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Report of the ICES Advisory Committee on Fishery Management, Advisory Committee on the Marine Environment and Advisory Committee on Ecosystems, 2006

Book 10
North Atlantic Salmon Stocks

International Council for the Exploration of the Sea

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EXECUTIVE SUMMARY

- Exploitation continued to decline and nominal catch of Atlantic salmon in 2005 was the lowest in the time-series.
- Marine survival indices suggest that natural mortality remains high.
- The North American Commission 2SW stock complex is suffering reduced reproductive capacity. There are very few fisheries in this area and therefore other factors (fish passage, water quality, natural mortality) are contributing to continued low adult abundance.
- The Northern North East Atlantic Commission stock complexes (1SW and MSW) are at risk of suffering reduced reproductive capacity.
- The Southern North East Atlantic Commission stock complexes (1SW and MSW) are suffering reduced reproductive capacity.
- There are no catch options for the 2006–2008 fisheries at West Greenland and the Faroes that would allow the stated precautionary management objectives to be met.
- ICES notes that the percentage of coastal fisheries catches remains high in the NEAC and NAC Commission and in fact has risen slightly within the NAC Area. ICES advice has been to reduce exploitation in all mixed-stock fisheries to allow river-specific conservation limits to be met. This is best achieved by only allowing fisheries in estuaries and rivers on stocks which are above their conservation limits.

1 INTRODUCTION

1.1 Main Tasks

At its 2005 Statutory Meeting, ICES resolved (C. Res. 2005/2ACFM04) that the Working Group on North Atlantic Salmon [WGNAS] (Chair: T Sheehan, USA) will meet 4–13 April 2006 in Copenhagen, Denmark, to consider questions posed to ICES by the North Atlantic Salmon Conservation Organisation (NASCO). The terms of reference were met and the sections of the report which provide the answers are below:

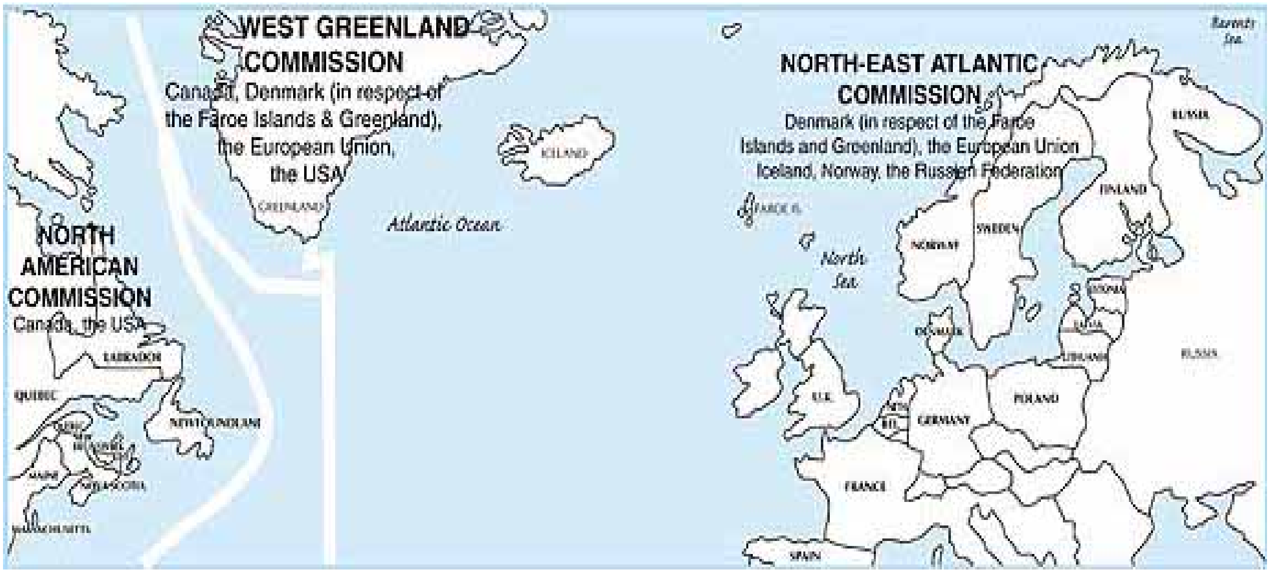
a)	With respect to Atlantic salmon in the North Atlantic Area:	Section 2
1)	provide an overview of salmon catches and landings, including unreported catches by country and catch and release, and worldwide production of farmed and ranched Atlantic salmon in 2005;	2.1 and 2.2
2)	report on significant developments which might assist NASCO with the management of salmon stocks including new or emerging threats to, or opportunities for, salmon conservation and management;	2.3
3)	report on developments in methods to identify origin of Atlantic salmon at a finer resolution than continent of origin (river stocks, country or stock complexes);	2.4
4)	describe sampling programmes for escaped farmed salmon, the precision of the identification methods employed and the reliability of the estimates obtained;	2.5
5)	provide an assessment of the minimum information needed which would signal a significant change in the previously provided advice for each Commission area;	2.6
6)	provide a compilation of tag releases by country in 2005;	2.7
7)	identify relevant data deficiencies, monitoring needs and research requirements [1].	Sec 6
b)	With respect to Atlantic salmon in the North-East Atlantic Commission area:	Section 3
1)	describe the key events of the 2005 fisheries and the status of the stocks[2];	3.9
2)	provide any new information on the extent to which the objectives of any significant management measures introduced in recent years have been achieved;	3.10
3)	further develop the age-specific stock conservation limits where possible based upon individual river stocks;	3.3
4)	provide annual catch options or alternative management advice for 2006-2008, if possible based on forecasts of PFA for northern and southern stocks, with an assessment of risks relative to the objective of exceeding stock conservation limits and advise on the implications of these options for stock rebuilding; [3]	3.4 and 3.6

5)	update and further refine estimates of by-catch of salmon in pelagic fisheries (including non-catch fishing mortality) with an assessment of impacts on returns to homewaters.	3.11
c)	With respect to Atlantic salmon in the North American Commission area:	Section 4
1)	describe the key events of the 2005 fisheries (including the fishery at St Pierre and Miquelon) and the status of the stocks; [2]	4.9
2)	provide any new information on the extent to which the objectives of any significant management measures introduced in recent years have been achieved;	4.10
3)	update age-specific stock conservation limits based on new information as available;	4.3
4)	provide annual catch options or alternative management advice for 2006-2008 with an assessment of risks relative to the objective of exceeding stock conservation limits and advise on the implications of these options for stock rebuilding. [3]	4.61 and 4.7
d)	With respect to Atlantic salmon in the West Greenland Commission area:	Section 5
1)	describe the events of the 2005 fisheries and the status of the stocks; [2, 4]	5.9
2)	provide any new information on the extent to which the objectives of any significant management measures introduced in recent years have been achieved;	5.11
3)	provide annual catch options or alternative management advice for 2006-2008 with an assessment of risk relative to the objective of exceeding stock conservation limits and advise on the implications of these options for stock rebuilding. [3]	5.4
Notes:	1. NASCO's International Atlantic Salmon Research Board's inventory of on-going research relating to salmon mortality in the sea will be provided to ICES to assist it in this task. 2. In the responses to questions 2.1, 3.1 and 4.1 ICES is asked to provide details of catch, gear, effort, composition and origin of the catch and rates of exploitation. For homewater fisheries, the information provided should indicate the location of the catch in the following categories: in-river; estuarine; and coastal. Any new information on non-catch fishing mortality, of the salmon gear used, and on the by-catch of other species in salmon gear, and on the by-catch of salmon in any existing and new fisheries for other species is also requested. 3. In response to questions 2.4, 3.4 and 4.3 provide a detailed explanation and critical examination of any changes to the models used to provide catch advice. 4. In response to question 4.1, ICES is requested to provide a brief summary of the status of North American and North-East Atlantic salmon stocks. The detailed information on the status of these stocks should be provided in response to questions 2.1 and 3.1.	

1.2 Management framework for salmon in the North Atlantic

The advice generated by ICES is in response to terms of reference posed by the North Atlantic Salmon Conservation Organization (NASCO), pursuant to its role in international management of salmon. NASCO was set up in 1984 by international convention (the Convention for the Conservation of Salmon in the North Atlantic Ocean), with a responsibility for the conservation, restoration, enhancement, and rational management of wild salmon in the North Atlantic. While sovereign states retain their role in the regulation of salmon fisheries for salmon originating from their own rivers, distant water salmon fisheries, such as those at Greenland and Faroes, which take salmon originating from rivers of another Party are regulated by NASCO under the terms of the Convention. NASCO now has seven Parties that are signatories to the Convention, including the EU which represents its Member States.

NASCO discharges these responsibilities via three Commission areas shown below:



1.3 Management objectives

NASCO (NASCO CNL31.210) has identified the primary management objective of that organisation as:

“To contribute through consultation and co-operation to the conservation, restoration, enhancement and rational management of salmon stocks taking into account the best scientific advice available”.

NASCO further stated that “the Agreement on the Adoption of a Precautionary Approach states that an objective for the management of salmon fisheries is to provide the diversity and abundance of salmon stocks” and NASCOs Standing Committee on the Precautionary Approach interpreted this as being “to maintain both the productive capacity and diversity of salmon stocks”.

NASCO’s Action Plan for Application of the Precautionary Approach (NASCO, 1999) provides interpretation of how this is to be achieved, as follows:

- “Management measures should be aimed at maintaining all stocks above their conservation limits by the use of management targets”.
- Socio-economic factors could be taken into account in applying the Precautionary Approach to fisheries management issues”:
- “The precautionary approach is an integrated approach that requires, inter alia, that stock rebuilding programmes (including as appropriate, habitat improvements, stock enhancement, and fishery management actions) be developed for stocks that are below conservation limits”.

1.4 Reference points and application of precaution

Conservation limits (CLs) for North Atlantic salmon stock complexes have been defined by ICES as the level of stock (number of spawners) that will achieve long-term average maximum sustainable yield (MSY). In many regions of North America, the conservation limits are calculated as the number of spawners required to fully seed the wetted area of the river. In some regions of Europe, pseudo stock-recruitment observations are used to calculate a hockey stick relationship, with the inflection point defining the conservation limits. In the remaining regions, the conservation limits are calculated as the number of spawners that will achieve long-term average maximum sustainable yield (MSY), as derived from the adult-to-adult stock and recruitment relationship (Ricker, 1975; ICES, 1993). NASCO has adopted the region-specific conservation limits (NASCO, 1998). The conservation limits are limit reference points (S_{lim}), which should be avoided with high probability.

Management targets have not yet been defined for all North Atlantic salmon stocks. When these have been defined they will play an important role in ICES advice.

For the assessment of the status of stocks and advice on management of national components and geographical groupings of the stock complexes in the NEAC area, where there are no specific management objectives:

- ICES considers a stock to be at full reproductive capacity when the lower bound of the 95% confidence interval of the current estimate of spawners is above the CL.

- ICES considers a stock to be at risk of suffering reduced reproductive capacity when the lower boundary of the confidence limit is below the CL, but the midpoint is above.
- ICES considers a stock to be suffering reduced reproductive capacity when the midpoint is below the CL.

It should be noted that this is equivalent to the ICES precautionary reference points (S_{pa}). Therefore, stocks are regarded by ICES as being at full reproductive capacity only if they are above the precautionary reference point (S_{pa}). This approach parallels the use of precautionary reference points used for the provision of catch advice for other fish stocks in the ICES area.

For management of the West Greenland fishery, NASCO has adopted a precautionary management plan requiring at least a 75% probability of achieving three management objectives:

- Meeting the conservation limits (S_{lim}) simultaneously in the four northern regions of North America: Labrador, Newfoundland, Quebec, and Gulf.
- Achieving increases in returns to the Scotia-Fundy and USA regions relative to the base years 1992–1996. Improvements of greater than 25% and 10% relative to base year returns are presented although, to achieve a 25% increase, by definition the 10% increase is also achieved.
- Meeting the conservation limits (S_{lim}) for the Southern NEAC MSW complex.

ICES applies the 75% treshold in the advice for the West Greenland fishery.

2 ATLANTIC SALMON IN THE NORTH ATLANTIC AREA

2.1 Catches of North Atlantic Salmon

2.1.1 Nominal catches of salmon

Nominal catches of salmon reported for each salmon-producing country in the North Atlantic are given in Table 2.1.1.1 for the years 1960–2005. These catches (in tonnes) are illustrated in Figure 2.1.1.1 for four North Atlantic regions. Catch statistics in the North Atlantic also include fish farm escapees and, in some North-East Atlantic countries, also ranched fish. Reported catches for the three NASCO Commission Areas for 1996–2005 are provided below.

AREA	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
NEAC	2750	2074	2225	2073	2736	2876	2495	2303	1977	1964
NAC	294	231	159	154	155	150	150	144	164	132
WGC	92	59	11	19	21	43	9	9	15	14
Total	3135	2364	2396	2246	2913	3069	2654	2456	2156	2110

The catch data for 2005 are provisional, but the total nominal catch of 2110 t is the lowest on record. Catches for most countries were below the recent 5 and 10 year averages, and in four countries were the lowest in the time series.

The nominal catch (in tonnes) of wild fish in 2005 was partitioned according to whether the catch was taken in coastal, estuarine, or riverine fisheries. These are shown below for the NEAC and NAC Commission Areas. It was not possible to apportion the small Danish catches in 2005 and these have been excluded from the calculation. The percentages accounted for by each fishery varied considerably between countries. In total, however, coastal fisheries accounted for 43% of catches in North East Atlantic countries compared to 20% in North America, whereas in-river fisheries took 50% of catches in North East Atlantic countries compared to 59% in North America:

AREA	COAST		ESTUARY		RIVER		TOTAL
	WEIGHT	%	WEIGHT	%	WEIGHT	%	WEIGHT
NEAC	843	43	129	7	987	50	1,959
NAC	27	20	27	20	78	59	132

ICES notes that the percentage of coastal fisheries catches remains high in the NEAC and NAC Commission areas and has increased within the NAC area (Figure 2.1.1.2). NASCO's management goal is to reduce exploitation to allow river-specific conservation limits to be met. This is best achieved by only allowing fisheries in estuaries and rivers which target stocks that are above the conservation limits. Therefore, the continuation of coastal fisheries in all Commission areas is of concern.

2.1.2 Catch and release

The practice of catch and release in rod fisheries has become increasingly common as a salmon management/conservation measure in light of the widespread decline in salmon abundance in the North Atlantic. For countries that reported such data in 2005, the percentage of the total rod catch that was released ranged from 17% in Iceland to 87% in Russia. Catch and release rates have generally increased over the last decade. Overall, almost 128 000 salmon were reported to have been released in 2005.

2.1.3 Unreported catches

The estimated unreported catch within the NASCO Commission Areas in 2005 was 717 t (Table 2.1.1.1), or 26% of the total catch. The unreported catch, expressed as a percentage of the total North Atlantic catch (nominal and unreported), has fluctuated between 23–34% since 1987. There has been a downward trend over the past 7 years, but this decrease is within the historical range of past variation. The introduction of carcass tagging programmes in Ireland and UK (N. Ireland) has lead to reductions in unreported catches in these countries. After 1994 there are no available data on the extent of possible salmon catches in international waters. Estimates (in tonnes) of unreported catches for the three Commission Areas for the period 1996–2005 are given below:

AREA	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
NEAC	947	732	1108	887	1135	1089	946	719	575	606
NAC	156	90	91	133	124	81	83	118	101	101
WGC	20	5	11	13	10	10	10	10	10	10

Expressed as a percentage of the total North Atlantic catch, unreported catch estimates range from 0% to 13% for individual countries. However, it should be noted that methods of estimating unreported catch vary both within and among countries. The non-reporting rates range from 2% to 56% of the total national catch in individual countries. An allowance for unreported catch is included in the assessments and catch advice for each Commission area.

2.2 Farming and sea ranching of Atlantic salmon

The provisional estimate of farmed Atlantic salmon production in the North Atlantic area for 2005 is 784 611 t. This represents a decrease on 2004 (831 207 t), but a 5% increase on the 5-year mean (2000–2004). Most of the North Atlantic production took place in Norway (72%) and UK (Scotland) (17%).

Worldwide production of farmed Atlantic salmon has been in excess of one million tonnes since 2002. Total production in 2005 is provisionally estimated at 1 261 638 tonnes (Figure 2.2.1), a 9% increase on 2004. Production outside the North Atlantic is currently estimated to account for 38% of total farmed production, with Chile (405 200 t) contributing the largest proportion of the production in this area. World-wide production of farmed Atlantic salmon in 2005 was almost 600 times the reported nominal catch of Atlantic salmon in the North Atlantic. Farmed salmon therefore dominate world markets.

Catches of ranched salmon have declined substantially from a high of over 500 t in 1993 to around 8 t in 2005 (Figure 2.2.2). This is due to the cessation of salmon ranching in Iceland from 1999.

2.3 NASCO has asked ICES to report on significant developments which might assist NASCO with the management of salmon stocks, including new or emerging threats to, or opportunities for, salmon conservation and management

2.3.1 Evaluation of options to develop a multi-year forecast of PFA_{NA} abundance

A forecast of the 1SW non-maturing fish PFA for North America is derived from the lagged spawner (LS) abundance which would contribute to the recruitment. ICES has previously described two temporal phases (ICES, 2003) of salmon production in the Northwest Atlantic. The PFA forecast model approximates production rate as a fixed parameter conditional on two levels of productivity. Using the PFA forecast model and the estimated lagged spawner values, three years of forecasts of PFA could be obtained. An evaluation of options for the development of a multi-year forecast and catch options was done using mid-point values of PFA and lagged spawner abundance. ICES concludes that the PFA forecast model can be used for up to three years and this approach was used to provide the multi-year forecasts of abundance for the North American PFA (Section 4.6–4.7).

2.3.2 Post-smolt trawling in the Labrador Sea, Fall 2005

In September 2005, the Canadian RV "*Wilfred Templeman*" carried out a series of trawl and gillnet surveys in areas of the Labrador Sea where salmon post-smolts and adult salmon had previously been caught. A total of 47 post-smolts and 11 adult salmon were caught during two gillnet sets, but only one post-smolt was caught during the trawling. This post-smolt was caught at night, suggesting that salmon might have been deeper in the water column during the day; salmon tagged with data storage tags have shown that salmon may be found closer to the surface at night.

A disease survey on 90 salmon collected in 2005 and 2001 indicated an absence of disease pathogens, including ISAV and VHSV. Based on these results, it is unlikely that these disease pathogens are prevalent in salmon in the Labrador Sea.

2.3.3 Fatty acid profiles and stock discrimination

The profile of fatty acids in selected tissues has been shown to differ between recognised stocks of fish. Results from a pilot project on fatty acid profiles in Atlantic salmon were presented to ICES and demonstrated a genetic component in the determination of the composition of the tissue fatty acids. The results indicated the potential for using fatty acid profiles in stock identification either on its own or in combination with other methods.

2.3.4 Preliminary investigations into the deterrence of cormorants to reduce predation on migratory smolts

ICES reviewed a study (Maine, USA) to assess the efficacy of non-lethal exclusion of double-crested cormorants from the lower Narraguagus River as a means of reducing predation on migrating Atlantic salmon smolts. Results of this study indicate that harassment activities were successful in displacing birds and changing their behaviour, but were not successful in excluding cormorants from the freshwater and estuary areas entirely. There was no apparent increase in smolt survival related to the cormorant harassment activities.

2.4 NASCO has asked ICES to report on developments in methods to identify origin of Atlantic salmon at a finer resolution than continent of origin (river stocks, country or stock complexes)

Within a mixed stock fishery, the identification of origin and composition of the catch is essential for responsible management. Various collaborative genetic stock identification projects are ongoing which may yield significant advances in techniques and methods in coming years:

- The Atlantic Salmon Arc Project (ASAP) – Aims to collect samples from the majority of salmon rivers on the Western Atlantic coast of Europe and use methods of Genetic Stock Identification (GSI) to 'genetically type' salmon from particular regions and rivers.
- SALMAN (Atlantic Salmon Microsatellite Analysis Network) – Aims to agree on standardised screening methods for data to develop an international database on microsatellite variation in Atlantic salmon for use in GSI work at local, regional and continental scales.
- FishTrace – an EU project to develop a reference database that links genetic, taxonomic, and biological data for the main European commercial fish species.
- Stock Identification of Irish Salmon Stocks – Aims to establish a baseline of genetic markers for all Irish salmon rivers combined with GIS mapping of spawning areas to provide information relative to identified spawning areas.

ICES recommends that sampling programmes for all mixed-stock fisheries and populations contributing to mixed-stock fisheries be continued or initiated to further support analyses on the impacts of mixed stock fisheries.

ICES recommends the continued development of genetic stock identification methods for determining the composition of mixed stock fisheries.

2.4.1 West Greenland mixed stock fishery

ICES previously endorsed the Probabilistic-based Genetic Assignment model (PGA) for partitioning the harvest of mixed stock fisheries at a finer scale than continent of origin (ICES 2005). New information was available for 2003–2004 which was in agreement with previous estimates that the North American stock complex dominated the catch since 2000 (approximately 64–73%). Furthermore, more than 96% of the North American contribution was from the Canadian stock complex.

2.4.2 Spatio-temporal distribution of North American Atlantic salmon populations off West Greenland

ICES previously noted that reference baseline datasets for the European and Canadian stock complexes lack adequate spatial and temporal coverage for finer scale assignments with acceptable accuracy. ICES was informed of a new project to evaluate the spatio-temporal distribution of North American Atlantic salmon populations on the west coast of Greenland, using microsatellite markers. To date, 70 rivers have been sampled and will comprise the reference populations for the analyses.

2.4.3 St. Pierre and Miquelon mixed stock fishery

ICES noted that a sampling programme was conducted in the mixed-stock fishery at St. Pierre and Miquelon in 2004. The PGA was applied to 134 scale and tissue samples. As expected, all the samples were assigned to North America; it was estimated that 2% of the harvest originated from USA while the remaining 98% originated from Canada.

2.5 NASCO has asked ICES to describe sampling programmes for escaped farmed salmon, the precision of the identification methods employed and the reliability of the estimates obtained

The production of farmed Atlantic salmon has increased considerably over the past 20 years, and farmed salmon now far outnumber their wild conspecifics. Some of these farmed fish escape into the wild, and this may lead to mixing with local stocks and to potentially harmful effects on these stocks and other species.

2.5.1 Techniques for identifying escaped farmed salmon

There are a range of techniques for identifying fish farm escapees:

- **Morphology / Morphometry** – Farmed salmon commonly have external defects on the fins and elsewhere, which can be used to distinguish them from wild fish. The extent to which such defects may be manifest will be affected by a range of factors, including the rearing conditions in the farm, the age and stage at the time of escape, and the period of time at large prior to capture. Such defects allow the identification of farmed salmon by laymen, although the reliability of detection is unclear. Discriminant models, based on measurements of fins and other morphological features have shown high accuracy (usually up to 100%) for fish that have recently escaped.
- **Scale and otolith pattern recognition** – Scales are not regarded as reliable for discriminating farmed fish that escape early in their life (e.g. at the fry stage) from wild fish. However, differences in growth patterns between farmed and wild fish can be detected in both scales and otoliths. In USA, using only images of scales from known origin adult salmon, readers had 80% accuracy distinguishing aquaculture fish from wild and restoration fish.
- **Biochemical and physiological markers** – Farmed fish are commonly vaccinated and this leads to intra-abdominal adhesions, which can be detected by inspection of the opened abdominal cavity. The use of carotenoid pigments (canthaxanthin and astaxanthin) in the food of farmed salmon provides another approach for identifying farmed fish and their progeny. In addition, trace elements and stable isotopes in fish can provide a chemical signature of the environment at the time of bone or scale formation. The accuracy of this technique is unknown.
- **Genetic markers** – The recent development of genetic markers has provided useful new methods for stock identification. By combining information from highly polymorphic DNA markers and new statistical methods (assignment tests) it is possible to assign probabilities that samples originate from different populations. Because farmed Atlantic salmon consist of relatively few strains, this technique has the potential to distinguish wild salmon from farmed salmon. However, to date this is not yet possible for populations that are close to farmed salmon cages. In the USA, aquaculture companies have proposed to apply genetic marking to develop a unique company mark.
- **Large-scale group marking in farms** – Large-scale marking programmes have the potential to provide 100% accuracy at identifying a farmed salmon. Some countries now require a proportion of the fish held in sea cages to be marked with coded wire tags.

