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Anadromous and Catadromous
Fish Committee

REPORT OF THE STUDY GROUP ON ANADROMOUS TROUT

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*General Secretary
ICES
Palægade 2-4
DK-1261 Copenhagen K
Denmark

Abstract

The natural distribution of anadromous brown trout (*Salmo trutta* L.) is limited by water temperature, dissolved oxygen, spawning conditions, habitat access, food availability, pollutants, biological competition, predation and human exploitation. naturally, this species is distributed in western Europe along Atlantic and Baltic coasts from the White Sea in the north-east to Spain in the South-West. Population abundance is good to satisfactory in many countries. The distribution has been reduced by physical encroachment in water courses, loss of habitats and pollution as e.g. in lower parts of the North Sea area (France, Belgium, Netherlands and Germany). Improvements of the water quality and habitat restaurations have, however, improved the situation for sea trout in these countries during the last decade. In some countries wild sea trout are endangered. In for instance Finland, all natural populations are regarded as endangered or extinct. In Ireland, rivers in the west have shown stock collapses since 1988. The Study Group had very little information about sea trout from Faroe Islands, Lithuania and Portugal.

Rainbow trout (*Oncorhynchus mykiss* (Walbaum)) occur in rivers and coastal waters throughout western Europe. However, successful spawning in rivers is uncommon but does occur. The majority of the fish are intentionally and/or unintentionally released from hatcheries and fish farms.

Anadromous brown trout populations are partly migratory, i.e. the populations are environmentally divided into non-migratory freshwater residents and migratory individuals moving between freshwater and the sea. Female is the prevalent sex among anadromous fish whereas males dominate numerically among the residents. Among the life history characters listed, sex ratio, mean smolt length and mean adult length appear to be the most stable traits among countries. Mean smolt age, annual growth increment at sea and mean age at maturity vary among localities. Recent changes in population structure of some local populations have been highlighted.

Population abundance is influenced by rate of exploitation, environmental variation, parasite infections and diseases, habit degradations and stocking. Experiences from various countries are presented.

Contents

1 Introduction

1.1 Background

Anadromous brown trout, commonly called sea trout (*Salmo trutta* L.) is an important sport fish in rivers, fjords and coastal areas along Atlantic and Baltic coasts from the White Sea in the north-east to Spain in the south-west. Although common, many aspects of its ecology are still not much studied (cf. Elliott 1994).

At present there is a growing interest in anadromous brown trout in Europe. This may partly be due to the reported population collapse of sea trout in Ireland and problems with populations in other countries waters, but also because of increased interest for sea trout fishing as well as new scientific information about population variation and regulation, population structure and life history strategies.

The native range of the rainbow trout (*Oncorhynchus mykiss* (Walbaum)) is the eastern Pacific Ocean and freshwater, mainly west of the Rocky Mountains, but it has been introduced to all the temperate and sub-Arctic parts of the World. It was introduced to western Europe towards the end of the 19th century. It was both intentionally and unintentionally released into lakes, rivers and coastal waters, but there are only a few reports on its distribution and ecology in the new environments (cf. Jonsson et al. 1993b) as well as on the performance of hatchery reared fish in nature (Jonsson et al. 1993a).

In this report from the Study Group on Sea Trout under the Committee of Anadromous and Catadromous Fishes in the International Council for the Exploration of the Sea (ICES), we summarize available information on distribution, population structure, life history and factors influencing the dynamics of anadromous trout in Atlantic and Baltic Europe, in light of the terms of reference given by the Council of ICES.

1.2 Terms of reference

The terms of reference for the Study Group were set out in the ICES C.Res 1993/2:61 as follows:

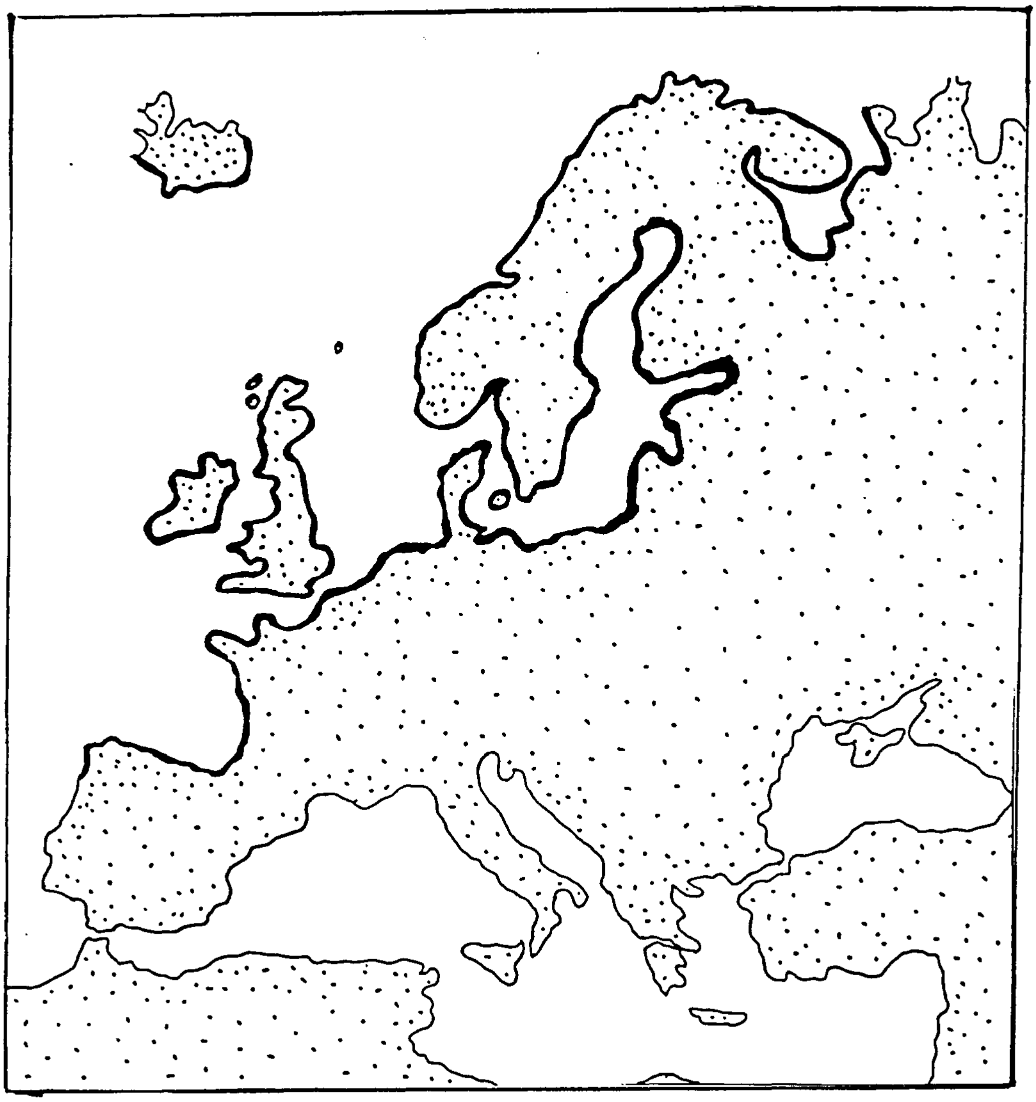
a) Gather information on the population status of anadromous brown trout and anadromous rainbow trout in different countries;

b) Summarize information on the variation in population structure (residents and migrants) and life history in anadromous brown trout in various areas;

c) Identify major causes of fluctuations in population abundance in anadromous brown trout.

1.3 Participants

C. Dieperink	Denmark
G. Euzenat	France
L.P. Hansen	Norway
M. Jóhannsson	Iceland
E. Jokikokko	Finland
B. Jonsson	Norway (Chairman)
L. Karlsson	Sweden
N. O'Maoileidigh	Ireland
R. Poole	Ireland
A.F. Walker	U.K. (Scotland)
A.J. Winstone	U.K. (England and Wales)



Figur 2.1 Native distribution of anadromous brown trout in Western Europe indicated by bold line.

2 Population Status

2.1. Introduction

2.1.1 Geographic Distribution

Anadromous brown trout populations occur in western Europe from latitude 42 degrees northwards and are found in countries with rivers flowing into the White Sea and Cheshkaya Gulf, Baltic Sea, North Sea, English Channel, Irish Sea and Atlantic Ocean as far south as the Bay of Biscay (Figure 2.1). Sea trout are absent from the Mediterranean Sea, but migratory brown trout are found in the Black Sea and Caspian Sea. Freshwater-resident populations of brown trout in western Europe must have arisen from migratory populations during the retreat of the last glaciation (c. 13,000 years ago), since most of the region had been covered with ice (Elliott 1989).

2.1.2 Factors Influencing Distribution and Population Status of Brown Trout

2.1.2.1 Water Temperature

Water temperature is believed to be the main factor determining the geographic range of brown trout. The limits for egg development are about 0-15 °C (Elliott 1981). The upper limit for survival of older stages ranges between 25 °C and 30 °C, depending on acclimation temperature (Elliott 1981, 1982).

2.1.2.2 Dissolved Oxygen

The second most important factor is believed to be the level of dissolved oxygen. A minimum concentration of 5.0-5.5 mg/l can be tolerated by free-swimming brown trout, but should be at least 80% of saturation (Mills 1971).

2.1.2.3 Spawning Conditions

Brown trout spawn only in fresh water, more commonly in streams, but sometimes along gravel, or stony shores in lakes. In the Northern Hemisphere, spawning normally occurs from October to December, but can extend into March (Frost & Brown 1967). Spawning tends to begin and finish earlier in areas with colder ambient air temperatures. The eggs are deposited in pockets within gravel (redds), which are excavated and then covered again by the female fish. Fertilisation of the eggs by the male trout occurs at the time of egg deposition (Stuart 1953). Brown trout is a polymorph species and the various forms may spawn together as part of one common population, or may exhibit temporal and/or spatial spawning segregation (Jonsson & Jonsson 1993). Sea trout, often predominantly female fish, commonly spawn together with freshwater-resident brown trout, often mainly males (Le Cren 1985). Egg developmental rate depends on water temperatures and, after hatching occurs, they develop into an alevin stage with attached yolk sac.

Emergence of fry from the gravel and commencement of exogenous feeding usually occurs in spring.

2.1.2.4 Diet

Newly-emerged fry disperse from the redds and attempt to establish feeding territories. During this early period, mortality levels are likely to be high (Elliott 1994). Feeding initially is on small invertebrates, including insect larvae, but larger food items are taken as the fish grow. Brown trout are usually opportunistic, generalist feeders, but some forms occurring in lakes may specialise in their feeding behaviour (Ferguson & Mason 1981).

2.1.2.5 Habitat Access

Water falls limit the distribution of brown trout in rivers. In isolated localities, individuals and forms of brown trout may remain stationary throughout their lives. If there is free access to neighbouring locality, individuals may migrate to habitats with better feeding and growth opportunities in larger streams and rivers, in lakes, in estuaries, or in the sea. (Jóhannsson & Einarsson 1993) Downstream migration of silvering juvenile sea trout (smolts), like Atlantic salmon, usually takes place from March to May, although it may take place as late as July in the north of their geographic range, e.g. in rivers in northernmost Norway and Finland.

2.1.2.6 Pollution

Numerous forms of pollution limit brown trout populations, including the effects of deoxygenation and toxins from domestic, agricultural and industrial effluents. Acid deposition, mainly from the burning of fossil fuels, may have serious effects in areas where waters are poorly buffered.

2.1.2.7 Physical Encroachment

Many physical factors restrict the range and abundance of sea trout populations. These include man-made obstructions such as dams, habitat degradation due to agricultural and forestry effects, including alterations in water flow regimes and canalisation.

2.1.2.8 Exploitation

Sea trout populations are vulnerable to excessive exploitation because they are highly desired for recreational and commercial use. This may take the form of coastal and marine exploitation or exploitation in rivers as they ascend for spawning. They may occur as a bycatch in fisheries targetted on other species such as salmon or whitefish.

Due to the economic importance of such fisheries, it may be difficult to effectively control the exploitation of sea trout.

2.2 The Status of Anadromous Brown Trout in Different Countries

2.2.1 Belgium

Sea trout population in the River Meuse has recovered during the last decade. Fed fry (3-6 cm in length) from wild spawners caught in the Netherlands have been stocked in the river. Several tens of migrants are trapped in fishways. The species is under total protection and no fishing is allowed (J. C. Philippart pers. comm.).

2.2.2 Denmark

Trout is the most common fish species in the upper reaches of many Danish rivers. It is widely distributed on the mainland of Jutland, on the larger islands Funen and Sealand and on the Baltic island Bornholm. The streams are mostly flowing through intensively cultivated arable land and the water velocity is generally low. Many streams are obstructed by dams, or have been physically altered by canalization and dredging. From data collected by the Inland Fisheries Laboratory, the number of river systems supporting sea trout at different periods have been as follows:

Periods	About 1900	About 1960	1988-1992
No. of streams	249	176	244

The loss of sea trout streams between 1900 and 1960 was mainly due to pollution alone, or in combination with water regulation and damming. The increase in sea trout streams since then has been primarily due to improved water purification, habitat restoration, construction of fish passes and restocking.

According to official statistics, the Danish landings of sea trout in 1992 by the commercial fishery amounted to 45 tonnes. However, 27 tonnes of this total were taken as a by catch in the Baltic offshore salmon fishery and were probably not of Danish origin. Unregistered catches, including from limited angling, were believed to be an order of magnitude greater than the commercial catch.

The need for stocking was evaluated on the basis of habitat and population density surveys in 696 rivers during 1988-92 and the stocking programme in 1992 included the following quantities of the various age and size categories of trout:

1 709 900	fry (fed for 3 weeks)	(42.9 % of wild origin)
486 700	half year old parr (6-10 cm)	(30.6 % - - -)
433 300	one year old parr (10-15 cm)	(22.2 % - - -)
111 900	one year old parr (17-23 cm)	(12.5 % - - -)
507 200	smolt, river mouth releases	(41.9 % - - -)
217 200	smolt, coastal releases	(4.6 % - - -)
16 000	smolt, lake releases	(0.0 % - - -)

2.2.3 Estonia

In Estonia (Anon 1994a), sea trout occur in about 20 rivers or streams discharging into the Gulf of Finland and 14 rivers and streams discharging into the Baltic Main Basin Anon 1994 a). Limitations on sea trout distribution include the presence of dams at some of the river mouths, and agricultural and industrial pollution. Regular stocking releases are carried out in some rivers. The status of sea trout populations in Estonian rivers has been assessed as follows:

Status	Gulf of Finland	Main Basin
poor	7	6
satisfactory	3	3
good	10	5

Nominal landings of sea trout from Baltic fisheries in 1993 were 15 tonnes. No information is available on angling fisheries.

2.2.4 Faroe Islands

Sea trout occur in a few of the small, steep rivers of the Faroe Islands (Walker pers. comm.). No other information is available to the Study Group.

2.2.5 Finland

The register of Finnish trout stocks contains information on 33 sea trout stocks. The status of the populations has been described as follows in the Finnish sea trout stock register:

Origin		Threat category							Threats					Management				
		D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
A	10	7			1	2			8	5	4	8	6	6	3	1	3	5
B	11	3	3	1		2	1	1	7	2	4	2	5	4	4	3	2	1
C	12					1		11	4	5	6		1		7	5		
Tot.	33	10	3	1	1	5	1	12	19	12	14	10	12	10	14	9	5	6

Note: Origin. (A)=original, (B)=mixed, (C)=introduced; Threat categories. (D)=endangered, (E)=vulnerable, (F)=declining (G)=rare, (H)=precarious, (I)=safe, (J)=no information; Threats. (K)=pollution, (L)=land use, (M)=construction, (N)=exploitaition, (O)=other; Management. (P)=natural, (Q)=natural and stocking, (R)=stocked, (S)=natural eggs, (T)=brood stock.

Many Finnish sea trout populations have been lost due to the construction of dams. Present threats are primarily overexploitation, especially in the sea, and damage to natural habitats in fresh water caused, for example, by forestry, agriculture and various forms of pollution. The significance of the so-called M74 disease, or condition, is now being studied (see notes on M74 in chapter 4.3.1). All of the original Finnish Baltic populations are regarded as endangered or extinct. Of the total 33 sea trout populations, 30 are in the Baltic Sea area and 23 of them are either partly or totally maintained by stocking. In the Barents Sea area there are three populations where no stocking has been carried out. In Finnish rivers in 1993, 266,000 fry, 130,000 one year old parr and 1.15 million smolts were stocked. The total Finnish sea trout catch in the Baltic in that year, of which angling provided a small proportion, was about 1250 tonnes (including recreational netting). The catches from the Baltic have been increasing annually. Finnish sea trout are mostly of the short-migrating type and so are exposed to local fisheries for salmon and whitefish. In 1992, about 6 tonnes of sea trout were reported caught in the most important rivers, the Tenojoki, Tornionjoki and Kymijoki. Catch statistics are unavailable from other rivers.

2.2.6 France

Sea trout probably occur widely along the Atlantic coastline of France, but little is known about the populations in most rivers. It is believed that sea trout populations have suffered from habitat degradation and dams preventing access to spawning grounds. Brown trout occur naturally or are stocked in many of the rivers and the extent to which these may migrate is unknown. Tagging studies in France have demonstrated that some stocked brown trout migrate to the sea and return as large fish. In the 1960's, sea trout from the Polish River Vistula were stocked in some rivers. Detailed scientific investigations are being undertaken in some rivers in north west France. Sea trout smolts tagged in the River Bresle in Normandy have been recaptured mainly locally and a few to the north, along the coasts of Netherlands and Denmark.

