The Standing Scientific Committee on Salmon

Independent Scientific Report to
Inland Fisheries Ireland

The Status of Irish Salmon Stocks in 2016 with Precautionary Catch Advice for 2017

April 2017

Report of the Standing Scientific Committee on Salmon to Inland Fisheries Ireland

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Executive Summary

A National Salmon Commission was established in 1999 under the 1999 Fisheries (Amendment) Act along with a Standing Scientific Committee "*to advise and assist the Commission on all technical and scientific matters in relation to the performance of the Commission's functions.*"

In 2008, the National Salmon Commission was dissolved but the Standing Scientific Committee was retained by the Department of Communications, Energy and Natural Resources with the same terms of reference.

In 2010, the Standing Scientific Committee on Salmon (SSCS) was re-established under Section 7.5 (a) and (b) of the 2010 Inland Fisheries Act:

The full Terms of reference of the SSC are provided in this report.

The purpose of this report, therefore, is to provide IFI with the technical and scientific information required in order to meet its terms of reference under the Act. This includes information on Irish salmon stocks, the current status of these stocks relative to the objective of meeting biologically referenced "Conservation Limits" and the catch advice which will allow for a sustainable harvest of salmon in the forthcoming fishing season and into the future. The report also outlines the scientific advice process leading to the formulation and presentation of the catch advice for the 2017 season.

The Conservation Limit applied by the SSCS to establish the status of individual stocks is the "maximum sustainable yield" (MSY) also known as the stock level that maximizes the long-term average surplus, as defined and used by the International Council for the Exploration of the Sea (ICES) and the North Atlantic Salmon Conservation Organisation (NASCO). The methodology for establishing Conservation Limits was modified for the 2013 catch advice by deriving new estimates of fecundity, average weights, sex and age ratio for Irish index rivers. Similarly, new wetted areas were derived based on a more robust statistical approach and these were also incorporated into the assessment for 2013. Therefore, on the basis of these modifications and the best information available on catches, counts or other estimates and application of a forecast model to these data, the Standing Scientific Committee advises that in 2017:

- 44 rivers have an advised harvestable surplus as they are exceeding their Conservation Limits.
- A further 27 rivers, may be opened on a catch and release only basis, subject to IFI management criteria based on having a high probability of achieving 65% of their CL or exceeding the qualifying fry threshold of > 17 fry (0+) per 5 min electrofishing (multiple site catchment average) .
- In addition 72 rivers are (a) failing to meet 65% of their CL or (b) recent data to determine their CL attainment status are lacking. Where there is a lack of

data, or where catchment-wide electro-fishing surveys indicate juvenile abundance below the SSCS fry threshold, the SSCS assumes that these rivers are failing to meet CL.

There are 16 rivers for which there are significant fisheries on the MSW (spring salmon) component of the stock and a separate assessment is made. Of these:

- 12 have an advised harvestable surplus as they are exceeding their Conservation Limits.
- Three rivers may be opened on a catch and release only basis subject to IFI management criteria as they are they have a high probability of achieving 65% of their CL or exceeding the minimum fry threshold in catchment wide electrofishing.
- One river is not meeting >65% CL and not exceeding the catchment wide electro-fishing salmon fry threshold.

Amongst the stocks being assessed are 54 river stocks where no rod catch data has been available since 2006 and the most recent annual average rod catch (2002-2006) has been less than 10 salmon, making a direct assessment difficult. Although these are insignificant fisheries (accounting for less than 0.5% of the total national rod catch when combined), their stocks are important as spawning populations in their own right, which must be maintained as constituent elements of biodiversity, as required under the EU Habitats Directive. Because there is no recent means of direct salmon stock assessment on these rivers, the SSCS have not provided an assessment of CL attainment on these rivers for the 2017 advice. The SSCS advise that these rivers remain closed until additional information is made available to assess stock status relative to their Conservation Limits. In effect this means that stocks in 89 salmon rivers are assessed annually.

There are currently 40 rivers or river tributaries of the 141 salmon rivers assessed by the SSCS in SACs where salmon have a qualifying interest under the EU Habitats directive. Of these, only 21 are above their CL.

