figures for the value of the various sectors, examines in detail the costs involved in lice reduction and devises a methodology for estimating and comparing the costs and benefits for the various participants involved. It does not focus on purely environmental policy objectives such as those enshrined in the EU Habitats Directive and in particular does not consider whether or how the “polluter pays” principle may apply to lice infestations. Nor does it consider the long-term future benefits which could arise from increased spawning escapement making good the present depleted state of the salmon resource.

6.2 Economic Evaluation of the Salmon-Based Businesses

The literature on economic evaluation of Atlantic salmon was thoroughly reviewed and a decision taken to adopt an “economic impact” approach. This means that certain types of non-consumptive value are not taken into account but the existing literature and data is too limited to provide reliable, comparable estimates of these. The approach adopted did, however, allow us to estimate for the first time the overall economic impact of the Atlantic salmon, across the three main sectors (game angling, commercial netting and salmon farming) in Ireland, Norway and Scotland.

The overall gross value of Atlantic salmon was estimated €1,900m., of which approximately €1,500m. relates to salmon aquaculture, €350m. to salmon angling and €10 m. to commercial netting of salmon. When these gross values are corrected for “import content”, displacement effects and multiplier effects, the overall economic impact of Atlantic salmon to the national economies was estimated at a total of €1,320m., of this €1,110m. in aquaculture, €200m. in salmon angling and €8m. in commercial fishing. Overall full-time job equivalents were estimated at 22,000 FTE, of which 15,000 were in the farming industry, 6,400 in angling tourism and 460 in commercial fishing.

There are striking differences in the size and nature of the businesses in each country. Norway has a huge farming business and a significant angling tourism sector, which is, however, less developed than in Scotland and Ireland. Scotland has a significant farming business and a well developed angling tourism. Ireland has a relatively substantial commercial fishery, which has, however, only limited economic impact, and a small farming business compared to Norway and Scotland. Generally, commercial fishing is insignificant in all countries compared to the two other sectors

The angling sector is, in view of the limited attention it receives in economic discussions, of surprising economic importance in all the countries. It is a relatively significant generator of jobs, especially on a “jobs per fish” basis. This is consistent with the pre-dominance of service-type jobs in sectors linked to tourism.

6.3 Costs of Sea Lice Treatment on Farms

Cost associated with improved/intensified sea lice treatment in farms was calculated for all three countries, and the costs are strongly correlated to the overall production of farmed salmon in each country. For illustrative purposes, the costs of a marginal, prophylactic treatment was estimated at €11.65m.; €3.28m. and €0.38m. for Norway, Scotland and Ireland respectively. The costs as a percentage of total production value were found to lie in the range 0.46 to 0.36 % for the three countries. The cost for a marginal treatment on a per kg produced fish basis was very similar across the countries and lay in a very narrow range, € 0.011 –

€0.013. These estimates are on a nationwide basis in each case. It is likely that treatment could be carried out more cost-effectively if it were targeted at areas or river systems where the returns were especially high, such as where very significant runs of wild fish occur and/or where infestation levels are especially high. More precise information is needed on the quantitative relationship between reductions in lice levels and improved runs.

6.4 Consequences of Stock Collapse and Costs of Preventative Treatment

The next part of the report focuses on what can be learned from the collapse in sea trout populations in the West of Ireland since the late 1980s. It documents and quantifies the resulting decline in angler numbers and estimates the consequential drop in tourist expenditure in the region. Angler numbers fell by more than 50 per cent and the loss in revenue from angling is estimated at €1.4m per annum for the Connemara region (in present day values).

By utilising some of the results and experience gained in Workpackage 7 of the SUMBAWS project, which is also based in the West of Ireland region, cost estimates for the preventative treatment of wild smolts are produced. It is shown that the feasibility of widespread use of preventative treatment is questionable and that, even if feasible, very substantial costs would be involved.

