European Community Directive
on the Conservation of Natural Habitats
and of Wild Fauna and Flora
(92/43/EEC)

Second Report by the United Kingdom under Article 17

on the implementation of the Directive from January 2001 to December 2006

Conservation status assessment for :

S1106: *Salmo salar* - Atlantic salmon.

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S1106 *Salmo salar* Atlantic salmon

Audit trail compiled and edited by JNCC and the Freshwater Inter-Agency Working Group

This document is an audit of the data and judgements on conservation status in the UK's report on the implementation of the Habitats Directive (January 2001 to December 2006) for this species. Superscript numbers accompanying the headings below, cross-reference to headings in the corresponding Annex B reporting form. This supporting information should be read in conjunction with the UK approach for species (see 'Assessing Conservation Status: UK Approach').

Obligations of the Habitats Directive relate to freshwater occurrence of Atlantic salmon only; the assessments below reflect this. However, where appropriate, reference is made to the influence that marine issues may have on species status.

1. Range Information[2.3]

The UK Atlantic salmon *Salmo salar* population comprises a significant proportion of the total European stock. Scottish rivers in particular are a European stronghold for the species. Atlantic salmon is widespread across the UK and occurs in several hundred rivers, with a focus in the north and west.

Map 1.1 shows the occupied 10-km squares for Atlantic salmon, which has been calculated at 1,210 10-km squares. The range data is an accurate reflection of the main bulk of the population but probably underestimates their distribution in central and southern England, where small populations still occur (e.g. on the Sussex chalk streams, Yorkshire Ouse and Trent).

1.1 Surface area of range[2.3.1]

165,049 km^2

The surface area estimate was calculated within the Alpha Hull software. Extent of occurrence was used as a proxy measure for range (see Map 1.1). The value of alpha was set at 25 km to reflect the mobility of this species. The range area was clipped to include inland areas only.

1.2 Date of range determination[2.3.2]

1990 – 2003

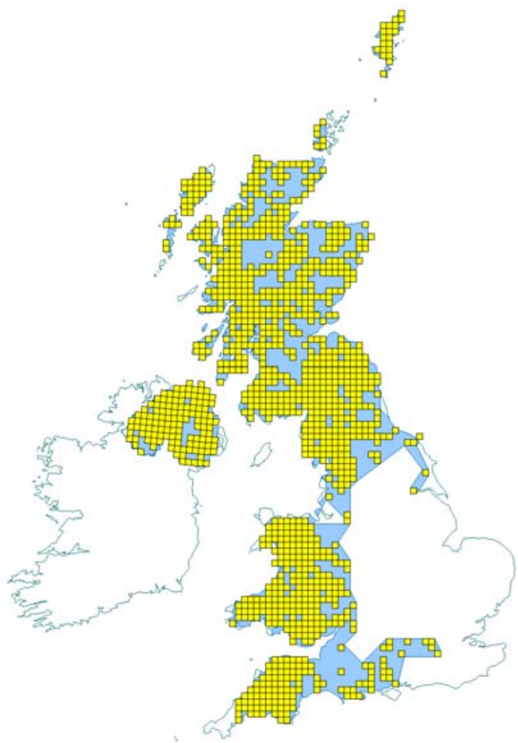
Records from 1990 to 2003 were used to calculate the current extent of occurrence; 2003 was the most recent record available via the NBN Gateway. These records provide the best available representation of current (2007) range.

1.3 Quality of range data[2.3.3]

Moderate

The current estimate is based upon data compiled from a variety of sources, and via a variety of monitoring methods (including electrofishing of juveniles, fish counters and catch returns from anglers). Therefore data quality is moderate rather than good. However, because this species is subject to regular survey, Map 1.1 is likely to offer a fair representation of current range.