Conclusion

Options for screening farmed fish cover different requirements and the choice of method needs to be evaluated against the objectives of particular programmes. The methods outlined above, with the possible exception of otolith microchemistry and genetic techniques, can class fish as either farmed or wild, but they cannot identify the origin of the farmed fish. Where greater certainty is required a combination of methods is likely to be required.

For routine monitoring purposes, and where there may be a requirement for fish to be kept alive, there is a need for relatively easy field sampling and laboratory processes. Currently a combination of morphological examination and scale analysis is currently considered be the most practical and cost-effective option in such cases. New genetic stock identification techniques may identify wild from farm salmon and may allow the identification of the origin of escaped farm salmon. These techniques may become the preferred method in the future.

However, the most important requirement is to limit the impact of farm escapees on spawning stocks. More emphasis should be placed on physical means to prevent escapes and restricting their access to spawning populations (e.g. in-river trapping facilities or fisheries targeting escaped farmed salmon).

2.5.2 Sampling programmes in different countries

ICES reviewed existing sampling programmes to screen for fish farm escapees. In the NAC area, targeted sampling in the USA occurs only when fisheries agencies examine returns to traps or weirs. There has been an annual monitoring programme in the New Brunswick salmon-farming region on the Magaguadavic River since 1992. Monitoring has also included counting fences in the Bocabec River (1999–2000) and Dennis Stream (2001–2002). All adult salmon, parr, or smolts included in supportive breeding programs are genetically screened for continent of origin and for distant origin. Rivers in New Brunswick with aquaculture hatcheries have been electrofished in an attempt to assess the scale of juvenile salmon escapes and their distribution.

Screening for farmed fish occurs in most NEAC countries. Programmes vary from voluntary reporting by anglers to targeted screening of catches and in-river traps. Most screening programmes rely on scale samples in conjunction with morphometric observations to categorise salmon as wild or farmed. Since escapees can be regarded as damaged fish and sold separately, these fish are sometimes not included in the main catches being examined. Furthermore, the level of expertise and consistency of scanning may be variable. Thus estimates of farmed fish in catches are usually regarded as minimum estimates. In Norway, the behaviour and dispersal of farmed salmon is currently under investigation by means of releases of tagged fish to simulate escaped fish. In Iceland, farms are required to tag approximately 10% of the salmon reared in sea-cages. There is little systematic reporting of fish farm escapees in riverine catches. Therefore there is a lack of information on the incidence of escapees in river catches or more importantly in spawning stocks.

2.5.3 Behaviour of escaped farmed salmon

Information was available of two studies on the behaviour of escape of farmed salmon: one based on tracking escaped farmed salmon with acoustic tags, and the other from analysis of tag recoveries from farmed and wild salmon tagged with external tags. The following conclusions were drawn:

1) Wild salmon returned to the river they left as smolts with high precision.
2) Hatchery-reared salmon released as smolts returned to spawn in the river in which they were released.
3) Hatchery-reared salmon released as smolts from a marine site returned to the same geographical sea area in which they were released, and entered rivers in this area to spawn.
4) Farmed salmon released as postsmolts from a marine site survived poorly and strayed in larger numbers and over greater distances than salmon released as smolts.
5) Escaped large farmed salmon were apparently ‘homeless’ and appeared to move with the prevailing current. Survival of these fish improved if they escaped close to maturity.
6) Survival and migratory patterns of farmed fish were dependent on the time of escape.
7) Survival and migratory patterns of farmed fish were also dependent on the life stage at escape.

2.6 NASCO has asked ICES to provide an assessment of the minimum information needed which would signal a significant change in the previously provided catch advice for each Commission area

ICES considers it highly unlikely that the catch options provided for each Commission area will change during the next three years. The lagged spawner abundance is set for the PFA years 2006–2008 for both NAC and NEAC stocks contributing to West Greenland. Those spawners have already returned to their natal rivers.

Any significant change in productivity can be identified by existing monitoring programmes routinely carried out across the North Atlantic. These changes can only be detected after all the monitoring has been carried out and the results have been analysed using traditional modelling techniques.

In order to assist managers in the use of the multi-year advice, advance notice of possible changes in stock status or productivity will require the development of specific indicators. Examples of possible indicators are:

- smolt return rates of 1SW and 2SW salmon
- overall returns to rivers as 2SW adults (Figure 2.6.1).

These indicators have not been fully explored and more work is needed to conclude on the relationships between indicator and variable of interest (e.g. PFA) In principal, return rates of smolts should be better indicators for the PFA state than the returns of salmon because they are corrected for smolt output.

The use of indicators to determine the abundance of salmon requires the development of an indicator framework which consists of: (1) a relationship between the indicator and the PFA and (2) an indicator trigger point that is related to a threshold PFA value (conservation limit) The decision rule would then be based on the indicator trigger point. The trigger point can be defined using past observations. The intention is to avoid false high states and false low states (Figure 2.6.2). A false high state may threaten conservation if fisheries were to proceed. A false low state would result in foregone harvest but would not threaten the resource. Thus the trigger point will need to balance the risk to the stock with the possibility of foregone harvest.

The decision rule in the indicator framework needs to be robust against measurement variability of the indicator (compliance rules). One year of positive indicators would be a risky basis for changing multi-year catch options. Compliance rules are used in salmon fisheries management in the UK (England and Wales).

A difficulty in developing indicator frameworks is that PFA histories for both NAC and the southern NEAC MSW stock complexes describe the movement from a high state to a low state, but there are no data on the movement from a low state to a high state. Atlantic salmon monitoring programmes across the North Atlantic which provide possible indicator variables should be continued and opportunities for initiating new monitoring programmes should be explored.

An example of an indicator framework based on the returns of 2SW salmon is shown in Figure 2.6.3. The returns of 2SW salmon were enumerated for a number of different rivers and the corresponding PFA state for that same year was assigned (high-low). The proportion of indicators that suggested a high PFA state was variable but when more than 50% of the indicators suggested a high PFA, the actual PFA abundance had been above the conservation limit (i.e. the threshold value).

2.7 Compilation of tag releases and finclip data by ICES member countries in 2005

Data on releases of tagged, fin-clipped, and otherwise marked salmon in 2005 were provided by ICES and are compiled as a separate report. A summary of tag releases is provided in Table 2.7.1.

2.8 Analysis of historic tagging data

With the recent focus on research on salmon at sea, ICES considered that there would be merit in examining historic data. Most countries in the North Atlantic have tagged large numbers of salmon at different life stages, but many of these data have not been properly analysed and published. ICES believes that analysis of this material will generate new information on the marine life history of salmon, for example the distribution of different stocks in time and space, migratory routes, migration speed and marine growth, and whether these have changed over time. Scale samples for these tagged fish might also enable investigation of scale microchemistry (e.g. trace elements/stable isotopes and genetic analyses). ICES therefore recommends that a workshop be held on the development and use of old tagging information from oceanic areas.

Table 2.1.1.1. Nominal catch of salmon by country (in tonnes round fresh weight), 1960–2005. (2005 figures include provisional data).

	NAC Area			NEAC (N. Area)							NEAC (S. Area)						Faroes & Greenland				Total	Unreported catches	
Year	Canada (1)	USA	St. P&M	Norway (2)	Russia (3)	Iceland Wild	Iceland Ranch	Sweden (West)	Den.	Finland	Ireland (4,5)	UK (E & W)	UK (N.Irl.) (5,6)	UK (Scotl.)	France (7)	Spain (8,9)	Faroes (10)	East Grld.	West Grld. (11)	Other (12)	Reported Nominal Catch	NASCO Areas	International waters (13)
1960	1,636	1	-	1,659	1,100	100		40	-	-	743	283	139	1,443	-	33	-	-	60	-	7,237	-	-
1961	1,583	1	-	1,533	790	127		27	-	-	707	232	132	1,185	-	20	-	-	127	-	6,464	-	-
1962	1,719	1	-	1,935	710	125		45	-	-	1,459	318	356	1,738	-	23	-	-	244	-	8,673	-	-
1963	1,861	1	-	1,786	480	145		23	-	-	1,458	325	306	1,725	-	28	-	-	466	-	8,604	-	-
1964	2,069	1	-	2,147	590	135		36	-	-	1,617	307	377	1,907	-	34	-	-	1,539	-	10,759	-	-
1965	2,116	1	-	2,000	590	133		40	-	-	1,457	320	281	1,593	-	42	-	-	861	-	9,434	-	-
1966	2,369	1	-	1,791	570	104	2	36	-	-	1,238	387	287	1,595	-	42	-	-	1,370	-	9,792	-	-
1967	2,863	1	-	1,980	883	144	2	25	-	-	1,463	420	449	2,117	-	43	-	-	1,601	-	11,991	-	-
1968	2,111	1	-	1,514	827	161	1	20	-	-	1,413	282	312	1,578	-	38	5	-	1,127	403	9,793	-	-
1969	2,202	1	-	1,383	360	131	2	22	-	-	1,730	377	267	1,955	-	54	7	-	2,210	893	11,594	-	-
1970	2,323	1	-	1,171	448	182	13	20	-	-	1,787	527	297	1,392	-	45	12	-	2,146	922	11,286	-	-
1971	1,992	1	-	1,207	417	196	8	18	-	-	1,639	426	234	1,421	-	16	-	-	2,689	471	10,735	-	-
1972	1,759	1	-	1,578	462	245	5	18	-	32	1,804	442	210	1,727	34	40	9	-	2,113	486	10,965	-	-
1973	2,434	3	-	1,726	772	148	8	23	-	50	1,930	450	182	2,006	12	24	28	-	2,341	533	12,670	-	-
1974	2,539	1	-	1,633	709	215	10	32	-	76	2,128	383	184	1,628	13	16	20	-	1,917	373	11,877	-	-
1975	2,485	2	-	1,537	811	145	21	26	-	76	2,216	447	164	1,621	25	27	28	-	2,030	475	12,136	-	-
1976	2,506	1	3	1,530	542	216	9	20	-	66	1,561	208	113	1,019	9	21	40	<1	1,175	289	9,327	-	-
1977	2,545	2	-	1,488	497	123	7	10	-	59	1,372	345	110	1,160	19	19	40	6	1,420	192	9,414	-	-
1978	1,545	4	-	1,050	476	285	6	10	-	37	1,230	349	148	1,323	20	32	37	8	984	138	7,682	-	-
1979	1,287	3	-	1,831	455	219	6	12	-	26	1,097	261	99	1,076	10	29	119	<0,5	1,395	193	8,118	-	-
1980	2,680	6	-	1,830	664	241	8	17	-	34	947	360	122	1,134	30	47	536	<0,5	1,194	277	10,127	-	-
1981	2,437	6	-	1,656	463	147	16	26	-	44	685	493	101	1,233	20	25	1,025	<0,5	1,264	313	9,954	-	-
1982	1,798	6	-	1,348	364	130	17	25	-	54	993	286	132	1,092	20	10	606	<0,5	1,077	437	8,395	-	-
1983	1,424	1	3	1,550	507	166	32	28	-	58	1,656	429	187	1,221	16	23	678	<0,5	310	466	8,755	-	-
1984	1,112	2	3	1,623	593	139	20	40	-	46	829	345	78	1,013	25	18	628	<0,5	297	101	6,912	-	-
1985	1,133	2	3	1,561	659	162	55	45	-	49	1,595	361	98	913	22	13	566	7	864	-	8,108	-	-
1986	1,559	2	3	1,598	608	232	59	54	-	37	1,730	430	109	1,271	28	27	530	19	960	-	9,255	315	-
1987	1,784	1	2	1,385	564	181	40	47	-	49	1,239	302	56	922	27	18	576	<0,5	966	-	8,159	2,788	-
1988	1,310	1	2	1,076	420	217	180	40	-	36	1,874	395	114	882	32	18	243	4	893	-	7,737	3,248	-
1989	1,139	2	2	905	364	141	136	29	-	52	1,079	296	142	895	14	7	364	-	337	-	5,904	2,277	-
1990	911	2	2	930	313	146	280	33	13	60	567	338	94	624	15	7	315	-	274	-	4,924	1,890	180-350

Table 2.1.1.1. continued

	NAC Area			NEAC (N. Area)							NEAC (S. Area)						Faroes & Greenland				Total	Unreported catches	
Year	Canada (1)	USA	St. P&M	Norway (2)	Russia (3)	Iceland Wild	Iceland Ranch	Sweden (West)	Den.	Finland	Ireland (4,5)	UK (E & W)	UK (N.Irl.) (5,6)	UK (Scotl.)	France (7)	Spain (8,9)	Faroes (10)	East Grld.	West Grld. (11)	Other (12)	Reported Nominal Catch	NASCO Areas	International waters (13)
1991	711	1	1	876	215	130	345	38	3	70	404	200	55	462	13	11	95	4	472	-	4,106	1,682	25-100
1992	522	1	2	867	167	175	461	49	10	77	630	171	91	600	20	11	23	5	237	-	4,119	1,962	25-100
1993	373	1	3	923	139	160	496	56	9	70	541	248	83	547	16	8	23	-	-	-	3,696	1,644	25-100
1994	355	0	3	996	141	141	308	44	6	49	804	324	91	649	18	10	6	-	-	-	3,945	1,276	25-100
1995	260	0	1	839	128	150	298	37	3	48	790	295	83	588	10	9	5	2	83	-	3,629	1,060	-
1996	292	0	2	787	131	122	239	33	2	44	685	183	77	427	13	7	-	0	92	-	3,135	1,123	-
1997	229	0	2	630	111	106	50	19	1	45	570	142	93	296	8	3	-	1	58	-	2,364	827	-
1998	157	0	2	740	131	130	34	15	1	48	624	123	78	283	8	4	6	0	11	-	2,396	1,210	-
1999	152	0	2	811	103	120	26	16	1	62	515	150	53	199	11	6	0	0	19	-	2,246	1,032	-
2000	153	0	2	1,176	124	83	2	33	5	95	621	219	78	274	11	7	8	0	21	-	2,913	1,269	-
2001	148	0	2	1,267	114	88	0	33	6	126	730	184	53	251	11	13	0	0	43	-	3,069	1,180	-
2002	148	0	2	1,019	118	97	0	28	5	93	682	161	81	191	11	9	0	0	9	-	2,654	1,039	-
2003	141	0	3	1,071	107	110	0	25	4	78	551	89	56	192	13	7	0	0	9	-	2,456	847	-
2004	161	0	3	784	82	130	0	19	4	39	489	111	48	245	19	7	0	0	15	-	2,156	686	-
2005	129	0	3	888	82	149	0	15	5	47	428	94	45	191	11	9	0	0	14	-	2,110	717	-
Average																							
2000-2004	150	0	2	1,063	109	102	0	28	5	86	615	153	63	231	13	9	2	0	19	-	2,649	1,004	-
1995-2004	184	0	2	912	115	114	65	26	3	68	626	166	70	295	12	7	2	0	36	-	2,702	1,027	-

Key:

1. Includes estimates of some local sales, and, prior to 1984, by-catch.
2. Before 1966, sea trout and sea charr included (5% of total).
3. Figures from 1991 to 2000 do not include catches taken in the recently developed recreational (rod) fishery.
4. From 1994, includes increased reporting of rod catches.
5. Catch on River Foyle allocated 50% Ireland and 50% N. Ireland.
6. Includes angling catch from 2002.
7. Data for France include some unreported catches.
8. Weights estimated from mean weight of fish caught in Asturias (80-90% of Spanish catch).
9. Catch data for 2005 not available at time of meeting; catch estimated as mean of previous 5 years.
10. Between 1991 & 1999, there was only a research fishery at Faroes. In 1997 & 1999 no fishery took place; the commercial fishery resumed in 2000, but has not operated since 2001.
11. Includes catches made in the West Greenland area by Norway, Faroes, Sweden and Denmark in 1965-1975.
12. Includes catches in Norwegian Sea by vessels from Denmark, Sweden, Germany, Norway and Finland.
13. Estimates refer to season ending in given year.

Table 2.7.1. Summary of Atlantic salmon tagged and marked in 2005 – 'Hatchery' and 'Wild' refer to smolts and parr; 'Adults' relates to both wild and hatchery-origin fish.

		Primary Tag or Mark				
Country	Origin	Microtag	External mark	Adipose clip	Pit tag	Total
Belgium	Hatchery	15,481	0	5,599	0	21,080
	Wild	0	0	0	0	0
	Adult	0	0	0	0	0
	Total	15,481	0	5,599	0	21,080
Canada	Hatchery	0	2,712	1,092,301	0	1,095,013
	Wild	0	22,199	8,760	0	30,959
	Adult	0	5,414	972	0	6,386
	Total	0	30,325	1,102,033	0	1,132,358
France	Hatchery	0	121,308	471,551	0	592,859
	Wild	0	10,387	698	3,655	14,740
	Adult	18	402	549	156	1,125
	Total	15	132,097	472,798	3,811	608,724
Germany	Hatchery	59,237	6,175	128,252	0	193,664
	Wild	0	0	0	0	0
	Adult	0	175	0	0	175
	Total	59,237	6,350	128,252	0	193,839
Iceland [1]	Hatchery	259,880	516	0	0	260,396
	Wild	3,386	0	0	0	3,386
	Adult	0	710	0	0	710
	Total	263,266	1,226	0	0	264,492
Ireland	Hatchery	333,575	0	0	0	333,575
	Wild	4,328	0	0	0	4,328
	Adult	0	0	0	0	0
	Total	337,903	0	0	0	337,903
Norway	Hatchery	48,399	0	0	0	48,399
	Wild	3,347	0	0	0	3,347
	Adult	0	0	0	0	0
	Total	51,746	0	0	0	51,746
Russia	Hatchery	0	0	1,576,200	0	1,576,200
	Wild	0	0	0	0	0
	Adult	0	2,074	0	0	2,074
	Total	0	2,074	1,576,200	0	1,578,274
Spain	Hatchery	163,881	0	308,562	0	472,443
	Wild	0	0	0	0	0
	Adult	0	0	0	0	0
	Total	163,881	0	308,562	0	472,443
Sweden	Hatchery	0	2,659	192,658	0	195,317
	Wild	0	400	0	0	400
	Adult	0	0	0	0	0
	Total	0	3,059	192,658	0	195,717
UK (England & Wales)	Hatchery	69,034	0	119,314	0	188,348
	Wild	12,240	0	14,080	0	26,320
	Adult	0	1,792	0	0	1,792
	Total	81,274	1,792	133,394	0	216,460
UK (N. Ireland)	Hatchery	14,617	3,741	32,476	0	50,834
	Wild	2067	0	0	0	2,067
	Adult	0	0	0	0	0
	Total	16,684	3,741	32,476	0	52,901
UK (Scotland) [2]	Hatchery	4135	1,250	0	0	5,385
	Wild	5860	1193	450	7,472	14,975
	Adult	0	595	0	0	595
	Total	9,995	3,038	450	7,472	20,955
USA [3]	Hatchery	0	172,969	311,487	2,901	487,357
	Wild	0	60	0	453	513
	Adult	0	3,550	0	0	3,550
	Total	0	176,579	311,487	3,354	491,420
All Countries	Hatchery	893,521	305,155	4,104,549	2,901	5,520,870
	Wild	31,228	34,239	23,988	11,580	101,035
	Adult	18	14,537	1,521	156	16,407
	Total	924,767	353,931	4,130,058	14,637	5,638,312

[1] The number of microtagged hatchery fish in Iceland includes 148,740 fish reared in sea-pens.

[2] PIT tagged juveniles in Scotland also adipose fin-clipped.

[3] Total numbers include internal tags.

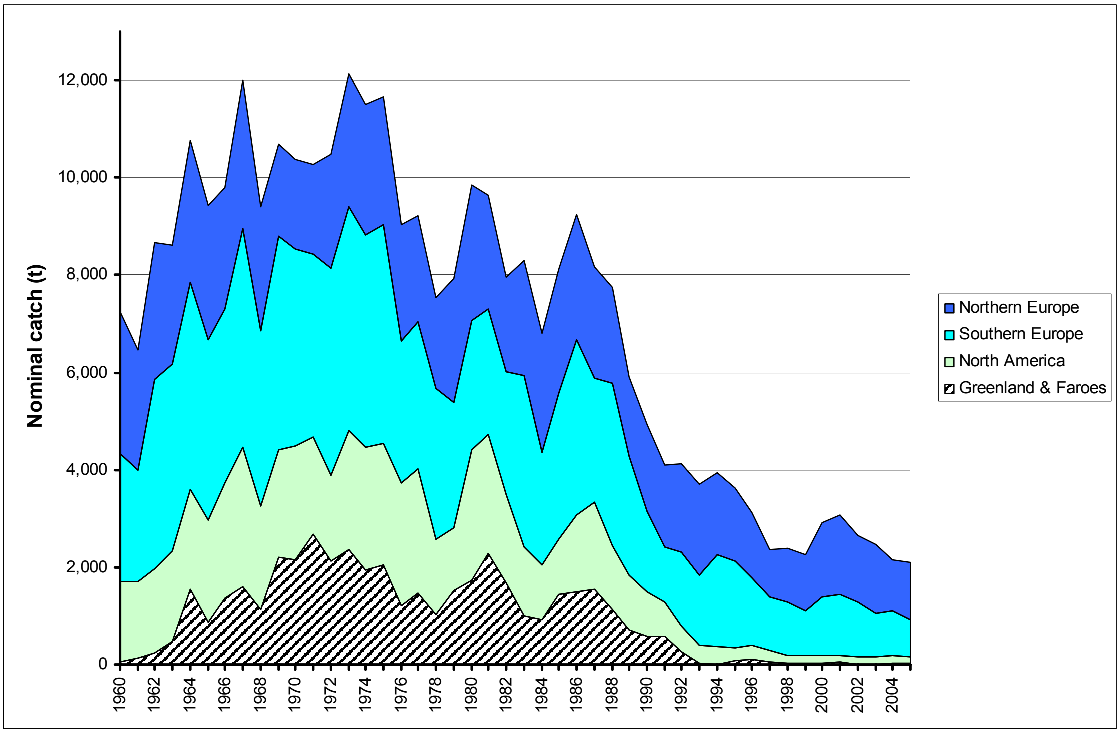


Figure 2.1.1.1. Nominal catches of salmon (tonnes round fresh weight) in four North Atlantic regions, 1960-2005.