2.2.7 Germany

Se trout spawn in the River Sieg, a tributary to the river Rhine, North-Wesphaly. The abundance and true origin (residual stock or introduced through reared brown trout stocking) of these fish is unknown (G. Marmulla pers. comm.). No other information was available to the Study Group.

2.2.8 Iceland

Sea trout are found in coastal rivers throughout Iceland. It is a most common and dominant species. Limited stocking of sea trout, mainly above impassable waterfalls, is carried out to enhance angling catches. More than 70% of the total reported Icelandic sea trout landings are from angling. For most rivers catches are poorly reported. In rivers in south-eastern Iceland, were reporting is good, catches show great fluctuations with a decline in recent years. Short time fluctuations in stock size are blieved to be governed by climatic and oceanic conditions.

2.2.9 Ireland

Sea trout are widespread in Ireland (at least 72 rivers), the majority being in the south west, west and north. Generally the sea trout rivers are those flowing over non-carboniferous (acidic) rocks. Sea trout have traditionally been plentiful in most short rivers running directly into the sea and in coastal lakes. They are found particularly in the coastal river systems of Kerry, Galway, Mayo and Donegal. Although mainly associated with salmon, there are many lesser streams or small lake systems that do not hold many salmon, but in which sea trout are numerous. Identified threats to Irish sea trout populations, not in order of importance, include drainage and gravel removal, forestry and acidification, peat siltation due to machine turf cutting and overgrazing, predation, marine ectoparasites (sea lice), increased fishing pressure (illegal and legal). Angling catches of sea trout have declined severely in western Ireland, but there has been no consistent, comparable decline in other parts of the country. Rivers in the west monitored by traps have shown stock collapses since 1988 (Anon 1993a). Urgent measures are being taken to protect and restore these stocks, including the imposition of new fishing restrictions, an aquaculture-free coastal zone and intensive restocking using ova derived from local brood fish.

2.2.10 Latvia

Sea trout occur in 15 larger rivers and some smaller streams in Latvia (Anon. 1994 a). Wild populations are supported by stocking mainly in the Gauja, Salaca and Venta Rivers. Constraints upon wild populations are similar to Estonia. The status of Latvian sea trout populations has been assessed as follows:

Status	Number of river stocks
Poor	2
Satisfactory	5
Good	8

Recent economic changes in the country have caused an increase in fishing effort in the coastal zone and in the rivers.

2.2.11 Lithuania

No detailed information is available.

2.2.12 Netherlands

Sea trout is widely distributed throughout the Dutch river systems, along the coast and in the Usselmeer. The sea trout catch in the rivers Rhine and Meus, in the coastal zone and the Usselmeer yielded ca. 2000 kg in 1993. (W.G Cazemier pers. comm.).

2.2.13 Norway

Sea trout are distributed in coastal rivers throughout Norway where they have free access from the sea and there are suitable spawning substrates. Atlantic salmon are their main competitor in rivers in southern Norway. In northern rivers, both salmon and Arctic charr constrain the success of sea trout. Sea trout have been recorded in 923 rivers and streams and a status report of these rivers is given below:

	Category						
County	1	2	3	4	5	6	Total
Østfold	14	11	3				28
Oslo and Akershus		5		2	1		8
Buskerud			1	1	1		3
Vestfold			5	3	1		9
Telemark				3	1		4
Aust-Agder	3	2	14	7	1		27
Vest-Agder			17	10	2	1	30
Rogaland			6	2	1	22	31
Hordaland	4	6	19	12	5		46
Sogn and Fjordane		1	3	27	9		40
Møre and Romsdal		5	23	28	46		102
Sør-Trøndelag			8	56	13		77
Nord-Trøndelag	3	1		93	29	1	127
Nordland		3	32	101	131	16	283
Troms		1		36	9	14	60
Finnmark	2			12	34		48
Total	26	35	131	393	284	54	923

Note: River categories: 1. Natural population extinct. 2. Endangered population. 3. Vulnerable population. 4. Small population size from natural causes. 5. Abundant populations. 6. Population status unknown.

In 2.8% of the rivers, former sea trout populations are now extinct. In 3.8% the populations are threatened by extinction and in 14% the populations are classified as vulnerable. Apparently, 73% of the populations are in good shape and in ca. 6% the population status is unknown.

Perceived problems for Norwegian sea trout in rivers where the populations are classified as vulnerable, endangered or extinct (categories 1-3 in the table above) are given below. The importance of each factor is given as the percentage of the total number of affected rivers.

Factor	Affected rivers (%)
Hydro power regulation	28
Other physical encroachments	15
Acidification	21
Agricultural sewage	16
Other pollution	7
Escapes from fish farms	7
Diseases	4
Overexploitation	2
Total	100

Note: Encroachment means any physical alteration of the river which may restrict the access for fish or decrease available habitat.

Acidification is most harmful in the southern and western parts of the country. Escapes from fish farms and diseases are more important in the south west, while other factors are more widespread. Sea trout are relatively more abundant than resident trout in rivers where growth opportunities are poor. Furthermore, the relative size of the sea trout part of the population seems to be larger in northern than in southern rivers. Annual reported catches are around 70 tonnes, but for various reasons this is a gross underestimate. In the 1980s, a questionnaire survey of the sport fishery indicated an average annual catch of around 500 tonnes.

2.2.14 Poland

Sea trout exist in at least 21 Polish rivers (Anon 1994a). Data on status is available for 17 of them:

Status	Number of river stocks
Poor	10
Satisfactory	6
Good	1

The most important population is in the River Vistula, the sea trout of which are large and rapid-growing. In 1969, the river was dammed, blocking access to the upper reaches and the main spawning grounds are now in the River Drweca (a tributary). All Polish sea trout are believed to migrate widely throughout the Baltic Main Basin and are taken in the offshore salmon fishery. Stocking is carried out widely (5.1 million fry and 985,000 smolts in 1993).

2.2.15 Portugal

Anadromous brown trout are distributed to ca. 42°N (border area between Spain and Portugal) (Ellitott 1994), but no information is available to the Study Group concerning possible presence in Portugal.

2.2.16 Russia

Sea trout occur in rivers entering the Baltic, the Barent and the White Seas. Little information is available to the Study Group on the status of these populations. Sea trout are common in the rivers of the Kola Peninsula, but are believed to be uncommon in the rivers flowing into the southern part of the White Sea. No stockings has been undertaken and no information is available on catches. It is thought that the sea trout only migrate downstream to the river estuaries, rather than to the sea. Sea trout have been taken as a bycatch to salmon in large traps set at river mouths. There are attempts now to encourage angling for sea trout, especially for tourism (Eero Niemelä pers comm.).

2.2.17 Spain

Sea trout are found in many coastal rivers and smaller streams from the Basque Country to Galicia in northern Spain, where they are exploited by angling. Overfishing, the presence of many dams of varying size and some pollution, exacerbated by high temperatures, are regarded as the main constraints upon the status of their populations. Acid precipitation is believed to be a problem in headwaters of some rivers in the north west part of the region. Catch data and information on any trends in their abundance are unavailable to the Study Group. Some stocking is carried out in an attempt to enhance angling catches (David Hay pers. comm.).

2.2.18 Sweden

At least 258 sea trout populations exist in Sweden. Most of them are small, and about half of them produce less than 1000 smolts/year each, see table below:

Region	Sea trout populations N	Production >1000 smolts/year, N	Acidified and/or limed streams, N
Bothnian Bay, Baltic	12	7	0
Bothnian Sea, Baltic	38	18	17
Main Basin, Baltic	74	38	23
West Coast, North Sea	134	53	38
Total	258	116	78

In the northern part of the Gulf of Bothnia, the Bothnian Bay, sea trout only occur in rivers which also have salmon stocks. Some small streams in this region have only nonmigratory stocks of brown trout. Almost all sea trout populations in this region are now close to extinction, mainly as a result of 20 years of overexploitation. Many trout streams, especially in northern Sweden, have been cleared and used for timber rafting. Nowadays, after truck transports have replaced rafting, efforts are underway to restore such streams to suitable rearing habitats. In south and west Sweden acidification is one of the main threats. About 31 % of all sea trout streams are acidified or have been limed, see table above. Severe summer droughts in recent years have probably considerably decreased smolt production in the smaller brooks in southern Sweden. Some of the populations show adaptations to low summer water flows, such as migrating downstream at a length of <10cm and an age of 1 year. The number of sea trout populations in southern Sweden has increased in recent years due to better pollution control and habitat improvement, but there is still room for considerable improvements. To compensate for losses of rearing habitat due to hydroelectric power production, about 0.6 million sea trout smolts are released annually in Swedish streams, most of them in rivers into the Gulf of Bothnia. In recent years an unexplained mortality, similar to M74 in salmon, has been observed occasionally in sea trout alevins in hatcheries. Investigations are in progress to determine whether the mortality is related to M74 (cf. chapter 4.3.1).

Sea trout are exploited in the offshore salmon fishery, on the coast and in the rivers. The angling catch is less than 15% of the total sea trout catch. The total Swedish sea trout catch in 1993 was about 210 tonnes (excluding non-commercial coastal netting and angling catches).

2.2.19 UK (England and Wales)

Sea trout occur throughout England and Wales, but are more common in northern, Welsh and south western rivers. Most eastern rivers are not well-suited for salmonid fish, due to their low gradients and eutrophication. In some rivers there are only freshwater-resident brown trout, possibly due to very favourable trophic conditions. There are also a number of important salmon rivers with poor catches of sea trout. These include the Exe, Severn, Wye, Usk and the Dee. About 70 rivers produce significant sea trout catches. Sea trout are exploited in various areas by coastal trap and beach seine net fisheries and by driftnet (gillnet) fisheries operating in the North Sea off the north east coast of England and the north and south coasts of Wales. The average net catch for England and Wales is about 60,000 fish and the average rod catch about 30,000 (139 tonnes and 32 tonnes, respectively). Low catches declared in 1989 to 1992 were believed to be largely due to low river flow conditions and catches have increased since then. Stocking is carried out in some rivers (ca. 50,000 smolts annually) to restore populations after major fish kills due to pollution. Acidification of headwater streams is considered to be the main problem for local sea trout populations.

2.2.20 UK (Scotland)

Sea trout are widespread in Scotland, probably being present in every river and stream accessible from the sea. The relative proportions of resident and sea trout vary greatly between and also within regions. In the River Tay System, for example, sea trout predominate (ca 85%) in one major tributary, the River Earn, whereas river-resident brown trout are the main form (ca 99%) in another, the River Tummel. There are no significant barriers to sea trout migration in either river and it may be that the difference in migratory tendency is due mainly to relative conditions for growth in fresh water as growth rate is higher in the River Tummel. Among sea trout populations, there are also large regional variations in adult size, growth rate and average longevity. In general, sea trout from the short, often biologically unproductive rivers of the western Highlands and the Western Isles, flowing into the Atlantic, are slower-growing and live to older ages than those from the longer, often more biologically productive rivers flowing into the North Sea.

In 1993, sea trout were exploited almost equally by commercial netting and by anglers (the reported catch by all-methods in 1993 was 63 tonnes). Information on the status of stocks is mainly based on long-term catch statistics (1952-93), but these have to be viewed with caution because of changes in effort (commercial netting activity has declined since the mid-1980's) and in fish catchability (annual variation in river flow conditions). Western rivers have suffered a long-term decline in angling catches, becoming more severe in recent years, whereas catches have been well-maintained in most eastern rivers. Although there are many local constraints on fresh water production, there is no indication of a general decline in the quantity or quality of fresh water habitats in western river systems. On present evidence, increased mortality at sea is believed to be the main cause of the population declines. A fall in the mean size of adults has also been observed, caused by a reduction in both the proportion of older sea age groups and in their mean size. This could be due to poorer growth at sea, or less time spent feeding there. Fecundity studies have shown a consequent substantial drop in egg production, even without the observed fall in population abundance. Some stocking has been attempted, with little observed effect so far. More than 100,000 fry, 30,000 parr and several thousand large (1-2 kg), two year olds, grown in cages in the sea, have been stocked in one north western river during the past ten years. The angling catches of sea trout continued to decline, although there were short-term recaptures of the recently-stocked, larger fish.

2.3 Rainbow trout

Rainbow trout occur in rivers and coastal waters throughout western Europe and few conditions seem to limit its distribution. However, successfull spawning in rivers is uncommon but occurs in e.g. the River Wye in Derbyshire in the UK (Frost & Brown 1967). To some extent the species is released deliberately in streams to sustain a sport fishery. Most releases are based on long-term hatchery-reared fish. Only a few of them have used steel head (anadromous) strains. The planted fish stay chiefly as freshwater residents near the site of release, although some migrate to sea (Jensen 1968). Rainbow trout are also farmed in coastal sea pens. For instance, in Norway more than 5000 tonns are produced annually (Central Bureau of Statistics 1990). However, some of the hatchery fish escape (Egidius et al. 1991), and escapes are regularily caught by anglers and fishermen along the coast. These fish also enter rivers to spawn, but few if any self-sustaining populations have been established from escaped fish.

Experimental releases with rainbow trout in fjords and rivers in Norway (Jonsson et al. 1993 a,b) indicate that some of the fish smolt and perform long migrations, e.g. from the Oslofjord to northernmost Norway, and some of the fish appear to return to the place of release after 1-3 years at sea. Thus, the fish appear to have retained at least parts of their homing ability even after ca. 100 years of hatchery rearing.

In Norway, rainbow trout enter rivers from the sea all months of the year, both for feeding and spawning (in spring). However, the reproductive success of the fish, measured as number of smolts produces, is extremely low. There is no evidence and little likelihood for continuing survival of escaped rainbow trout in the wild, and the presence of the fish depends on intentional and/or unintentional releases.

3 Population Structure

3.1 Freshwater residence versus anadromy

The European brown trout is a polymorphic species that has been classified in the past based on morphological, physiological and ecological variation. Populations consist of interbreeding resident and migratory individuals. Moreover, eggs of resident fish can also produce migratory fish, and offspring of migrants may become residents (Rounsefell 1958, Skrochowska 1969).

Distinct genetical differences have been found between geographically separate populations, both within and among catchments (e.g. Cross 1985, Hansen et al. 1993, Hindar et al. 1991, Ryman & Ståhl 1981). Observed ecological differences (growth rate, fecundity, age at first maturity) between trout populations, even within the same catchment, also strongly support the existence of genotypic differences between stocks (Ryman et al. 1979, Elliott et al. 1992).

Recent mt DNA studies (H. Hall personal comm.) of 13 river systems in England and Wales has revealed clear divergence of the populations into two distinct groups. Variation within river systems is less than that between river systems.

Samples, collected during the smolt run on the Conwy River (Wales) and throughout the adult sea trout run on the River Dee (Wales), showed no evidence of genetic differences between fish migrating at different times during the season (Hall op. cit.). Comparable studies from other systems are not currently available.

Both resident and migratory forms of trout co-exist within any location. Purely resident or purely anadromous populations are more the exception than the rule. The data from sympatric and allopatric populations of brown trout are conclusive. It is known that resident and migratory forms interbreed within locations, and there is no evidence to suggest that they are genetically distinct. There is reason to believe that the life history "decision", migration versus maturity and residency, is partly determined by environmental and partly by genetic factors (Jonsson & Jonsson 1993).

Migratory trout usually show a skewed sex ratio with female dominance, whereas resident trout exhibit male dominance. Migration to sea increases the feeding opportunities and is a means of obtaining a higher reproductive potential. At the same time however, it increases the risk of mortality. For males, the gain in reproductive fitness by migration may be small as they exhibit alternative mating strategies (i.e. sneaking versus fighting, Gross 1984, Jonsson 1981, 1985). Females, on the other hand, increase their fecundity significantly by their increase in body size, and have as far as is presently known, no alternative ways of increasing their reproductive success. This differential gain between sexes in fitness is the most probable reason for the skewed sex ratio observed in anadromous trout (Gross 1987).

Variations in life history patterns have been observed over the geographical ranges. Fish of sea ages 0+ to 3+ may adopt one of three options for their winter habitats:

- As mature fish spawning in fresh water
- As immature fish in fresh water
- As immature fish in salt water.

The migratory behaviour of brown trout is partly determined by genetics and partly by environment. However, the relative importance of genetics and environment on the migratory behaviour have not yet been quantified. Variations in catchment productivity and habitat characteristics may determine the relative proportions of migrants versus residents. For example, it is now clear from smolt trapping in western Ireland that the progeny of resident brown trout make a significant contribution to the sea trout smolt production, e.g. Table 3.1, but the size of the contribution has yet to be determined (Sea Trout Working Group 1993).

Recent data from west Scotland have shown an extremely low percentage (4 %) of mature freshwater resident females in systems with anadromous populations (Walker 1994). However, along with a collapse in rod catches, there has been an increase in average size of the resident trout but no change in the sex ratio has been detected so far; although this has not been discounted. Therefore, almost all the ova production in these systems must still be from sea trout. It is not as yet clear whether ova production from resident females will increase in response to accelerated growth, although this is believed likely.

Landlocked populations are found in many catchments, where upstream passage from the sea is impossible due to waterfalls, construction of dams etc. Such landlocked populations are genetically different from the migratory populations further downstream (Jonsson 1982). At the other extreme, some populations are apparently based on migratory specimens, as summer drought makes the streams dry up.

Table 3.1. Upstream counts, rod catch and smolt output for the Gowla system, west Ireland (1994 data are provisional, from Gargan, pers. commun.).