Map 1.1. Current extent of occurrence and occupied 10-km squares (1990-2003)



Data sources provided in Section 6

1.4 Range trend[2.3.4] and range trend magnitude[2.3.5]

Stable

For a relatively long-lived species such as Atlantic salmon, the post-1994 trend represents at most 4-5 generations. Identification of a clear range trend over this period is therefore difficult.

Subsequent to historic declines, there have been recolonisations of various, formerly occupied industrialised rivers since 1995, especially in north east England (Tyne, Tees, Wear), central Scotland (Clyde) and South Wales (Tawe, Neath, Taff) (Doughty & Gardiner, 2003; Mawle & Milner, 2003). Small numbers of fish have also been reported entering the Mersey, Yorkshire Ouse and Trent. A reintroduction programme in the Thames has so far had limited success.

For the reason given above, these re-colonisations are unlikely to have resulted in a notable UK trend at a coarse 10km scale. It is more probable that the UK range of Atlantic salmon has remained mostly stable since the Habitats Directive came into force.

1.5 Range trend period [2.3.6]

1994 – 2006

1.6 Reasons for reported trend in range[2.3.7]
Not applicable

1.7 Favourable reference range[2.7.1]
165,049 km^2 (Equal to current)
The decision tree in Note 1 has been used as a guide in determining the favourable reference range estimate (see 'Assessing Conservation Status: UK Approach').

Atlantic salmon were formerly ubiquitous in Britain, with the exception of the low-gradient rivers in East Anglia (Mawle & Milner, 2003). Most of the contraction in range occurred in urbanised catchments during the Industrial Revolution, due to a combination of pollution and barriers to migration (Doughty & Gardiner, 2003; Mawle & Milner, 2003). During the early and middle 20th century, reservoir construction in upland areas and acidification had significant effects on distribution at a catchment scale, especially in Wales, southern Scotland and parts of England. In lowland rivers, agricultural intensification and river modification likewise caused localised contractions in range, especially in southern England (see also sections 2 and 3 below).

A gradual recovery in range has been observed however, predominately associated with the decline in heavy industry between 1970 and the present day. Further, because Atlantic salmon are heavily exploited in the UK, there has been considerable management effort to restore this species, particularly with regard to maintaining / restoring existing populations. However, this management does not constitute 'intensive conservation care'; although natural recolonisation often follows improvements to habitat or access, stimulating further restoration work, there is little evidence that direct stocking programmes alone have been successful in re-establishing Atlantic salmon populations. Therefore, on the basis that current range is stable and not restricted (for the purpose of this reporting process) the current estimate has been set as the baseline favourable reference value.

1.8 Range conclusion[2.8]
Favourable
The range is stable and not less than the minimum favourable reference value.

2. Population of the Species[2.4]

2.1 Population estimate[2.4.1]
c. 556,500 spawning adults
The International Council for the Exploration of the Seas (ICES) (2007) reported a UK spawning population of approximately 480,000 in 2006. However, because salmon populations fluctuate from year to year, it is considered more useful to consider the 10-year average, rather than annual counts; the 1997-2006 average has therefore been reported above. The ICES (2007) data used to calculated this estimate are reproduced in Table 2.1.

With regards to the returning adult population, the 2006 UK estimate was approximately 590,000 (ICES, 2007); the 1997-2006 10-year average was approximately 723,000.

All estimates reported in this document include both grilse (or one-sea-winter) and multi-sea-winter salmon.

Table 2.1 UK estimates of spawning and returning adults (grilse and sea-winter) between 1994 and 2006

Year	Number of spawners	Number of returns
1997	459,942	669,979
1998	671,849	875,973
1999	397,911	546,120
2000	624,001	832,436
2001	602,676	780,140
2002	503,973	678,133
2003	542,421	675,203
2004	650,310	804,189
2005	632,657	778,727
2006	479,744	589,169
10-YEAR AVERAGE	556,548	723,007

SOURCE: Data have been extracted from the ICES 2007 report

2.2 Date of population estimate[2.4.2]

1997 - 2006

The current population estimate is based on a 10-year average (ICES, 2007).