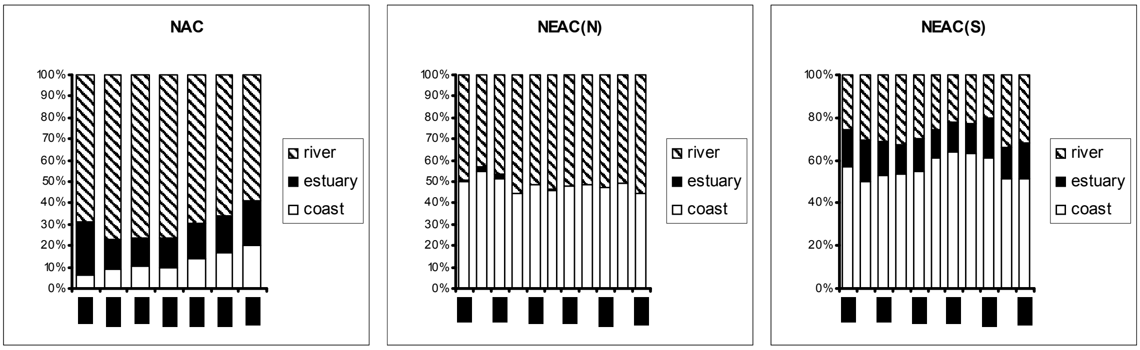


Figure 2.1.1.2. Percentages of nominal catch taken in coastal, estuarine, and riverine fisheries (1995–2005) for the NAC area and for the NEAC northern and southern areas.

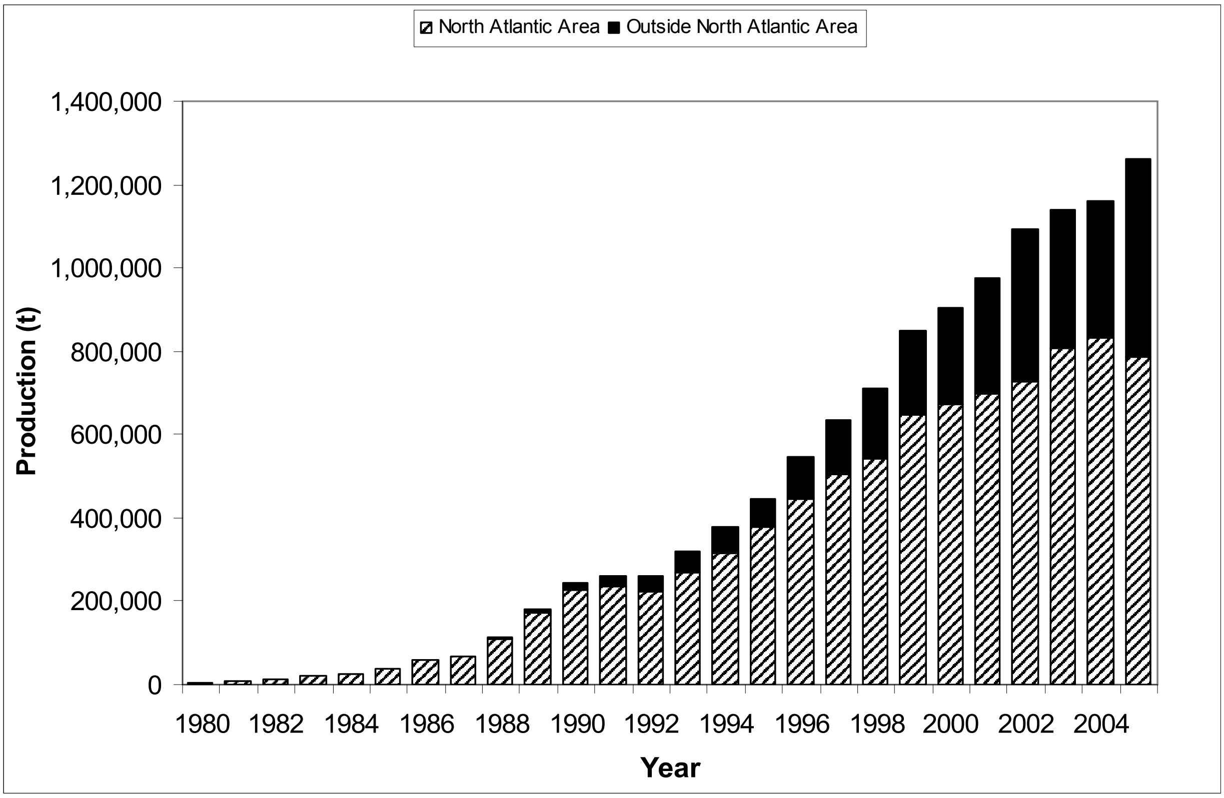


Figure 2.2.1. World-wide production of farmed Atlantic salmon, 1980–2005.

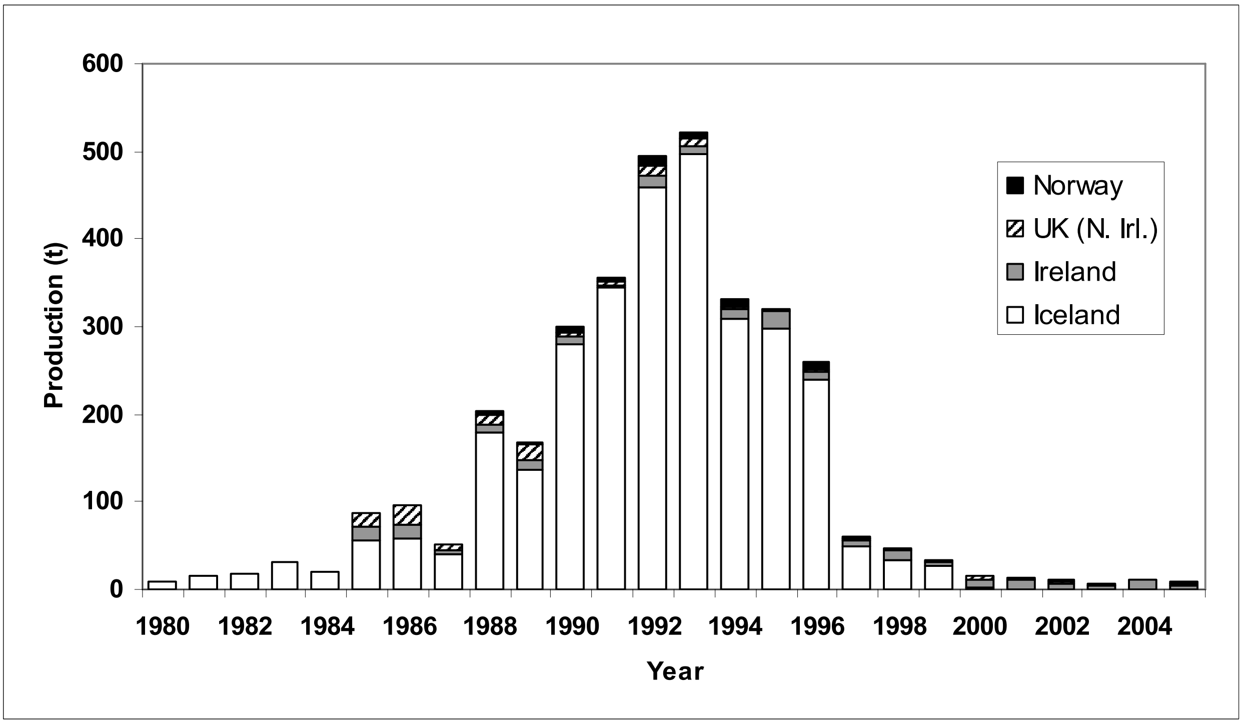


Figure 2.2.2. Production of ranched Atlantic salmon (tonnes round fresh weight) as harvested at ranching facilities in the North Atlantic, 1980–2005.

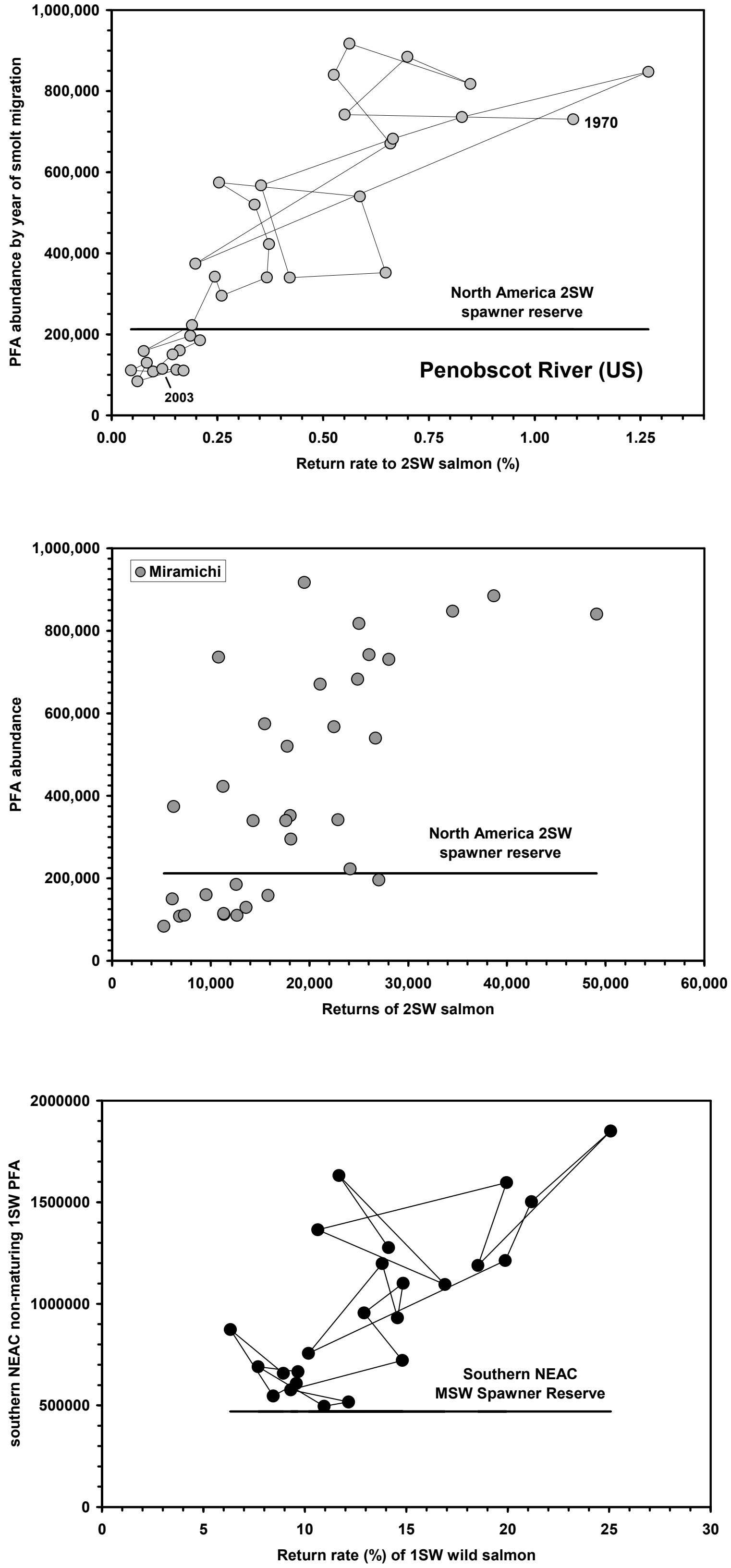


Figure 2.6.1. Examples of indictors and their relationship with PFA reconstructed estimates from North America (top, middle) and NEAC (bottom).

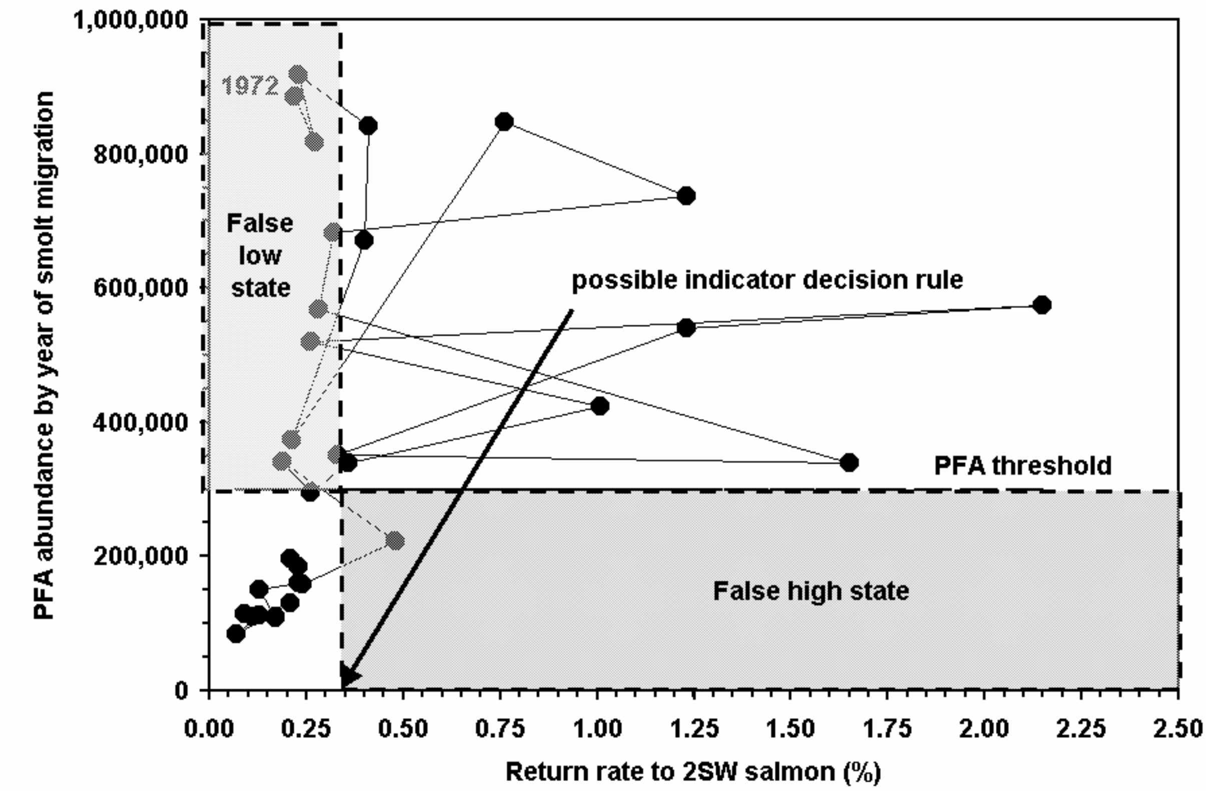


Figure 2.6.2. Illustration of PFA threshold, potential indicator decision rule, and false high state and false low state zones used to objectively define the indicator decision rule relative to a value function that penalizes wrong assignments of PFA state, i.e. observations in either the false high state or false low state quadrats.

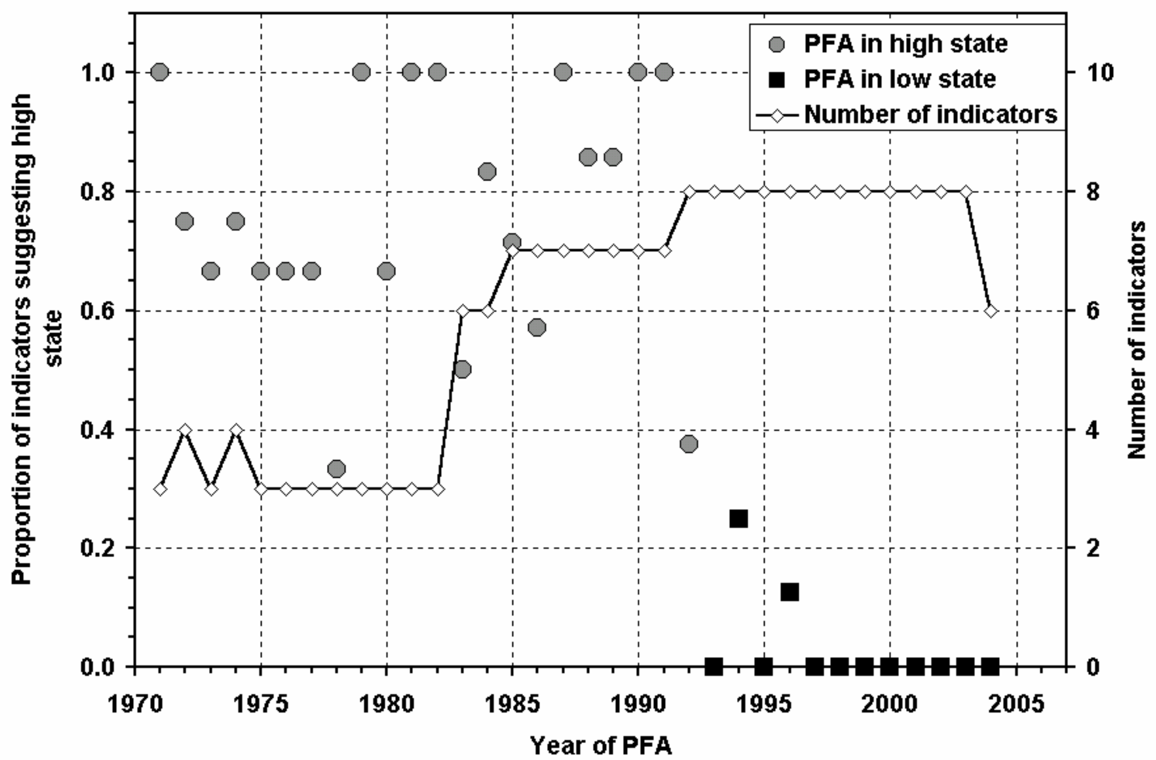


Figure 2.6.3. Assigning the state of PFA abundance for the years 1971 to 2004 using the returns of large/2SW salmon simultaneously for three to eight monitored rivers in North America.

3 NORTH-EAST ATLANTIC COMMISSION

Conservation limits (CLs) for North Atlantic salmon stock complexes have been defined by ICES as the level of stock (number of spawners) that will achieve long-term average maximum sustainable yield (MSY). NASCO has adopted this definition of CLs (NASCO, 1998). In this regard, the CL is a limit reference point (S_{lim}) which should be avoided with high probability. Management advice for Atlantic salmon is referenced to the CL, therefore stocks assessed here are reported as not being at full reproductive capacity when the confidence limits of the most recent stock estimate includes the CL.

Regarding the assessment of the status of stocks and advice on management of national components and geographical groupings of the stock complexes in the NEAC area, where there are no specific management objectives:

- ICES considers a stock to be at full reproductive capacity when the lower boundary of the 95% confidence interval of the current estimate of spawners is above the CL.
- ICES considers a stock to be at risk of suffering reduced reproductive capacity when the lower boundary of the confidence limit is below the CL, but the mid point is above.
- ICES considers a stock to be suffering reduced reproductive capacity when the midpoint is below the CL.

For catch advice on fish exploited at West Greenland (non-maturing 1SW fish from North America and non-maturing 1SW fish from Southern NEAC), ICES has used the risk level of 75% that is part of the agreed management plan (ICES, 2003).

For stock assessment purposes, ICES groups NEAC stocks into two stock groupings; northern and southern NEAC stocks. The composition of these groups is shown below:

Southern European countries:	**Northern European countries:**
Ireland	Finland
France	Norway
UK (England & Wales)	Russia
UK (Northern Ireland)	Sweden
UK (Scotland)	Iceland (north/east regions)
Iceland (south/west regions)[1]	

3.1 Status of stocks/exploitation

The status of stocks is shown in Figure 3.1.1.

ICES classifies the stock complexes with respect to conservation requirements as follows:

Both Northern stocks (1SW and MSW) were estimated to be **at risk of suffering reduced reproductive capacity.** Both Southern stocks (1SW and MSW) were estimated to be **suffering reduced reproductive capacity.** The stock status is elaborated in Section 3.9.

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[1] The Iceland stock complex was spilt into two separate complexes for stock assessment purposes in 2005. Prior to 2005, all regions of Iceland were considered to contribute to the Northern European stock complex.

Estimated exploitation rates have generally been decreasing over the time period for both 1SW and MSW stocks in Northern and Southern NEAC areas (Figure 3.1.2). Exploitation on Northern 1SW stocks is higher than on Southern 1SW and considerably higher for MSW stocks. There has been a slight increase in exploitation on 1SW and 2SW northern stocks since 2002. However, the current estimates for both stock complexes are amongst the lowest in the time series.

3.2 Management objectives

This commission area is subject to the general NASCO management objectives as outlined in Section 1.3.

3.3 Reference points

Section 1.4 describes the derivation of reference points for these stocks and stock complexes.

3.3.1 Progress with setting river-specific conservation limits

Specific progress in individual countries is summarised below:

In Ireland in 2004 and 2005, modifications were made to the conservation limits to allow for uncertainty in meeting the CL in each river simultaneously in each district. Harvest guidelines established in 2003 were also modified to reflect the changes in the derivation of the CLs and the catch advice.

In UK (Scotland) work has begun to develop a procedure for setting river-specific CLs. Initial work has concentrated on developing a map-based useable wetted area model for salmon, which can be readily applied to any catchment, regardless of physical size. This has been developed using GIS applications in conjunction with field-based observation and literature review of salmon distribution in Scotland. The next stage of the project will investigate the transportability of a CL, derived from a monitored catchment, to other catchments by means of the useable wetted area model.

In UK (England & Wales), the CL for one river in the south west of the country (River Tamar) was revised following re-evaluation of the accessible wetted area and inclusion of river-specific data on fry and parr densities.

So far only France, Ireland, and UK (England & Wales) have implemented river-specific conservation limits and UK (Scotland) is developing such conservation limits.

3.3.2 National conservation limits

The national model has been run for all countries that do not have river-specific conservation limits (i.e. all countries except France, Ireland, and UK (England & Wales)).

Iceland, Russia, Norway, UK (Northern Ireland), and UK (Scotland) have provided regional input data for the PFA analysis (1971–2005). For these countries the lagged spawner analysis has been conducted by region. The regional results were combined to estimate conservation limits based on a pseudo stock-recruitment relationship for the country. Outputs from the national model are only designed to provide a provisional guide to the status of stocks in the NEAC area.

To provide catch options to NASCO, conservation limits are required for stock complexes. These have been derived either by summing of individual river CLs to national level, or by taking overall national CLs, as provided by the national model. For the NEAC area, the conservation limits have been calculated by ICES as 275 630 1SW spawners and 142 651 MSW spawners for the northern NEAC grouping, and 622 079 1SW spawners and 275 326 MSW spawners for the southern NEAC grouping.

3.4 Management advice

ICES has been asked to provide catch options or alternative management advice, if possible based on a forecast of PFA, with an assessment of risks relative to the objective of exceeding stock conservation limits in the NEAC area.

ICES emphasised that the national stock conservation limits discussed above are not appropriate for the management of homewater fisheries, particularly where these exploit separate river stocks. This is because of the relative imprecision of the national conservation limits and because they will not take account of differences in the status of different river stocks or sub-river populations. Nevertheless, ICES agreed that the combined conservation limits for the main stock groups (national stocks) exploited by the distant water fisheries could be used to provide general management advice to the distant water fisheries.