Year	Upstream count [migratory stock]	Rod catch	Smolt output
1985		1035	
1986		967	
1987		266	
1988		210	
1989		0	
*1990		0	
*1991	13	0	7557
*1992	1	N/F	5999
*1993	2	N/F	4087
*1994	600	N/A	4000

N/F = not fished N/A = not available * = catch & release

3.2. Life history characteristics

3.2.1. Smolt characteristics

The mean smolt age (Table 3.2) is related to smolt length (Table 3.3) as well as to sex ratio and parr growth rates (Økland et al. 1993). Differential migration of smolts has been observed in many systems, with larger (older) smolts migrating earlier in the season than smaller (younger) smolts (Berg & Jonsson 1989). Some studies have shown that male smolts tend to migrate at earlier ages than female smolts (Pemberton 1976, Dieperink 1988). The sexual differentiation is probably due to the male parr maturation, a process that has often been shown to inhibit later smolting (Jonsson 1985, Dellefors & Faremo 1988).

Smolt may start growing in freshwater the same spring as they smoltify ("B-type growth"; Fahy 1978). The extent of B-type growth is inversely related to the age/size at smolting (Dieperink 1988). Compensatory B-type growth may enable relatively young and small parr to achieve a critical size treshold, necessary for environmental stimuli to trigger migration, and thus become smolts late during the smolt migration period. Studies have shown that growth rate was more important than the actual size of the parr for triggering migration. Very small smolt sizes may be seen as adaptations to extreme conditions, such as wide variations in flow and low water conditions during summer. The mean smolt age (MSA) seems to be more variable among countries than is the mean smolt length (MSL).

Table 3.2. Mean smolt age (MSA) and the range of variation in mean smolt ages among studied populations in the respective countries.

	MSA (yrs.)	MSA - range	References
Denmark	2.0	1.8 - 2.2	Christensen et al. 1993
England/Wales	2.2	1.9 - 2.8	Solomon, 1994
Finland	-	3.0 - 6.0	Jokikokko 1994, Niemelä & McComas 1985
France	1.3	1.1 - 1.6	Euzenat et al. 1990
Iceland	3.1	2.8 - 3.4	Jóhannsson & Einarsson 1993 Gudjónsson 1993
W.Ireland	2.4	2.3 - 2.5	Poole et al. 1994
Norway	3.0	1.5 - 6.0	L'Abée-Lund et al. 1989
Scotland	2.4	1.8 - 3.2	Nall, 1930
Sweden	2.5	1.5 - 3.5	Karlsson 1994, Andersson 1954, Titus 1991
All	2.4	1.1 - 6.0	

Mean smolt age increases with latitude between 70 and 54°N (Jonsson & L'Abée-Lund 1993). The youngest mean smolt ages were recorded in France and the oldest in northernmost Finland and Norway. Variations in smolt age have been related to parr growth rates, and faster growing parr usually become smolts at an earlier age than slower growing ones. Therefore, both habitat characteristics and environmental conditions (i.e. temperature) may be expected to influence the age composition of a particular smolt run.

Table 3.3. Recorded mean smolt lengths (MSL) and the range of variation in individual smolt lengths (SL) in populations of trout in various countries.

	MSL (cm)	SL - range	References
Denmark	17	8 - 30	Dieperink 1988
England/ Wales	17	8 - 27	Solomon 1994
Finland	-	15 - 30	Jokikokko 1994 Niemeta & Mc Comas 1985
France	20	11 - 33	Euzenat et al. 1994
Iceland	18	12 - 30	Jóhannsson & Einarsson 1993, Gudjónsson 1993
Ireland	20	14 - 29	Poole et al., in press
Norway	17	7 - 29	Jonsson & L'Abée-Lund 1993 L'Abée-Lund et al. 1989
Scotland	18	14 - 23	Nall 1930
Sweden	16	7 - 27	Karlsson 1994
All	18	7 - 30	

3.2.2 Habitat and migrations at sea

Sea trout migrations are shorter than those of Atlantic salmon. The fish usually remain within a relatively short distance of their native stream, generally close to the shore or in shallow water. Most information on post smolt habitat and life at sea has been gathered from tagging experiments in Denmark, (e.g. Kristiansen & Rasmussen 1993), Norway (Sundal 1991), Wales (see section 2.2), Scotland (Johnstone et al. in prep.) and France (Euzenat et al. 1994). The listing below, based on 1903 recoveries from 63526 Carlin-tagged sea trout smolt, shows that the majority of the sea trout are recaptured within a radius of less than 50 km from the release point (Table 3.4) (Kristiansen & Rasmussen 1993). However, long distance migrating sea trout occur, especially in the Baltic Sea area (Svärdson & Fagerström 1982).

Table 3.4. The percentage distribution of recapture distances from releases of Carlin tagged sea trout smolts in Denmark (Kristiansen & Rasmussen 1993).

Distance (km) >250:	0-50	50-100	100-150	150-200	200-250	>250
Average percentage of recaptures:	63	16	8	5	3	5

In France (data presented to the Study Group) recaptures of sea trout, Carlin-tagged on the rivers Orne and Bresle in Normandy, have shown:

- a migration towards the North Sea, probably an inshore movement with incursions into estuaries and lower river reaches.
- feeding grounds of the French sea trout is to be found in the North Sea. Trout tagged in the River Bresle as smolt were recaptured along the north-western Danish coastline as well as in the Baltic Sea. These movements are consistent with the dominant water currents in the English Channel and in the North Sea.
- fish may do incursions, often repeated, into estuaries and rivers both in summer and in winter. French smolts have been recaptured in the Rhine and 0+ sea age fish, tagged in the Rhine (by Caziemer, the Netherlands) were recaptured in the Bresle traps one year later, both as ascending fresh-run fish and as descending kelts.

Evidence of homing to specific locations within a river system by individual fish is stated by Sambrook (1983) and recent tagging experiments have shown that the homing of mature trout is very precise (Le Cren 1985, Jóhannsson & Einarsson 1993). Solomon (1994) cites evidence that large numbers of non-maturing fish overwinter in "foreign" rivers and in estuaries and tidal reaches of rivers other than their own. However, it is not known whether these fish would have returned to their natal rivers if they had been released.

Large sea trout, particularly in the North Sea, have shown wider migration ranges and individual fish may undertake relatively large migrations, but these are more the exception than the rule.

Smolts are known to move with ebbing tides during estuarine migrations and recent investigations have demonstrated an additional movement at sea during ebb tides (Johnstone et al. in prep).

Immature sea trout are frequently recaptured in freshwater systems other than their own.

Distinct genetic differences within river systems, and even between spawning tributaries underline the existence of accurate homing (Hindar et al. 1991).

3.2.3 Growth, age and length at sea

Studies of growth in the marine environment have generally been based on freshwater sampling operations at the beginning and end of the marine phases.

Marine growth is determined by both feeding opportunities and temperature at sea, the size of the migrating fish, and the age and reproductive history of the fish. Table 3.5 shows the mean annual growth increment for sea trout. The table is mainly based upon captures and ageing of fish in freshwater, which may cause some bias due to the fact that the growth increments listed for sea age 0+ and 1+ do not include the non-maturing fish, which do not enter freshwater until in their third year at sea. It has been found that the length increment during a single sea run is about twice as high for immature rather than mature fish at the same age (Jonsson 1985). When comparing lengths at age of males and females, the size of the sexes may be similar to immatures, or the females may be larger than males. At old age, males are often the largest. One reason for this may be a more variable age at maturity in males than females (Jonsson 1985).

Table 3.5. Annual mean growth increment at sea (cm). Numbers in brackets indicate the ranges. Data based upon back-calculated lengths.

	0+	1+	2+	3+	4+	5+
Denmark	14	11	8	9	8	4
England/ Wales	14 [11-18]	14 [10-21]	9 [4-12]	13 [12-16]	-	-
Finland	8 [3-16]	11 [7-15]	10 [6-13]	10 [9-11]	6 [5-9]	-
France	17 [14-22]	16 [14-21]	11 [8-13]	4 [3-6]	6 [3-5]	-
Iceland*	12	12	9	6	5	-
Ireland	8	9	7	4	6	-
Norway	13 [11-16]	10	6	4	-	-
Scotland	7	6	7	4	5	7
Sweden	16 13-18	12 11-20	12 5-14	10 6-11		

Data based on references given in Tables 3.2 and 3.3.

3.2.4 Age and size at maturity

There is considerable variation in age and size at maturity. Adult sea trout vary between 20 and 100 cm in length and range from 2 to 15 years of age (Jonsson 1994). Population means of mature fish seem to vary from 30 cm to 75 cm in length, and from 2 to 10 years of age (Table 3.6). Within populations, the total age at maturity increases with increasing smolt age, but the sea age at maturity decreases with increasing smolt age (Jonsson 1985). There is a great variation both within and between countries.

In anadromous trout, the males are either younger than or at the same age as females (L'Abée-Lund et al. 1989). Among countries, the overall mean length at maturity varies from 30 cm to 50 cm with fastest growth in the Baltic and French stocks.

Age at maturity is influenced by growth rate. It has been observed that fish mature younger when the length increment was reduced in the second year relative to the first year at sea. In England and Wales increased marine growth tends to lower the rate of maturation fish after one year at sea (Solomon 1994).

Table 3.6. Mean lengths, ages, and ranges for spawners.

	Mean length for spawners (cm)	Range for mean length for spawners	Mean age of spawners	Range for mean age of spawners	References
Denmark	40	30-65	4.0	3.0-5.0	Christensen et al. 1994
England/ Wales	40	30-65	3.5	2.5-4.0	Solomon 1994
Finland	-	40-53	5.5	5.0-6.5	E. Nylander pers comm. Niemelä & Mc Comas 1985
France	55	45-60	3.0	2.0-4.5	Euzenat et al. 1990
Iceland	40	40-65	5.0	4.0-8.0	Jóhannsson & Einarsson 1993, Gudjónsson 1993
Ireland	40	35-50	4.0	2.5-5.0	SRTII 1987
Norway	45	30-70	5.5	5.0-10.0	L'Abée-Lund et al. 1989, Jonsson et al. 1991
Scotland	40	30-65	4.0	3.0-5.0	Jonsson & L'Abée-Lund 1993
Sweden	50	30-75	5.0	4.0-10.0	Andersson 1954, Järvi 1940

Although most anadromous trout appear to spawn once, repeat or multiple spawning is relatively common with 20-30 % spawning at least once in many populations (Table 3.7). In Norway, the incidence of repeat spawning appears not to be related to latitude, but rather to the size of the river (L'Abée-Lund et al.1989). In the Baltic Sea the mean percentage repeat spawners is very low, probably due to high exploitation rate.

Table 3.7. Mean age at maturity and mean percentage repeat spawners.

	Mean age at maturity	Mean percentage repeat spawners
Denmark	3.5	30
England/Wales	2.5	40
Finland	5.0	<5
France	2.0	20
Iceland	4.5	30
Ireland	3.5	20
Norway	5.0	30
Scotland	3.0	50
Sweden	4.5	10

References as in Table 3.6.

3.2.5 Reproduction

Fecundity

Within any given population, the egg number can generally be related to female length by a power law model (Jonsson 1985, Walker 1994, Solomon 1994, O'Farrell et al 1989).

Few measurements of sea trout fecundity have been made, but information is available for rivers in Ireland (Erriff & Burrishoole), Scotland (Ewe), France (Bresle), Norway (several rivers) and England and Wales (Dyfi & Cumbrian rivers).

It is known that fresh water age (smolt age) and history of previous spawning influence fecundity, although only the Irish data shows examination of this. Observations from the Erriff (O'Farrell et al. 1989) have shown:

- maturing fish derived from 3+ smolts had a lower fecundity per unit length than those from 2+ smolts.

- Previously spawning fish were less, but not significantly less, fecund than maiden fish of the same length.

- It appeared that larger fish (or more frequently spawning fish) had more residual ova than smaller, younger fish; possibly indicating a decreased spawning efficiency with larger size. Ova from very large sea trout may not be a viable as those from middle-sized fish.

The mean fecundity of Burrishoole sea trout increases with sea age, but it drops again in the older age groups and multiple spawners (Table 3.8).

Table 3.8. Fecundity of Burrishoole sea trout.

Sea Age	n	Mean length (cm)	Fecundity:	No./kg
0	16	28.0		754
1+	62	36.0		1 027
2+	12	43.0		1 318
3+	2	47.0		1 843
4+	1	53.0		1 638

Sea trout in the French rivers with 1+ sea age (mean length = 53 - 60 cm) had fecundity values of 2 120 - 2 450 ova/kg.

In Scotland, the overall mean length of the sea trout sampled in the Ewe System fell from 432 mm in 1980, to 404 mm in 1989, 366 mm in 1990, 349 mm in 1991 and to 341 mm in 1992. Fecundity data obtained from Ewe sea trout suggest that a decline in mean length of this magnitude for the population as a whole would approximately halve the overall number of eggs available for deposition (Table 3.9), even if the numbers of sea trout had remained constant. The true extent of the decline in egg deposition cannot be estimated since data on adult abundance are unavailable.

Table 3.9. Estimated egg numbers per annual mean lengths of Ewe System sea trout samples (1980-92), Scotland (Walker 1994)

Year	Numbers of fish	Mean standard length ± error (mm)	Egg Number	No./kg
1980	1 089	434 ± 3	1 143	1 262
1989	136	404 ± 7	945	1 302
1990	171	366 ± 5	713	1 322
1991	232	349 ± 4	623	1 322
1992	135	341 ± 5	583	1 337

Some studies on the Norwegian Voss R. have demonstrated an overall fecundity value of 1700 ova/kg. for a sample of all sea ages.

Information from Wales indicates that the numbers of eggs obtained by stripping live fish give an underestimate of the natural egg production capacity of the fish. Comparision of the number of eggs found retained in stripped fish and in kelts that had spawned naturally showed that fewer were retained by natural kelts.

Full elucidations of ova/trout size relationships is important for any fishery management action aimed at protecting or enchancing egg deposition rates.

Trends of increasing egg size with female length have been found in England & Wales, Ireland and Scotland. The recent study by L'Abée-Lund & Hindar (1990) of 9 Norwergian sea trout rivers also found positive correlations between fish length and egg size in all but two populations, where the relationship was still positive but not significant. In general, larger eggs give rise to larger fry, thereby determining the length of time for which fry can tolerate starvation after emergence from the gravel.

Data from Norway, Scotland and Ireland have shown that faster growing populations have higher fecundity values and relatively small eggs, but slower growing populations produce fewer larger eggs. Resident trout within migratory populations tend to produce few but larger eggs.

3.2.6 Adult survival

Adult survival may be separated into two stages, marine survival and post-spawning freshwater survival.

Quantitative data is available for post-smolt survival in Ireland (see Section 3.2.7.). About 37% of Norwegian first time migrants survived in the sea. High post-smolt mortality has been estimated in estuarine water in Denmark due to pound net exploitation and in the northern Baltic due to whitefish gillnetting.

Marine survival of repeat migrants in the river Vardnes in northern Norway ranges from 56-68 % (Berg & Jonsson 1990). In Ireland the recapture rate is approximately 40% (Mills et al. 1990) and in France the recapture rate in home waters is 31-50 % (Fournel et al. 1990). Exploitation rates are discussed in Section 4.

Postspawning freshwater survival of adult trout (>30 cm) range from 30-80 % (Burrishoole , Ireland) and 66-74 % in Norway.

3.2.7 Population changes - Ireland

A number of changes in sea trout populations has been observed in some Irish sea trout fisheries; particularly in the mid-west region. Studies on the Burrishoole, Erriff, Gowla, Invernmore and Costello Fisheries have given reasonably consistent results over the region. Little such information from other countries are available. Other population changes are referred to in section 4.

Population number

While some sea trout fisheries were reporting a downward trend in catches, the Connemara fisheries including Erriff & Delphi, were performing well into the mid 1980's. In Burrishoole, the overall stock increased from when records began in 1971 to 1975 and 1976 and subsequently the stocks dropped gradually. The trend changed in 1987 and 1988 and the stock collapsed in 1989. Rod catches and trap counts have shown that some other fisheries in the mid-west showed a significant change after 1986 (e.g. Gowla, Delphi, Erriff), while other fisheries showed little change until 1989 (e.g. Kylemore, Newport) when all the mid-west fisheries collapsed. Minor increases have been reported in some fisheries after 1991, but these have been limited to post-smolts. The upstream migration of sea trout in Burrishoole was 3 200 in 1976 and 1 200 in 1986 but slumped to minimal counts of around 150 from 1990 to 1993. In the Gowla, counts of 13 (1991), 1 (1992), 2 (1993) and 600+ (1994) were recorded. The total recorded rod catch in Connemara is shown in Section 4.

Smolt characteristics

Annual smolt number in Burrishoole, while variable, showed no significant trend between 1971 and 1989. However, the smolt migrations from 1992 to 1994 were the lowest recorded; probably due to the reduction in spawning stock. In other fisheries, the smolt number has also dropped but not as far as would be predicted from the spawning stock (Table 3.10).

Table 3.10. Smolt counts for three fisheries west of Ireland.

Year	Burrishoole	Gowla	Erriff	
1970-79	4 176			
1980-84	4 038			
1985-89	4 119		2 877	1988
1990	2 063		2 448	
1991	2 530	7 557	3 018	
1992	1 936	5 999	1 857	
1993	1 720	4 087	470	
1994*	1 127	4 000	1 600	

*Provisional data

The age structure for west of Ireland sea trout smolts has historically remained quite consistent with 68 % 2+ year olds and 32 % 3+ years olds. More recently, there have been changes to similar numbers of smolts at each age, although in 1992 in both the Erriff and Burrishoole there were significant changes to older smolts of 3+ and 4+ years of age.

There has been an increase in the mean length of each age cohort with a significant trend for 3+ year old smolts. The reason for these increases are not known, but may be related to freshwater population density. Similar increases in the mean size of resident trout have been observed in Scotland (Walker 1994).