2.3 Method of population estimate[2.4.3]

2 = Extrapolation from surveys of part of the population, sampling

UK annual counts are based a mathematical model of post-exploitation numbers of grilse and multi-sea-winter spawners in UK waters developed by the ICES.

2.4 Quality of population data[2.4.4]

Good

This species is monitored annually in considerable detail. Although different organisations use slightly different protocols, data are largely comparable both spatially and temporally. Any uncertainty in the data reflects the inherent difficulty of sampling fish populations and natural variability in numbers from year to year.

2.5 Population trend[2.4.5] and population trend magnitude[2.4.6]

Decreasing

During the last Biodiversity Action Plan (UKBAP) reporting round, the UK population trend was reported as decreasing (see Table 2.2). This is supported by information published in the ICES (2007) report; total UK figures for both returns and spawners show a decreasing trend between 1994 and 2006.

Approximately 80% of the UK resource is found in Scotland and the overall Scottish rod catch figures have remained reasonably stable since 1994. This is not the case for all stock components however. The early running multi-sea-winter component, for example, has declined significantly in many rivers and this continues to be a cause for concern (Fisheries Research Services 2006). However, in England and Wales, the rod catch dropped substantially for a sustained period between 1989 and 2003, when all years except for 1994 were well below the long-term average (CEFAS & Environment Agency, 2007). No catch information was available for Northern Ireland at the time of survey.

Overall therefore, the UK populations are considered to be in decline. However, with approximately 80% of the resource in a stable condition (i.e. the Scottish population), and a strong programme of conservation measures, the overall decline is unlikely to have exceeded 1% per annum since 1994.

Table 2.2 National trends

Country	Trend	Data Source/ Comments
UK	Declining	
England	Declining	In spite of some recent significant local increases (for example the industrialised rivers of NE England), the overall trend is declining. Half the rivers in England (not including 'non salmon' rivers such as the Trent or Thames) do not meet their EA management targets, and the status of a further 20% is uncertain. Some improvement is predicted by 2011.
Scotland	Stable	Although absolute numbers of fish have stayed stable both since 1994 and over a longer timescale, the declining MSW component is a cause for concern, as is the poor condition of small west coast populations.
Wales	Declining	In Wales acidification and agrichemical pollution has had significant effects on many *S. salar* populations. Only one river in Wales currently meets its spawning target, with more than 60% failing and the rest uncertain. However, this situation is expected to improve somewhat by 2011 (CEFAS and Environment Agency, 2006).
Northern Ireland	Unknown	

2.6 Population trend period[2.4.7]
1994 – 2005

2.7 Reasons for reported trend in population[2.4.8]
2 = Climate change
3 = Direct human influence (restoration, deterioration, destruction)
4 = Indirect anthropo(zoo)genic influence
In general, the quality of the freshwater environment is no longer deteriorating and small improvements are evident in some parts of the country. Moreover, exploitation has been greatly reduced, with net fisheries and fixed engines removed and rod fisheries increasingly switching to catch and release. For example, measures to reduce exploitation in England and Wales have resulted in a reduction in catch from around 41,000 fish in 1988-92 to around 9,500 fish in 2003-2006 (CEFAS and Environment Agency, 2007).

Recent declines are primarily related to changes to the marine habitat of Atlantic salmon, which has direct and indirect impacts on both Atlantic salmon and its prey. These are primarily driven by climate change and are outside the direct control of the UK government.

2.8 Justification of % thresholds for trends[2.4.9]
Not applicable

2.9 Main pressures[2.4.10]
Atlantic salmon is a widespread, migratory species that occurs in rivers in a wide range of landscapes. Consequently, they are subject to a wide range of pressures. In many cases, populations are affected by cumulative pressures or interactions between different pressures.