In addition, there are stocks in four major rivers used for hydro power which have been assessed as being below their conservation limits above the impoundments i.e. Upper Liffey (Dublin), Upper Lee (Cork), Upper Shannon (Limerick) and the River Erne and following the scientific advice already provided for other rivers, there should be no harvest fisheries on wild salmon in these specific rivers. It is also recognised however, that the release of hatchery reared salmon has resulted in fishery opportunities within these rivers for these stocks. Restoration programmes should therefore be given precedence until such time as significant improvements to the generation of self-sustaining runs of salmon above these impoundments has been made within the context of agreed restoration plans.

The SSCS note however, that by closing rivers to harvest, there will be an absence of catch data and it will not be possible to provide a direct assessment of the status of some stocks. Therefore alternative stock assessment techniques and information will be required over a number of years. The SSCS recommends that information is made available to allow the committee to provide a stock assessment or index of stock status for all rivers annually. This should be based on at least one of the following indices collected over a suitable time period:

Primary Assessment data for stock assessment:

- Adult counts from fish counter installations (including both main stems and/or tributaries).
- Adult stock indices from existing traps.
- Rod catch data including catch and release.
- Mark recapture assessments.

Data required for stock status indices:

- Juvenile assessment surveys benchmarked against indices of total stock from index rivers.
- Indices of population size, which could be developed in the future, include effective population size (N_e) and number of breeders (N_b), which are based on genetic data.

Redd count data is available for a range of salmon rivers and may be useful as an index of stock if benchmarked against other indices of total stock for index rivers. While information is lacking for many rivers, this is being rectified by active programmes of monitoring (counters and electrofishing) and efforts to improve the quality and quantity of catch returns (i.e. logbooks) from anglers. In this regard, significant progress was made between 2009 and 2016 with the further development of a national electro-fishing programme which could be benchmarked against index rivers (with known juvenile production to adult return relationships). Currently this index is providing an assessment as to whether significant spawning took place in the previous year based on salmon fry abundance. For many systems it is the sole indicator of 'performance'. However, further statistical analyses confirming the relationship between these indices and the stock size will be required to estimate the number of fish in excess of the Conservation Limit and set harvestable surpluses. Work is ongoing by the SSCS in this regard. The installation of twelve new fish counters since 2010 under the Salmon Conservation Fund, administered by IFI, will provide further direct assessment of attainment of Conservation Limits on these rivers.

Despite the considerable reductions in commercial catches, following the closure of the mixed stock fishery at sea in 2007, only 50% of Irelands 89 assessed salmon rivers are currently estimated to be meeting biologically based Conservation Limits. While 27 more rivers could open for catch and release angling, as assessments indicate relatively high juvenile abundances or the stocks are meeting >65% of CL, it is clear the overall proportion of Irish rivers with good population status is low.

Marine survival values in the past 5 years are amongst the lowest recorded since the salmon smolt coded wire tagging programme commenced in 1980. Changes in oceanic conditions leading to poor recruitment of salmon have been implicated by the North Atlantic Salmon Conservation Organisation (NASCO) following international investigations into the decline of salmon stocks (e.g. SALSEA Merge). Recent stock forecasts from the International Council for the Exploration of the Seas (ICES) for stocks in the southern range of the North East Atlantic, indicate that this low stock situation will prevail at least until 2018. Given the current levels of poor survival, the expectation of large catches is unrealistic at present and priority should be given to conservation objectives rather than catch increases until there is a noticeable improvement in stock abundance.

While the main focus of this report is on fisheries and fisheries effects, there are real concerns relating to quality of freshwater environment, factors causing mortality at sea such as diseases and parasites, marine pollution, availability of prey, predator populations and climate change. Presently, there is insufficient empirical information to allow anything other than general advice to be given on these factors *i.e.* the more the effects of each individual factor can be reduced the more salmon will return to our coasts and rivers. Clearly, more directed investigations need to be carried out on these other factors and this is outside the scope of this report.