Given the status of the stocks ICES provides the following advice on management:

- **Northern European 1SW stocks:** ICES considers that the overall exploitation of the stock complex should decrease so that the conservation limit can be consistently met. In addition it should be noted that the inclusion of farmed fish in the Norwegian data would result in the stock status being overestimated. Since very few of these salmon have been caught outside homewater fisheries in Europe, even when fisheries were operating in the Norwegian Sea, management of maturing 1SW salmon should be based upon local assessments of the status of river or sub-river stocks. Thus, fisheries on maturing 1SW salmon should only be on river stocks shown to be at full reproductive capacity.
- **Northern European MSW stocks:** ICES considers that the overall exploitation of the stock complex should decrease so that the conservation limit can be consistently met. In addition it should be noted that the inclusion of farmed fish in the Norwegian data would result in the stock status being overestimated. Since very few of these salmon have been caught outside homewater fisheries in Europe, even when fisheries were operating in the Norwegian Sea, management of non-maturing 1SW salmon should be based upon local assessments of the status of river or sub-river stocks. Thus, fisheries on maturing MSW salmon should only be on river stocks shown to be at full reproductive capacity.
- **Southern European 1SW stocks:** As this stock complex is suffering reduced reproductive capacity, ICES considers that reductions in exploitation are required for as many stocks as possible, to increase the probability of the complex meeting conservation limits. Furthermore, due to the different status of individual stocks within the stock complex, mixed stock fisheries present particular threats to stock status. Thus, fisheries on maturing 1SW salmon should only be on river stocks that are shown to be at full reproductive capacity.
- **Southern European MSW stocks:** The quantitative forecast of PFA for 2006 (489 000) indicates that stock levels will remain close to current levels at least in the next year. Therefore, ICES considers that reductions in exploitation are required for as many stocks as possible, to increase the probability of the complex meeting conservation limits. Furthermore, due to the different status of individual stocks within the stock complex, mixed-stock fisheries present particular threats to stock status. As there is a less than 75% probability that the PFA forecast for 2006–2008 will be above the spawner escapement reserve (SER), there should be no fishing on this complex at West Greenland. The 2006–2008 PFA forecast midpoints are below the SER, indicating that this stock complex is suffering reduced reproductive capacity and therefore should not be fished at the Faroes. Furthermore, fisheries on maturing MSW salmon should only be on river stocks that are shown to be at full reproductive capacity. *(Management advice for this stock complex at West Greenland is provided in Section 5).*

3.5 Relevant factors to be considered in management

ICES considers that management for all fisheries should be based upon assessments of the status of individual stocks. Fisheries on mixed stocks, either in coastal waters or distant waters, pose particular difficulties for management as they cannot target stocks that are at full reproductive capacity. Conservation would be best achieved if fisheries target stocks that have been shown to be at full reproductive capacity. Fisheries in estuaries and rivers are more likely to meet this requirement.

NEAC PFAs from the national models are combined to provide NASCO with catch advice or alternative management advice for the distant water fisheries at West Greenland and Faroes. These groups were deemed appropriate by ICES as they fulfilled an agreed set of criteria for defining stock groups for the provision of management advice that were considered in detail at the 2002 meeting (ICES, 2002) and re-evaluated at the 2005 meeting (ICES, 2005).

Consideration of the level of exploitation of national stocks at Faroes and West Greenland fisheries resulted in the proposal that advice for the Faroes fishery (both 1SW and MSW) should be based upon all NEAC area stocks, but that advice for the West Greenland fishery should be based upon Southern European MSW salmon stocks only (comprising UK, Ireland, France, and Iceland (south/west regions)).

3.6 Pre-Fishery Abundance forecast for 2006

In order to develop quantitative catch options for NEAC stock complexes, forecasts of PFA are required for each stock complex and for each sea age component. These are currently only available for the non-maturing 1SW component of the southern European stock complex. The forecast of this PFA for 2006 has been used to provide management advice for West Greenland (Sections 5.1–5.7) and Faroes (Section 3.4) for 2006. ICES has adopted a model to forecast the pre-fishery abundance (PFA) of non-maturing (potential MSW) salmon from the Southern European stock group (ICES, 2002; 2003). Model options were re-evaluated in 2006 when ICES explored the relative contribution of several variables to predictions of PFA. As for 2004 and 2005, ICES decided to apply a model that used only the *Year* and

Spawners terms to predict the PFA of non-maturing salmon where it was fitted to data from 1978–2004 and used to update the PFA in 2005 and to forecast the PFA in 2006 (Figure 3.6.1).

Forecasts and 95% confidence limits of PFA non-maturing 1SW salmon for Southern NEAC are given below:

YEAR	PREDICTED	LOWER	UPPER
2005	505 000	332 000	768 000
2006	489 000	320 000	748 000

3.7 Pre-Fishery Abundance forecast for 2007–2008

The quantitative prediction for the southern NEAC MSW stock component gives a projected PFA (at 1st January 2007 and 1st January 2008) for catch advice in 2007 and 2008 (Figure 3.6.1). No projections are available beyond that, or for other stock components or complexes in the NEAC area. The mid-points of the projections are both below the SER and therefore there is no surplus available for exploitation.

YEAR	PREDICTED	LOWER	UPPER
2007	461 000	301 000	706 000
2008	440 000	286 000	676 000

3.8 Comparison with previous assessment

3.8.1 PFA forecast model

The revised forecast of the southern NEAC MSW PFA for 2005 provides a PFA mid-point of 505 000. This is close to the value forecast last year at this time of 486 000.

3.8.2 National PFA model and national conservation limit model

Provisional catch data for 2004 were updated where appropriate. In addition, two countries made changes to the input data.

Changes were made to some of the exploitation rate indices used for the Irish input data based on new or updated information. Further efforts were made to remove hatchery reared fish from the catch series as these fish are not considered to contribute significantly to spawning or are removed as broodstock in rearing programmes. The presence of these fish may mask declines in wild stocks and over-estimate attainment of CLs.

The conservation limit for UK (England & Wales) was amended to take into account changes in the assessment for the River Tamar (see Section 3.3.1).

3.9 NASCO has requested ICES to describe the key events of the 2005 fisheries and the status of the stocks

3.9.1 Fishing at Faroes in 2004/2005

No fishery for salmon was carried out in 2004/2005 or, to date, in 2005/2006. Consequently, no sample data are available from the Faroese area for this season. No buyout arrangement has been in effect since 1999.

3.9.2 Significant events in NEAC homewater fisheries in 2005

In several countries, measures aimed at reducing exploitation were implemented or strengthened in 2005. These include: a reduction of net fisheries in UK (England & Wales), a continuing reduction of TAC used in Ireland to limit catches, and the buy-out of bag nets in a region of Norway.

3.9.3 Gear and effort

No significant changes in the types of gear used for salmon fishing were reported in the NEAC area and the number of licensed gear units has, in most cases, continued to fall. There are no such consistent trends for the rod fishing effort in NEAC countries over this period.

3.9.4 Catches

In the NEAC area there has been a general reduction in catches since the 1980s (Table 2.1.1.1). This reflects the decline in fishing effort as a consequence of management measures as well as a reduction in the size of stocks. The provisional declared catch in the NEAC area in 2005 was 1964 tonnes, very similar to that in 2004 (1977 t), but down on the previous 5-year mean. The catch in the Southern area has declined over the period from about 4500 t in 1972–1975 to below 1500 t since 1986, and is now well below 1000 t. The catch declined particularly sharply in 1976 and again in 1989–91. The catch in the Northern area also shows an overall decline over the time-series, but this is less steep than for the Southern area. The catch in the Northern area varied between 1850 and 2700 t from 1971 to 1986, fell to a low of 962 t in 1997, and then increased to over 1500 t in 2001. The catch has shown a downward trend again since this time. Thus, the catch in the Southern area, which comprised around two-thirds of the NEAC total in the early 1970s, has been lower than that in the Northern area since 1999.

3.9.5 Catch per unit effort (CPUE)

CPUE can be influenced by various factors, and it is assumed that the CPUE of net fisheries is a more stable indicator of the general status of salmon stocks than rod CPUE since the latter may be more affected by varying local factors.

An overview of the CPUE data for the NEAC area was undertaken. In the Southern NEAC area, CPUE shows a general decrease in the UK (Scotland) net and coble fishery, whereas no trend was observed in UK (Scotland) fixed-engine fishery, UK (England & Wales) net fisheries, or in French rod fisheries. In most of the Northern NEAC area, there has been a general decreasing trend in the CPUE figures for various fisheries in recent years.

3.9.6 Age composition of catches

1SW salmon comprised 67% of the total catch in the Northern area in 2005 which was above the 5- and 10-year means (61% and 63% resp.). In general, there has been greater variability in the proportion of 1SW fish between countries in recent years (since 1994) than prior to this time. For the Southern European countries, the overall percentage of 1SW fish in the catch (61%) was close to the 5- and 10-year mean (61% and 60% resp.).

3.9.7 Farmed and ranched salmon in catches

The contribution of farmed and ranched salmon to national catches in the NEAC area in 2005 was again generally low (<2% in most countries) and is similar to the values that have been reported in previous reports (ICES, 2005). Thus, the occurrence of such fish is usually ignored in assessments of the status of national stocks. However, in Norway farmed salmon continue to form a large proportion of the catch in coastal, fjordic and rod fisheries. An assessment of the likely effect of these fish on the output data from the PFA model has been reported previously (ICES, 2001).

3.9.8 National origin of catches

ICES reviewed information presented by Ireland on the origin of tagged salmon recovered from their screening programme of Irish fisheries over the period 1985–2005. In 2005, 51 tags originating from fish released from five other countries were recovered in Irish fisheries: 28 from UK (Northern Ireland), 10 from UK (England & Wales), 7 from Spain, 5 from Germany, and 1 from Denmark were added to the dataset. The number of tagged salmon recovered is raised to the total fishery to give an indication of the relative contribution of non-Irish salmon. The analysis indicated that the highest average recapture rates for non-Irish tagged salmon are UK (N. Ireland), UK (Scotland), Denmark, France, UK (England and Wales), Spain, Germany, and Norway, respectively.

These data provide little information on exploitation rates of fish from each country which are taken in Irish fisheries and therefore the potential impacts on individual stocks. Previously (ICES, 2004) ICES reviewed information resulting from analysis of tagging programmes in UK (England & Wales) and tag recovery programmes in Ireland to estimate the effects of Irish fisheries on salmon stocks returning to UK (England & Wales). River-specific models based on the run reconstruction approach were presented for a number of English and Welsh stocks; the inclusion of confidence limits on the estimates of exploitation marked a further advance on earlier models. ICES endorsed this approach. The results demonstrated that: salmon from all parts of England and Wales are exploited in the Irish coastal fishery, exploitation levels vary among regions and years, and there has been a general decline in exploitation following the introduction of management measures in the Irish fishery since 1997. ICES recognised that exploitation rates varied considerably from year to year and that exploitation rates on particular stocks may still be relatively high in some years and negligible in others. For stocks below their conservation limit, ICES noted that even low levels of exploitation may represent an impediment to stock recovery.

3.9.9 Trends in the PFA for NEAC stocks

In the evaluation of the status of stocks in Figure 3.1.1, estimated recruitment (PFA) values should be assessed against the SER values, while the estimated spawning escapement values should be compared with the conservation limit.

Northern European 1SW and MSW stocks: Recruitment of maturing 1SW salmon (potential grilse) in Northern Europe showed a steady decline from the mid-1980s to the mid-1990s (Figure 3.1.1). Following an upturn in the late 1990s, there has been a steep downturn in recent years. Numbers of non-maturing 1SW recruits (potential MSW returns) for Northern Europe (Figure 3.1.1) are also estimated to have fallen throughout the period from the early 1980s to the late 1990s.

Apart from a short period from 2000 to 2003 the 1SW stock complex has not been at full reproductive capacity for most of the time-series. More recently, the spawner value shows that the stock complex suffered reduced reproductive capacity in 2004 and was at risk of suffering reduced reproductive capacity in 2005. Similarly, the number of MSW spawners shows that apart from a brief period from 2000 to 2003, this stock complex has not been at full reproductive capacity for most of the time-series. Again, the spawner value shows that the stock complex was suffering from reduced reproductive capacity in both 2004 and 2005. These trends in recruitment for the Northern European stocks are broadly consistent with the limited data available on the marine survival of monitored stocks in the Northern area.

Southern European 1SW and MSW stocks: The estimated numbers of maturing 1SW recruits have fallen substantially since the 1970s. The PFA estimates of non-maturing 1SW recruits in Southern Europe suggest that the number has followed a fairly steady and substantial decline over the past 30 years (Figure 3.1.1).

With the exception of the early 1970s, four years in the 1980s and more recently in 1998 and 2000, the number of 1SW spawners has not been at full reproductive capacity. In contrast, with the exception of one year in the late 1970s the number of MSW spawners was at full reproductive capacity until 1995. Thereafter, spawners have not been at full reproductive capacity. This is broadly consistent with the general pattern of decline in marine survival of 1SW and 2SW returns in most monitored stocks in the area.

3.9.10 Survival Indices for NEAC stocks

An overview of the estimates of marine survival (1988–2004) for wild and hatchery-reared smolts returning to homewaters (i.e. before homewater exploitation) is presented in Figure 3.9.10.1. The survival values presented are standardized (Z-score) indices relative to the averages of the time-series.

The overall trend in both the Northern and Southern NEAC areas, both wild and hatchery smolts, suggest a decline in marine survival over the past 10–20 years. The steepest decline appears for the wild smolts in the Southern NEAC area. Northern smolts, both hatchery and wild, also show a decline in survival with the exception of slight increases in the early 2000s. For both stock complexes, wild smolt survival has been more variable than their hatchery counterparts. Results from these analyses are consistent with the information on estimated returns and spawners (Section 3.1), and suggest that returns are strongly influenced by factors in the marine environment.

3.10 NASCO has requested ICES to provide any new information on the extent to which the objectives of any significant management measures introduced in recent years have been achieved

The effect of specific management measures on stocks and fisheries has been evaluated in a number of NEAC countries (Table 3.10.1). Countries not represented within this table haven't reported on recent management measures implemented by their national governments. Apart from national and local objectives, all of the EU countries have been provided with a specific conservation objective arising from the implementation of Council Directive 92/43/EEC (on the conservation of natural habitats and of wild flora and fauna). This directive states that

"If a species is included under this Directive, it requires measures to be taken by individual member states to maintain or restore them to favorable conservation status in their natural range".

Member States are obliged to take measures to ensure that the exploitation of salmon stocks is compatible with their being maintained at a favourable conservation status. Under the terms of the Directive, every 6 years member states are obliged to submit a report detailing the conservation status of their salmon stocks. The first such report is due to be submitted in 2007.

Conclusion

Most management measures introduced in recent years in relation to international, national, and local objectives have aimed to reduce levels of exploitation on NEAC stocks, to increase freshwater escapement and in some countries specifically to meet river specific conservation limits. Some measures have had notable success, however, ICES notes that all four NEAC stock complexes are currently either suffering, or at risk of suffering reduced reproductive capacity.

3.11 NASCO has requested ICES to update and further refine estimates of bycatch of salmon in pelagic fisheries (including non-catch fishing mortality) with an assessment of impacts on returns to homewaters

Information for this task was expected from the Study Group on the Bycatch of Salmon in Pelagic Trawl Fisheries (SGBYSAL). SGBYSAL was to work by correspondence in 2006. Unfortunately, the SGBYSAL was not able to report before the ICES WG meeting. However, ICES received some information from Russia, Iceland, and Faroe Islands and this is reviewed here.

Russia – In 2005 Russia continued the programme to study potential Atlantic salmon bycatch in pelagic fisheries in the Norwegian Sea. As in previous years, it consisted of both the pelagic fish survey conducted by research vessel and the screening of commercial catches by observers. In June–July 2005 the Russian RV “Fridtjof Nansen” participated in the annual international herring survey in the Norwegian Sea. A total of 101 pelagic hauls were taken by a research trawl with an opening of 45 x 40 m and 24-mm mesh blinder in accordance to standard methods. The whole catch was screened and each fish was identified and handled individually. One adult salmon was found in catches taken in the northern part of the Norwegian Sea between 71–74° N in the beginning of June. Another 20 days of trawling in the southern part of the Norwegian Sea between 61–64° N took place but no salmon were observed. In July, the central part of the Norwegian Sea between 65–71° N was surveyed and one adult salmon was found.

A screening programme on a Russian FV “Persey-4” was carried out in the Norwegian Sea from 24 June to 27 August 2005 during commercial pelagic fishing for mackerel, blue whiting, and herring. The area covered is located between 64°00 and 74°00 N, and from 03°30 W to 14°30 E.

Samples of pelagic species were taken from commercial hauls by pelagic trawl. The mesh size in the cod-end was 125 mm, and 40 mm in the trawl blinder. Trawl parameters were: vertical opening 35–65 m, distance between doors 58–65 m. The trawl was not rigged with additional floats. A headline was towed at depths of 1–350 m. A total of 182 pelagic hauls were taken and 20 777 fish of various species were handled individually for measurement and other purposes.

In June–July fishing for mackerel took place in the international waters of the Norwegian Sea and in a strip of water adjacent to the 200-mile limits of the Faroe Islands and Norway. The total catch of pelagic fish was 849 t. No post-smolts or adult salmon were found in any catches. In the first half of August fishing for blue whiting took place in the international waters of the Norwegian Sea. Total catch of pelagic fish was 328 t. Neither post-smolts nor adult salmon were found. In the second half of August fishing for Atlanto-scandian herring took place in the northern part of the Norwegian Sea. Total catch of herring and blue whiting was 354 t. Post-smolts of Atlantic salmon occurred as bycatch in the period from 17 to 20 August, when near-surface aggregations of herring (headline depth 15–30 m) were fished SW of Bear Island. A total of 9 post-smolts were found in catches.

Low catches of salmon in both Russian surveys suggest that Russian vessels in the pelagic fisheries in the Norwegian Sea using traditional pelagic trawl design and rigging are unlikely to catch significant numbers of salmon post smolts or adult salmon. Most salmon catches probably take place during trawl retrieval.

Iceland – In 2004, the Institute of Freshwater Fisheries and the Federation of Icelandic River Owners made a contract with IMG-Gallup in Reykjavik, Iceland, to include two questions regarding salmon bycatch in Gallup’s annual fisher questionnaire. The questionnaires were run during late December when virtually all Icelandic fishing vessels are at port. The results gave much higher values of bycatch of salmon than anticipated. In order to get more detailed information, a new contract with IMG-Gallup was made in 2005. At the time of the survey 3826 fishers were registered to Icelandic fishing vessels. A telephone survey including 1 114 fishers provided a response rate of 61.0% (680 fishers) and 21.2% (141) reported salmon by-catch compared to 15.5% in the previous survey. The mean number of salmon reported by those who reported bycatch was 6.3. The total number of salmon caught as bycatch by Icelandic fishers in 2005 was estimated at 5110 salmon (3165 to 7055, 95% CL). Compared to the total catch of 1 667 286 t of all species caught by the Icelandic fishing fleet in 2005, this salmon bycatch was considered to be very small (<0.001%). The survey gives no information on the origin of the salmon caught. A majority of the salmon caught within the EEZ was taken at East and South Iceland during the summer months, June–August, the months of salmon return migration. Grilse comprised 64% of the catch whereas the proportions of post smolts and MSW fish were 19.9% and 21.3%, respectively. The vessels sharing most frequent records of salmon catches were the larger ships (>500t) using pelagic trawls and purse seines.

The low frequency of salmon bycatch in Icelandic fisheries suggests that bycatch regulation may not be possible. Further cooperation with the fishers could be useful to collect information on salmon at sea through the bycatch sampled by fishers. In addition, surveys such as those conducted in Iceland can be used for collecting information about salmon by-catches. These methods are less expensive than direct onboard observation and sampling on the vessels.

Faroe Islands – No salmon bycatches have been reported in the Faroese herring fisheries in 2005.

Germany – Germany was the only country to respond to the SGBYSAL request to supply disaggregated data. As SGBYSAL did not meet no further analysis was performed.

ICES concludes that in the absence of the 2006 SGBYSAL report the conclusions made last year (ICES, 2005) are still valid, i.e. low impacts of salmon bycatches on PFA or returns to homewaters.

Non-catch mortality of salmon related to the operation of fishing gears was not considered by ICES as no new information was made available. ICES recommends that information about non-catch mortality should be compiled and analysed.

Table 3.10.1. Summary of national objectives, recent management measures and attainment of management objectives.

Country	Objective	Measure	Assessment	Outcome/extent achieved	Further consideration
Russia	Reduce fishing effort and enhance recreational catch and release fisheries	Various management measures including prohibition of some important in-river fisheries	Examination of catch statistics	Mean commercial catch reduced by 55% (2001-2005 compared to 1996-2000). Catch and release increased by 50% in past 5 years	Further reductions likely to be introduced
Ireland	Reduce exploitation rates and increase freshwater returns leading to 75% probability of simultaneous attainment of CLs in all rivers	TAC imposed in 2002 which has been reduced by 17%, 11%, 14% annually or 36% in total. Restrictions in angling catch including bag limits	Examination of coded wire tagging returns to Irish and UK rivers pre and post imposition of TACs Examination of fish counter data	Homewater exploitation rate reduced from 61% (pre-2002) to 46% (post 2002) for wild salmon, 82% to 69% for hatchery salmon Exploitation rate on UK stocks reduced by about 50% following management measures in 1997 and imposition of TACs	Further restrictions to fisheries including a lower TAC in 2006 (91,000 salmon) and restrictions on angling fisheries. Proposal to end mixed stock fisheries on stocks below CL by 2007
	Maintain salmon stocks in SAC rivers at favourable conservation status	TAC imposed in 2002 which has been reduced by 17%, 11%, 14% annually or 36% in total. Restrictions in angling catch including bag limits	Examination of counter/rod data to assess CL compliance for 26 SAC rivers	10 are probably meeting CL, 8 are above 50% of CL, 6 are below 50% of CL , and 2 are of uncertain status.	EU Water framework Directive likely to have a beneficial effect on salmonid habitat
UK (England	Safeguard MSW stock component	Spring salmon - measures introduced in 1999	Estimated 1,200 salmon saved from net fisheries. 1,700 saved from rod fisheries in 2005	Spawning escapement of spring salmon may have increased by up to one third on some rivers due to measures	Measures will remain in place till 2008 at least
	Stocks to meet or exceed CLs in at least 4 years of 5	Mixed stock fisheries measures including phase out, closures or reductions in fisheries	Examination of catch statistics and annual compliance	Coastal fishery catch reduced from average of 41,000 (88-92) to under 32,000 (98-02) and 10,000 (03-05). Declared rod catch in 5 north east rivers 55% higher on average in 3 years since buyout (2003) relative to average of 5 years before buyout	Continuing to phase out remaining mixed stock fisheries and focus on other limiting factors
			Examination of counter information	Recorded runs into the Tyne 98% higher since 2003 compared with mean of previous 5 years.	Continue monitoring
	To meet a management target on the River Lune of 14.4 million eggs or about 5,000 adults	Regulations on River Lune 2000 to reduce exploitation in net and rod fisheries by 50% and 25% resp.	Assessment of counter data catch statistics and juvenile assessment	Increase in salmon spawning from 3618 +/- 575 to 7,102 =/- 1,539. Management target exceeded in all years since the regulation Increase in juvenile production 80% increase in net catch in 2005	Continue to meet management objectives
	Maintain salmon stocks in SAC rivers at favourable conservation status	As above	Examination of counter/rod data to assess CL compliance for 18 SAC rivers	2 are currently considered to be complying with the management objective	Continue with management plan to meet management objectives

Table 3.10.1. Cont'd. Summary of national objectives, recent management measures and attainment of management objectives.