6.5 Modelling the Effects of Sea Lice Treatment

Based on the material in earlier chapters, a computer model is developed of the key stages in the assumed causal chain between enhanced lice treatment, through better smolt survival and improved returns to the coast to economic and social benefits in the form of greater income and employment in the commercial and angling sectors. The main output from the model is a series of Cost/Benefit ratios aimed at summarising the economic impacts from treatments with varying levels of effectiveness. A number of plausible scenarios are simulated to illustrate how these ratios vary with changes in the assumptions. It is found that a 10 per cent improvement in the smolt survival, combined with a moderate response by anglers to the improved runs, would lead to costs of treatment exceeding benefits in Norway while benefits would exceed costs in Scotland and Ireland. A 20 per cent improvement in smolt runs would lead to costs exceeding benefits in all three countries. In all the cases examined, the benefits would exceed costs in Ireland (due to the small size of the farming sector and the good returns in terms of expenditure and employment to improved angling catches).

Some of the estimates incorporated in the model are speculative. However, the main value of the modelling approach is that it clearly highlights what factors are most important for the Cost/Benefit ratio and how they interact. Thus, it is clear that the cost of marginal treatment depends crucially on the size of the fish farming sector. This means, for instance, that the cost in Norway for a nationwide treatment is very high. It would be very important in this case to target and limit the intervention to particular regions or systems where the benefits are expected to be especially large, such as key angling systems or areas where lice infection is especially high.

The models also emphasise what types of benefit are likely to arise and to whom they will accrue. Thus, in all three countries the largest benefits from improved runs are likely to accrue to the angling sector rather than to the commercial fishing operations, due to the relatively small size of the latter. The modelling approach also indicates the key areas on which future economic research should focus. These include improved estimates of angler response, better quantified biological information on the likely response in terms of improved runs to improvements in treatment and to more detailed data to improve the estimates of the costs involved on a national, or perhaps even more importantly, a regional or river system basis.

7 References

- Anon 1992 Sea Trout Action Group Report, 1991. Sea Trout News No. 3. February 1992.
- Anon., 1991-94. Reports of the Sea Trout Working Group. Fisheries Research Centre, Department of the Marine, Dublin
- Anon 2002. Report of the Sea Trout Working Group 2002, Fisheries Research Centre, Department of the Marine, Dublin
- Atlantic Salmon Federation 1998. "The Atlantic Salmon Accord"
<http://www.asf.ca/Nasco/Nasco.html#anchor642056>
- Bell, F. W. 1989 "The Main Quarry Hypothesis and Salmon Angling", *Journal of Marine Resource Economics*, pp. 71-82.
- Bjørn, P.A., Finstad, B. & Kristoffersen, R. (2001). Salmon lice infection of wild sea trout and Arctic char in marine and freshwaters: the effects of salmon farms. *Aquaculture Research*. 32, 947-962.