Marine Survival

Marine survival can be calculated both for smolt to first return as 0+ sea age (finnock) and as total survival to first return (as 0+ and 1+ sea age). Both determinations show the same patterns (Poole et al. in press). The survival of smolt to finnock in the same year historically ranged from 11.4 % to 32.4 %. Table 3.11 shows the survival data for Burrishoole. The collapse in marine survival can be seen from 1988, before any change in smolt number, and subsequent increases and decreases are consistent with salmon farm fallowing in Clew Bay.

Survival of smolts returning to the Gowla trap were 0.2 % (1991), 0.02 % (1992), 0.1 % (1993) and 15 % in 1994. Gowla R. flows into Bertraghboy Bay which has undergone salmon farm fallowing in late winter and early spring 1994 for the first time. Similar changes were observed in Killary Harbour (See Section 4).

Table 3.11. The long-term trend in sea trout populations in the Burrishoole system is indicated by the table below:

Year	% survival of smolt as finnock	% survival of smolts to first return	Downstream migration smolts (no.)	Upstream migrating finnock and adults
71	23.8	52.5	3 000	1 250
72	20.4	40.8	5 465	2 200
73	23.4	41.0	6 071	2 800
74	32.4	60.0	4 527	2 900
75	30.8	65.0	3 587	3 230
76	28.1	43.0	5 270	3 200
77	18.6	35.0	3 889	2 100
78	12.1	40.0	3 167	1 600
79	11.4	20.0	5 676	2 200
80	26.6	56.0	2 337	1 800
81	12.7	19.0	6 710	1 756
82	20.1	27.0	3 907	1 400
83	18.3	33.0	4 852	1 300
84	23.3	50.0	2 383	1 275
85	16.2	30.0	4 238	1 250
86	20.4	31.0	3 454	1 200
87	13.7	25.0	3 371	900
88	8.5	11.0	4 290	800
89	1.5	1.8	3 719	200
90	5.7	12.1	2 001	155
91	10.0	12.8	2 137	342
92	3.7	4.6	1 936	151
93	6.2	-	1 698	155

Marine Growth

A decrease in marine growth was recorded in some fisheries (i.e. Costello, Delphi, Burnshoole) with, for example, the modal length of finnock falling from 28 cm in 1987 to 26 cm in 1990.

Adult Stock Composition

The length distribution of sea trout in the west of Ireland and scale reading showed 56 % of the population measured less than 32 cm, 33 % between 32 and 40 cm and 12 % greater than 40 cm. From 1989, there was a dramatic change with the loss of almost all large sea trout. (Table 3.12).

Table 3.12. Percentage sea age composition of sea trout in Burrishoole.

Year	0+	1+	2+	3+
1985	56.9	33.8	8.5	0.8
1986	56.0	39.0	5.0	-
1990	85.6	6.5	7.9	-
1991	73.0	27.0	0.0	-
1992	54.0	34.0	12.0	-

4 Factors Affecting Population Abundance

4.1 Catch and Exploitation

4.1.1 Catch

Data on catch are valuable, though may be relatively insensitive to changes in stock status. Changes in fishing effort, fish catchability and availability (often related to river flows) reporting bias and market forces can all affect catch statistics.

The following presents a brief summary of catches in each country:

4.1.1.1 Denmark

According to the official fisheries statistics, the Danish total landings of sea trout in 1992 by the commercial fishery amounted to 45 tonnes. A substantial part (27 tonnes) was taken as a bycatch in the Baltic offshore salmon fishery and are probably not of Danish origin. The statistics are however unreliable and the total catch is belived to be aound 10 times higher with angling accounting for 10 %.

4.1.1.2 Finland

Sea trout are mostly exploited during the first year at sea, mainly by gill nets set for whitefish. According to official statistics commercial catches in the coastal fishery have grown from 40 tonnes in 1980 to 220 - 230 tonnes in 1993. Total catches, of which non-commercial catches comprise around 70 %, have varied from around 190 tonnes in 1980 to over 1200 tonnes in 1993.

4.1.1.3 France

Catch data for the whole country are not available. In the north west Seine maritime rivers net catch has ranged from 1500 (3.7 tonnes) to 2800 (7 tonnes) fish between 1986 and 1992, with lower catches in recent years due to increased no-fishing areas. Rod catches have ranged from 200 (0.5 tonnes) to 350 fish (0.9 tonnes) in the same period in this area. For the whole north west, which accounts for around 80 % of licenced sea trout anglers, rod catch is around 4 tonnes.

4.1.1.4 Iceland

In southern Iceland the majority of the catch is by rods. Catches are variable both between years and between rivers. In recent years reporting rates have been higher and new fishing areas have been developed. Mean annual catches for 7 rivers between 1970 and 1993 were 2266 fish with an average weight of 1.8 kg giving an average annual rod catch of 4.1 tonnes. Catch data for the whole country are not available.

4.1.1.5 Ireland

The National catch statistics are believed to be unreliable. The effort put into the collections of these statistics varies between years and the published data reflects these variations rather than fluctuations in catches (Anon. 1991). Net catches are unreliable and not reported fully. Annual rod catches for selected Connemara fisheries (1980 to 1988) range from 4954 fish (approx. 1.7 tonnes) to 12 354 fish (approx. 4.3 tonnes). A major collapse in catches occured between 1989 and 1992 (highest catch 776 fish) with a small recovery in 1992 to 1206 fish (Sea Trout Task Force Report 1994).

4.1.1.6 Norway

Annual reported catches are around 70 tonnes, but for various reasons this is a gross underestimate. In the 1980s a questionaire survey of the freshwater and marine sport fishery indicated an average catch of around 500 tonnes (Anon. 1994b).

4.1.1.7 Sweden

In the Gulf of Bothnia the registered coastal net catch between 1986 and 1993 ranged from 24 to 78 tonnes, although this does not include a large, unregistered catch. The in-river catch has varied from 37 to 54 tonnes between 1988 and 1993 of which over 50 % is taken by rods. Total estimated catches in the Baltic between 1979 and 1993 vary from 200 to 1955 tonnes, which include sea, coastal and rod catches from Denmark, Estonia, Finland, Germany, Latvia, Poland and Sweden.

4.1.1.8 UK

Scotland

The national reported catch in 1993 was 59 458 fish weighing 63 tonnes, shared almost equally between rods and nets. Catches by both methods have been low in recent years. Long term catch statistics show a strong similarity in pattern between fishing methods and over wide areas of the country, although reduction in netting effort, particularly in eastern areas, may have limited netting catches and augmented angling catches from the mid 1980's. Western rivers have suffered a long term decline in angling catches, the decline becoming especially severe in recent years, while eastern and northern rivers have fared better. A substantial decline in the mean size of sea trout has also been observed in north western fisheries, but not elsewhere.

England and Wales

Reported net catches have varied from 41 803 to 91 447 fish between 1987 and 1992. The average annual catch for this period is 63 856 fish (139 tonnes). Reported rod catches for the same period have averaged 30 354 fish (range 14 742 to 55 863) weighing 31.6 tonnes. Rod catches for the period 1989 to 1992 were generally lower than the long term average.

4.1.1.9 General Comments

There is clearly considerable variation in the quality of data both between countries and over different time periods which makes comparisions difficult. The summary table shows that the relative importance of net and rod catches varies between countries. There is a need to improve the quality of catch statistics and attempt to standardize the type of data collected.

4.1.2 Exploitation Rates

Information on exploitation rates either by rod or net fisheries are scarce, although high rates by certain net fisheries have been implicated in population reductions.

In Ireland on the Burrishoole system annual rod exploitation rates have varied from 4.2 % to 18.8 % with a mean of 10.5 % (Mills et al. 1990) whilst on Tawnyard lough the rates have varied from 5.6 % to 16.1 % over four years (O'Farrell & Whelan 1991). In England and Wales, rod exploitation rates are generally low varying from 0.5 to 2.2 % on the Welsh Dee; 2.8 % on the Coquet, 2.5 % on the Axe, up to a high level of 30 % on the Tawe in South Wales. This latter figure represents a rehabilitated stock on a river close to an area of high population.

On the River Bresle in NW France in 1993 exploitation by nets was calculated at 25 % and by rods 7.5 to 10 % of the stock.

These limited data show that rod exploitation rates can vary considerably between rivers, although are generally in the range of 2 to 20 %. Net exploitation rates are likely to depend on the fishing method and location and size selectivity of the gear in relation to the population structure. Particular age and size groups may be more vulnerable to capture than others.

In order to obtain meaningful data on exploitation rates, high quality data is required on catch and river size of the various stock components.

Table 4.1 Annual catches of sea trout (tonnes).

Country	*Period*	*Rod*	*Net*	*Total*	*Comments*
Denmark	1992	50	450	500	1)
Finland	1980-1993	-	-	190-1200	2)
France	1986-1992	0.5-0.9	3.7-7.0	4.2-7.9	3)
Iceland	1970-1993	4.1	-	4.1	4)
Ireland	1980-1988	1.7-4.3	-	1.7-4.3	5)
Norway	1980	500	-	500	6)
Sweden	1988-1993	19-27	65-92	86-119	7)
Baltic	1979-1993	-	-	200-1855	8)
Scotland (UK)	1993	32	31	63	-
England & Wales (UK)	1987-92	31.6	139	170.6	-

1) Estimate only
2) Assumes non commercial catch is 70 % of total
3) NW Region only
4) Southern Iceland (7 rivers)
5) Connemara fisheries only
6) Questionaire Survey in the 1980s
7) Gulf of Bothnia only. Assumes 50 % in river catch by rods
8) Sea, coastal and river catches by several countries

4.1.3 Overexploitation

Sea trout stocks in some parts of the Baltic are much below their potential because of overexploitation. For instance, in the Swedish part of the Bay of Bothnia, migratory parts of several stocks are on the verge of disapperance (Anon. 1994a). Decreases in sea trout stock in this area are due mainly to overexploitation (Andersson 1988). It was suggested that the decline was closely linked to the free setting of the coastal fishery in the 1950s in combination with introduction of modern net materials. Regulation of the commercial coastal fishery in areas around the river mouths in early 1980s was directed mainly at protecting wild salmon spawners. Consequently, the regulations have not been sufficient efficient in counteracting the decline of sea trout stocks. Sea trout is often caught as a bycatch in the economically important fishery on withefish, which makes it difficult to reduce exploitation. However, measures introduced in 1993 are meant to decrease coastal exploitation of late-ascending sea trout spawners. There is no doubt, however, that almost all sea trout populations in the Bothnian Bay region are seriously threatened.

Danish studies of postsmolt survival have shown that pound net bycatches may in some estuaries be detrimental to the migratory sea trout smolts (Dieperink 1994, Rasmussen 1992). In the Ringkøbing Fjord, estuary of the River Skjern Å, the 1991 pound net bycatches of smolts accounted to 55 000 smolts, compared to the total smolt output of 40 000. This is only possible when, on the average, the smolts are caught and released more than once. (Dieperink 1994). Field experiments revealed, that the risk of mortality was about 0.6 per catch and subsequent release of individual smolts. Combining these informations, a total mortality of around 33 000 smolts can be estimated.These data show the potential of an estuarine pound net fishery to reduce the passage of smolts to a point of below 20 % of the initial smolt run (Dieperink 1994).

4.2 Environmental Variation

In general sea trout are more restricted in their migrations to coastal areas than Atlantic salmon, although in some areas such as the Baltic, tag recapture pattern indicate some extensive migrations. Therefore, local variations in estuary and marine conditions and feeding opportunities are likely to have a significant effect.

Temperature in spring may have quite different effects in different countries. For example, elevated spring temperatures in Ireland and Scotland lead to low flows at smolt migration, warm water, both freshwater and marine, and optimum conditions for lice infestation. However, elevated temperatures in Scandinavia increase the amount of snow and ice melt giving high fresh water flows for smolt exodus and reduce the salinity in the fjords, thereby reducing the possibilities for lice infestation.

Freshwater environment can also have an importance influence on growth rate of parr, smolt age and migratory behaviour of both smolts and adults.

4.2.1 Growth in freshwater

Parr growth increases with increasing river temperature and length of the growth season (when water temperature >4ºC). This means that the fish grow generally faster in the southern than in the northern part of its area of distribution. For instance, in southernmost Norway (ca 58°N), population means in length of 2-year-old brown trout can be up to ca. 15 cm, whereas in the northernmost part of the country (ca 70°N) the fish take use 3-4 years to reach the same average size (L'Abée-Lund et al. 1989).

The reason for the growth variation is probably differences in water temperature and feeding opportunities. Productivity and feeding opportunities are expected to increase with water temperature. Moreover, optimal temperature for growth is 15-16°C in some rivers (Allen 1985, L'Abée-Lund et al. 1989, Jensen 1990, Forseth & Jonsson 1994), but this trait can vary genetically among populations and may be as low as 10-12°C in cold rivers e.g. in northern Norway (Forseth 1994). Anadromous brown trout exploiting rivers and sea with very different temperature regimes, as the fish from the river Lærdal, Norway, appears more closely adapted to the prevailing sea than freshwater temperatures.

4.2.2. Smolt age and size

Among populations, age and size at smolting increase with latitude and decrease with increasing water temperature. For example mean age and size of Norwegian smolts of brown trout vary from less than 2 years to almost 6 years and from 10 to 23 cm, respectively (L'Abée-Lund et al. 1989). Within populations, there is no definite smolt age or size. Both are influenced by growth-rate. The faster the fish grow, the younger and smaller they are at smolting (Økland et al. 1993). In southernmost Norway, mean smolt age was close to 2 years and 14 cm, in northernmost Norway ca. 4 years and 18 cm. There is some variation among populations, e.g. very small streams may have younger and smaller smolts than larger ones at the same latitude.

Smolt size may be related to water temperature. Elliott (1985) showed that smolt size was dependent on the temperature conditions experienced by the year class. Moreover, in cold glacier fed rivers in southern Norway, smolt size tends to be small. On the other hand, in rivers emptying into a cold sea, as at the northern border of distribution of the species, smolts tend to be large (Jensen & Johnsen 1986). The reason may be that small smolts osmoregulate less well in cold sea water than larger smolts (Hoar 1976, Finstad et al. 1988).

Smolt age tends to increase with latitude. This is probably both a consequence of the decreasing growth rate from south to north and the general increase in smolt size from south to north.

4.2.3 Sea growth

Marine growth may be determined by habitat, enrionmental variables and age history of the fish. In Norway, the length increment during the first summer at sea is usually between 10 and 15 cm although population means as high as 21 and as low as 8 cm have been observed (L'Abée-Lund et al. 1989). Sea growth decreases with latitude, but not to the same degree as the freshwater growth does. Sea growth increase with water temperature at sea expressed as number of degree-days during the period when the sea water temperature is above 4°C. Longevity decreases with increasing water temperature and increasing growth rate of the fish.

The annual length increment decreases with sea-age. For immature sea trout from the Voss River, it was found to decrease ca. 20% during the second year and another 20% during the third year at sea relative to first-time migrants (Jonsson 1985). The length increment of matures was ca. 50% of immatures of the same age.

4.2.4 Age and size at maturity

Adult size varies between 20 cm and 1 m and adult age between 3 and 15 years. Within populations, there is considerable variation in age and size at maturity, and more so among males than females (Jonsson 1989). Age at maturity seems to decrease with decreasing smolt age, whereas there is a tendency that sea age at maturity decreases with increasing smolt age (Jonsson 1985). Among populations, mean sea age at maturity increases with latitude. Mean sea age at maturity in southernmost Norway is ca. 2 years, in northermost Norway it is 3 years or more. Size at maturity, on the other hand, does not change with latitude (L'Abée-Lund et al. 1989, Jonsson et al. 1991). In anadromous brown trout, the sexes mature at the same sea age, or males mature younger.

There are differences in size between adult sea trout spawning in the upper and lower parts of long rivers. The fish are often larger in the upper than in the lower parts (L'Abée-Lund 1991). Furthermore, very small streams seem to have smaller fish than large rivers (Jonsson 1985).

Adult body size does not change with water temperature or growth rate at sea. However, it increases with decreasing river temperature and growth rate in fresh water. Large sea trout are often found in rivers which are cold for its latitude (Jonsson et al. 1991).

4.2.5 Summer drought and stock development

In the last few years, severe summer droughts have created unusually poor conditions in many small sea trout streams in southern Sweden. This has probably decreased production considerably in many streams (Eklöv & Olsson 1994, Ottosson et al. 1994). However, no effort has been made to quantify losses due to drought. Adaptations of sea trout to severe summer drought were studied by Titus (1991). For instance, smolting at age 1 may occur in small, unstable streams such as

Tullviksbäcken, 95 km NE of Stockholm, which dries up, on average, every second or third summer (Titus & Mosegaard, 1989). In this stream a considerable proportion of the parrs emigrated in March-April at age 1 and sizes around 10 cm. Titus and Mosegaard (op. cit.) considered this to be an important adaptation because entire year-classes of trout parr might be eliminated by summer drought unless they liveve the streams in before hand. Moreover, habitat suitable for 1+ and older parr may be scarce in such streams, especially in dry years. Adaptations of this kind could be very important to survival of the stocks under such circumstances (Borgstrøm & Heggenes 1988). Similarly, emigrations of very small smolts, <10 cm, as early as March were reported from a smolt trap placed in a small stream on the west coast (Brodde Almér pers. comm.). No smolt migration occurred later in the spring. Another important adaptation is that in small streams such as Tullviksbäcken, streams on Gotland and elsewhere, spawners enter the streams immediately before spawning and leave them directly after spawning (Titus 1991). Spawning normally occurs in September-November, but may occur even later if autumn rains are necessary to make the stream accessible to spawners. In Skåne, spawning may occur as late as January (Johan Wagnström pers. comm.). In addition to such adaptations by the fish, human efforts to increase the summer water flow, shade of streams to decrease water temperature and low levels of pollution are especially important in droughts years (Ottosson et al. 1994). Elliott (1994) reported that summer droughts in 1969, 1976 and 1983 had a strong influence on increasing loss rates of trout in a small stream.