Country	Objective	Measure	Assessment	Outcome/extent achieved	Further consideration
UK (Scotland)	Improve status of early running MSW salmon	Agreement by Salmon Net Fishing Association to delay fishing to beginning of April from '2000	Examination of catch statistics	80% reduction in MSW net fishery catch in February to March relative to previous 5 yr mean	Further reduction in exploitation
		Bervie, N. and S. Esk salmon district net fishery delayed till May with catch and release only for angling	Examination of catch statistics	Believed to have increased escapement	Measure to be considered again in 2006
France	Reduce exploitation on MSW in particular and increase escapement and compliance with river specific CLs	Closure since 1994 of Loire-Allier sport and commercial fisheries	Measured against compliance objectives for the area	This did not seem to enhance salmon numbers	Physical obstructions and other environmental factors also being considered as potential limiting factors
		TACs introduced in 1996 in Brittany and Lower Normandy. MSW TACs have lead to temporary closures on some rivers	Examination of catch statistics	Reduced catch in MSW catch in Brittany since 2000 and Lower Normandy since 2003. Reduced catch has probably allowed an increase in escapement.	Monitored river (Scorff) has failed to meet CL consistently since 1994 so further measures may be considered.
		Management measures in the Adour-Gaves basin in 1999 and '2003	Examination of catch statistics	Rod catch increased in 2004 and 2005 when measures lapsed. A steady increase in effort and catch of estuary drift net fishery for 1999 to 2004 also occurred. Some reduction in rod catch but current regulations have been unable to reduce overall exploitation or pressure on MSW stocks	Continue to monitor stock status
Germany	Reintroduction of Atlantic salmon stocks extinct since the middle of 20th century but improvements in conditions and water quality were thought to be sufficient to support salmon	Restocking of rivers running into North Sea (Rhine, Ems, Weser and Elbe). 2 million juveniles (mainly fry) released annually	Trap and counter data (Sieg, upper Rhine)	200-500 adults recorded annually. Return rates of less than 1%	Low return rates thought to reflect obstructions to migration in the Rhine delta as well as spawning tributaries and probably due to bye-catch in non-target fisheries
	Establish free migration routes for salmon and other migratory fishes and rehabilitation of habitat in rivers basins	Collaborative programme has started e.g. Rheineprogramm 2020	Assessment in progress	Assessment in progress	Assessment in progress

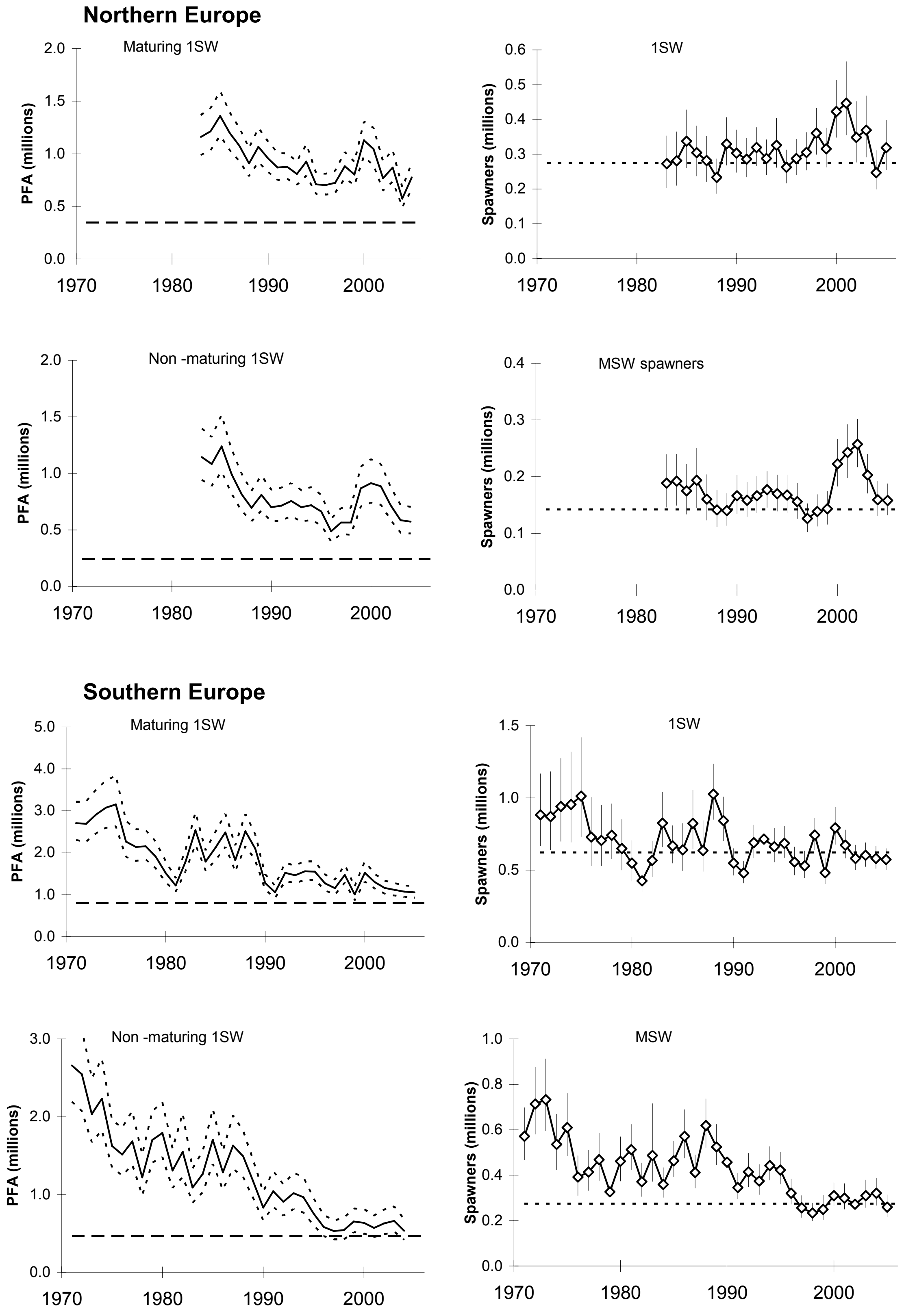

Figure 3.1.1 Estimated recruitment (PFA), with 95% confidence limits, and Spawning Spawning Escapement Reserve for maturing and non-maturing salmon in Northern and Southern Europe.

Estimated spawning escapement and with 95% confidence limits, and conservation limits for 1SW and MSW salmon in Northern and Southern Europe.

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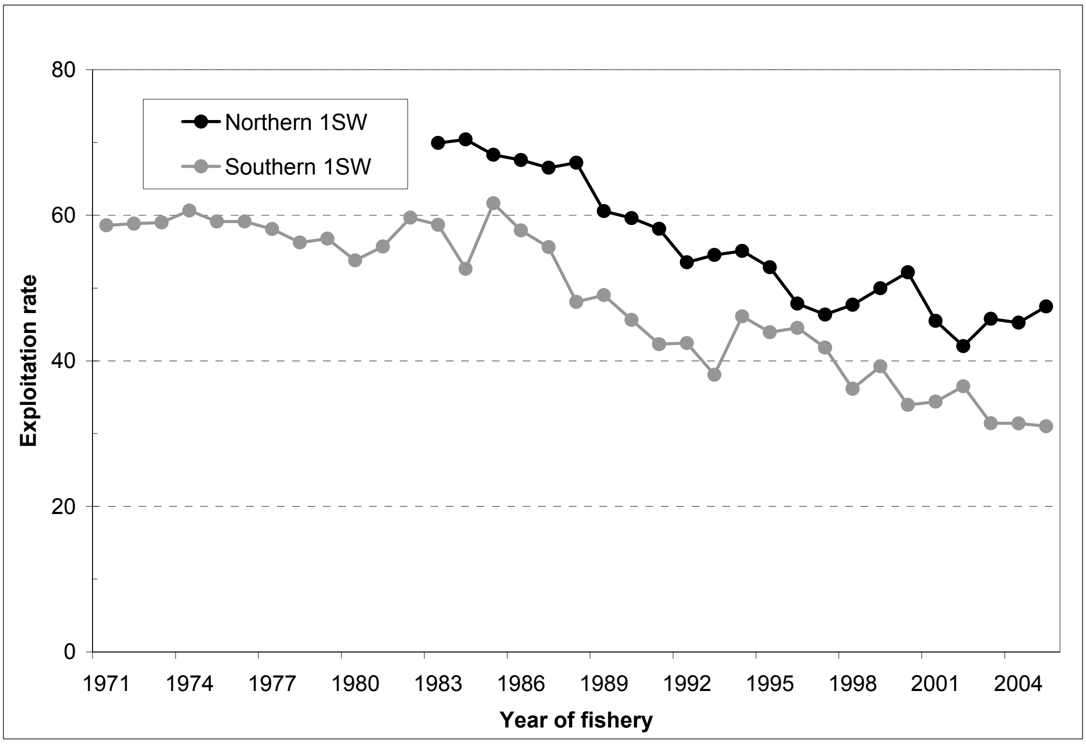


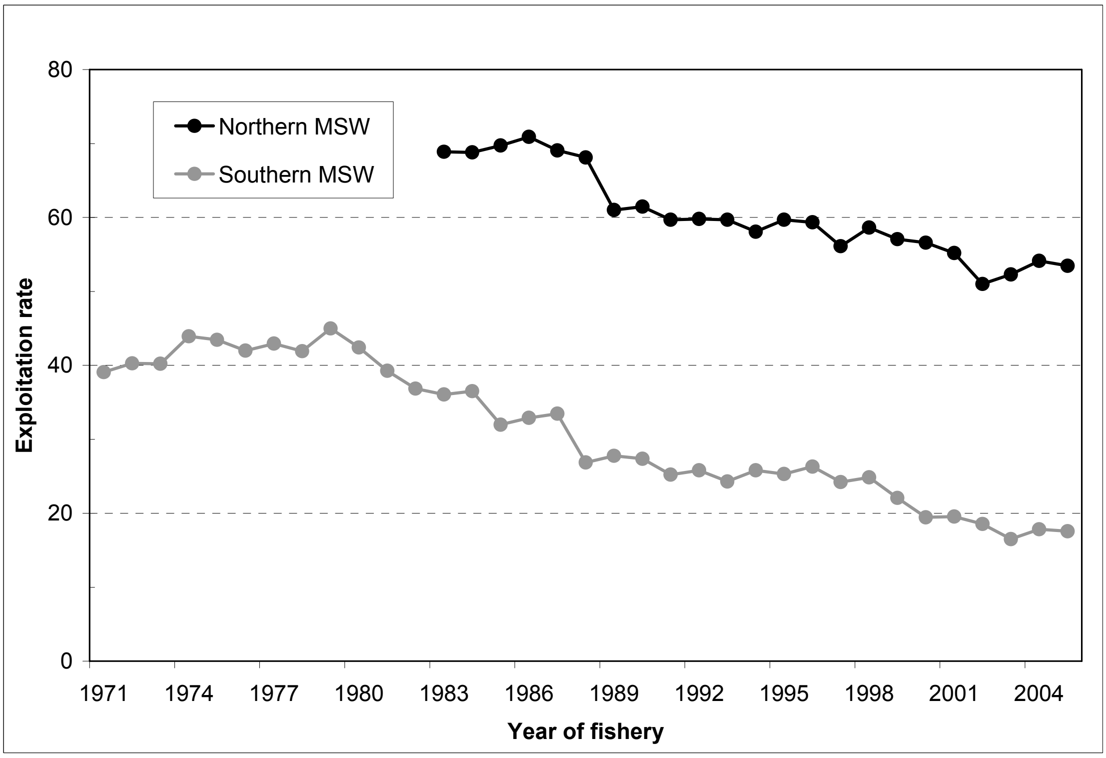


Figure 3.1.2. Estimated mean exploitation rates (1971–2005) for Northern and Southern European 1SW and MSW stocks.

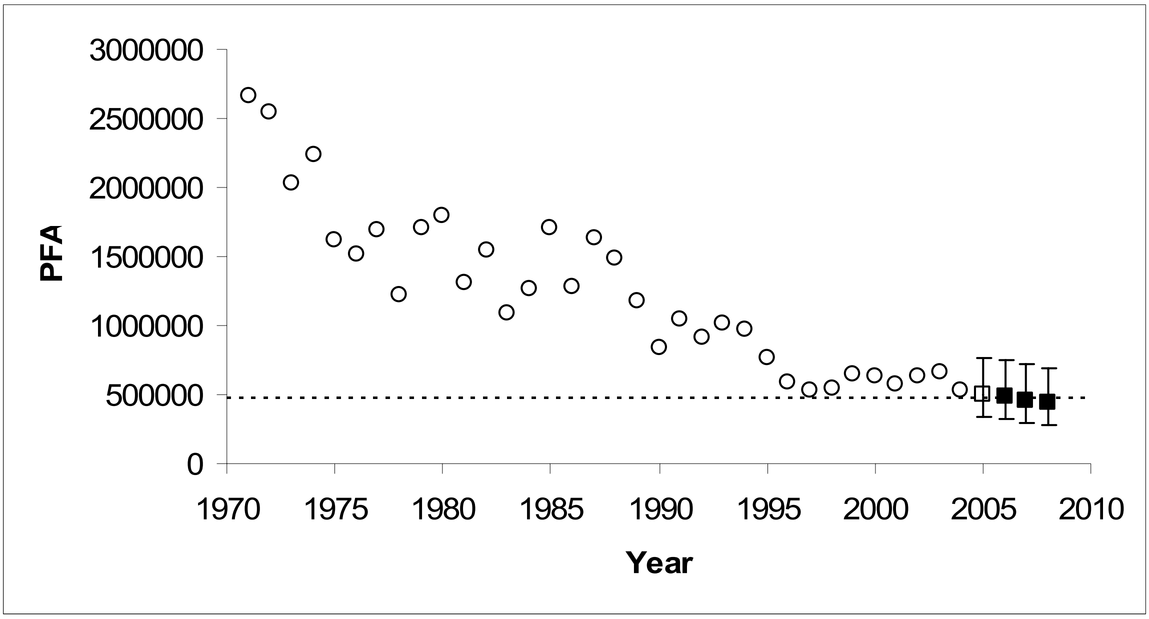


Figure 3.6.1. PFA trends and predictions (+/- 95% confidence limits) for non-maturing 1SW European stock. *Note: open square is 2005 update and blocked squares are 2006 to 2008 forecasts.*

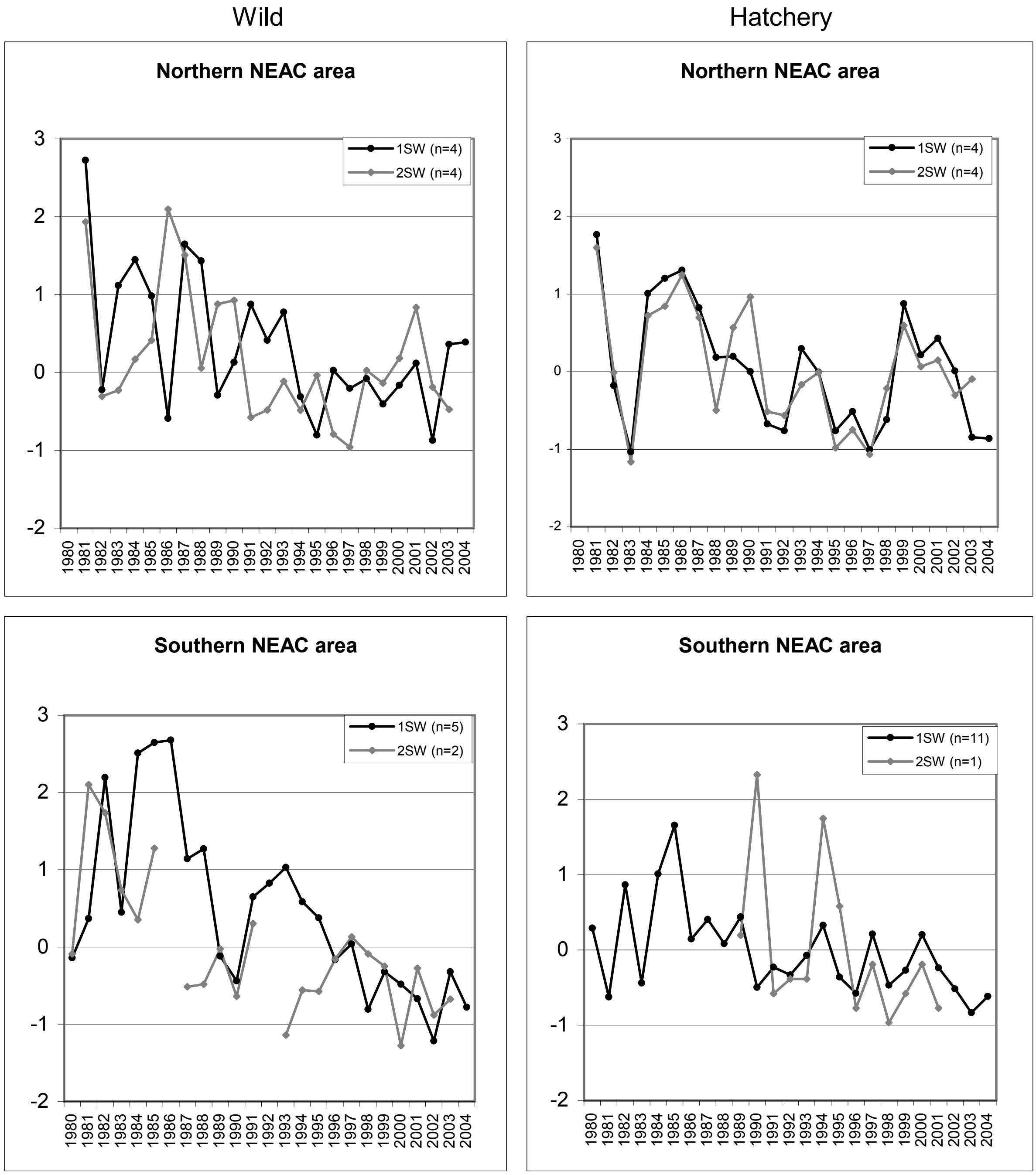


Figure 3.9.10.1. Survival indices of wild and hatchery smolts to adult returns to homewaters (prior to coastal fisheries) in the Northern and Southern NEAC Areas. Vertical axes represent standardised (Z-score) survival estimates and are relative to the average of the time series (0) derived from periods where data from the majority of the rivers are available (ie. Northern wild, from 1987; Northern hatchery, from 1984; Southern wild 2SW from 1980 (recent data not updated); Southern hatchery 1SW from 1984; and Southern hatchery 2SW from 1989). The number of rivers included is indicated in each panel legend.

4 NORTH AMERICAN COMMISSION

4.1 Status of stocks/exploitation

In 2005, the spawner estimates for six geographic areas indicated that all areas except Newfoundland were below their conservation limit for 2SW salmon and are suffering reduced reproductive capacity. Newfoundland was at risk of suffering reduced reproductive capacity.

The stock status is elaborated in Section 4.9.

4.2 Management objectives

Management objectives are included in Section 1.4.

4.3 Reference points

There are no changes recommended in the 2SW salmon conservation limits from those identified previously. Conservation limits for 2SW salmon for Canada now total 123 349 and for the USA 29 199, giving a combined total of 152 548.

4.4 Management advice

River-specific management of catch is required to meet river-specific biological conservation limits. If river-specific conservation limits are not being exceeded there is no scope for harvest. If conservation limits are being exceeded, there are no biological reasons to restrict harvest of the surplus. Advice regarding management of this stock complex in the fishery at West Greenland is provided in Section 5.

4.5 Relevant factors to be considered in management

ICES considers that management for all fisheries should be based on assessments of the status of individual stocks. Fisheries on mixed stocks, either in coastal waters or on the high seas, pose particular difficulties for management as they cannot target stocks that are at full reproductive capacity. Conservation would be best achieved if fisheries target stocks that have been shown to be at full reproductive capacity. Fisheries in estuaries and rivers are more likely to meet this requirement.

4.6 Revised forecast of 2SW maturing fish for 2006

Catch options are only provided for the non-maturing 1SW and maturing 2SW components as the maturing 1SW component is not fished outside home waters, and in the absence of significant marine interceptory fisheries, is managed in home waters.

Catch options are provided for the North American Commission area for four years. The revised forecast for 2006 for 2SW maturing fish is based on an updated forecast of the 2005 pre-fishery abundance, accounting for fish which were already removed from the cohort by fisheries in Greenland and Labrador in 2005 as 1SW non-maturing fish. The estimates for the 2007 to 2009 fisheries on maturing 2SW salmon are based on the pre-fishery abundance forecast for 2006 to 2008 from Section 5.

The salmon caught in the West Greenland fishery are mostly (>90%) non-maturing 1SW salmon, most of which are destined to return to home waters in Europe or North America as 2SW fish. Repeat spawners, including salmon that spawned first as 1SW, contribute only a small fraction to this fishery. Therefore PFA and conservation limits for the North American stock complex are only referenced to in terms of 2SW fish.

4.6.1 Catch options for 2006 fisheries on 2SW maturing salmon

The updated forecast of the pre-fishery abundance for 2005 provides a PFA midpoint of 126 000, about 5% higher than the forecast last year (see Section 5.8). The 2005 pre-fishery abundance of maturing 2SW salmon will be available in homewaters in 2006.

To compare the PFA to conservation limits, the pre-fishery abundance of 126 000 fish can be expressed as 2SW equivalents by considering natural mortality of 3% per month for 11 months resulting in 90 584 2SW salmon equivalents. There have already been harvests of this cohort as 1SW non-maturing salmon in 2005 for both the Labrador (823 midpoint of estimates) and Greenland (3360) fisheries. Adjusted for natural mortality, these catches equate to 2952 2SW salmon equivalents which potentially leaves 87 346 2SW salmon to return to rivers in North America in 2006.

As the predicted number of 2SW salmon returning to North America in 2006 is substantially lower than the 2SW conservation limit of 152 548, there are no catch options at probability levels of 75%. Catch options refer to the composite North American fisheries. As the biological objective is to have all rivers reaching their conservation requirements, river-by-river management is necessary. On individual rivers, where spawning requirements are being achieved, there are no biological reasons to restrict the harvest.

4.7 Catch options for 2007–2009 fisheries on 2SW maturing salmon

Catch options derived from the pre-fishery abundance forecast for 2006 to 2008 would apply principally to North American fisheries in 2007 to 2009. Accounting for potential catches in 2006 to 2008, and natural mortality to home waters, the management objective to achieve conservation escapements, as well as the allocation of 60% of the surplus to North America, the only risk-averse catch option for 2SW salmon in 2007 to 2009 is zero catch on the composite North American stock (see Sections 5.6 and 5.7).

4.8 Comparison with previous assessment and advice

The revised forecast of the pre-fishery abundance for 2005 provides a PFA midpoint of 126 000. This is about 5% higher than the value forecast last year at this time of 120 400. This is mainly due to slight changes in the input values to the model used to forecast PFA for these stocks, as well as changes in the parameter values resulting from the additional year of PFA and lagged spawner values used in the model.

4.9 NASCO has requested ICES to describe the key events of the 2005 fisheries and the status of the stocks

4.9.1 Fisheries in 2005

Homewater fisheries

Three user groups exploited salmon in Canada in 2005: Aboriginal peoples, residents fishing for food in Labrador, and recreational fishers. There were no commercial fisheries in Canada in 2005. All commercial and recreational fisheries for sea-run Atlantic salmon within the USA remained closed. Thus, there was no harvest of sea-run Atlantic salmon in the USA in 2005.

The provisional harvest of salmon in 2005 by all users was 129 t (Table 2.1.1.1), about 20% lower than the 2004 harvest. The 2005 harvest was 41 709 small salmon and 10 949 large salmon, 23% less small salmon and 15% less large salmon, compared to 2004. The dramatic decline in harvested tonnage since 1988 is in large part the result of the reductions in commercial fisheries effort, the closure of the insular Newfoundland commercial fishery in 1992, the closure of the Labrador commercial fishery in 1998, and the closure of the Québec commercial fishery in 2000. These reductions were introduced as a result of declining abundance of salmon.