Those key to species decline include:
200 Fish and Shellfish Aquaculture
211 Fixed location fishing
213 Drift-net fishing
220 Leisure fishing
243 Trapping, poisoning, poaching
300 Sand and gravel extraction
701 Water pollution
811 Management of aquatic and bank vegetation for drainage purposes
830 Canalisation
850 Modification of hydrographic functioning, general
852 Modifying structures of inland water courses
853 Management of water levels
910 Silting up
920 Drying out
952 Eutrophication
953 Acidification
971 Competition (mainly with other salmonids)
962 Parasitism
963 Introduction of disease
964 Genetic pollution

2.10 Threats[2.4.11]
200 Fish and Shellfish Aquaculture
211 Fixed location fishing
213 Drift-net fishing
220 Leisure fishing
243 Trapping, poisoning, poaching
300 Sand and gravel extraction
701 Water pollution
811 Management of aquatic and bank vegetation for drainage purposes
830 Canalisation
850 Modification of hydrographic functioning, general

852 Modifying structures of inland water courses
853 Management of water levels
910 Silting up
920 Drying out
952 Eutrophication
953 Acidification
971 Competition (mainly with other salmonids)
962 Parasitism
963 Introduction of disease
964 Genetic pollution

2.11 Favourable reference population[2.7.2]

c. 741,000 spawning adults

The decision tree in Note 1 has been used as a guide in determining the favourable reference population estimate (see 'Assessing Conservation Status: UK Approach').

The 1994 UK estimate of adult spawners was approximately 810,000 (ICES, 2007). However, as discussed in section 2.1, salmon populations fluctuate from year to year. Therefore, since ICES 2007 provides count data as far back as 1971, expert opinion is that the long-term average from 1971 – 1994 (740,839) provides the most appropriate baseline for comparison. Figure 2.1 plots change over this period.

Although there have been declines in Atlantic salmon since 1994, these have been driven predominately by external pressures, such as changes in marine habitat, and this reporting process only covers the freshwater habitat of the species. Furthermore, it is difficult to argue that a population of approximately 741,000 spawning adults would not be large enough to maintain and perpetuate itself in the absence of these external pressures.

For this reason, the 1971-1994 average has been set as the minimum favourable reference population.

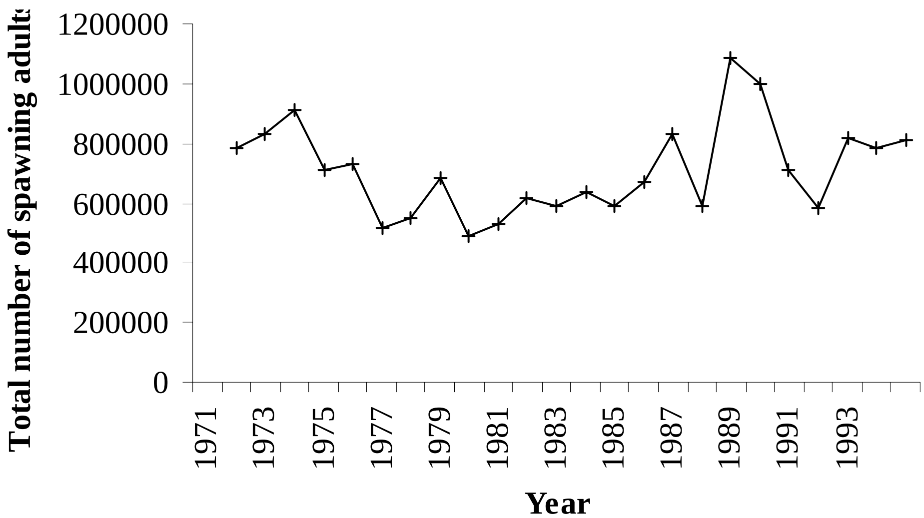
2.12 Population conclusion[2.8]

Unfavourable – Inadequate

The current estimate (based on a 1997-2006 average) is 25% below the favourable reference population estimate (a 1971-1994 average). EC guidance states that where the current estimate is more than 25% below the favourable reference population, the parameter conclusion should be Unfavourable – Bad; therefore this assessment falls just short of that threshold. Furthermore, because the decline is not likely to have exceeded 1% per annum, population is reported as Unfavourable – Inadequate.