Radio tracking studies of adult sea trout carried out in the River Tywi in south Wales have indicated a profound effort of low freshwater flows on migration from the estuary into freshwater. Under low flows a significant proportion of sea trout which enter the estuary did not ascend into freshwater and their fate is unknown.

Timing of sea trout smolt migration is determined by environmental factors such as temperature and flow rate. Timing can affect subsequent survival in the sea. For example sea trout smolt migration to the sea on the Burrishoole system in Ireland normally commences in late March or early April and is completed by the end of May. While migration may commence at a mean temperature of 5.4°C the main decent takes place at temperatures above 7°C, pulsing with rainfall peaks. Once a temperature of 13°C is reached, migration decreases, particularly in low water conditions. Analysis of the comprehensive data from the Burrishoole fishery suggests that, although adverse temperature conditions may have contributed to the severity of the sea trout collapse in the late 1980's, the basic problem lies in the marine environment (Sea Trout Working Group Report 1993). In years of dry and warm spring weather, migrating smolts may experience additional stress because of a wider temperature gap between fresh and sea water. In northern rivers with low water temperature, cold springs may delay or inhibit the smolt migration.

4.3 Diseases and parasites

Two vital pieces of evidence in this regard have been shown: that the sea trout smolts are consistently affected by juvenile lice (Tully et al. 1993a, b, c) and that the vast bulk (>95%) of the lice in the affected bays in the west of Ireland emanante from salmon farms (Tully & Whelan 1993). Tully et al. (1993b) have also shown that the fisheries entering a specific bay have similar lice infestation characteristics, indicating that the problem is specific to bays rather than individual river systems. Despite high levels of juvenile lice production throughout the February to July period, sea trout post-smolts with heavy lice infestations only appeared in the estuaries of neighbouring systems for a three to five week period after enteing saltwater (Tully & Whelan 1993). Therefore, the infestation by juvenile lice and the severe morphological damage to the sea trout occurs immediately after entry to saltwater.

4.3.1 Diseases

4.3.1.1 Denmark

Denmark has a high production of hatchery reared salmonids, mainly of rainbow trout in fresh water. The presence or absence of diseases such as furunculosis, Infectious Pancreatic Necrosis (IPN), Viral Haemorrhagic Septicaemia (HVS) etc, are recorded during regular disease screening. As Denmark is subdivided into veterinary zones, strict regulation in relation to transfers of fish from a zone of higher disease incidence to zones of lower incidence are in force. Although not generally perceived as a serious threat at the moment, an investigation into the significance of some of these diseases in relation to wild fish populations has begun.

4.3.1.2 Finland

A syndrome similar to M74 has been reported by hatchery managers in Finland but does not appear to causing significant mortalities at present. The impact of the syndrome is currently being investigated (see Sweden).

4.3.1.3 France

No significant disease problems have been reported for wild sea trout populations in France, except for furunculosis on wild spawners in the 1970's.

4.3.1.4 Iceland

No significant disease problems have been reported for wild sea trout populations in Iceland.

4.3.1.5 Ireland

While furunculosis has been detected in many hatchery stocks in Ireland over the years, it was detected from only population of sea trout sampled from the wild in 1991 and from 3 other stocks being maintained at a hatchery site. All of these stocks were from the West of Ireland, within the area affected by a sudden collapse in sea trout stocks. As it was not possible to identify whether the infection had been carried in with the fish, present in the facility or on equipment used to transfer the fish. It was concluded that furunculosis was present in at least one wild stock (Anon. 1991). Further research was carried out in 1992 (Anon 1992). Descending sea trout smolts from the Gowla River, Connemara and lice infested sea trout postsmolts from the Costello River, Connemara, were stress tested under controlled conditions. None of these fish (which represent samples from two of the catchments most affected by the sea trout population collapse) showed any evidence of stress inducible furunculosis.

During the same period kidney smears were cultured from 28 lice infested fish prematurely returning post smolts from four other sites in the West of Ireland. Furunculosis was not detected in any of the samples examined. (Anon 1992)

Histological and virological studies were carried out on samples from affected rivers in the West of Ireland. Tissues from 57 fish in 1990, 76 fish in 1991 and 36 fish in 1992 were examined. The histological changes were varied with no consistent pattern. Debilitated fish from affected rivers and estuaries exhibited histological signs of low nutritional status and increased protein catabolism. Gill hyperplasia and minor heart lesions such as mural thrombi were observed in fish from affected and unaffected regions (Anon 1992).

4.3.1.6 Norway

Furunculosis was observed for the first time in Norway in 1964, where it was imported into the country with rainbow trout from Denmark (Håstein & Lindstad 1991). In 1985, furunculosis was identified from farmed salmon. It is believed that this was as a result of importing smolts from Scotland. Since then, the disease has spread to many areas of the country, and has been identified from wild fish in 74 rivers (Johnsen et al. 1993). In some cases the disease has caused mortality of adult salmon in freshwater. The long term effects of furunculosis on Norwegian salmon populations is unknown. Little is known about the impact of the disease on sea trout stocks.

IPN has been detected from wild salmonids during screening of broodstock but not believed to be a significant problem for wild fish at present. UDN is reported occasionally but is not causing any significant problems for the wild stocks.

Recent work (Nylund & Jakobsen, in press) on infecting sea trout with ascites from salmon infected with infectious salmon anaemia virus (ISAV) has indicated that sea trout did not develop symptoms or gross clinical signs of the disease although propagation of the virus and a drop in haemocrit values was noted. Following sea water challenges, signs of ISA and differential mortality were noted. It was also shown that when salmon and sea trout were kept together the virus was transmitted from trout to salmon.

4.3.1.7 Sweden

In recent years furunculosis has spread to fish farms in many parts of Sweden. It has also been identified from salmon in five different rivers, both on the west coast and in the Baltic. Sea trout occur in these rivers, but there are no signs that furunculosis causes mortalities among sea trout. Another disease, caused by *Aeromonas salmonicida* subsp. *achromogenes,* occurs in the most Swedish trout hatcheries. It causes mortalities in the range of 0-25% among trout parr. It is unknown, however, to what extent it also causes mortality in wild sea trout.

Over the past three years high mortalities (70 - 98%) due to M74 have been observed among salmon alevins in Swedish hatcheries. (Anon. 1994c). The first visible symptoms occurs during resorption of the yolk sack which is followed by rapidly accelerated mortalities. Although it is not known what causes the syndrome, environmental pollutants have been implicated. M74 has only been found in the offspring of Baltic salmon females that have returned to the rivers to spawn. The syndrome has not been observed in salmon from the Swedish coast which feed in the Atlantic.

In reared Swedish stocks of sea trout in the Baltic an unexplained mortality, similar to M74, occurs occasionally according to hatchery managers. The symptoms are similar to those of alevins suffering from M74 (discoloration and aberrant swimming behaviour) and physiological studies are now in progress to try to determine whether the mortality is somehow related to M74.

4.3.1.8 UK (England and Wales)

Screening for diseases from wild broodstocks has been carried out regularly but significant problems have not been reported in wild stocks.

4.3.1.9 UK (Scotland)

A recent study in Scotland (Mc Vicar et al. 1992) investigated the significance of diseases on sea trout populations. Early results did not identify any disease which was having a significant detrimental effect. Since then studies have continued on finnock and adult sea trout and have been extended to include parr and smolts in freshwater.

Since 1990 over 500 sea trout have been sampled and analysed for the presence of viral agents (Mc Vicar et al. 1993b). Infectious Pancreatic Necrosis (IPN) was detected in 16 fish in June 1991, which were taken from two different rivers within the north western fishery district. Since then no other virus was detected.

No bacteriological disease has been detected from 245 sea trout.

4.3.2 Parasites

Parasites and diseases are transferred naturally between wild fish stocks and high mortalities due to these pathogens are often recorded (Roberts et al. 1970). Such mass mortalities are generally rare in wild populations. For wild salmonid populations, which may be small and/or discrete, these mass mortalities are not often recorded but would be particularly damaging to the overall stock status. Fish farm installations may act as a reservoir for certain pathogens and heavy parasite infestations and disease outbreaks. Significant mortalities in the cages have been described from salmon farms. There is concern that these installations may increase the transfer of pathogens to wild stocks and this area of research has attracted considerably more interest in recent years particularly in relation to establishing naturally occurring levels of parasites and disease in populations and/or increased or new transfers of pathogens from fish culture.

In the latter half of the 1980's, salmon production along the mid-west coast of Ireland expanded rapidly. Sea lice levels on farms rose during this period and as a consequence juvenile lice production increased. Sea trout migrated into this changing marine environment each spring. These fish are well known to be susceptible to sea lice infestation. It is, therefore, reasonable to assume that in a situation where the levels of juvenile lice were increased, due to the combined effect of a far larger host population (each 100 tonnes of reared salmon is roughly equivalent to 50 000 individuals) and a marine environment which may have favoured sea lice production, the infestation of the smolts could have increased in proportion (Tully 1992, Whelan 1993, Whelan & Poole 1993).

4.3.2.1 Denmark

No specific parasites are causing major problems for sea trout in Denmark at present. The study which has been initiated to examine diseases in wild populations will also incorporate parasitological investigations.

4.3.2.2 Finland

There is no evidence at present to suggest that *Lepeophtheirus salmonis* cause sea trout mortality in the Finnish rivers. No other parasites are cinsidered to be a danger to sea trout populations.

Gyrodactylus salaris is not considered to be a major danger to sea trout populations at present.

4.3.2.3 France

Infestations of parasites on sea trout are not considered to be causing a problem for sea trout populations.

4.3.2.4 Iceland

Parasite infestations are not considered to be a major problem affecting wild populations in Iceland.

4.3.2.5 Ireland

Coinciding with the collapse of fisheries in W and NW since 1989, the phenomenon of early returning postsmolts, kelts and adult fish with heavy infestations of juvenile sea lice *(Lepeophtheirus salmonis)* indicating recent and high rates of transmission (Anon 1993) of sea lice. In association with this severely emaciated sea trout were noted in 1989.

In 1991 the main problem affecting sea trout stocks in the West of Ireland was defined (Anon. 1991a) as:

- the premature return of sea trout smolts,
- severe infestations of juvenile lice
- the presence of badly emaciated fish (in 1989)
- a drastic reduction in the spawning stock

A summary of lice infestation information for 27 Irish Rivers is given in Appendix 2.

The main conclusions from this study can be summarised as follows:

1 The model was developed predicting that the logarithm of lice infestation (abundance, intensity etc, dependant variables) should be a linear function of the logarithm of linear distance (r) to the nearest fish farm. This model was tested using least squares regression and testing for significant relationships using analysis of variance.

2 The relationship between the infestations on individual sea trout with linear distance to fish farms is significant and is best described by a log-log plot. Although there are only a few sites representing locations distant from fish farm sites, this is not unduly affecting the regression.

3 Having established that a relationship exists using the data for individual fish, the relationship between the accepted parasitological paramters of abundance and intensity with distance from fish farms was tested and found to be highly significant. The relationship with abundance indicated an r^2 value of 0.78 and for intensity the r^2 was 0.66 indicating that a significant amount of the variance associated with the relationship could be explained using linear sea distance alone.

4 The investigation indicate that lice infested farmed salmon at distances greater than 25 km from a sea trout river does not transmit lice to those sea trout.

Other parasites

A number of studies were aimed at examining other parasite infestations of sea trout. During histological and virological examinations in 1990, 1991 and 1992 samples of fish from three catchments in the West of Ireland were parasitised with internal metozaon and pleroceroids of Diphyllobothrium spp. Protozoan parasites were present in the intestine (*Eimeria sp.*) and kidneys (*Chloromyxum* sp.) of fish caught in three rivers. There was no evidence of a virum aetiology as virus isolation studies were negative. It was concluded that there was no indication that the sea trout population had systematic infectious aetiology.

In 1990, samples of sea trout were examined from three sites from the West of Ireland, the Burrishoole and Killary Harbour (areas affected by the sea trout population collapse) and Drumcliff Bay. The following parasites were recorded.

Lecithaster gibbosus
Discocotyle sagittata
Diphyllobothrium ditremum
Eubothrium crassum
Chystidicola farionis
Hysterothylacium aduncum
Pomphorhynchus laevis
Acantocephalus clavula
Acantocephalus lucii
Salmonicola salmoneus

No consistent pattern was shown which could indicate the cestodes, acantocephala or digenea had a role in the collapse of sea trout populations in the West of Ireland. While the intensity of nematode infestaions was higher in the Killary harbour sample, the prevalence was only slightly higher. A small proportion of the host population was shown to be carrying most of the parasites and this is considered to be typical of many parasite species.

4.3.2.6 Norway

Similar studies of infection of salmon lice on brown trout in Norway (as in Ireland) have shown that sea trout in some systems also may have problems with heavy infestations and prematurely returning to freshwater, but there is little information about the impact on stocks. Investigations to examine whether salmon lice also affect wild sea trout have been initiated. Results of sampling for sea liced sea trout indicated high infestation levels in netted samples taken at sea close to fish farms, but lower infestations in an area distant from farms. Sampling sites in northern Norway indicated that sea trout captured in freshwater during June to August, were heavily infested with chalimus stages. Overall, however, it appeared that the incidence of sea lice infestations in 1993 was significantly lower along the coast to middle Norway than in 1992. This may have been due to lower sea temperatures and/or efficient management of the fish farms.

Plankton hauls in northern Norway allowed examination of the numbers of sea lice nauplier stages close to and distant from farms. The results indicated that densities of these larvae decreased with increasing distance from farms.

More significant problems may arise when fish are moved from one isolated geographic locality to another, where there is a risk of importing parasites and diseases the local fish are not adapted to. An example of this is probably the recent introduction of the monogean parasitic fluke *Gyrodactylus salaris* to Norway (Johnsen & Jensen 1991). *G. salaris* was observed for the first time on Atlantic salmon in Norway in 1975. However, while sea trout may act as a carrier, there is evidence to show that the parasite has no harmful effect on sea trout. This transfer rate is probably low, but as sea trout may travel between salt and freshwater a number of times in a season and travel some distance upstream, they can act as a potential source of infection. A similar situation is apparent for escaped rainbow trout and anadromous Arctic charr which can both harbour *Gyrodactylus*.

4.3.2.7 Sweden

There is no specific case where parasites are known to have impacted wild sea trout.

4.3.2.8 UK (England and Wales)

Tagging studies carried out by the Ministry of Agriculture, Fisheries and Food have shown that sea trout from rivers from the north east of England migrate into the southern part of the north sea and are exploit in the coastal fishery off East Anglia. This is the only substantial marine fishery in England and Wales operating on sea trout in their feeding area rather than on fish on their return migration to freshwater. Sampling of the fishery in 1992 and 1993 showed that no sea trout were observed with exceptionally heavy infestations of sea lice, the majority of fish having less than 10 lice per individual. There has been no evidence that lice loading has varied with fish size or time of sampling.

4.3.2.9 UK (Scotland)

Investigations into the effects of sea lice infestations of sea trout have been carried out in Scotland (McVicar et al. 1993a). Sampling of 9 rivers indicated that two species *L. salmonis* and *Caligus elongatus* were present on 81 sea trout taken in the study. *L. salmonis* was present at all locations while *C. elongatus* was found in only 1 east coast river. Details of these lice infestations are given in Table 4.2. The greatest mean numbers and maximum numbers of lice were found in the River Morar while the lowest maximum numbers were shown from the River Hope. Major differences in the infestations of sea trout in the River Ewe were noted between 1991 and 1992. The infestations were typical of parasite infestations with over dispersed distributions and the majority of the infestation being carried by a small number of fish in the sample. The sampling indicated that the numbers of lice on sea trout caught in the same area and even at the same time can vary greatly. When samples were grouped within areas it was reported that higher numbers of lice per sea trout were found in the North West Region than in other areas around Scotland. These higher lice burdens were generally associated with areas where most fish farms are found. However, it was also noted that relatively high levels (up to 46 lice) could be found on sea trout taken from areas remote from fish farming.

Table 4.2. Per cent sea trout infected with sea lice, mean and maximum number of lice per fish.

Area	River	No Fish	% Infected with lice	Mean number of lice/fish	Maximum number of lice/fish
			1991		
East	Don	4	100	4.5	9
	Ythan	13	100	5.0	11
	(Ythan)	(13)	(85)	(10.6)	(49)
North	Hope	8	25	14	10
N West	Ewe	4	75	20.5	38
	Squod	2	100	7.0	12
	Morar	19	100	23.8	83
West	Euchar/Creran	3	100	5.0	9
Clyde	Eachai	20	75	10.7	46
			1992		
N West	Ewe	8	100	63.9	216

The highest proportion of infestations by juvenile lice was found on the west coast suggesting a higher acquisition of infestation in these areas. No apparent relationship between condition of infected fish and intensity of infection was found but lice associated damage to the head and fins was noted by McVicar et al. (1993b) particularly up to early June.

Details of a cage experiment were presented which was set up to evaluate some of the aspects of the survival of sea trout in the critical period just after migration. Stocks used were from local river sources and hatchery reared sea trout and placed strategically in an area adjacent to fish farms where no problems with sea trout stocks had been reported, adjacent to fish farms but in an area where stocks had declined and finally in an area approximately 20 km from the nearest fish farm installation. Mortality levels were low at all sites. Sea trout at all sites became infected with *L. salmonis.* but infestations were different in each area. Fish in the cage adjacent to fish farms and with an associated stock decline showed the highest infestation and a wide range of lice stages, indicating continual infestation with lice over the entire period. Fish in the other sites showed a narrower range of lice maturity stages and less lice. There was no marked difference in the prevalence of infestation (number of fish infested in relation to the number examined) between the wild and hatchery fish. However, despite the infestations, no lice related lesions were noted on any of the fish.