The Aboriginal peoples' harvests in 2005 was 56.4 t, representing a decrease of 7% from 2004 and an increase of 14% over the previous 5-year mean harvest (by weight). The estimated harvest for residents fishing for food in Labrador was 2.6 t, about 1135 fish (80% small salmon by number). The recreational fisheries harvest in 2005 totalled 32 585 small and large salmon, 31% below the previous 5-year average, 32% below the 2004 harvest level, and the lowest total harvest reported. The small salmon harvest of 28 468 fish was 34% below 2004 and the previous 5-year mean. The large salmon harvest of 4117 fish was 7% below the previous five-year mean and 10% below 2004. The small salmon size group has contributed 87% on average of the total harvests since the imposition of catch-and-release recreational fisheries in the Maritimes and insular Newfoundland in 1984.

France (Islands of Saint-Pierre and Miquelon)

In 2005, there were 14 professional and 52 recreational gillnet licenses issued for the fishery that operates between May 1 and July 31. These figures do not reflect accurately the fishing effort: in 2005, only 8 professional and 24 recreational fishers actually fished.

The total reported harvest in 2005 was 3.3 t, an increase of 0.5 t from 2004 and among the largest catches recorded since 1983 (Table 2.1.1.1). Professional and recreational fishers reported catching 2243 kg and 1044 kg of salmon, respectively, in 2005. There is no estimate of unreported catch.

In 2005, 310 salmon were sampled, of which 295 were measured for fork length. The smallest fish was 49 cm, the largest 90 cm. There were two distinct size modes, 72% of the fish being smaller than 63.0 cm. These salmon are in large part maturing 1SW fish.

YEAR	PROFESSIONAL LICENSES (KG)	RECREATIONAL LICENSES (KG)	TOTAL (KG)
1990	1146	734	1880
1991	632	530	1162
1992	1295	1024	2319
1993	1902	1041	2943
1994	2633	790	3423
1995	392	445	837
1996	951	617	1568
1997	762	729	1491
1998	1039	1268	2307
1999	1182	1140	2322
2000	1134	1133	2267
2001	1544	611	2155
2002	1223	729	1952
2003	1620	1272	2892
2004	1499	1285	2784
2005	2243	1044	3287

4.9.2 Status of the stocks

In 2005, the midpoints of the spawner estimates for six geographic areas indicated that all areas, except Newfoundland, were below their conservation limit for 2SW salmon and are suffering reduced reproductive capacity. Newfoundland was at risk of suffering reduced reproductive capacity (Figure 4.9.2.1).

Estimates of pre-fishery abundance suggest a continuation of low numbers of North American adult salmon over the last 10 years. The total population of 1SW and 2SW Atlantic salmon in the northwest Atlantic has oscillated around a generally declining trend since the 1970s (Figure 4.9.2.2). During 1993 to 2005, the total population of 1SW and 2SW Atlantic salmon was about 600 000 fish, about half of the average abundance during 1972 to 1990. The decline from earlier higher levels of abundance has been more severe for the 2SW salmon component than for the maturing 1SW age group (Figure 4.9.2.3).

In 2005, the overall conservation limit for 2SW salmon was met only in Newfoundland.

The returns in 2005 of 2SW fish increased slightly from 2004 in Labrador, Newfoundland, and in the Gulf of St. Lawrence but declined in Québec, Scotia Fundy and in the USA (Figure 4.9.2.1). However, in all areas returns remain close to the lower end of the 35-year time-series (1971–2005). While 2SW salmon are a minor component of Newfoundland stocks even here decreases of about 30% have occurred from peak levels of the 1990s. Returns in 2005 of 1SW salmon increased from 2004 in Newfoundland and Labrador but declined or were similar in all other areas.

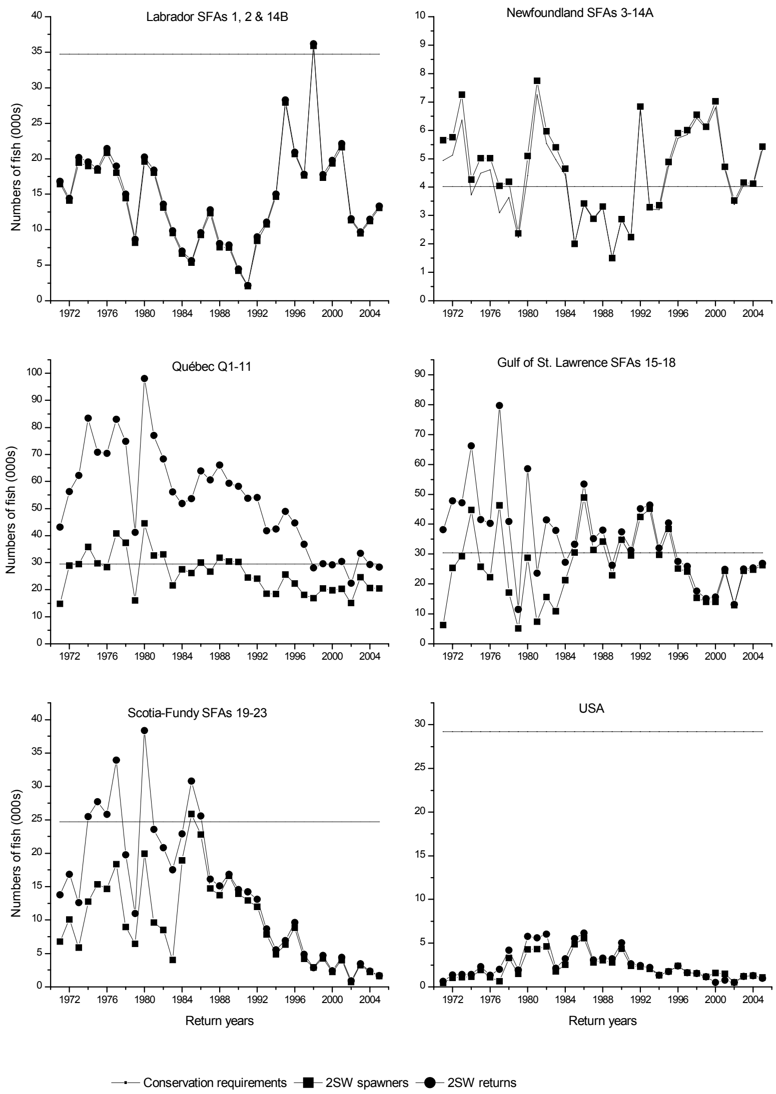
Egg depositions by all sea-ages combined in 2005 exceeded or equalled the river-specific conservation limits in 34 of the 81 assessed rivers (42%) and were less than 50% of conservation limits in 26 other rivers (32%, Figure 4.9.2.4).

Generally wild smolt production declined in monitored rivers of eastern Canada in 2005. Measures of marine survival rates over time indicate that survival of North America stocks to home waters have not increased as expected as a result of fisheries changes. Return rates to 1SW and 2SW salmon remain variable and unpredictable with higher return rates in the northern areas (Newfoundland) and lower rates in the southern areas, including southern Newfoundland, Maritimes, and USA (Figure 4.9.2.5).

Based on the genera1 decrease in 1SW returns in 2005 in most areas except Newfoundland and Labrador a decrease is expected for 2SW salmon in 2005. Return rates of 2SW salmon in monitored stocks remain low. An additional concern is the number of salmon stocks suffering reduced reproductive capacity in eastern Canada, particularly in the Bay of Fundy and Atlantic coast of Nova Scotia. USA salmon stocks exhibit these same downward trends. Most salmon rivers in the USA are hatchery-dependent and remain at low levels compared to conservation requirements. Despite major changes in fisheries management, returns have continued to decline in these southern areas and many populations are currently threatened with extirpation.

4.10 NASCO has requested ICES to provide any new information on the extent to which the objectives of any significant management measures introduced in recent years have been achieved

There have been no significant management measures introduced within the NAC in recent years.



Stock Area	2SW spawner requirement
Labrador	34 746
Newfoundland	4022
Gulf of St. Lawrence	30 430
Québec	29 446
Scotia-Fundy	24 705
USA	29 199

Figure 4.9.2.1. Comparison of estimated midpoints of 2SW returns, 2SW spawners, and 2SW conservation requirements for six geographic areas in North America. Returns and spawners for Scotia-Fundy do not include those from SFA 22 and a portion of SFA 23.

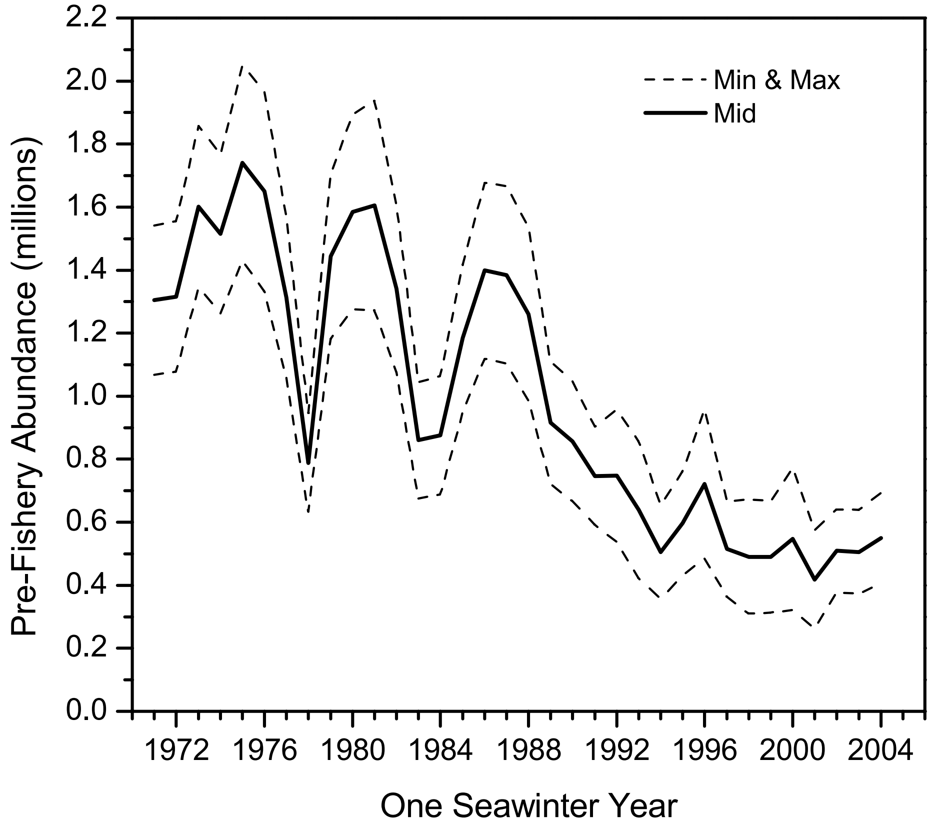


Figure 4.9.2.2. Total 1SW recruits (non-maturing and maturing) originating in North America

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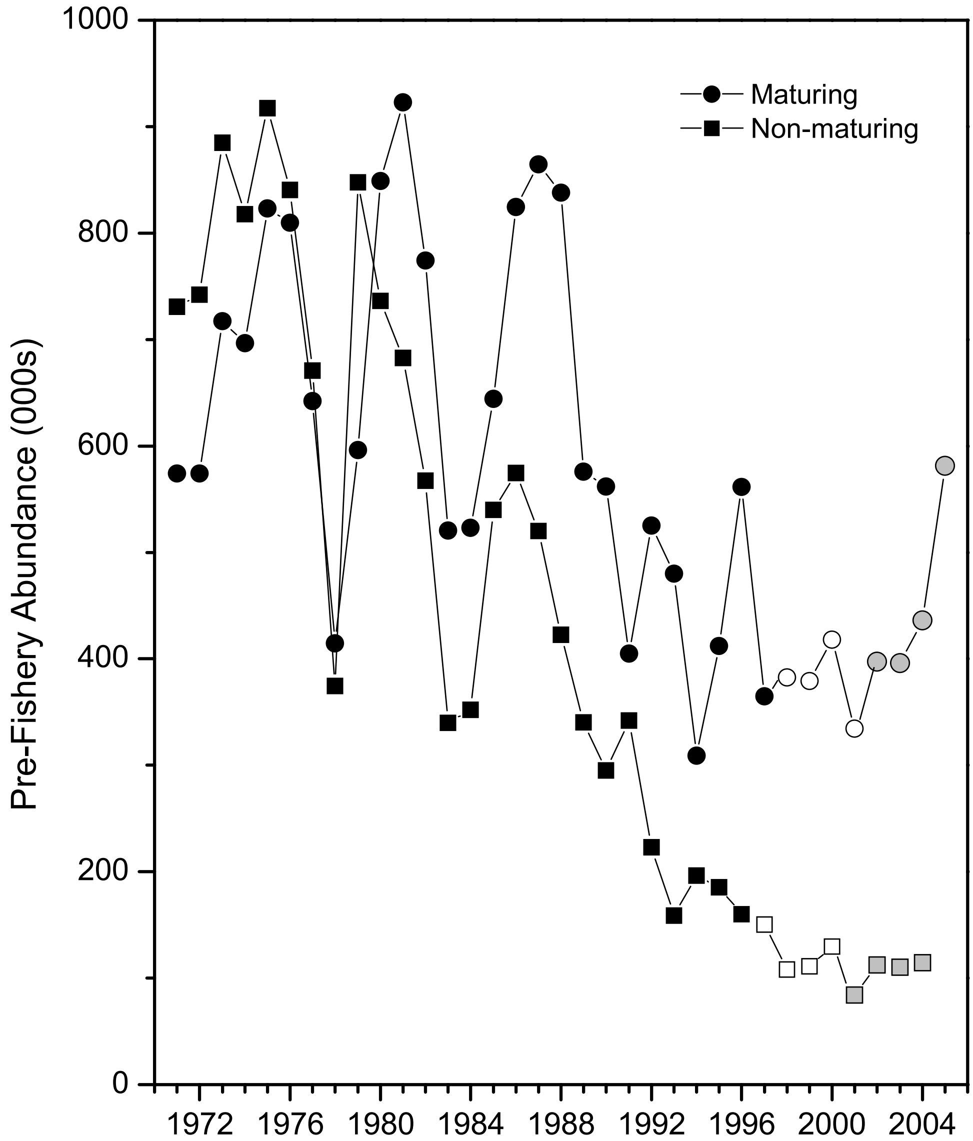

Figure 4.9.2.3. Pre-fishery abundance estimate of maturing (1SW) and non-maturing (2SW) salmon in North America. Open symbols are for the years that returns to Labrador were assumed as a proportion of returns to other areas in North America and the grey symbols for deriving returns to Labrador using returns per unit of drainage area.

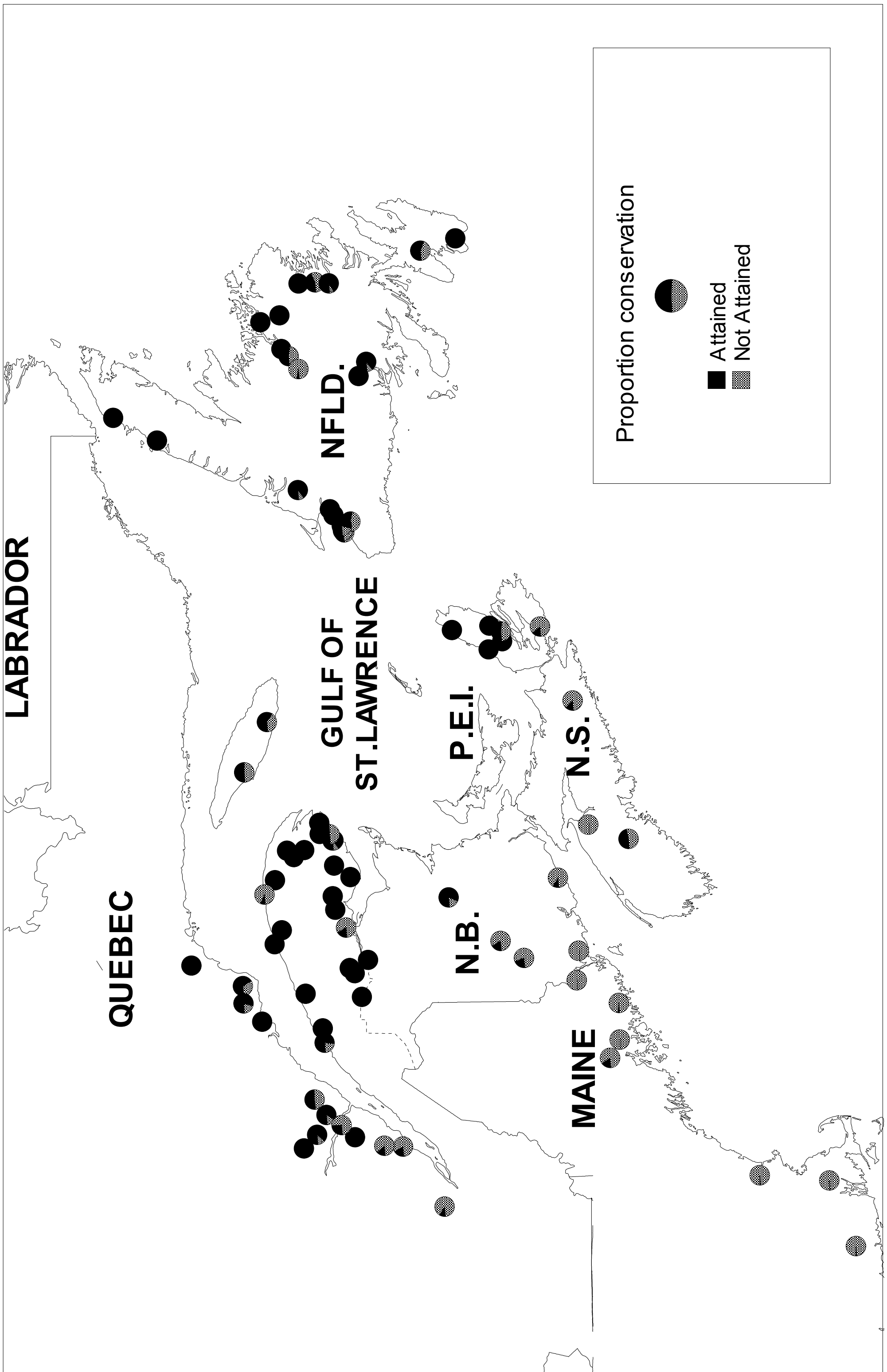

Figure 4.9.2.4. Proportion of the conservation requirement attained in assessed rivers of the North American Commission in 2005.

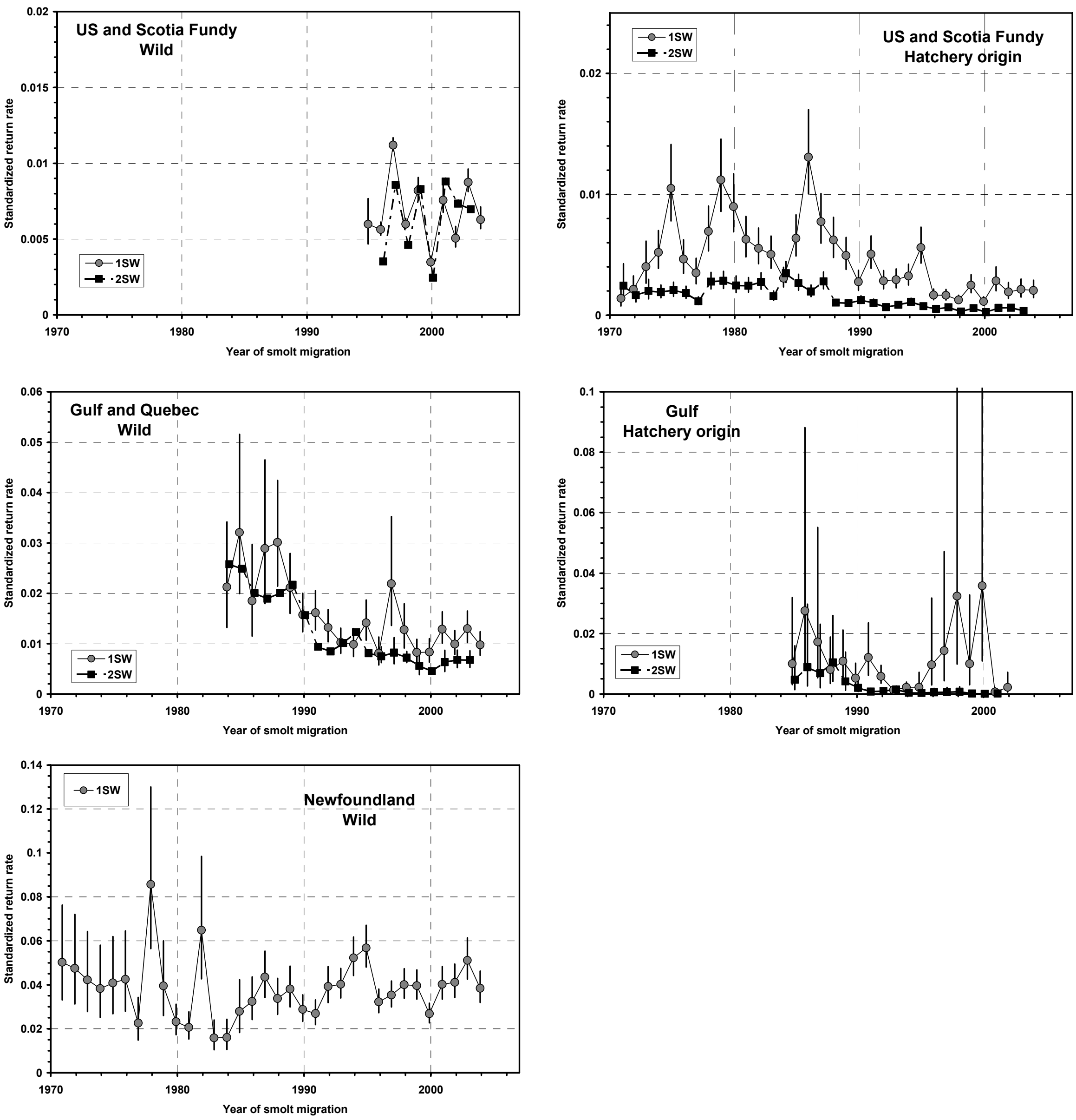

Figure 4.9.2.5. Standardized return rate indices of wild and hatchery origin smolts to adult returns to rivers in the south (USA and Scotia-Fundy), north (Gulf and Québec), and Newfoundland regions. The standardized values are annual means derived from a GLM analysis for a reference river in the each time-series, age group, and region. Survival rates were log-transformed prior to analysis.

5 ATLANTIC SALMON IN THE WEST GREENLAND COMMISSION

5.1 Status of stocks/exploitation

ICES considers the stock complex at West Greenland to be below the conservation limit (CL) and thus **suffering reduced reproductive capacity.**

The salmon caught in the West Greenland fishery are mostly (>90%) non-maturing 1SW salmon, most of which are destined to return to home waters in Europe or North America as MSW fish. The primary European stocks contributing to the fishery in West Greenland are thought to originate from the southern MSW stock complex, although low numbers may originate from other stock complexes. Most MSW stocks in North America are thought to contribute to the fishery at West Greenland. Repeat spawners, including salmon that spawned first as 1SW, and 2SW salmon also contribute to the fishery.

North American stocks

ICES notes that the North American stock complex of non-maturing salmon has declined to among the lowest levels in the time-series (Figure 4.9.2.3). In 2005, the estimated overall spawning escapement was below the conservation limit for the stock complex. Specifically, 2SW spawners in the regions (Figure 4.9.2.1) are:

- **Newfoundland:** at risk of suffering reduced reproductive capacity (132% of 2SW CL)
- **Labrador:** suffering reduced reproductive capacity (38% of 2SW CL)
- **Québec:** suffering reduced reproductive capacity (70% of 2SW CL)
- **Gulf of St. Lawrence**: suffering reduced reproductive capacity (86% of 2SW CL)
- **Scotia-Fundy:** suffering reduced reproductive capacity (6% of 2SW CL)
- **United States:** suffering reduced reproductive capacity (4% of 2SW CL) with stocks in the Gulf of Maine Distinct Population Segment listed as Endangered under the Endangered Species Act.