Although the Scottish resource is relatively stable, in parts of the W Scottish mainland and in the southern part of its UK range, many Atlantic salmon populations are small and vulnerable to stochastic events such as drought or disease. Most of these southern populations are failing their conservation limits (CEFAS and Environment Agency, 2007), making them especially vulnerable. Further, Atlantic salmon mortality rates at sea are thought to be approximately double that in the 1970s.

Figure 2.1 Total number of spawning multi-sea-winter Atlantic salmon and grilse caught between 1971 and 1994



SOURCE: Data extracted from the ICES 2007 report

Due to changing conditions at sea, the number of grilse in Scottish rivers now exceeds the number of multi-sea-winter Atlantic salmon, often by a factor of 5-7. (Between 1952 and 1980, the number of multi-sea-winter Atlantic salmon exceeded the number of grilse in 26 of 29 years (Fisheries Research Services, 2006)). Grilse are generally, (but not always) smaller than multi-sea-winter Atlantic salmon. This may, because fecundity is considered to be positively correlated with fish size (Hendry & Cragg-Hine 2003), impact both the numbers and pattern of egg deposition within rivers. In reality, however, the situation is likely to be complex Empirical data is not available, however, to quantify the scale of this problem, or to demonstrate that this is indeed a significant issue. Whilst shallow redds may be lost by the mobilisation of bed material, it is also worth noting that redds which are too deep, or have been buried under deeper gravels as a result of bed mobilisation, can also be negatively impacted by groundwater conditions in the hyporheic zone (i.e Youngson *et al.* 2004; Cardenas & Wilson 2006).

Grilse and multi-sea-winter fish are both important components of the Atlantic salmon resource in the UK. The switch to dominance by grilse in certain rivers does appear to signify a change from what may be considered to be the ‘norm’ by many, although this may be part of a longer-term cycle. Clearly, this is an area worthy of further investigation.

Atlantic salmon are divided into discrete, genetically distinct populations both between and within rivers. Based on an understanding of pressures and threats (see sections 2.9 and 2.10), maintenance and restoration of this genetic diversity is vital for species survival in the long term.

3. Habitat for the Species in the Biogeographic Region or Sea[2.5]

Freshwater: Clean well-oxygenated river gravels for spawning. Rivers with good water quality, coarse boulder / cobble / pebble substrates for fry and parr (juvenile fish), preferably with appropriate additional cover from woody debris, overhanging vegetation, aquatic macrophytes *etc.* Abundant supply of insect prey both from the river and from surrounding terrestrial habitats. Unimpeded access to and from the sea.

Marine: Nutrient-rich, cold water habitat supporting abundant plankton, especially krill, squid and small fish (*e.g.* sandeels, sprats, anchovies). Most multi-sea-winter UK fish feed off Greenland.

3.1 Surface area of habitat [2.5.2]

Unknown

Based on expert opinion, the accessible wetted area for England and Wales is 117.4km^2. No figures are available for Scotland or Northern Ireland. However, based on the surface area of these countries, it is likely that this figure would increase by a factor of approximately 2.5.

However, this can only be considered a ‘best guess’. Therefore, habitat area has been reported as unknown, until more definitive data becomes available.

3.2 Date of estimation[2.5.3]

Not applicable

3.3 Quality of data on habitat area[2.5.4]

Poor

3.4 Habitat trend[2.5.5]

Stable (Freshwater habitat)

Obligations of the Habitats Directive relate only to freshwater occurrence. Freshwater systems across the UK have most likely been stable and possibly improved slightly since the Habitats Directive came into force. On this basis, trend has been reported as stable.