- Bord Iascaigh Mhara 2003 Irish Aquaculture Production 2003 BIM Dublin
- Butler, J.A. (2002). Wild salmonids and sea lice infestations on the west coast of Scotland: sources of infection and implications for the management of marine salmon farms. *Pest Manage. Sci.* 58, 595-608.
- Central Fisheries Board 2003. Wild Salmon and Sea trout Tagging Scheme – Fisheries Statistics Report 2001-2003 CFB, Dublin
- Clawson and Knetch 1966. *Economics of Outdoor Recreation*. Johns Hopkins Press. Baltimore Maryland
- Collette, B.B. 1990. Problems with grey literature in fishery science. Pp. 27-32 in Hunter, J. (ed.). *Writing for fishery journals*. American Fisheries Society.
- Dervo, B. & Knutsen, S. 2004. Handlingsplan. Næringsutvikling i utmark. (Task plan – development of nature based tourism based on fish and wildlife resources in Norway). Norwegian Commercial Development Fund, Oslo. In Norwegian only. 17 pp.
- European Commission 1998. Communication Of The European Commission To The Council And To The Parliament On A European Community Biodiversity Strategy
<http://europa.eu.int/comm/environment/docum/9842sm.htm>
- FHL Aquaculture 2005. Aquaculture in Norway a statistical overview. Link from
<http://www.fhl.no/category/English/category.php?categoryID=73>. Last cited 21 June 2005.
- Fingleton P. 1990. "Declining Sea Trout Runs in Western Ireland: Some Tourism Effects" The Sea Trout Action Group
- Fisheries Research Services 2003a Scottish Fish Farms Annual Production Survey 2002 Scottish Executive Edinburgh
- Fisheries Research Services 2003b Scottish Salmon and Sea Trout Catches, 2002 Scottish Executive Edinburgh
- Fiske, P. & Aas, Ø. 2001. *Laksefiskeboka*. (How to manage salmon fisheries). NINA Temahefte 20. In Norwegian only. 100 p. ISBN 82-426-1267-6.
- Gargan, P.G., K.F. Whelan and B.J. Whelan 1998 "An Illustrative Grilse Survival Model for an Irish Salmon Fishery" in Hickley and Tompkins (eds) *Recreational Fisheries – Social, Economic and Management Aspects* FAO ISBN 0-85238-248-0
- Gillen 1982 "Economic Value of Salmon Angling: Estimates from Hedonic Functions" Canadian Regional Science Association Meetings Vancouver
- Gravil, H.R. (1996). Studies of the biology and ecology of the free swimming larval stages of *Lepeophtheirus salmonis* (Krøyer) and *Caligus elongatus* Nordmann 1832 (Copepoda: Caligidae) pp. 1-299. PhD thesis, University of Stirling, Stirling, Scotland UK
- Heuch, P.A. & Mo, T.A. (2001). A model of salmon louse production in Norway: Effects of increasing salmon production and public management measures. *Dis. Aquat. Org.* 45, 145-152.
- Heuch, P.A., Bjørn, P.A., Finstad, B., Holst, J.C., Asplin, L. & Nilsen, F. (2005). A review of the Norwegian national action plan against salmon lice on salmonids: the effect on wild salmonids. *Aquaculture* 246, 79-92.
- Holst, J.C., Jacobsen, P., Nilsen, F., Holm, M., Asplin, L., & Aure, J. (2003). Mortality of seaward-migrating post-smolts of Atlantic salmon due to salmon lice infection in Norwegian salmon stocks. In *Salmon at the Edge*. (ed. by D. Mills), pp. 136-137. Oxford: Blackwell Science.
- Indecon 2003 An Economic / Socio-Economic Evaluation of Wild Salmon in Ireland Central Fisheries Board, Dublin