European stocks

The non-maturing 1SW salmon from Southern Europe have been declining steadily since the 1970s (Figure 3.1.1). The midpoint of spawners has been close to or below conservation limits in recent years. Specifically:

- **Southern European stock complex:** suffering reduced reproductive capacity (94% of 2SW CL).

Status of stocks in the NEAC and NAC areas are presented in the relevant commission sections (Sections 3 and 4).

5.2 Management objectives

For management of the West Greenland fishery, NASCO has adopted a precautionary management plan requiring at least 75% probability of achieving three management objectives:

- Meeting the conservation limits simultaneously in the four northern regions of North America: Labrador, Newfoundland, Quebec, and Gulf.
- Achieving increases in returns to the Scotia-Fundy and USA regions relative to the base years 1992–1996. Improvements of greater than 25% and 10% relative to base year returns are presented although, to achieve a 25% increase, by definition the 10% increase is also achieved.
- Meeting the conservation limits for the Southern NEAC MSW complex.

5.3 Reference points

The reference points for West Greenland catch options refer to the spawner reserves for North American regional and Southern European stock complexes. Spawner reserves are the number of salmon required at West Greenland to ensure that returns to a region the following year achieve region-specific conservation limits. Spawner reserves account for expected losses from natural monthly mortality over the migration from West Greenland to home rivers (eight months for Southern Europe and eleven months for North America). Region-specific conservation limits are derived in three ways:

In many regions of North America, the conservation limits are calculated as the number of spawners required to fully seed the wetted area of the river.

In some regions of Europe, pseudo stock-recruitment observations are used to calculate a hockey stick relationship, with the inflection point defining the conservation limits.

In the remaining regions, the conservation limits are calculated as the number of spawners that will achieve long-term average maximum sustainable y

NASCO has adopted these region-specific conservation limits (NASCO, 1998). The conservation limits are limit reference points (S_{lim}), which should be avoided with high probability.

Conservation limits for North American stocks are limited to 2SW salmon and southern European stocks are limited to MSW fish because fish at West Greenland are primarily (> 90%) 1SW non-maturing salmon destined to mature as either 2SW or 3SW salmon.

The North America 2SW conservation limit is approximately 152 500 fish (see Section 4.3). The conservation limit for the Southern European MSW stocks is approximately 275 000 fish (Section 3.3.3). Tagging information and biological sampling indicate that the majority of the European salmon caught at West Greenland originate from the southern stock complex. There is still considerable uncertainty in the conservation limits for European stocks and estimates may change from year to year due to new data in the pseudo stock-recruitment relationship.

5.4 Management advice

ICES provides management advice for the West Greenland fishery, based on the NAC and NEAC stock complexes.

ICES advises that there should be no catch on the stocks at West Greenland in 2006, 2007, or 2008.

Risk analyses for these years illustrate that attaining CLs for the NAC stock complex is sensitive to the magnitude of catch at West Greenland (Tables 5.4.1 and 5.4.2). Therefore, where catches are allowed, it is imperative that fishing is closely monitored and full details are provided to ICES (Section 5.9).

5.5 Relevant factors to be considered in management

For all fisheries, ICES considers that management should be based on assessments of the status of individual stocks. Fisheries on mixed stocks, either in coastal waters or on the high seas, pose particular difficulties for management, as they cannot target only those stocks that are within precautionary limits. Conservation would be best achieved if fisheries can be targeted at stocks that have been shown to be within precautionary limits. Fisheries in estuaries and rivers are more likely to fulfil this requirement.

5.6 Pre-Fishery Abundance forecast for 2006

5.6.1 North American stock complex

ICES has described two temporal phases (ICES, 2003) of salmon production in the Northwest Atlantic. Lower recruitment rates are evident throughout eastern Canada and USA. The PFA_{NA} forecast for 2006 has a median value of 119 000. In the absence of any marine fishing mortality, there is a very low probability (3% probability) that the returns of 2SW salmon to North America in 2007 will be sufficient to meet the conservation limits of the four northern regions (Labrador, Newfoundland, Quebec, and Gulf) (Table 5.4.1). There is essentially no chance (<1%) that the returns in the southern regions (Scotia-Fundy and USA) will be 10 or 25% greater than the returns observed in the 1992–1996 base period. Furthermore, there is a 65% probability that returns in all regions of North America will be greater than the average of the period 2001 to 2005 in the absence of a fishery (Table 5.4.2).

None of the stated management objectives would allow a fishery at West Greenland to take place in 2006.

5.6.2 Southern European MSW stock complex

The southern European PFA forecast for 2006 has a median value of 489 000 (Figure 3.6.1). The spawning escapement to southern Europe MSW stocks has not exceeded conservation limit throughout the recent time period (Figure 3.1.1). There is a 68% probability that the MSW conservation limit for southern Europe will be met in 2006 (Table 5.4.1).
None of the stated management objectives would allow a fishery at West Greenland to take place in 2006.

5.7 Pre-Fishery Abundance forecast for 2007 and 2008

Projections of PFA are made for three years for the NAC and the NEAC. The forecasts for 2007 and 2008 are based on the same models that generated the 2006 PFA forecast. In the NAC area, the probability of being in the low phase was the same as used in the 2006 forecast.

5.7.1 North American stock complex

For 2007 and 2008, the PFA_{NA} forecasts are 114 000 and 120 000 fish (median values). The forecasted PFA_{NA} remain among the lowest in the time-series and it is unlikely that the 2SW spawner reserve of 212 189 fish to North America will be met.

In the absence of any marine fishing mortality, there is a very low probability (3%) that the returns of 2SW salmon to North America in 2008 and 2009 will be sufficient to meet the conservation limits of the four northern regions (Labrador, Newfoundland, Quebec, and Gulf) (Table 5.4.1). There is essentially no chance (<1%) that the returns in the southern regions (Scotia-Fundy and USA) will be 10 or 25% greater than the returns observed in the 1992–1996 base period.

There is a 61% probability for 2008 and a 66% probability for 2009 that returns in all regions of North America will be greater than the average of the period 2001–2005 (Table 5.4.2).

None of the stated management objectives would allow a fishery at West Greenland to take place in 2007 or 2008.

5.7.2 5.7.2 Southern European MSW stock complex

The PFA for the NEAC MSW southern stock complex is expected to decline in 2007 and 2008 to median values of 461 000 and 440 000 fish (Figure 3.6.1). It is unlikely that spawner reserves will be met in either year. In the absence of any fisheries at West Greenland, there is a 60% and 54% probability that the MSW conservation limit for southern Europe will be met in 2008 and 2009 (Table 5.4.1).

None of the stated management objectives would allow a fishery at West Greenland to take place in 2007 or 2008.

5.8 Comparison with previous assessment and advice

The management advice for the West Greenland fishery has been the same since 2003.

The modelling approach has provided consistent estimates of the previous year's predictions and updated PFA_{NA}. For 2005, the median value of the updated NAC analysis has been reestimated from 120 400 (predicted in the previous year's analysis) to 126 000 fish. The southern NEAC MSW PFA for 2005 has been reestimated from 486 000 to 505 000. For both NAC and NEAC, the variability of the two predictions for 2005 was similar.

5.9 NASCO has requested ICES to describe the events of the 2005 fishery and status of the stocks

At its annual meeting in June 2005 NASCO agreed to restrict the fishery at West Greenland *to that amount used for internal subsistence consumption in Greenland, which in the past has been estimated at 20 tons*. Consequently, the Greenlandic authorities set the commercial quota to nil, i.e. landings to fish plants, sale of salmon to shops, and commercial export of salmon from Greenland was forbidden. Licensed fishers were allowed to sell salmon at the open markets, to hotels, restaurants, and institutions. A private fishery for personal consumption without a license was allowed. All catches, licensed and private were to be reported to the License Office on a daily basis. In agreement with the Organization for Fishermen and Hunters in Greenland the fishery for salmon was allowed from August 1 to October 31.

5.9.1 Catch and effort in 2005

By the end of the season a total of 13.8 t of landed salmon were reported. In total, 145 reports were received, which is lower than the 169 reports last year. Similar to last year, total reported landings in northern NAFO divisions (1A and 1B; Figure 5.9.1.1) were higher than they have generally been previously. Reported landings from the more southerly divisions (1C, 1D, 1E, and 1F) were around levels that have been observed in recent years. The temporal distribution of the reported landings varies annually. In 2005, reported landings were lower in standard weeks 33 and 34 than in the first week of the season, then increased over the next four weeks and declined thereafter. Harvest in weeks 33 and 34 may have been influenced by the opening of an unrestricted harvest season for caribou. It is difficult to interpret if the temporal distribution of reported landings represents changes in stock distribution, in fishing effort, or in reporting practice.

The number of active participants in the salmon fishery has decreased sharply since 1987, when more than 500 licenses were active and there was an allowable catch of more than 900 tonnes. 185 licenses were issued in 2005, an increase from approximately 150 in 2003 and 2004. For the 2005 fishery, 75 fishers, of whom 29 were licensed, reported catches. The number of fishers reporting catches has increased from 42 to 75 over the last 3 years. Approximately 57% of the licenses were issued in the northern two NAFO Divisions 1A and 1B. Given that sampling has provided more fish than were reported in Nuuk in 2005 and only a low proportion of license holders report catches, this suggested that the nominal catch is underestimated.

There is presently no quantitative approach for estimating the magnitude of personal consumption or subsistence fishing. The unreported catch is assumed to have been at the same level as estimated in recent years (around 10 t).

5.9.2 Biological characteristics of the catches

The international sampling program for landings at West Greenland initiated by NASCO in 2001 was continued in 2005. Sampling teams from Greenland, Ireland, UK (Scotland), UK (England & Wales), and USA were in place at the start of the fishery and continued through October. In total, 854 salmon were inspected for the presence of tags, representing 23 % (by weight) of the reported landings. Of these, 767 were measured for fork length and weight, scales were collected and tissue removed for DNA analysis. The broad geographic distribution of the subsistence fishery caused practical problems for the sampling teams. However, temporal coverage was adequate. More salmon have been sampled than reported in the official statistics for the third year in a row in Nuuk, and for the sixth time since 2002 when including all the sampling areas. Therefore, the total landings were corrected for the weight of fish sampled for assessment calculations.

Tissue and biological samples were collected from four landing sites: Qaqortoq (NAFO Div. 1F), Nuuk (NAFO Div. 1D), Maniitsoq (NAFO Div. 1C), and Qasigiannguit (NAFO Div. 1A) (Figure 5.9.1.1). The average weight of a fish from the 2005 catch was 3.31 kg across all ages, with North American 1SW fish averaging 65.9 cm and European 1SW fish averaging 66.4 cm in length (Table 5.9.1.1).

The river ages of European salmon ranged from 1 to 5 (Table 5.9.1.1). Over half (61%) of the European fish in the catch were river-age 2 and 15% were river-age 3. The proportion of the European origin river-age 1 salmon in the catch has ranged between 9% and 19% since 2001. North American salmon up to river-age 6 were caught at West Greenland in 2005, with approximately 36% being river-age 3 and 31% being river-age 4.
In 2005, 97% of the European samples were 1SW salmon and 2% were previous spawners. 1SW salmon also dominated the North American component (94%), but repeat spawners increased from 2 to 6% compared to 2004 (Table 5.9.1.1).

Tissue for disease testing was obtained from 81 fish in Nuuk. These samples were tested for the presence of ISAv by RT-PCR assay only and all test results were negative.

The sex was determined by examining gonads for 148 salmon (95 whole and 53 viscera); of these 16 (11%) were males and 132 (89%) females.

All 767 tissue samples were genotyped at 11 microsatellites. A database of approximately 5000 Atlantic salmon genotypes of known origin was used as a baseline to assign these 767 salmon to continent of origin. In total, 76.3% of the salmon sampled were of North American origin and 23.7% fish were of European origin (Table 5.9.1.1). Applying the continental percentages to the adjusted total catch (15.8 t) resulted in estimates of 12.1 t of North American origin and 3.7 t of European origin fish (2900 and 900 rounded to the nearest hundred fish, respectively) landed in West Greenland in 2005 (Table 5.9.2.1).

5.10 NASCO has requested ICES to provide a detailed explanation and critical examination of any changes to the models used to provide catch options

There were no changes to the models used to provide catch options.

5.10.1 Forecast models for pre-fishery abundance of 2SW salmon

The Working Group has described two temporal phases (ICES, 2003) of salmon production in the Northwest Atlantic. A phase shift in recruitment per spawner in the northwest Atlantic became apparent during the last two decades. The lower recruitment rate is evident throughout the southern Canadian and USA regions. Given the present status of salmon stocks, there is no evidence from any of the regions in North America that there will be a turnaround in abundance in 2006–2008.

The forecast model used to estimate pre-fishery abundance of non-maturing 1SW salmon for North America in 2006 was the same as that used in 2004 and 2005 (ICES, 2004; 2005). The approach accounts for uncertainty in the data and in model selection. The overall approach of modelling the natural log-transformed PFA_{NA} and LS_{NA} using linear regression and the Monte Carlo method used to derive the probability density for the PFA_{NA} forecast was also retained from previous years.

The modelling to forecast pre-fishery abundance of non-maturing (potential MSW) salmon from the Southern European stock group (ICES, 2002; 2003) was similar to previous years. The best model was selected by adding variables (e.g. spawners, habitat, PFA of maturing 1SW salmon and year) until addition of any other parameter was not significant (ICES, 2004). The same variables, *Spawners* and *Year*, were selected in 2005 and 2006.

The 2006–2008 PFA estimates were then used to develop the risk analysis and catch options presented in Section 5.4. The risk assessment for the two stock complexes in the West Greenland fishery is developed in parallel and then combined at the end of the process into a single summary plot or catch options table. The primary inputs to the risk analysis for the complex at West Greenland are:

- PFA forecast for the year of the fishery; PFA_{NA} and PFA_{NEAC}
- Harvest level being considered (tonnes of salmon)
- Conservation spawning limits.

The final step in the risk analysis of the catch options involves combining the conservation limits with the probability distribution of the returns to North America and Southern Europe for different catch options. The returns to North America are partitioned into regional returns based on the regional proportions of 2SW returns of the last five years (2001–2005). Returns to Southern Europe are treated as a stock complex. Estimated returns to each region are compared to the conservation limits. Estimated returns for Scotia-Fundy and USA are compared to the objective of achieving an increase of 10% and 25% relative to average returns of the base period (1992–1996).

5.10.2 Critical evaluation

There were no changes to the model in 2006.

5.11 NASCO has requested ICES to provide any new information on the extent to which the objectives of any significant management measures introduced in recent years have been achieved

NASCO management is directed at reducing exploitation to allow river-specific conservation limits to be achieved. The measures are related to increasing spawning escapement to homewaters. Although influenced by measures taken in homewaters, it is possible to directly evaluate the extent to which management at West Greenland successfully achieved the objectives (Table 5.11.1):

The objective of simultaneous attainment of conservation limits in Labrador, Newfoundland, Quebec, and the Gulf of St. Lawrence has not been achieved.

There has not been a 10% or 25% increase in spawners to either Scotia-Fundy or the USA.

The objective of meeting the conservation limits for the Southern NEAC MSW complex has also not been achieved.

Table 5.4.1. Catch options (T) for West Greenland harvest in 2006, 2007, and 2008 with the probability of meeting management objectives: meeting the 2SW conservation limits simultaneously in the four northern areas of North America; achieving increases in returns from base year average (1992–1996) in the two southern areas; and meeting the MSW conservation limit of the southern European stock complex relative to quota options.

2006

West Greenland Harvest (T)	Simultaneous Conservation (Lab, NF, Queb, Gulf)	Improvement (SF, USA) of Returns		Conservation MSW Salmon Southern NEAC
		> 10%	> 25%	
0	0.029	0.003	0.002	0.685
5	0.027	0.003	0.001	0.681
10	0.026	0.003	0.001	0.677
15	0.024	0.003	0.001	0.672
20	0.023	0.002	0.001	0.668
25	0.022	0.002	0.001	0.661
30	0.021	0.002	0.001	0.656
35	0.019	0.002	0.001	0.650
40	0.018	0.002	0.001	0.646
45	0.017	0.002	0.001	0.641
50	0.016	0.002	0.001	0.636
100	0.010	0.001	**0.001**	0.592

2007

West Greenland Harvest (T)	Simultaneous Conservation (Lab, NF, Queb, Gulf)	Improvement (SF, USA) of Returns		Conservation MSW Salmon Southern NEAC
		> 10%	> 25%	
0	0.030	0.006	0.003	0.602
5	0.028	0.006	0.003	0.599
10	0.026	0.006	0.003	0.596
15	0.025	0.006	0.003	0.590
20	0.024	0.006	0.003	0.586
25	0.023	0.005	0.003	0.581
30	0.022	0.005	0.003	0.577
35	0.021	0.005	0.003	0.572
40	0.020	0.005	0.003	0.567
45	0.019	0.004	0.003	0.561
50	0.019	0.004	0.003	0.557
100	0.013	0.003	0.002	0.506

2008

West Greenland Harvest (T)	Simultaneous Conservation (Lab, NF, Queb, Gulf)	Improvement (SF, USA) of Returns		Conservation MSW Salmon Southern NEAC
		> 10%	> 25%	
0	0.032	0.007	0.004	0.537
5	0.031	0.007	0.004	0.533
10	0.030	0.006	0.004	0.526
15	0.028	0.006	0.004	0.521
20	0.027	0.006	0.004	0.517
25	0.026	0.006	0.004	0.511
30	0.024	0.006	0.003	0.506
35	0.024	0.006	0.003	0.501
40	0.023	0.006	0.003	0.495
45	0.021	0.005	0.003	0.490
50	0.020	0.005	0.003	0.487
100	0.014	0.004	0.002	0.438

(Lab, NF, Queb, Gulf) = Labrador, Newfoundland, Quebec, Gulf of St. Lawrence
(SF, USA) = Scotia-Fundy and USA
A sharing arrangement of 40:60 (F_{NA}) was assumed.

Table 5.4.2. Probability of 2SW returns in 2007, 2008, and 2009 being less than the previous five-year (2001–2005) average returns to regions of North America, relative to catch options at West Greenland.

West Greenland Harvest	2007	2008	2009
Tons	Probability	Probability	Probability
0	0.345	0.393	0.339
5	0.370	0.418	0.365
10	0.397	0.446	0.393
15	0.421	0.471	0.415
20	0.450	0.496	0.439
25	0.473	0.519	0.466
30	0.498	0.540	0.489
35	0.523	0.565	0.514
40	0.546	0.587	0.538
45	0.567	0.610	0.561
50	0.586	0.632	0.585
100	0.765	0.792	0.768

Table 5.9.1.1. Nominal catch and biological characteristics of the West Greenland catch, 2005.

Distribution of 2005 nominal catch (metric tonnes) among NAFO Divisions.

Total	NAFO Division					
	1A	1B	1C	1D	1E	1F
14	1	3	2	1	3	4

RIVER AGE DISTRIBUTION (%) BY ORIGIN

	1	2	3	4	5	6	7	8
NA	2.7	21.4	36.3	30.5	8.5	0.5	0	0
E	19.2	60.5	15	5.4	0	0	0	0

Biological Characteristics of Atlantic salmon sampled from the 2005 West Greenland food fishery.

Continent of Origin (%)	
North America	Europe
76.3	23.7

Sea age composition by continent of origin: North America (NA) and Europe (E)

	Sea-age composition (%)		
	1SW	2SW	Previous Spawners
NA	92.4	1.2	6.4
E	96.7	1.1	2.2

Length and weight by origin and sea age.

	1 SW		2 SW		Previous spawners		All sea ages	
	Fork length (cm)	Whole weight (kg)	Fork length (cm)	Whole weight (kg)	Fork length (cm)	Whole weight (kg)	Fork length (cm)	Whole weight (kg)
NA	65.9	3.19	83.3	7.05	73.7	4.31	66.6	3.31
E	66.4	3.33	75.5	4.19	62.3	2.89	66.4	3.33

Table 5.9.2.1. The catch weighted numbers of North American (NA) and European (E) Atlantic salmon caught at West Greenland 1995-2005. Numbers are rounded to the nearest hundred fish.

YEAR	NUMBERS OF SALMON CAUGHT	
	NA	E
1995	22 100	10 400
1996	23 400	8700
1997	17 200	4300
1998	3200	900
1999	5600	700
2000	5800	2500
2001	9900	4500
2002	2300	1100
2003	2800	1300
2004	4000	1500
2005	3700	1200

Table 5.11.1. Assessing meeting the objectives of NASCO management of the West Greenland fishery.

OBJECTIVE	ASSESSMENT	OUTCOME/EXTENT ACHIEVED	FURTHER CONSIDERATION
Reduce exploitation.	Assessment, reported and unreported landings compared to negotiated catch quotas for the fishery.	The fishery caught no more than the negotiated amount	
75% chance of meeting the conservation limits simultaneously in the four northern regions of North America	Assessment of returns to North America. Run reconstruction to estimate overall returns (S4.9) related to estimated spawning escapement reserve at West Greenland.	This objective has not yet been achieved in the last five years (% of CL for 2001 – 2005 average) Labrador (38%), Quebec (69%), Gulf (74%), Newfoundland (107%)	Restrict fisheries on mixed stocks and stocks below Conservation Limits. Examine other limiting factors such as causes of increased marine mortality, habitat quality, predators etc.
75% chance of achieving increases in returns relative to previous years with the hope that this leads to the rebuilding of Scotia-Fundy and USA stocks.	Assessment of returns to North America. Run reconstruction to estimate overall returns (Sec. 4.9). Improvements of greater than 10% and greater than 25% relative to returns are evaluated (Sec 4.9)	This objective has not been achieved. 10% targets for Scotia-Fundy = 9,659 and USA = 2,242, Not achieved in any year since 2001. 25% targets also not achieved.	Restrict fisheries on mixed stocks and stocks below Conservation Limits. Examine other limiting factors such as causes of increased marine mortality, habitat quality, predators etc. Recovery plans developed for these stocks listed as endangered/ at risk.
75% chance of meeting spawner escapement requirement for the Southern NEAC MSW complex.	Assessment of returns to Southern NEAC. Run reconstruction to estimate overall returns (Sec. 3.3) related to estimated spawning escapement reserve at West Greenland.	This objective has not been achieved. Southern NEAC stock complexes in 2005 (94%) and below for previous years	Restrict fisheries on mixed stocks and stocks below Conservation Limits. Examine other biologically limiting factors such as causes of increased or high marine mortality, habitat quality, bycatch, predators etc.