Caution was expressed over the possible interpretation of this experiment as it was not possible to say whether the infestations reflected the type of lice infestation which a wild migrating smolt would experience. Holding the fish in a cage would have lead to abnormal exposure and wild fish may not necessarily remain at the site of a potential heavy infestation.

Investigations are continuing to clarify the significance of the level of lice detected in different areas of the country.

4.4 Habitat Degradation

A number of human activities can adversely affect the distribution and abundance of sea trout populations. The impact can be in the form of a long term decrease in productivity from such activities as afforestation and overgrazing of stream banks which reduce habitat diversity and increase siltation.

Alternatively, changes can be more immediate and dramatic resulting from such activities as dam building for hydroelectric production and culverting and dredging of rivers. Such activities have been cited as reasons for declining populations in many countries, particularly in Norway, Sweden, Finland, France and Denmark. In Sweden most larger running waters have in the past been used for timber rafting. To facilitate this activity stream obstructions such as boulders and large stones have been removed. This has resulted in the deterioration of trout habitat in many streams. These streams are characterized by a canal-like appearance, shallow water and hence a lack of suitable stream positions for fish.

In the UK and France the building of tidal barrages for amenity purposes is a major concern. The provision of adequate fish passage facilities for both adults and smolts in complex, tidal locations is poorly understood and may lead to changes in fish behaviour and abundance.

4.5 Stocking

The release of artificially reared fish has been a popular stock enhancement method. Although fish are still stocked regardless of any documented demand, there is an increased acceptance that stocking of trout should only be carried out where there is a documented demand for it.

Stocking is carried out to maintain populations in rivers where the spawning grounds have been destroyed by human activity. In such cases fry or parr are released. When the parr feeding grounds have been destroyed, smolts are released. Sea trout production has been enhanced by the release of hatchery fish upstream of the natural area of the fish. It is difficult to run a biologically sound and effective stock enhancement programme. Detailed knowledge of the biology of the wild and the hatchery fish, and about the problems in the river is required. The knowledge of the success of stocking programmes and effects on the wild fish are sparse.

4.5.1 Denmark

A evaluation system based on electrofishing has been developed and of 696 river systems evaluated during the period 1988-1992, 63 were considered to have a satisfactory natural production. In 188 systems the natural reproduction was considered to be unsatisfactory and in 92 rivers there were no natural reproduction. The two groups were considered qualified for stocking. The stocking schemes are revised every 6 years. In addition to fry and parr released in rivers, relatively high numbers of smolts are released at river mouths and on the coast:

Quality	Catchment area km²				
	<100	100-199	200-499	>500	Total
Natural reproduction satifactory Stocking not needed	63	0	0	0	63
Natural reproduction insufficiant Qualified for supplementary stocking	135	24	16	13	188
No natural reproduction Qualified for stocking	91	1	0	0	92
Not qualified as trout waters	351	2	0	0	353

The stocking programme in 1992 included the following quantities of the various age and size categories of trout:

1 709 900	fry (fed for 3 weeks)	(42.9% of wild origin)
486 700	half year old parr (6-10 cm)	(30.6% - - -)
433 300	one year old parr (10-15 cm)	(22.2% - - -)
111 900	one year old parr (17-23 cm)	(12.5% - - -)
507 200	smolt, river mouth releases	(41.9% - - -)
217 200	smolt, coastal releases	(4.6% - - -)
16 000	smolt, lake releases	(0.0% - - -)

4.5.2 England & Wales

A major sea trout rearing and stocking programme is being carried out on the River Mawddach in west Wales to restore stocks after a major fishkill in 1984. Between 1988 and 1992, a total of 335 000 fed fry, 135 000 0+ parr and 132 000 1 year old fish, all from local broodstock have been stocked into the river.

Of these fish ca 60 000 one-year old smolts and 40 000 1+ parr have been marked with coded wire tags. Recaptures of adults have been obtained from rods and from broodstock trapping on selected spawning streams. The recapture rate from 1+ parr has averaged 0.04 % of fish tagged whilst that of smolts has averaged 0.14 %. The sea age of returning adults has been 15 % for .0+, 67 % for .1+, 7 % for .2+ and less than 1 % for .3+.

The use of streamside volitional release ponds for smolts increased recapture rates by between 4 and 7 times compared with the direct release of smolts to the river. Based on a production cost of 68 p per one year old fish, each angling recapture has costed between £ 80 for one-year old smolts stocked into release ponds, and up to ca £ 500 per rod recapture from 1+ fish released directly into the river. These costs do not take into account fish which evade recapture to spawn naturally and contribute to the natural production in the system.

4.5.3 Finland

Without stockings, sea trout abundance would soon decline in Finland because of heavy fishery in the rivers and at sea. Because the sea trout are mostly nonmigratory in the Gulf of Finland and in the Gulf of Bothnia (Ikonen & Auvinen 1984), the Finnish sea trout stocks are exposed to a local fishery and should thus be managed on a national or local basis. There is no need for special fishing regulations in the Baltic main basin in order to protect the Finnish sea trout stocks. The regulation needed is mostly the same that is needed to save the salmon stocks.

Finnish sea trout are supported by releases of young fish. They have been stocked from about 0,5 million (all age groups less newly hatched) at the end of 1970's to the level of 1,5 million from the middle of 1980's to today. About one million of them are smolts, which are released off the Finnish coast in the Baltic Sea. Fry and parr have also been stocked in rapids of many rivers in order to create new stocks or to support the rivers' natural stock. Often the rapids or drainage basins are badly dredged, ditched or otherwise in poor condition because of the human activities that their restoration is needed before there is any benefit to make stockings. Currently, there are five different original brood stocks which are used for stockings (Koljonen & Kallio-Nyberg 1991). For stockings made in sub-divisions 30, 29 and 32 the sea trout originate almost solely from the river Isojoki, and this stock is the most widely used sea trout stock in Finland. In the northern Bothnian Bay (sub-div. 31) the most often used stocks originate from the rivers Tornionjoki, Iijoki and Oulujoki. In several of the main rivers used for electric power production compensatory rearings of smolts occur. Because the stockings have not given very good results especially in the northern Bothnian Bay, it has been discussed, if there are other reasons than "overfishing" for the poor results.

At present Finnish Game and Fisheries Research Institute together with the companies making the compensatory stockings, study if the effect of stockings could be improved by changing the time of fish release. In nature, sea trout smolts migrate to the sea during the spring flood, much earlier than the reared smolt are stocked now. Experimental releases under the ice in spring have improved fish return. Physiologically, the hatchery reared smolts appear to be ready for migration earlier than previously believed. Under the ice, the smolts escape from bird predation (gulls and mergansers) which may also enhance the survival of early released smolts.

Iceland has limited stocking of sea trout, the releases are chiefly fed fry above impassable waterfalls to enhance angling. Ranching experiments, in Dyrhóláos South Iceland, have shown good growth rate of released fish.

4.5.4 Ireland

Over the past three years the possibilities for producing reared trout for stocking has been explored and developed. The traditional method of obtaining ova is by stripping wild parents and rearing the fish to unfed fry or parr before release. The level of stock collapse in the mid-western fisheries precluded this option and novel techniques were developed to on-rear wild and first-generation reared broodstock.

The development of these techniques involved a detailed assessement of factors such as stock density, fecundity and fertility rate of individual females. Disease monitoring and prevention were high priorities within the programme, as well as retention of the genetic integrity of individual stocks.

The ongrowing rearing programme is unique and necessitates the rearing of adult broodstock at sea and their transfer to freshwater caged for stripping as broodstocks; the fish remain in freshwater from late September to the following late January or early February. Due to the longevity of the sea trout an individual may undergo five such transfers during its life span. The management of this programme requires an in-depth knowledge of the reproductive biology of the sea trout and the techniques to minimise stress during transfer.

The husbandry of large numbers of sea trout and the transfer of these at the eyed ova stage to sattelite hatcheries has also been undertaken by the Agency. Rearing techniques from fry to summerling stage have been refined and work is continuing on improving survival at the critical ova stage.

So far the programme has continued to do well, but although a few groups of young trout have been released, it remains to release larger groups of young fish and assess the results.

4.5.5 Norway

Stocking of sea trout takes place in several Norwegian river systems. Most of the fish are released as fry or fed fry. Smolt stocking is carried out mainly as compensation for lost freshwater habitat because of river regulations, and as a research activity. At present about 425,000 fry, 330,000 parr and 232,000 smolts are released in Norwegian rivers. There are very few evaluations of the stocking programmes, but some interesting patterns have appeared. In release experiments with tagged brown trout "smolts", it has become apparent that large numbers of the fish became freshwater residents and do not migrate to sea (Jensen et al. 1993 and personal observations at Ims). Of a number of 8211 1 yr and 14839 2 yr old smolts from 11 stocks released at the mouth of the River Imsa, south-west Norway, it was demonstrated that the recapture-rate and estimated yield were higher for 2 than for 1 yr old smolts, although recapture-rates varied between years of release and stocks (Jonsson et al. 1994). The recature-rate increased with mean individual weight at time of release. Total estimated yield of trout released as 1 yr olds ranged from 2 to 20 kgs per 1000 trout released whereas for fish released as 2 yrs old, between 11 and 250 kgs per 1000 fish released. Releases of trout directly in Oslofjord gave even higher recapture-rates and yields, but this fjord is nutrient rich and very productive for the latitude.

4.5.6 Sweden

Beginning in the late 1940s, there was a rapid expansion of hydroelectric power production in Sweden, and many of the country's sea trout and salmon rivers were dammed. To compensate for the loss of production caused by the hydrodams, methods for rearing smolts were developed, and the first smolts were released around 1950. Once it became clear that smolt releases were successful, fishery authorities requested, and water courts decided that power companies had to compensate for reductions in natural smolt recruitment through artificial smolt production. It was decided that the different river stocks should be kept separate from each other. For a given river, this was accomplished by only releasing smolts of the stock native to that river and by using spawners returning to the river as broodstock in the hatchery. At present, about 400 000 fry, 700 000 parr and 600 000 sea trout smolts are annually planted in Sweden. Most of them are released as compensation for damage in rivers, but a small proportion is also used for enhancement purposes to improve angling. In some areas these releases of reared fish have been the basis for a rather intense fishery. Especially in northern Gulf of Bothnia, the Bothnian Bay area, such fishery has contributed to overexploitation of natural sea trout stocks.

In each year 15000-25000 sea trout smolts are tagged externally (Carlin tags). Taggings in 1986-89 gave the following reported yields.

Area	Weight (in kg) of recoveries per 1000 released
1. Bothnian Bay	92
2. Bothnian Sea	169
3. Main Basin	349
4. West coast	54

The yields differ greatly among areas. In the Bothnian Bay and on the west coast about 50% of all recoveries are made during the release year, which partly explains the low summed weight of all recoveries in these areas. The higher productivity of the environment in the Main Basin, compared with the Bothnian Sea, may explain part of the difference between these two parts of the Baltic. Another explanation is that many taggings in the Main Basin were made on the fast growing and widely migrating River Mörrum stock. These are not recovered at small sizes to the same extent as short-distance migrating sea trout.

4.6 Pollution

Sea trout populations are adversely affected in some rivers and streams by pollution from agricultural and industrial sources. The impact can be chronic, causing eutrophication and siltation of spawning gravels, whilst episodic events can, on occations cause significant fish kills. In some areas e.g. in Østfold county in southeast Norway, Hansen (1989) observed that in nearly half of 23 small streams examined, sea trout were extinct because of pollution from agricultural activity and other urban pollution.

Acidification of freshwater is a significant problem in several areas where sea trout occur. The results of the acid water may be that the stock is completely wiped out, or a reduction in freshwater productivity. The higher the concentration of labile aluminium in the water, the more poisonous the water is to anadromous salmonids. It has been shown for Atlantic salmon that exposure of smolts to Al rich low pH water reduces the ability of the fish to osmoregulate in salt water. Sea trout can survive worse acid conditions than Atlantic salmon, and are therfore not affected to the same degree. However, in several rivers in south Norway the situation is critical. Of 31 rivers examined in this area, 14 sea trout stocks are reduced because of acidification, and in two rivers sea trout have been completely wiped out (Sivertsen 1989). Several liming programmes have been initiated.

In Cumbria, mid-Wales, U.K. and south west Scotland surface water acidification is a major problem. In Wales 20% of the country is classified as acid vulnerable. These mountainous areas contain 28% of stream length considered to be significant for trout. The headwaters of many important sea trout fisheries lie in this vulnerable area. Reductions in fish abundance have been recorded in many of these catchments, particularly in those which are also afforested.

Acidification is a major problem in the southern part of Sweden, and several sea trout stocks are affected. Large liming programmes are in operation to counteract the problem. At least 79 (30.6 %) of the sea trout streams and rivers in this survey were deemed acidified or had been limed. In the late 70s and early 80s, before large scale mitigation started, many of the sea trout stocks were threatened because of acidification. Degerman et al. (1985) compared data on information on pH and alkalinity for seven rivers on the west coast of Sweden. They found that in the middle and upper reaches of small rivers (catchment area <1000 km^2) the alkalinity and abundance of salmonid parrs had decreased significantly from 1955 to 1984. They concluded that the abundance of the youngest age groups of salmonids were significantly higher at stations with an alkalinity above 0.25 mekv/l compared to stations with a lower alkalinity. Degerman et al. (1990) who evaluated stock development before and after mitigation found that densities of parr increased significantly after liming. Several of the streams also showed generally higher levels of sea trout, whereas trout decreased after liming of streams that also contained salmon. In two of four reference streams with sea trout stocks, densities decreased after acidic spring flows, but the stocks recovered within one year.

4.7 Availability of prey

Many of the factors described above will also affect the abundance of prey items available to sea trout. Very little information is available on the marine feeding habits of sea trout. Recent work in Scotland (Wright et al. 1993) describes the distribution and availability of sandeel, one of the principal prey items of the sea trout at sea, in relation to the decline of sea trout stockson the west coast of Scotland. This report concluded that:

1) sandeel was widely distributed through Scottish waters
2) the density of 0-group sandeels can fluctuate markedely between years and such changes are often unrelated to the size of the fished spawning stock.
3) the 1991 year class was very large both around the Scottish west coast and the Northern Isles, suggesting that prey availabilityto salmonids should also have been high.
4) the west coast sandeel fishery has never accounted for a high proportion of 0-group mortality and 0-group sandeels only become accessible to the fishery some time after salmonid smolt migration

Sea trout samples taken in the west coast of Ireland (Tully et al. 1990) showed that sea trout were probably feeding on on the most abundant local source of food. Dietary items included juvenile fish species, sandeels, sprat, elvers, crab larva, shrim and prawn. As there was a wide range of food items it did not appear that low availability of prey items could be a major factor impacting on sea trout populations.

In the coastal fishery off East Anglia where sea trout are caught on their feeding area, sampling by MAFF in 1992 and 1993 showed clear differences in the diet of different size groups of fish. Smaller fish (<35cm), consumed predominantly small clupeids and sandeels; only 20% were found with empty stomachs. Larger sea trout were more likely to have empty stomachs (approximately 50%), but where food had been eaten, the fish had consumed sandeels almost exclusively. During the winter months sprats become an important component of the diet when sandeels are unavailable.

Despite extensive experimental stocking of sea trout into a Danish estuary, preliminary indications are that there has been no reduction in the availability of prey species in this area.

5 Recommendations

This Study Group has identified lack of knowledge in a number of areas, and the following recommendations are given for further research and management of anadromous trout:

(1) Population ecology:

* Continued and more detailed research on the dynamics between resident and migratory trout in different types of rivers.

* Detailed studies on sexual differencs, marine migrations, behaviour and resource use of anadromous trout at sea in different geographic areas.

* Investigations on the winter habitat of sea trout from different types of localities.

* Performance of coordinated studies in Europe on population status and effects of climatic variables on population dynamics and survivial of sea trout

* Establishment of "index" rivers for sea trout covering different types of populations and areas. This will be long term studies to provide information on population fluctuations (adults and smolts), population structure and life history variation. Stock-recruitment relationships need to be developed.

* Investigations of egg deposition targets in various river types.

(2) Sea lice infestation:

* Continued research on effects of sea lice infestations;
  a) what level of infestation can be sustained without significantly affecting sea trout populations?
  b) what is the relationsip between lice burdens in fish farms and the lice burdens on wild sea trout in the area?
  c) investigate fish farming protocols which may reduce or eliminate any negative impacts on wild sea trout.

(3) Harvesting:

* Development of harvesting models for anadromous brown trout.

* The quality (and quantity) of sea trout catch data needs to be improved and should be published on an annual basis. These data should include: marine/coastal catch, in river rod and net catch, fish number and weight, and appropriate measures of fishing effort.

* Investigate the amount of sea trout in bycatches.

* Investigations of gear selectivity (species and size) of different harvesting methods.

(4) Population enhancement:

* Development of a rearing and stocking protocol.

* Development of habitat improvement strategies for juvenile trout.

* Investigation of requirements for fish passage facilities for sea trout.

(5) Rainbow trout:

* Perform a comprehensive review of the current status of rainbow trout in natural waters and identify factors influencing reproduction in the wild.

(6) Further activity:

* Arrange a new ICES Study Group on sea trout in a few years time to summarize new information.

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Appendix 1

Documents submitted to the Study Group:

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Appendix 2.

Sea lice infestations in Ireland

The highest infestations and variation in infestation are seen in proximity to fish farms (Figs. 2.1, 2.2, 2.3, Table 2.1, 2.2). At points further from fish farms the infestations and their variance decrease progresively and the variation in the infestations are reduced.