- Josefsen, E. (2004). Lakselus til besvær – en lønnsomhetsanalyse av ulike avlusningsmetoder på laks. Fiskerikandidatoppgave, Norges Fiskerihøgskole, Universitetet i Tromsø, Tromsø, Norway. 87pp.
- McKibben, M.A. & Hay, D.W. (2004). Distributions of planktonic sea lice larvae *Lepeophtheirus salmonis* in Loch Torridon, Western Scotland in relation to salmon farm production cycles. *Aquaculture Research*. 35, 742-750.
- McGinnity P., P. Prodo, A. Ferguson, R. Hynes, N. O' Maoléidigh, N. Baker, D. Cotter, B. O'Hea¹, D. Cooke, G. Rogan, J. Taggart and T. Cross (2003) "Fitness reduction and potential extinction of wild populations of Atlantic salmon, *Salmo salar*, as a result of interactions with escaped farm salmon" The Royal Society, London
- Mills, D. 1991. Ecology and Management of Atlantic Salmon. Chapman and Hall. London
- Mørkved, O.J. & Krokan, P.S. 1997. Inntekts- og kostnadsforhold i det norske sjølaksefisket med faststående redskap. (Revenue- and cost aspects of the Norwegian fixed net fisheries for Atlantic salmon). Report from The College of Nord-Trøndelag to the Norwegian Sea Ranching Program. In Norwegian only. 61 pp.
- Norwegian Official Statistics 2005. Statistics of catches of salmon in fixed net fisheries: <http://www.ssb.no/sjofiske/>. Last cited 21 June 2005.
- O'Donoghue, G., Costello, M. & Costello, J. (1998). Development of a management strategy for the reduction/elimination of sea lice larvae *Lepeophtheirus salmonis* parasites of salmon and trout. Marine Resource Series NO. 6, pp. 1-51. The Marine Institute, Dublin, Ireland
- Penston, M.J., McKibben, M.A., Hay, D.W. & Gilibrand, P. (2004). Observations on open-water densities of sea lice larvae in loch Shieldaig, Western Scotland. *Aquaculture Research*. 35, 793-805.
- Pollock K., C.M. Jones, T.L. Brown. 1994 Angler Survey Methods and Their Application in Fisheries Management American Fisheries Society Special Publication 25, Bethesda, Maryland
- Poole, W.R., M. Dillane, E. DeEyto, G. Rogan, P. McGinnity and K. Whelan 2004. "Characteristics of the Burrishoole sea trout population: census, marine survival, enhancement and stock recruitment, 1971-2003" Paper presented to the 1st International Symposium on the Conservation and Management of Sea Trout. Cardiff, July, 2004.
- Radford A.F., A. Hatcher, D. Whitmarsh 1991 An Economic Evaluation of Salmon Fisheries in Britain Research Report No. 16 Centre for the Economics and Management of Aquatic Resources, University of Portsmouth
- Radford A.F., G. Riddington, D. Tingley 2001 Economic Evaluation of Inland Fisheries Technical Report Environment Agency R& D Technical Report W2-039. Module A Produced by MacAlister Elliott and Partners
- Radford, A., G. Riddington, J. Anderson, H. Gibson. 2004 The Economic Impact of Game and Coarse Angling in Scotland. Scottish Executive Edinburgh
- Spurgeon J., G. Colarullo, A. Radford, G. Riddington, D. Tingley 2001 Economic Evaluation of Inland Fisheries Technical Report Environment Agency R& D Technical Report W2-039. Module B Produced by MacAlister Elliott and Partners
- Tully O. and K.F. Whelan 1993 "Production of nauplii of *Lepeophtheirus salmonis* (Kroyer) (Copepoda: Caligidae) from farmed and wild salmon and its relation to the infestation of wild sea trout (*Salmo trutta* L.) off the west coast of Ireland in 1991". *Fisheries Research* 17: 187-200.
- Tully, O., Poole, W. R., Whelan, K. F., and Merigoux, S. 1993b. Parameters and Possible Causes of Epizootics of *Lepeophtheirus salmonis* (Kroyer) Parasitic on Sea Trout (*Salmo trutta* L.) on the West Coast of Ireland. Proceedings of the First European Crustacea Conference. Paris, August 31 – September 5, 1992 .
- Tully, O., Poole, W. R., and Whelan K. F. 1993a. Infestation Parameters for *Lepeophtheirus salmonis* (Kroyer) copepoda: caligidae Parasitic on Sea Trout (*Salmo trutta* L.) Post Smolts on the West Coast of Ireland during 1990 and 1991. *Aquaculture and Fisheries Management*. 24, No. 4: 545-557.
- Tully, O. & Whelan, K.F. (1993). Production of nauplii of *Lepeophtheirus salmonis* (Krøyer) (Copepoda: Caligidae) from farmed and wild salmon and its relation to the infestation of wild sea trout (*Salmo trutta* L.) off the west coast of Ireland in 1991. *Fish. Res.* 17, 187-200.
- Whelan, K.F. 1991. Disappearing sea trout - decline or collapse? *The Salmon Net* No. 23. 24-31.
- Whelan, K.F. 1992. Management of salmon and sea trout stocks. Environment and Development in Ireland. Proceedings of a Conference held at University College Dublin. The Environmental Institute, University college Dublin. 457-466.

- Whelan, K.F. 1993. Historic overview of the sea trout collapse in the west of Ireland. In: Aquaculture in Ireland - towards sustainability. Ed. J. Meldon. Proceedings of a Conference held at Furbo, Co. Galway. 30th April - 1 May. 1993. 51-53. An Taisce, Dublin.
- Whelan, K.F. and W.R. Poole 1996 "The Sea Trout Collapse 1989-92" in J.D. Reynolds (ed.) The Conservation of Aquatic Systems 101-110 Dublin. Royal Irish Academy
- Øvretveit, S. (2004). Feed conversion ratio in practical Atlantic salmon (*Salmo salar* L.) farming. Master thesis, Department of Fisheries and Marine Biology, University of Bergen, Bergen, Norway. 90pp.
- Aas, Ø. 1997. Characteristics of freshwater anglers fishing without the compulsory national fishing licence in Norway. Fisheries Management and Ecology 1997, 4, 77-79.

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