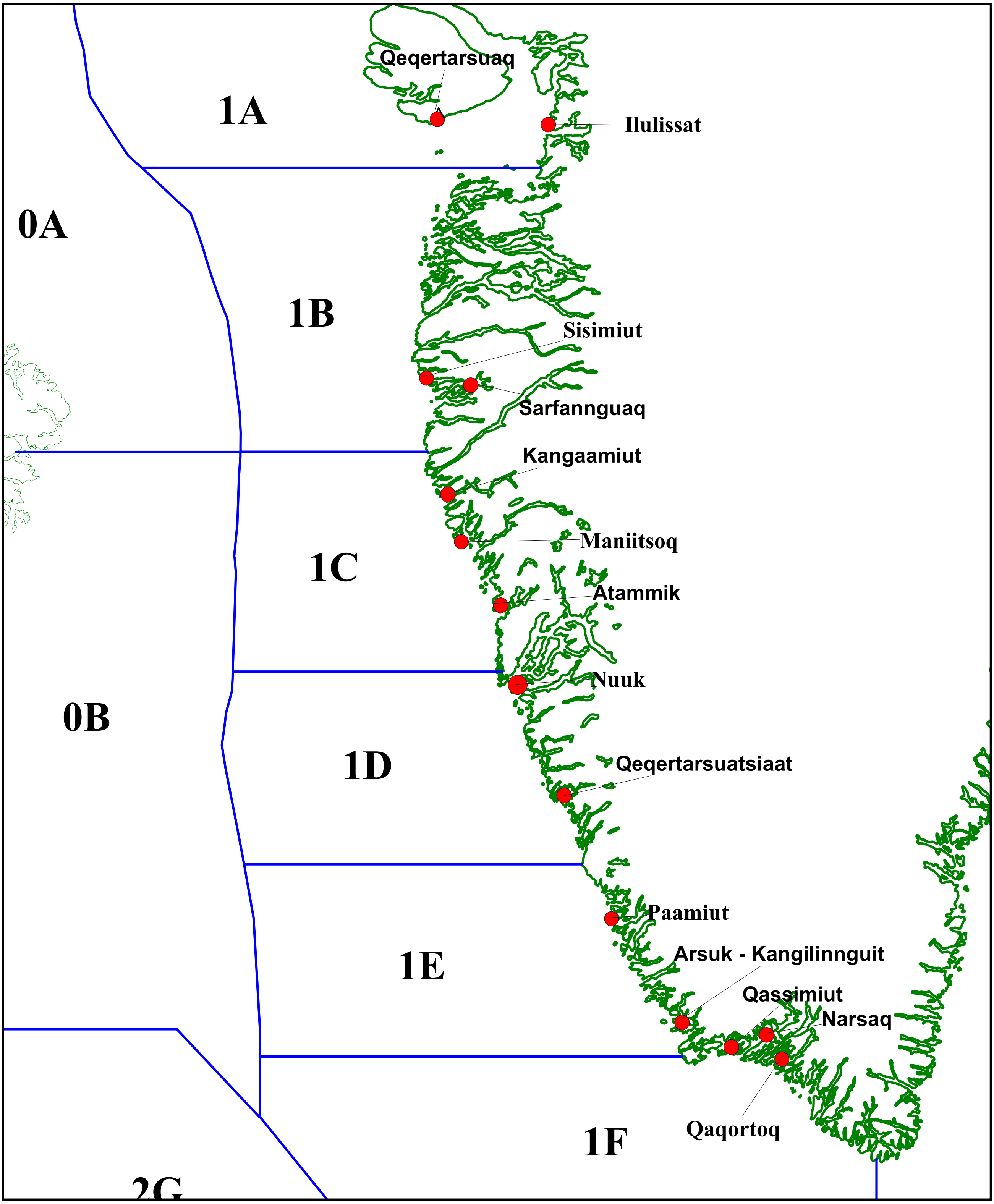

Figure 5.9.1.1. West Greenland NAFO divisions.

6 NASCO has requested ICES to identify relevent data deficiencies, monitoring needs and research requirements taking into account NASCO's international Atlantic salmon research board's inventory of on-going research relating to salmon mortality in the sea

6.1 Data deficiencies and research needs

Recommendations from Section 2 – Atlantic salmon in the North Atlantic Area:

1) ICES recommends that NASCO considers supporting the development of collaborative efforts to genetically characterize salmon stocks across the North Atlantic and the development or continuation of genetic sampling programmes for all mixed stock fisheries and populations contributing to mixed-stock fisheries.
2) ICES recommends that NASCO encourage all Parties to support the continuation of current monitoring programmes across the North Atlantic and encourage the development of opportunities for initiating new monitoring programmes.
3) ICES recommends that a workshop be organized to assemble and analyze historical tagging information to investigate trends in migration and marine distribution of Atlantic salmon at sea.

Recommendations from Section 3 – Fisheries and Stocks from the North East Atlantic Commission Area:

1) ICES recommends that non-catch mortality in relation to bycatch of Atlantic salmon at sea be evaluated.

Recommendations from Section 4 – Fisheries and Stocks from the North American Commission Area:

No recommendations from the North American Commission area.

Recommendations from Section 5 – Atlantic Salmon in the West Greenland Commission Area:

1) ICES recommends that the Home Rule Government of Greenland provides information on the extent of fishing activity by all license holders. Furthermore, it would be helpful if reports filled out by fishers offered the option to report date of catch and number of fishing nets.
2) ICES recommends that a broad geographic sampling program be undertaken (multiple NAFO divisions) to more accurately estimate continent of origin in the mixed-stock fishery.
3) ICES recommends that the Home Rule Government of Greenland improves the estimates of the annual catches of salmon taken for private sales and local consumption in Greenland.

7 To assess the genetic effects of the introgression of farmed Atlantic salmon on wild salmon populations

Request

This is part of continuing ICES work to consider information on interactions between farmed fish and wild fish stocks and related risks.

Recommendations and advice

ICES recommends that Member Countries consider the following management measures aiming at minimising the risk of genetic introgression between wild and farmed Atlantic salmon:

- The Guidelines on Containment of Farm Salmon, developed by the North Atlantic Farming Industry and the North Atlantic Salmon Conservation Organization (NASCO) should be the minimum standard for the construction and operation of fish farms. Research into further improving both technological and operation standards should be undertaken.
- Smolt rearing units should not outflow into salmon rivers (as already required in Norway).
- Marine cages should not be situated within 30 km of salmon rivers.
- Where escapes occur, appropriate recovery plans and resources should be available for immediate deployment.
- If it is intended to introduce sterile transgenic salmon in the industry in the future, research should be undertaken prior to permission being granted to determine the ecological impact that such fish may have on wild populations.

ICES further recommends that Member Countries should support research focussing on the following issues:

- the use of triploids and other bioconfinement methods;
- The further development of realistic life history impact models, which can be used to assess risks of direct genetic interactions;
- indirect genetic and ecological impacts associated with issues such as introduction disease and effects of density dependant population dynamics;
- Spatial and temporal studies on genetic interactions between wild and farmed Atlantic salmon.

Summary

This sections describes risks associated with genetic impacts of escaped farmed Atlantic salmon (*Salmo salar*) on wild stocks of the same species. It briefly summarises the principal findings of twenty years of research into the genetic effects of the introgression of farmed Atlantic salmon on wild salmon populations, to report on attempts to incorporate the data arising from these studies into realistic life history impact models, to review some of the most recent research in the area, to summarise some of the implications of this research for the management of wild fisheries and to recommend appropriate management actions and useful avenues for future research.

Scientific background

Detailed Information is provided in section 2.4 of the 2006 report of the ICES Working Group on the Application of Genetics in Fisheries and Mariculture (WGAGFM) below.
This text was based on a working paper prepared by P. McGinnity and Eric Verspoor; adopted by WGAGFM at Newport, Ireland in 2006.

7.1 Introduction

Since its origin in 1969, salmon farming in the North Atlantic has increased production to c. 800 000 million tonnes in 2004, with Norway and Scotland being the major producers in Europe. NASCO (2005) reports that during the same period the international catch of Atlantic salmon has declined from the 10 000 tonnes reported in the 1960s to 2100 tonnes in 2005. Currently in the order of 2 million salmon escape from salmon farms each year in the North Atlantic, which is equivalent to about 50% of the wild pre-fishery abundance of salmon in this ocean. Escaped farm salmon comprise some 20–40% of the salmon in some North Atlantic areas and rivers with over 80% in some Norwegian rivers (Ferguson *et al.,* 2006). Farm salmon parr also escape from juvenile rearing units but the extent of this has been poorly studied.

Two decades of intensive research into the genetic impacts of farm escape salmon on natural populations has provided a substantial body of useful quantitative data. It is worth noting that this has been one of the best and most successful examples of the application of genetics in answering a difficult fisheries management question. For comprehensive reviews of this research see, Youngson and Verspoor (1998), Naylor *et al.,* (2005), Ferguson *et al.,* (2006), and most recently Hindar *et al.,* (2006).

The objective of this paper is to briefly summarise the principal findings of twenty years of research into the genetic effects of the introgression of farmed Atlantic salmon on wild salmon populations, to report on attempts to incorporate the data arising from these studies into realistic life history impact models, to review some of the most recent research in the area, to summarise some of the implications of this research for the management of wild fisheries and to recommend useful avenues for future research.

7.1.1 Genetic impacts (taken directly from the summary presented in Ferguson *et al.*, 2006 with permission of authors)

Farm salmon are genetically different from wild stocks due to geographical origin, founding effects, and as a result of deliberate and accidental selection, and genetic drift, during domestication. Many farm salmon differences can be related to selection for faster growth and later maturity together with inadvertent changes affecting survival, deformity, feed conversion rate, spawning time, morphology, aggression, egg viability, egg production, and risk-taking behaviour.

Escaped salmon enter rivers generally adjacent to the site of escape but sometimes at considerable distances. These fish have been shown to breed, and interbreed with wild fish, although the greater reproductive success of farm females relative to males, and differences in behaviour, mean that more hybrids are produced than pure farm offspring.

Farm salmon have both indirect and direct genetic effects on wild populations. Indirect genetic effects occur due to behavioural, ecological, and disease interaction thereby reducing the effective population size of the wild population and increasing genetic drift. In particular competition with farm fish and hybrids, which are larger, can reduce wild smolt production. Direct genetic effects occur due to interbreeding with wild fish and backcrossing in subsequent generations.

Farm salmon offspring and hybrids show substantially reduced lifetime success with poorer survival in the early juvenile stages and again in the sea. This results in a loss of fitness (reduced recruitment) in individual wild populations. Since farm escapes are regular occurrences, such reductions in fitness are cumulative and potentially lead to an extinction vortex in 'weak' populations (i.e. on the verge of self sustainability).

Hybridisation and introgression can change the performance characteristics in wild populations with, for example, an increase in multi sea winter salmon in otherwise predominantly grilse populations, which may be desirable from an angling perspective in such rivers. However, given their reduced lifetime success, 'hybrids' do not compensate for the loss of wild recruitment resulting in a decrease in fitness in the population.

Hybridisation and introgression due to backcrossing will result in gene flow from farm to wild. As only a few farm strains are used throughout the industry, this gene flow will reduce the natural inter-population heterogeneity found in Atlantic salmon, thereby reducing the adaptive potential of the species.
Genetically modified (transgenic) salmon would be expected to result in the same genetic effects as non-modified ones, both with respect to changes in genetic structure and with respect to fitness. However, the negative impact on fitness is likely to be even greater.

7.1.2 Incorporating data into life history models

Experimental studies confirm that in at least some situations escaped farm salmon can have major negative impacts on wild populations. However the experimental work is confined to only a few of the potential escape interaction scenarios, which are likely to exist. As such existing information is still inadequate for providing robust scientific information on the management of farm escapes in many situations. In light of the length of time and cost of undertaking experimental studies of a range of escape scenarios the only realistic way forward is to develop predicative models which allow for risk assessment across the range if escape scenarios which could be expected to be encountered. This could range from a few farm escapes interbreeding with a large healthy population in which case it would be unlikely that there would be a large negative impact, to a situation where you have a large continuous input into a small depressed population. Furthermore in light of the fact that we know that farm escapes have this negative impact, the political will to support studies where we are deliberately releasing farm fish into control situations on a wide-scale is unlikely to be there and justifiably so. This means that the only realistic way forward to progress understanding and assess risk is through computer based modelling of the data that has already been collected or that will collected in the future from a few dedicated facilities. In the case of Atlantic salmon this is a very real option because of the detailed understanding that already exists regarding the population dynamics of wild populations and the good understanding of the genetic implications of the interbreeding of farm and wild fish. Furthermore, in recent years theoretical geneticists have begun to develop realistic multi-locus models of genetic structuring in populations (hybrid zone scenarios, etc.).

A recent example of the potential of modelling is Hindar *et al.,* (in press) where they provide a quantitative picture of the rapid change likely to occur in many wild populations as a consequence of farm escapes. Based on data from spawning and whole-river experiments, they model the future of wild salmon populations experiencing invasions of escaped farm salmon. Simulations with a fixed intrusion rate of 20% farm escapes at spawning suggest that substantial changes take place in wild populations within ten salmon generations. Low-invasion scenarios suggest that farm offspring are unlikely to establish in the population, whereas high-invasion scenarios suggest that populations are eventually composed of hybrid and farm descendants. Recovery of the wild population is not likely under all circumstances, even after many decades of no further escapes. They also observe that managers of wild fish will have problems finding broodstock of the original wild population after a few generations of high intrusion rates.

A recent initiative to examine the scope for modeling and the ways forward has been put in place as part of the recently funded EU GENIMPACT community action where a workshop will review this issue. The workshop will bring together researchers working on farm wild interactions in a range of European aquaculture species with modelers attempting to identify the key research questions and the most optimum approach to answering questions and also to develop research initiatives for future EU funding. For example, from the work of Hindar *et al.* (2006), as well as others (Gilbey *et al*., in prep; Bacon *et al.,* unpublished) have identified density dependent factors as being critical in providing realistic outputs from these models. Furthermore it is clear that the genetic model used also is critically important in determining the predictive power of these models.

7.1.3 Update of most recent research

Evolutionary change in farmed populations

Roberge *et al*. (2006) compared the transcription profiles of 3557 genes in the progeny of farmed and wild salmon from Norway and Canada grown in control conditions and showed that five to seven generations of artificial selection led to heritable changes in gene transcription profiles (see Box 1) the average magnitude of the differences being 25% and 18% for at least 1.4% and 1.7% of the expressed genes in juvenile salmon from Norway and Canada, respectively. Remarkably, genes showing significant transcription profile differences in both farmed strains all exhibited parallel changes. The authors of this paper suggest that these findings, along with the identification of several genes whose expression profiles were modified through artificial selection, suggest how gene flow from farm escapes may affect the genetic integrity of wild populations. It also suggests that we are closer to understanding the specific genetic differences between farmed and wild stocks that are responsible for the fitness differences seen in the wild that arise due to selective breeding and domestication. Once these are understood this information can be used to provide more realistic genetic models of interactions, which can be used in modelling exercises.

Potential for indirect genetic effects of farm escapes on natural salmon populations

While direct genetic effects of introgression between wild and hatchery-reared salmon have been demonstrated (McGinnity *et al.,* 2003), the impact of diseases originating from aquaculture (Håstein and Lindstad, 1991; Johnsen and Jensen, 1994; McVicar, 1997) on the genetic integrity of wild fish has not been addressed (E. deEyto, Marine Institute, Ireland, unpublished) compared genotype frequencies of Atlantic salmon (*Salmo salar*) surviving in a natural river six months after their introduction as eggs with frequencies expected from parental crosses. In order to distinguish between natural selection and other forces that might impact on genetic variation, they included eight putatively neutral microsatellite loci in the analysis as controls as well as immunogenetic loci (see Box 2) from both MHC Class I and class II. They found that Atlantic salmon MHC class II alpha genes were under selection in the wild, while the MHC class I-linked microsatellite or at eight non-MHC-linked microsatellite loci were not. They concluded that selection at the MHC class II locus was a result of an immune response, rather than any demographic event. They also showed that survival was associated with additive allelic effects rather than heterozygote advantage at the MHC class II locus. These results have implications for both the conservation of wild salmon stocks, and also the susceptibility of hatchery fish to disease. The authors concluded that natural or hatchery populations have the best chance of dealing with episodic and variable disease challenges if MHC genetic variation is preserved both among and within populations.

Indirect genetic effects on co-occurring wild sea trout

Several studies have documented the genetic effects of intra-specific hybridisation of reared and wild Atlantic salmon, most notably Youngson *et al.,* 1993. However, the effects of salmon aquaculture on wild congeners are less well understood. It is possible that diseases, introduced or increased in incidence by salmon aquaculture activities, have the potential to impact co-occurring wild sea trout (*Salmo trutta* L.). Coughlan *et al.,* (in press) have recently presented data that suggests that salmon farming and ocean ranching can have an indirect genetic effect (most likely mediated by disease) on cohabiting sea trout by reducing variability at major histocompatibility class I genes. Samples of DNA extracted from scales taken from sea trout in the Burrishoole River, in the west of Ireland, before and at intervals during aquaculture activities, were investigated. In these samples allelic variation at a microsatellite marker tightly linked to a locus critical to immune response (*Satr-UBA*) was compared with variation at six neutral microsatellite loci. A significant decline in allelic richness and gene diversity at the *Satr-UBA* marker locus, that was observed since aquaculture started (and which may be an indication of a selective response), was not reflected by similar reductions at neutral loci.

7.1.4 Management considerations (taken directly from Ferguson *et al.*, 2006)

- The Guidelines on Containment of Farm Salmon, developed by the North Atlantic Farming Industry and the North Atlantic Salmon Conservation Organization (NASCO) should be the minimum standard for the construction and operation of fish farms. Research into further improving both technological and operation standards should be undertaken.
- Smolt rearing units should not outflow into salmon rivers (as already required in Norway).
- Marine cages should not be situated within 30km of salmon rivers.
- Where escapes occur, appropriate recovery plans and resources should be available for immediate deployment.
- Further investigations in the use of triploids and other bioconfinement methods should be undertaken.
- If it is intended to introduce sterile transgenic salmon in the industry in the future, research, should be undertaken, prior to permission being granted, to determine the ecological impact that such fish may have on wild populations.

Additional recommendations

- Building of realistic working simulation models, which can be used to assess risks of direct genetic interactions, which can be used to identify research priorities.
- Research into indirect genetic and ecological impacts associated with issues such as introduction disease and effects of density dependant population dynamics.
- Spatial and temporal studies.

Box 1.

Transcription profiles are the direct intensity measurements of "**gene expression"** levels for individual genes using DNA "**micro-array"** technology. "**Gene expression**" is the term used to describe the transcription of the information contained within the **DNA**, the repository of genetic information, into messenger RNA (mRNA) molecules that are then translated into the proteins that perform most of the critical functions of cells. A DNA "**micro-array"** is a tool for analysing gene expression that consists of a small membrane or glass slide containing samples of many genes arranged in a regular pattern. It works by exploiting the ability of a given mRNA molecule to bind specifically to, or hybridise to, the DNA template from which it originated. By using an array containing many DNA samples the expression levels of hundreds or thousands of genes within a cell can be determined simultaneously in a single experiment by measuring the amount of mRNA bound to each site on the array. With the aid of a computer the amount of mRNA bound to the spots on the microarray is precisely measured, generating a profile of gene expression in the cell.

Box 2

The genes of the major histocompatibility complex (MHC) encode proteins that play a crucial role in the vertebrate immune response and several lines of evidence suggest that MHC variability is maintained by pathogen-driven balancing selection.

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Annex 1: Glossary of acronyms used by the Working Group on North Atlantic Salmon, 2006

1SW *(One-Sea-Winter)* Maiden adult salmon that has spent one winter at sea.

2SW *(Two-Sea-Winter)* Maiden adult salmon that has spent two winters at sea.

ASAP *(The Atlantic Salmon Arc Project)* The initial aim of ASAP is to collect samples from the majority of salmon rivers on the Western Atlantic coast of Europe and use methods of Genetic Stock Identification (GSI).

CL, i.e. S_{lim} *(Conservation Limit)* Demarcation of undesirable stock levels or levels of fishing activity; the ultimate objective when managing stocks and regulating fisheries will be to ensure that there is a high probability that undesirable levels are avoided.

CPUE *(Catch Per Unit Effort)* A derived quantity obtained from the independent values of catch and effort.

CWT *(Coded Wire Tag)* The CWT is a length of magnetized stainless steel wire 0.25 mm in diameter. The tag is marked with rows of numbers denoting specific batch or individual codes. Tags are cut from rolls of wire by an injector that hypodermically implants them into suitable tissue. The standard length of a tag is 1.1 mm.

BHSRA *(Bayesian Hierarchical Stock and Recruitment Approach)* Models for the analysis of a group of related stock–recruit data sets. Hierarchical modeling is a statistical technique that allows the modeling of the dependence among parameters that are related or connected through the use of a hierarchical model structure. Hierarchical models can be used to combine data from several independent sources.

DST *(Data Storage Tag)* A miniature data logger with sensors including salinity, temperature, and depth that is attached to fish and other marine animals.

FV *(Fishing Vessel)* A vessel that undertakes cruise for commercial fishing purposes.

GIS *(Geographic Information Systems)* A computer technology that uses a geographic information system as an analytic framework for managing and integrating data.

GSI *(Genetic Stock Identification)* Methods used to 'genetically type' salmon from particular regions and rivers across Atlantic.

ISAV *(Infectious Salmon Anemia Virus)* ISA is a highly infectious disease of Atlantic salmon caused by an enveloped virus.

MSY *(Maximum Sustainable Yield)* The largest average annual catch that may be taken from a stock continuously without affecting the catch of future years; a constant long-term MSY is not a reality in most fisheries, where stock sizes vary with the strength of year classes moving through the fishery.

MSW *(Multi-Sea-Winter)* An adult salmon which has spent two or more winters at sea, or a repeat spawner.

PFA *(Pre-Fishery Abundance)* The numbers of salmon estimated to be alive in the ocean from a particular stock at a specified time.

PGA *(The Probabilistic-based Genetic Assignment model)* An approach to partition the harvest of mixed-stock fisheries into their finer origin parts. PGA uses Monte Carlo sampling to partition the reported and unreported catch estimates to continent, country, and within country levels.

PIT *(Passive Integrated Transponder)* PIT tags use radio frequency identification technology. PIT tags lack an internal power source. They are energized on encountering an electromagnetic field emitted from a transceiver. The tag's unique identity code is programmed into the microchip's nonvolatile memory.

Q Areas for which the Ministère des Ressources naturelles et de la Faune manages the salmon fisheries in Québec.

RV *(Research Vessel)* A vessel that undertakes cruises to conduct scientific research.
SAC *(Special Areas of Conservation)* To comply with the EU Habitats Directive (92/43/EEC) on Conservation of Natural Habitat and of Wild Fauna and Flora, which stipulates that member states maintain or restore habitats and

species to favourable conservation status, a number of rivers in the NEAC area that support important populations of vulnerable qualifying species have been designated SACs. Where salmon is a "qualifying species", additional protection measures specifically for salmon are required.

SER *(Spawning Escapement Reserve)* The CL increased to take account of natural mortality between the recruitment date (1st January) and return to home waters.

SFA *(Salmon Fishing Areas)* Areas for which the Department of Fisheries and Oceans (DFO) Canada manages the salmon fisheries.

SGBYSAL *(Study Group on the Bycatch of Salmon in Pelagic Trawl Fisheries)*. The ICES Study Group that was established in 2005 to study Atlantic salmon distribution at sea and fisheries for other species with a potential to intercept salmon.

S_{lim}, i.e. CL *(Conservation Limit)* Demarcation of undesirable stock levels or levels of fishing activity; the ultimate objective when managing stocks and regulating fisheries will be to ensure that there is a high probability that the undesirable levels are avoided.

TAC *(Total Allowable Catch)* The quantity of fish that can be taken from each stock each year.

VHSV *(Viral Haemorrhagic Septicaemia Virus)* VHS is a highly infectious virus disease caused by the virus family *Rhabdoviridae*, genus *Novirhabdovirus*.

VIE *(Visual Implant Elastomer)* The VIE tags consist of fluorescent elastomer material which is subcutaneously injected as a liquid into transparent or translucent tissue via a hand-held injector.

This glossary has been extracted from various sources, but chiefly the EU SALMODEL report (Crozier et al., 2003).

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