The observed variance is large (Table 2.3). Thus, to test the hyhpothesis that infestation is a function of proximity to fish farms the mean squre linear regression with the mean square deviation from the regression was compared. In a traditional analysis the former would have been compared to the total error term (within sites + deviation from the regressions). The test used here is not only a more conservative approach, but will also take account of the extreme variation aroud the regression line for some distance values shown in the data. The regression line (Figure 2.2 and 2.3) is significant ($p<0.01$) and hence there is a decline in total lice infestation as distance from fish farms increases.

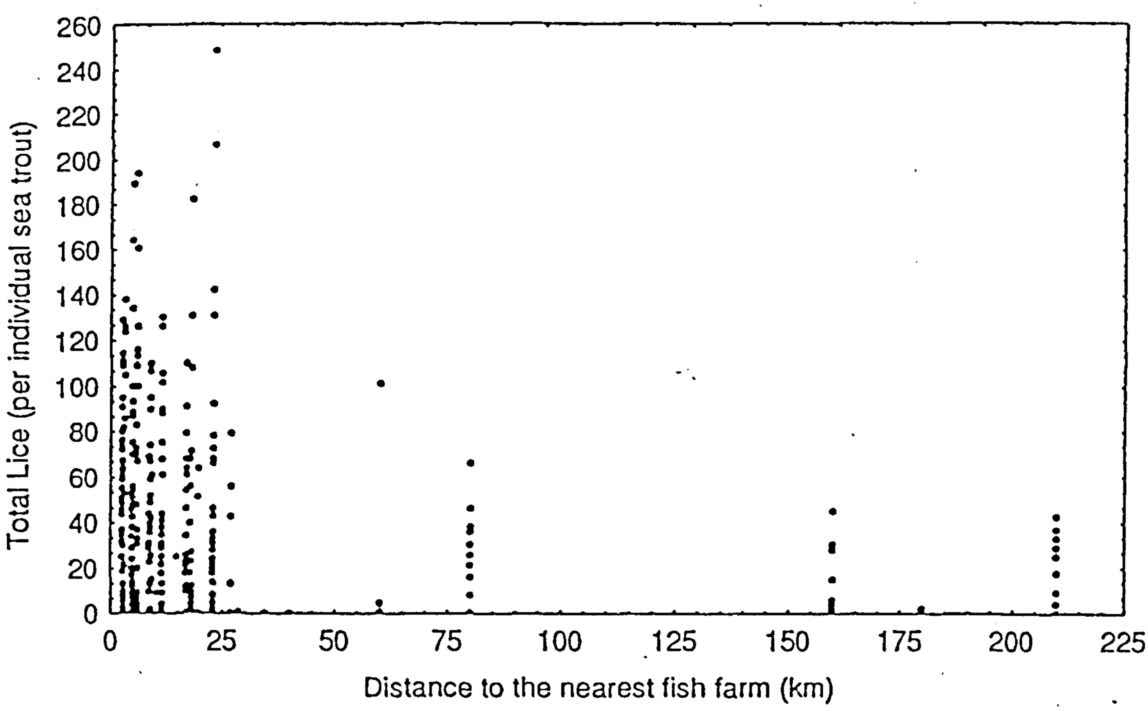

Figure 2.1. Lice infestations on individual sea trout.

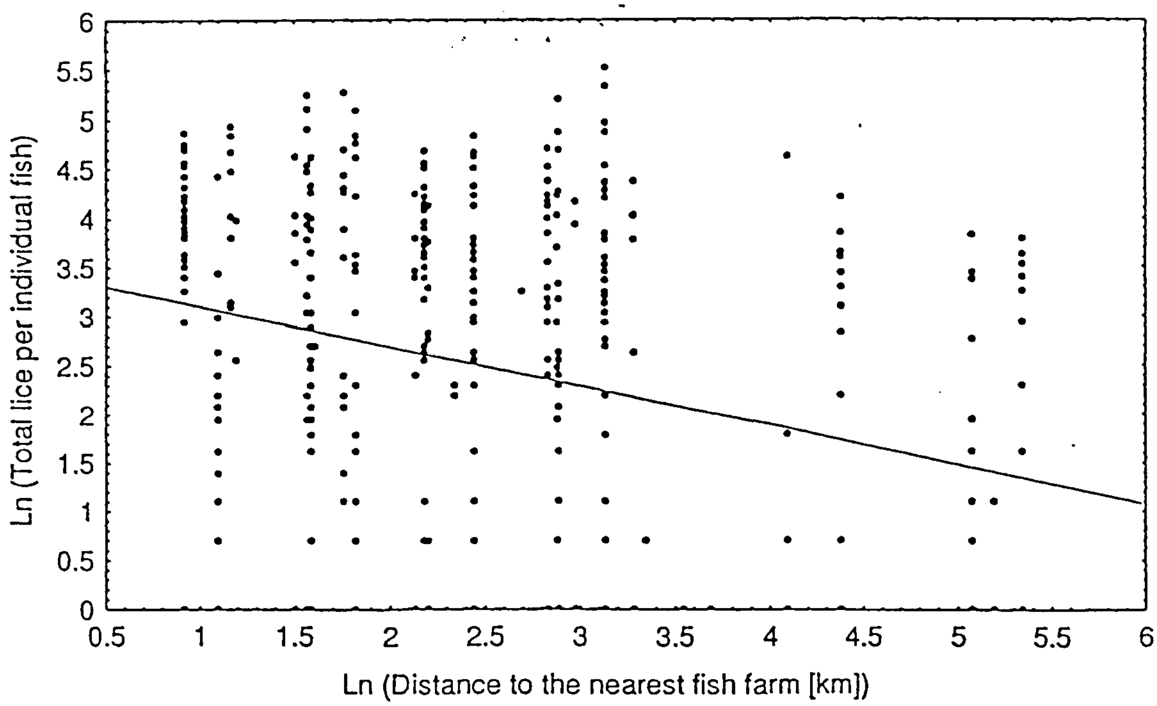

Figure 2.2 Lice infestations on individual sea trout (log transformed values).

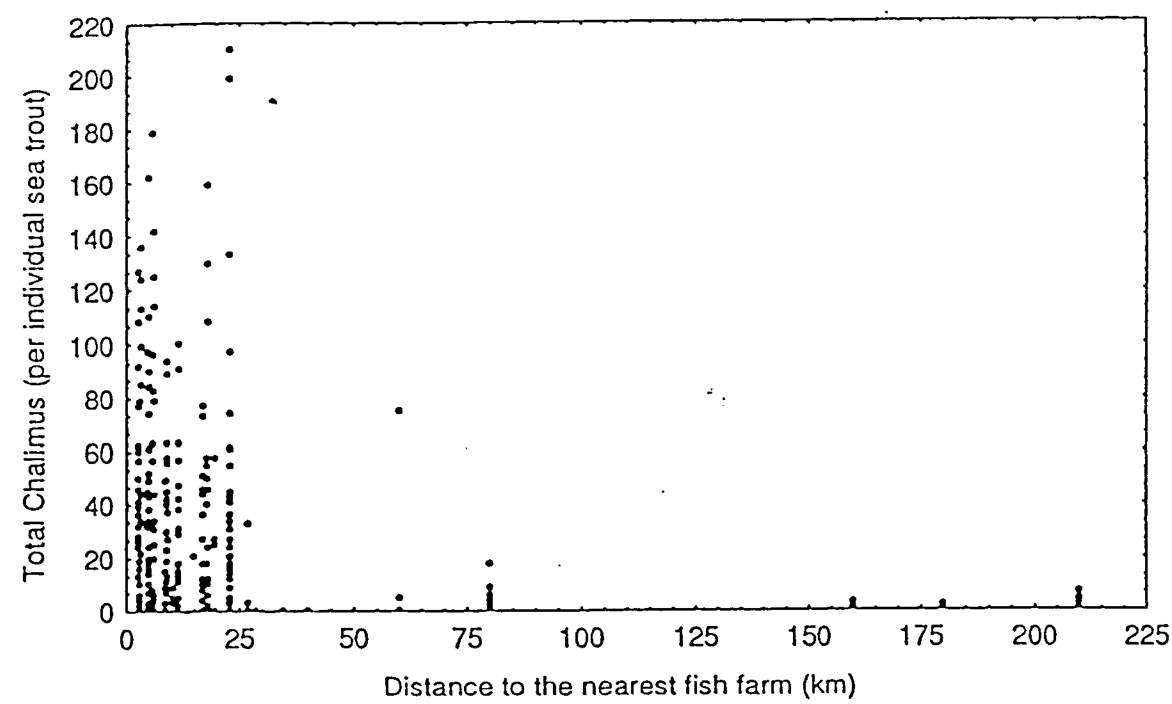

Figure 2.3. Chalimus infestations on individual sea trout.

A similar analysis using the intensity of chalimus infestation was also carried out (Figures 2.3 and 2.4 and Table 2.4). Once again the regression term is significant and there is a significant decline in the chalimus infestation as distance from fish farms increases.

Figure 2.5 shows the log-log plot of chalimus abundance and distance from farm. Table 2.5 is a summary of the associated regression analysis. The following should be noted:

1 To preserve zero abundances the log of (abundance + I) is used
2 Because there is considerable heterogeneity of variance, inverse variance weighting has been employed, i.e. the variation associated with the raw data used in the previous analysis is applied in this analysis to reduce the effects of heterogeneity. Therefore, sites displaying high variation in infestation are weighted less than sites with low variation.

A significant decline in chalimus abundance with increasing distance from fish farms is evident ($p<0.01$).

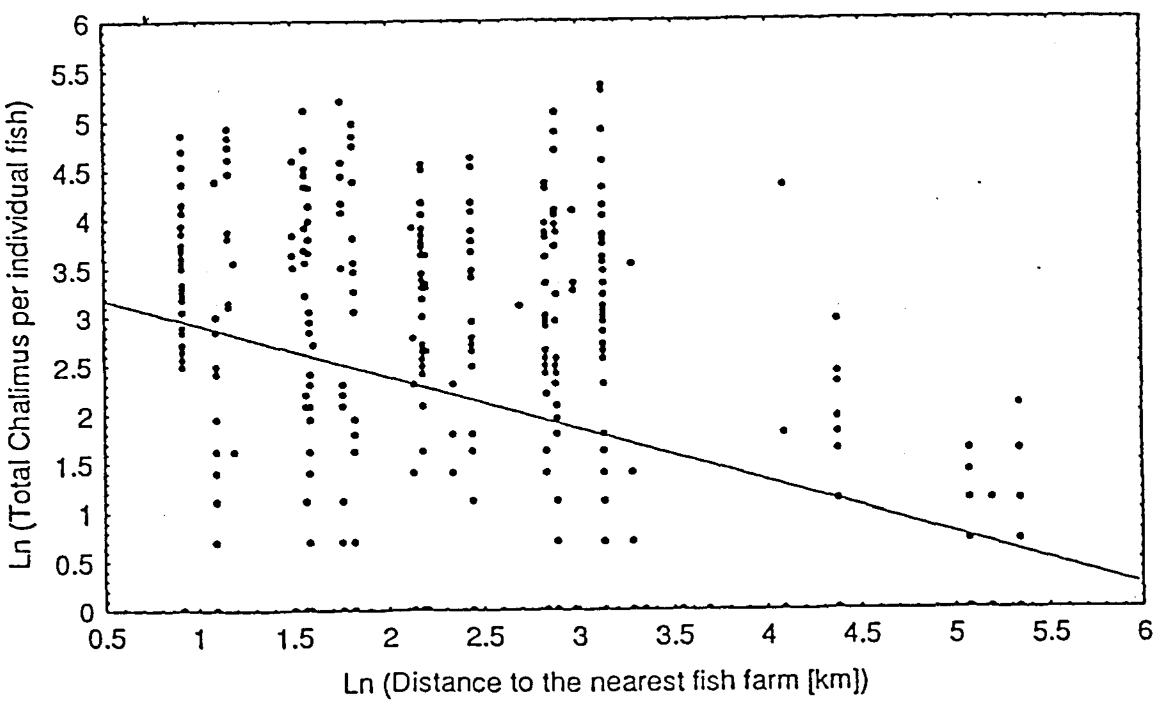

Figure 2.4. Chalimus infestations on individual sea trout (log transformed values).

Table 2.1. Lice infestation detail and abundance statistics for sites with greater than 3 valid fish

REF		DIST	TF	TV	% VAL	TL	TC	Tot L	Tot C	Pr L (%)	Pr C(%)	Ab L	SE	Ab C	SE
3	Ballinahinch	9	8	6	75.0	5	5	183	91	83.3	83.3	30.5	10.0	15.2	7.2
6	Bride	180	23	22	95.7	1	1	2	2	4.5	4.5	0.1	0.1	0.1	0.1
8	Bunree	80	21	4	19.0	1	0	1	0	2.0	0.0	0.3	0.3	0.0	0.0
14	Costello	17	27	21	77.8	19	19	905	523	90.5	90.5	43.1	6.6	24.9	4.9
15	Crana	6	35	24	68.6	17	16	835	749	70.8	66.7	34.8	10.2	31.2	9.5
17	Dargle	210	20	12	60.0	10	4	235	14	83.3	33.3	19.6	4.3	1.2	0.6
18	Dawros	5	37	26	70.3	24	23	710	570	92.3	88.5	27.3	5.4	21.9	4.3
19	Delphi	9	19	8	42.1	6	5	161	116	75.0	62.5	20.1	7.8	14.5	5.1
20	Drumcliffe	80	34	11	32.4	11	8	357	63	100.0	72.7	32.5	4.7	5.7	1.7
21	Eany	3	39	37	94.9	18	16	207	175	48.6	43.2	5.6	2.4	4.7	2.2
23	Eske	18	28	24	85.7	16	16	626	536	66.7	66.7	26.1	9.8	22.3	9.0
26	Glenamoy	40	5	4	8.0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
28	Gowla	3	45	39	86.7	38	38	2409	1655	97.4	97.4	61.8	4.5	42.4	4.6
29	Inny	12	137	39	28.5	33	31	1016	777	84.6	79.5	26.1	4.4	19.9	4.1
30	Invermore	9	39	36	92.3	36	34	1726	1147	100.0	94.4	47.9	4.9	31.9	3.7
35	Leannan	18	31	18	58.1	12	12	285	269	66.7	667	15.8	5.3	14.9	4.9
38	Nanny	160	13	10	76.9	8	7	131	13	80.0	70.0	13.1	5.0	1.3	0.4
40	Oily	5	16	16	100.0	13	13	964	845	81.3	81.3	60.3	15.2	52.8	13.9
41	Owenea	60	15	12	80.0	3	2	107	80	25.0	16.7	8.9	8.4	6.7	6.2
42	Owengarve	20	15	4	26.7	3	3	166	110	75.0	75.0	41.5	14.2	27.5	11.9
44	Owenshaugh	3	9	9	100.0	9	9	721	691	100.0	100.0	80.1	15.3	76.8	14.8
46	Palmerstown	80	6	6	100.0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
47	Roughty	23	52	47	90.4	42	41	1863	1553	89.4	87.2	39.6	7.5	33.0	6.6
48	Sneem	6	13	12	92.3	12	11	643	537	100.0	91.7	53.6	16.5	44.8	15.7
49	Spiddal	27	7	7	100.0	4	3	191	37	57.1	42.9	27.3	12.1	5.3	4.6
50	Stragar	5	11	10	90.9	5	5	291	242	50.0	50.0	29.1	11.1	24.2	10.0
53	Waterville	12	37	11	29.7	11	9	758	346	100.0	81.8	68.9	13.4	31.5	6.4
	n = 27														

Table 2.2. Lice infestation details and intensity statistics for sites with greater than 3 infected fish.

REF		DIST	TF	TV	% VAL	TL	TC	Tot L	Tot C	L Int	SE	C Int	CE	C IV	SE
3	Ballinahinch	9	8	6	75.0	5	5	183	91	36.6	9.7	18.2	8.0	18.2	8.0
14	Costello	17	27	21	77.8	19	19	905	523	47.6	6.4	27.5	5.1	27.5	5.1
15	Crana	6	35	24	68.6	17	16	835	749	49.1	12.9	46.8	12.1	44.1	12.6
17	Dargle	210	20	12	60.0	10	4	235	14	23.5	4.1	3.5	0.7	1.4	1.3
18	Dawros	5	37	26	70.3	24	23	710	570	29.6	5.6	24.8	4.5	23.8	4.6
19	Delphi	9	19	8	42.1	6	5	161	116	26.8	8.8	23.2	5.4	19.3	4.6
20	Drumcliffe	80	34	11	32.4	11	8	357	63	32.5	4.7	7.9	1.7	5.7	1.7
21	Eany	3	39	37	94.9	18	16	207	175	11.5	4.5	10.9	4.3	9.7	4.7
23	Eske	18	28	24	85.7	16	16	626	536	39.1	13.6	33.5	12.8	33.5	12.8
28	Gowla	3	45	39	86.7	38	38	2409	1655	63.4	4.3	43.6	4.5	43.6	4.5
29	Inny	12	137	39	28.5	33	31	1016	777	30.8	4.7	25.1	4.5	23.5	4.7
30	Invermore	9	39	36	92.3	36	34	1726	1147	47.9	4.9	33.7	3.7	31.9	3.7
35	Leannan	18	31	18	58.1	12	12	285	269	23.8	7.0	22.4	6.3	22.4	6.3
38	Nanny	160	13	10	76.9	8	7	131	13	16.4	5.7	1.9	0.5	1.6	0.5
40	Oily	5	16	16	100.0	13	13	964	845	74.2	16.4	65.0	15.2	65.0	15.2
44	Owenshaugh	3	9	9	100.0	9	9	721	691	80.1	15.3	76.8	14.8	76.8	14.8
47	Roughty	23	52	47	90.4	42	41	1863	1553	44.4	8.1	37.9	7.3	37.0	7.3
48	Sneem	6	13	12	92.3	12	11	643	537	53.6	16.5	48.8	15.7	44.8	16.6
49	Spiddal	27	7	7	100.0	4	3	191	37	47.8	13.8	12.3	7.9	9.3	10.3
50	Stragar	5	11	10	90.9	5	5	291	242	58.2	11.4	48.4	12.4	48.4	12.4
53	Waterville	12	37	11	29.7	11	9	758	346	68.9	13.4	38.4	6.4	31.5	5.4

n = 21

DIST	Distance to the nearest farm (km)
TF	Total number of fish sampled
TV	Total number of "valid" fish, i.e. fish within the length and sampling data specifications
% VAL	Valid fish as a percentage of the total
TL	Total number of lice infected valid fish
TC	Total number of chalimus infected valid fish
Tot L	Total number of lice recovered from valid sample
Tot C	Total number of chalimus recovered from valid sample
Pr L (%)	Prevelance (All stages) = TL / TV
Pr C (%)	Prevelance (Chalimus only) = TC / TV
L Int	Mean Intensity (All stages) = Tot L / TL
C Int	Mean Intnsity (Chalimus only) = Tot C / TC
C IV	Average number of chalimus per infected fish = Tot C / TL
Ab L	Abundance (All stages) = Tot L / TV
AB C	Abundance (Chalimus only) = Tot C / TV

Table 2.3. Completed anova table with regression for Log(Total lice +1) v's Log(distance to the nearest fish farm).