However, changes in marine habitat can have profound effects on the population. The changing marine environment is favouring small grilse over larger life forms. Because these grilse have lower fecundity, declines in marine habitat will have notable negative effects on species survival, irrespective of freshwater recovery. Therefore, although the assessment (by necessity) is based on freshwater habitat only, consideration to both is given below.

Freshwater

Subsequent to historic declines, pollution levels in freshwater systems have been reduced in recent years (as a result of a decline in heavy industry and investment in the treatment of sewage effluent). Across much of the range practical works have also taken place in many rivers to remove man-made obstacles to Atlantic salmon migration. This is exemplified by the EU LIFE-Nature Conservation of Atlantic Salmon in Scotland (CASS) project and many other smaller ventures. Therefore, the extent of available habitat may also have increased in recent years.

Marine

Marine habitat has declined as a result of changes in climate. In the sea, Atlantic salmon feed pelagically on small fish and crustaceans. Much of this feeding occurs in very specific thermal habitat off Greenland. Climate change has caused the extent of this habitat to reduce substantially in recent years. Furthermore, climate change is thought to have caused the timing of the seaward migration to be poorly synchronised with conditions in the marine environment (Friedland *et al.*, 2003).

3.5 Habitat trend period[2.5.6]

1994 – 2006

3.6 Reasons for reported trend in habitat[2.5.7]

Not applicable

Historic declines resulted from organic pollution, industrial pollution and restriction of access by weirs *etc.* This decline has been curbed in recent years, as a result of positive conservation management and legislation.

3.7 Suitable habitat for the species (in km^2)[2.7.3]

Unknown

All rivers in the UK (the area of which is unknown).

3.8 Habitat conclusion[2.8]

Unfavourable – Inadequate but improving (Freshwater habitat)

Although freshwater habitat has been identified as stable and possibly improving, habitat quality has not yet sufficiently recovered from historic declines to ensure the long-term survival of this species throughout its range. (This judgement is based on expert opinion, backed up by Common Standards Monitoring results, which indicate that only two of 33 SACs designated for this species are in favourable condition; 28 were unfavourable, two have yet to be surveyed.)

The assessment for freshwater habitat is therefore Unfavourable – Inadequate, but improving to reflect positive conservation management discussed in section 3.4.

Although the marine habitat of Atlantic salmon is outside the control of the UK government (and hence not accounted for in the above conclusion) there is widespread agreement among fisheries scientists that changes in this environment are facilitating population declines in UK freshwater habitat. Implications of these declines are considered more fully in the Future Prospects section below.

4. Future Prospects[2.6]

Poor prospects (Freshwater)

The Atlantic salmon is a key species, symbolising the health of a river (not where status is driven by marine issues), and is being considered as a priority species under the UK Biodiversity Action Plan. Most people are proud of having this species in their local river, and there are many interest groups, both locally and nationally, dedicated to its conservation. This has resulted in Atlantic salmon being very well studied and monitored. Action driven by the Habitats Directive, the Water Framework Directive and other initiatives may cause some improvements to habitat and water quality; in freshwater systems across much of the UK conditions are improving due to declines in heavy industry and active conservation efforts. Additionally, reductions in livestock numbers following changes to agricultural subsidy rules are likely to improve habitat in many areas.

The effects of climate change on freshwater species over the next 12 years are difficult to predict. Findings of a preliminary study by Solomon (2005) suggest that high temperatures may have already affected the survival of southern chalk stream salmon during hot, dry summers; human activities such as historic removal of tree cover, abstraction, fish farming, sewage treatment works effluent, and water-meadow operation are thought to be contributing to higher river temperatures. In these areas, changes in climate may exacerbate the situation. However, predictive models are still at an early stage of development, and the extent and certainty of climate change effects are still largely unknown, particularly at a UK level.