Source of variation	SS	*df*	MS	F	p
Among Sites	612.14	32	19.13	10.44	<0.001
Linear regression	118.71	1	118.71	7.46	0.01
Deviation from regression	493.42	31	15.92	8.69	<0.001
Within sites	826.27	451	1.83		
Total	1438.41				

Table 2.4. Completed anova table with regression for Log(Total Chalimus +1) v's Log(distance to the nearest fish farm)

Source of variation	SS	*df*	MS	F	p
Among Sites	544.22	32	17.01	9.60	<0.001
Linear regression	207.33	1	207.33	19.07	<0.001
Deviation from regression	336.89	31	10.87	6.14	<0.001
Within sites	789.75	451	1.77		
Total	1333.97				

Table 2.5. Regression of log(Chalimus abundance + 1) and log distance to the nearest farm.

Source of variation	SS	*df*	MS	F	p
Regression	44.58	1	44.58	94.03	.000000
Residuals	12.80	27	0.47		
Total	57.38				

Ln(Chalimus abundance +1) = -0.83 Log(distance) + 4.91 R^2 = 0.78

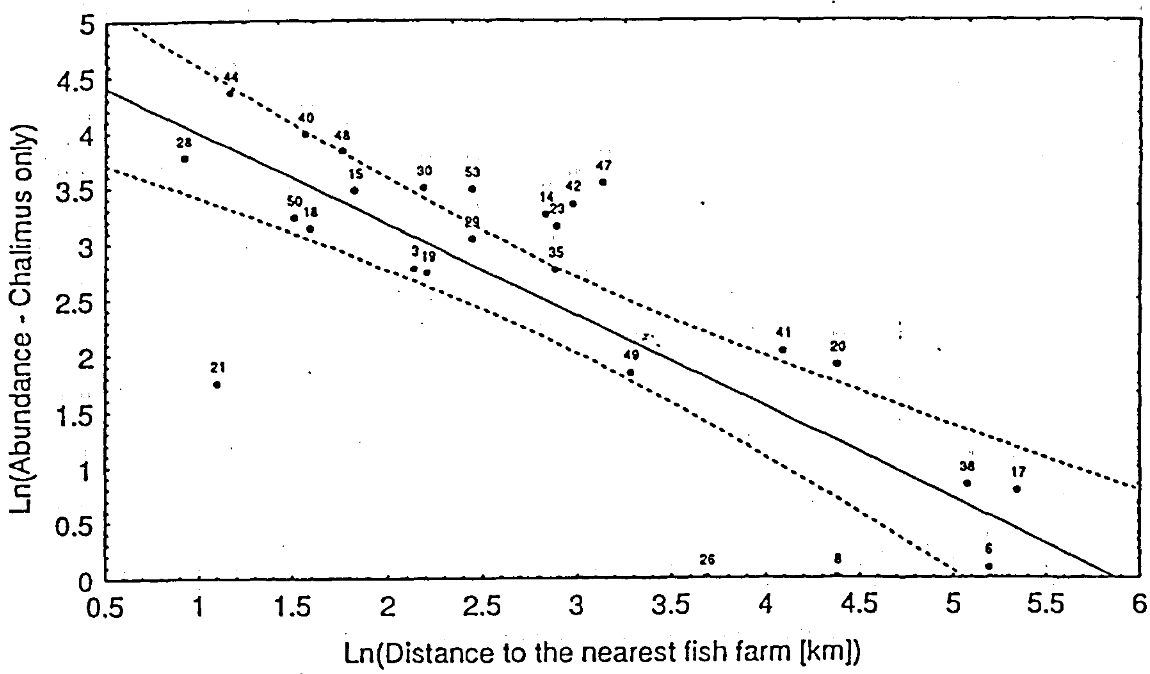

Figure 2.5. Chalimus abundance (log transformed values).
Ln((Average number of Chalimus per valid fish) +1)

Table 2.6 contains the results of a Shapiro-Wilks test of the normality of the error terms derived from the previous regression. From this analysis, there is evidence to suggest that this assumption has been violated. This is due to the inclusion of a single point which was identified as being atypical of the data, having a very high standardised residual and a large Cooks distance (>30 times the mdian, and >10 times the next largest value for the Roughty sample, Table 2.7). While accepting that there is no biological evidence to deem this point an outlier, it is the presence of this single data point which has given rise to the apparent lack of normality observed in the error terms. This is shown by removing this point and repeating the analysis. Table 2.8 shows the results of a Shapiro-Wilks test carried out on the residuals. There is no longer any reason to suspect that the error terms are not normally distributed, and it is concluded that there is insufficient grounds to negate the original regression analysis.

The same approach is adopted for the analysis of lice intensity parameters. Figure 2.6 shows the log-log plot of chalimus intensity from farm. In this case the hypothesis that chalimus intensity declines at increased distance from fish farms is examined. Table 2.9 is a summary of the associated regression analysis.

On the basis of the very significant regression ($p<0.01$) it was concluded that there is a significant decline in chalimus intensity with increasing distance from fish farms.

Table 2.6. Testing the normality of the log(Chalimus abundance + 1) and log distance to the nearest farm.

	Statistic	df	p
Shapiro-Wilks	0.8844	29	<0.01
K-S (Lilliefors)	0.1397	29	0.1553

Table 2.7. Identification of outliers.
Residual analysis of regression of the log(Chalimus abundance + 1) and log(distance to the nearest farm). The table includes residuals for the regression with and without Eany, and includes values for the two most extreme cases Eany and Roughty.

Site	Standard Residuals		Cooks Distance	
	With Eany	Without Eany	With Eany	Without Eany
Eany	-3.34	.	0.68	.
Roughty	1.77	2.19	0.06	0.09
Inny				0.13
For all sites				
Minimum	-3.34	-1.30	0.00	0.00
Maximum	4.77	2.19	0.68	0.13
Mean	0.00	0.00	0.04	0.04
Median	0.20	0.15	0.02	0.03

Table 2.8. Testing the normality of the residuals obtained from the regression of the log(Chalimus abundance + 1) on log(distance to the nearest farm), without Eany.

	Statistic	df	p
Shapiro-Wilks	0.9536	26	0.3573

Table 2.9. Regression of log(Chalimus intensity + 1) and log distance to the nearest farm.

Source of variation	SS	*df*	MS	F	p
Regression	11.82	1	11.82	37.2	0.000007
Residuals	6.04	19	0.32		
Total	17.86				

Ln(Chalimus abundance +1) = -0.63 Log(distance) + 4.69 R^2 = 0.66

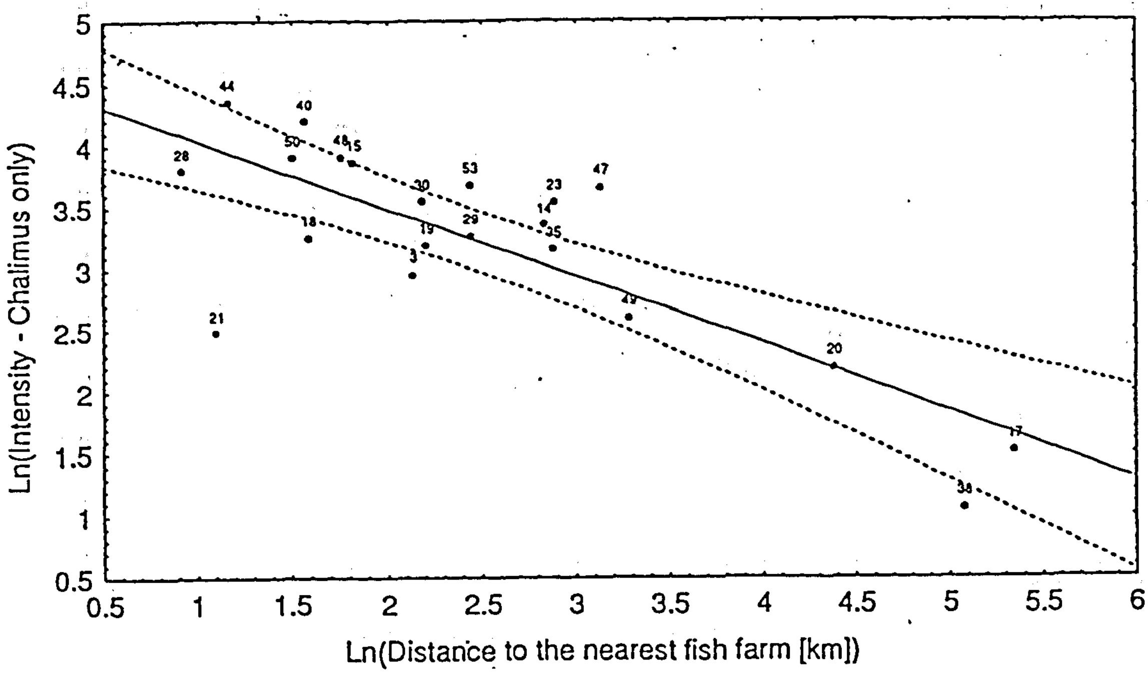

Figure 2.6. Chalimus Intensity (log transformed values)
Ln ((Average number of Chalimus per infected valid fish) +1)

Numbers of farmed salmon and ovigerous lice production in relation to zoned distance from fish farms

The total number of farmed salmon within 5 km bands, up to 75 km from a sea trout river was calculated. The relationships between infestation paramters for *L. salmonis* infesting sea trout and the number of farmed salmon in 5 km distance zones from the sea trout river were lower than those found by using simple linear distance (Table 2.10). The best correlations are found by incorporating all salmon within 20 km and 25 km zones of the nearest river. Inclusion of salmon at greater distance reduces the regression statistics, suggesting that lice infesting farmed salmon at distances greater than 25 km from a sea trout river do not transmit lice to those sea trout.

Ultimately, if cross-transmission of lice between wild and farmed fish occurs it is the number of *larvae* produced by the lice on farmed fish which is important. The best available indicator of this is the number of ovigerous female lice on a farm at a particular sampling date. This information is available from the fish farm monitoring programme, and has been incorporated into this analysis by multiplying the mean number of ovigerous lice per farmed fish during April and May 1993 by the total number of fish, to give an estimate of the size of the ovigerous lice population at that time. The cumulative number of ovigerous lice within successive 5 km zones to sea trout rivers is then related to the sea lice infestation paramters (Table 2.11). The most significant regressions are again apparent by including farmed lice only up to 20-25 km. Inclusion of lice of farm origin situated beyond this range leads to progressive reduction in the significance of the regressions. Although the incorporation of infestation levels on farms was carried out in an attempt to explain more of the observed variation in infestation levels between sea trout sites, this has not been noted.

Table 2.10. ANOVA statistics relating the number of chalimus of *L. salmonis* infesting sea trout smolts to the total number of farmed salmon within accumulating 5 km distance bands. The highest variance is expalined by incorporating only those salmon within 20 km of the rivers where sea trout were sampled.

Distance (km)	R^2	F	P
<5	23.8	5.93	0.025
<10	37.2	11.30	0.006
<15	28.6	7.22	0.025
<20**	53.5**	20.70**	0.000**
<25	30.1	7.75	0.012
<30	21.1	4.81	0.041
<35	16.1	3.46	0.079
<40	12.0	2.46	0.134
<45	8.9	1.76	0.200
<50	11.6	2.35	0.140
<55	2.7	0.45	0.490
<60	4.5	0.85	0.370

Table 2.11. ANOVA statistics relating the total number of *L. salmonis* infesting sea trout smolts to the total number of ovigerous *L. salmonis* infesting farmed salmon within accumulating 5 km distance bands. The highest variance is expalined by incorporating only those salmon within 25 km of the rivers where sea trout were sampled.

Distance (km)	R^2	F	P
<5	4.7	0.90	0.340
<10	8.7	1.80	0.190
<15	9.5	1.80	0.186
<20	19.2	4.28	0.053
<25**	35.0**	9.69**	0.006**
<30	23.6	5.37	0.029
<35	23.7	5.58	0.029
<40	23.1	5.39	0.032
<45	21.0	4.77	0.042
<50	20.1	4.52	0.048
<55	20.9	4.75	0.043
<60	20.7	4.71	0.044

Consideration of differences in population structure (% at each life history stage) between locations and over time indicated variation in the intensity and timing of transmission of infective larvae to fish. Sea trout samples infested with high numbers of young infective stages indicate recent high rates of transmission, whereas infestations consisting predominantly of preadults and adults indicates that recent transmission rates were not high. Figure 2.7 examines the percentage composition of each life history stage in relation to distance to the nearest farm. All dataes are combined. Site categories in relation to distance to the nearest farm are also expressed differently. All sites less than 30 km from fish farms are grouped and compared with those sites greater than 20 km, greater than 30 km, greater than 60 km and greater than 100 km from the nearest farm. The population structure expressed in this way at sites greater than 100 km is almost the mirror image of sites less than 20 km from the nearest farm. Fish at sites closest to farms are infested primarily by chalimus while fish at great distances are infested mainly be adults. Recent infestation is apparent therefore at sites close to farms while it is not so at sites distant from farms. By succesively excluding sites within 20,30 and 60 km from the nearest farm, the population structure at sites less than 20 km away is seen to gradually merge into the form present at sites more than 100 km distant.

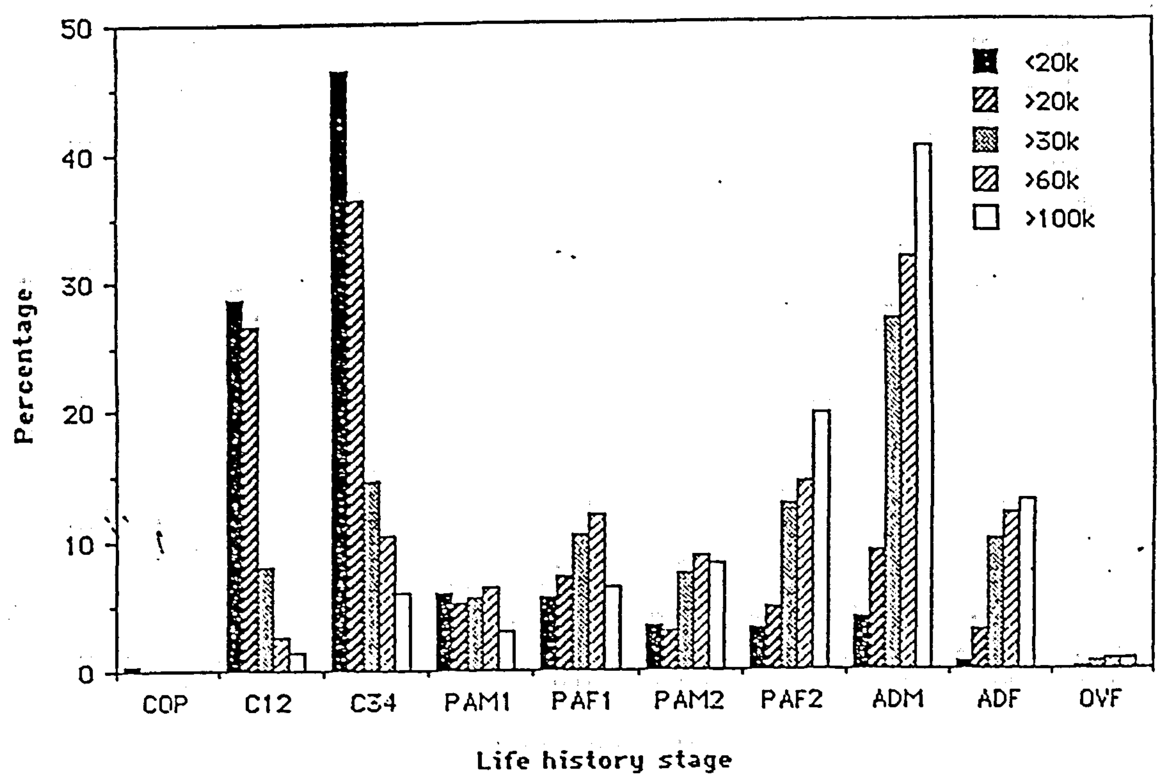

Figure 2.7. Population structure (%) of *L. salmonis* infesting sea trout smolts at various distances from the nearest salmon farm between May 1 and June 15.