Populations are continuing to decline at a steady rate in England and Wales, however, and as discussed in section 2.12, evidence suggests that the proportion of small grilse in freshwater populations is increasing (i.e. Fisheries Research Services, 2006). Although these changes are primarily attributed to external factors (i.e. changes in marine habitat), they make it difficult to confidently report that Atlantic salmon “will survive and prosper over the next 12 years”. A judgement of poor has therefore been given for this reporting round.

4.1 Future prospects conclusion[2.8]

Unfavourable – Inadequate

This species is subject to a high level of management, and freshwater conditions are largely improved following historic declines. However, due to external pressures, future prospects have been reported as poor. Hence, the conclusion for this parameter is Unfavourable – Inadequate.

External pressures

Although many high seas fisheries exploiting Atlantic salmon have been bought out, climate change has caused a major increase in mortality at sea. There seems little short-term prospect of taking effective action to improve marine habitat, which is strongly driven by large-scale oceanic and climatic processes (Hughes & Turrell, 2003). Since current climate change is driven by past emissions, this means that even under favourable emissions scenarios, marine habitat quality and extent will inevitably continue to decline for the next few decades. Recent observations that the Greenland ice mass may be at risk of disappearing altogether (Luthcke *et al.*, 2006) suggest that major and potentially catastrophic changes to the oceanic habitat of Atlantic salmon could occur in coming decades, further exacerbating the situation. If this were taken into account, the future prospects would be rated Unfavourable - Inadequate and deteriorating

5. Overall Conclusion [2.8]

Unfavourable – Inadequate

Based on the Population and Future prospects assessments, the overall conclusion is Unfavourable – Inadequate.

Table 5.1. Summary of conclusions

Parameter	Judgement	Grounds for Judgement (in accordance with Annex C)	Reliability*
Range	Favourable	Range is stable and not less than the favourable reference range	2
Population	Unfavourable – Inadequate	Any other combination The population estimate is below the favourable reference population, but not by more than 25%. Population decline is less than 1% per annum.	2
Habitat (freshwater)	Unfavourable – Inadequate but improving	Any other combination Note that although UK freshwater systems are stable, marine systems are declining	2
Future Prospects (freshwater)	Unfavourable – Inadequate	Any other combination Species is subject to a high level of management and freshwater conditions are largely improved. However, due to external pressures, future prospects have been reported as poor. Threats of climate change with regard to marine habitat may prove significant to long term survival. If this were taken into account the future prospects would be rated unfavourable - inadequate and deteriorating	2
Overall Assessment	Unfavourable - Inadequate	All parameters are Unfavourable – Inadequate	2

*1=High, 2=Moderate, 3=Low

High – Expert opinion is that the concluding judgement accurately reflects the current situation based on a professional understanding of the species. For range, population, and habitat, quality of data used to establish the current estimate has been identified as “good”; data used to inform trends is comprehensive and up to date.

Moderate – A greater understanding of the feature, or the factors affecting it, is required before a confident concluding judgement can be made by experts. For range, population, and habitat, the current estimate and/or trend are based on recent, but incomplete or limited survey data; or alternately, a comprehensive, but outdated (pre-1994) review.

Low – Judgements, and comprising estimates, are based predominately on expert opinion.

N/A – Assessment conclusion is “unknown”, on the basis of insufficient reliable information

6. References

CARDENAS, M.B. & WILSON, J.L. 2006. The influence of ambient groundwater discharge on exchange zones induced by current–bedform interactions. *Journal of Hydrology* **331:** 103– 109.

CENTRE FOR ENVIRONMENT FISHERIES & AQUATIC SCIENCE (CEFAS) & ENVIRONMENT AGENCY. 2007 *Annual assessment of salmon stocks and fisheries in England and Wales, 2006*. Cardiff: Environment Agency

CRISP, D.T. & CARLING, P.A. 1989. Observations on the siting, dimensions and structure of salmonid redds. *Journal of Fish Biology* **34:** 119-134.

DEVRIES, P 1997. Riverine salmonid egg burial depths: review of published data and implications for scour studies. Canadian Journal of Fisheries and Aquatic Sciences 54: 1685-1698.

DAVIES, C.E., SHELLEY, J., HARDING, P.T., MCLEAN, I.F.G., GARDINER, R & PEIRSON, G (eds.) 2004. *Freshwater fishes in Britain. The species and their distribution*. Colchester: Harley Books.

DOUGHTY, R. AND GARDINER, R. 2003. The Return of Salmon to Cleaner Rivers – A Scottish Perspective. Chapter 15 in: *Salmon at the Edge* (Ed. MILLS, D.). Oxford: Blackwell Scientific.

ENVIRONMENT AGENCY. 2006 *Fisheries Statistics* 2005 - *Salmonid and freshwater fisheries statistics for England and Wales, 2005*. Bristol: Environment Agency.

FISHERIES RESEARCH SERVICES 2006. *Scottish Salmon and Sea Trout Catches, 2005. Statistical Bulletin.* Fisheries Series No. Fis/2006/1. FRS Freshwater Laboratory, Montrose.

FRIEDLAND, K.D., REDDIN D.G., MCMENEMY, J.R., & DRINKWATER, K.F. 2003. Multidecadal trends in North American Atlantic salmon (*Salmo salar*) stocks and climate trends relevant to juvenile survival. *Canadian Journal of Fisheries and Aquatic Sciences* **60**: 568-583.

HENDRY, K. & CRAGG-HINE, D. 2003. *Ecology of the Atlantic salmon.* Conserving Natura 2000 Rivers - Ecology Series No. 7. English Nature, Peterborough. 32pp.

HUGHES, S & TURRELL,W.R. 2003. Prospects for Improved Oceanic Conditions. Chapter 20 in: *Salmon at the Edge* (Ed. MILLS, D.). Oxford: Blackwell Scientific.

INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA. 2000. *Report of the Working Group on North Atlantic Salmon. Copenhagen, 3-13 April 2000*. Copenhagen: International Council for the Exploration of the Sea (ICES CM2000/ACFM:13).

INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA. 2003. *Report of the Working Group on North Atlantic Salmon. Copenhagen, 31 March – 10 April 2003*. Copenhagen: International Council for the Exploration of the Sea (ICES CM2003/ACFM:19).

INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA. 2007. *Report of the Working Group on North Atlantic Salmon.*(ICES CM2007/ACFM:13).

LUTHCKE, SB, ZWALLY, HJ, ABDALATI, W, ROWLANDS, DD, RAY, RD, NEREM, RS, LEMOINE, FG, MCCARTHY, JJ AND CHINN, DS. 2006. Recent Greenland Ice Mass Loss by Drainage System from Satellite Gravity Observations. *Science* **314** (24 November 2006): 1286-1289

MAWLE, GW & MILNER, NJ. 2003. The Return of Salmon to Cleaner Rivers – England and Wales. Chapter 16 in: *Salmon at the Edge* (Ed. MILLS, D.). Oxford: Blackwell Scientific.

SOLOMON, DJ. 2005. *Anthropogenic influences on the temperaature regime in a chalk river*. Science Report SC040025/SR. Bristol: Environment Agency

YOUNGSON, A.F., MALCOLM, I.A., THORLEY, J.L., BACON, P.J. & SOULSBY, C. 2004. Long-residence groundwater effects on incubating salmonid eggs: low hyporheic oxygen impairs embryo development. *Canadian Journal of Fisheries and Aquatic Sciences* **61:** 2278–2287.

Map Data Sources

Biological Records Centre - Database for the Atlas of Freshwater Fishes; Joint Nature Conservation Committee - Marine Nature Conservation Review (MNCR) and associated benthic marine data; Highland Biological Recording Group Fish and Herptiles dataset; Countryside Council for Wales - Pembrokeshire Marine Species Atlas (via the NBN Gateway)