The Status of Irish Salmon Stocks in 2016 and Precautionary Catch Advice for 2017

Introduction

Up to 2001, the Irish fishery for salmon (*Salmo salar*) was managed by a combination of effort limitation and the application of technical conservation measures relating to size and type of fishing gear. While these measures regulate the efficiency of the fishery, they are not sensitive to the stock available and allow the same level of fishing even when stocks are low. In recognition of this and growing evidence both nationally and internationally of a widespread decline in salmon stocks, a National Salmon Commission was established in 1999 under the 1999 Fisheries (Amendment) Act. Under this Act, provision was made for the establishment of a Standing Scientific Committee (SSC). While the National Salmon Commission was dissolved in 2008, the Standing Scientific Committee continued to function under the aegis of the Department of Communications, Energy and Natural Resources.

In 2010, the Standing Scientific Committee on Salmon (SSCS) was re-established under Section 7.5 (a) and (b) of the 2010 Inland Fisheries Act:

a. IFI may establish a Standing Scientific Committee to advise and assist it on all technical and scientific matters relating to the management of the State's inland fisheries resource.
b. The terms of reference including the composition and membership of a Committee established under *paragraph (a)* will be set by IFI with the agreement of the Minister.

The Terms of Reference of the SSC are as follows:

The Standing Scientific Committee on Salmon (SSCS) is established under Section 7.5 (a) of the 2010 Inland Fisheries Act. The purpose of the committee is to provide scientific advice to guide IFI in the management decisions and policy development aimed at ensuring the conservation and sustainable exploitation of the Ireland's salmon stocks. IFI requests the SSCS to provide an annual report on the status of salmon stocks for the purpose of advising IFI on the sustainable management of Irish salmon stocks. IFI may also request the SSCS to offer scientific advice on the implications of proposed management decisions or policies on salmon or seek advice on scientific matters in relation to salmon. All scientific advice provided by SSCS will be considered as independent advice by IFI.

For the purpose of advising the IFI, the SSCS shall develop age specific conservation limits for individual river stocks and estimate the overall abundance of salmon returning to rivers in the State.

The SSCS shall carry out an assessment of salmon stocks using internationally accepted best scientific practice which should demonstrate whether:

a. conservation limits are being or likely to be attained on an individual river basis and
b. favourable conservation status is being attained within special areas of conservation (SACs) and nationally as required under the habitats directive or otherwise.

The assessment shall take account of mixed stock fishing on salmon stocks including the potential effects on freshwater salmon populations from rivers other than those targeted.

In cases where stocks are determined to be below the conservation limits the Committee shall advise the level to which catches should be reduced or other measures adopted on a fishery basis in order to ensure a high degree of probability of meeting the conservation limits.

The Committee shall provide the IFI with an independent report, which contains the following information:

a. an annual overview of the status of Irish salmon stocks and catches on an individual river basis.
b. catch advice with an assessment of risks associated with the objective of meeting conservation limits in all rivers,
c. an evaluation of the effects on salmon stocks and fisheries of management measures or policies.
d. advice on significant developments and other relevant factors which might assist the IFI in advising the Minister on methods he or she might adopt for the management of salmon stocks.

The SSCS comprises scientific advisers drawn from the State Agencies in Ireland with responsibility for salmonid research, management, protection and restoration i.e. Marine Institute (MI), Inland Fisheries Ireland, the Environmental Protection Agency (EPA), National Parks and Wildlife Service (NPWS), Bord Iascaigh Mhara (BIM), the Electric Ireland (ESB Ireland), The Loughs Agency, the Agriculture, Food and Biosciences Institute for Northern Ireland (AFBINI), (see Appendix I). Although the scientists are drawn from these agencies, the advice from the SSCS is independent of the parent agencies and is considered as independent advice by IFI.

The purpose of this report, therefore, is to provide the technical and scientific information required in order to meet these terms of reference. This includes information on Irish salmon stocks, the current status of these stocks relative to the objective of meeting Conservation Limits (CLs), and the catch advice which will allow for a sustainable harvest of salmon into the future. The report also outlines the scientific advice process leading to the formulation and presentation of the catch advice for the 2016 season following the Irish Government's decision in 2006 to move towards single stock fisheries on stocks meeting Conservation Limits and to end mixed stock fishing at sea.

National Objectives

Government Policy

http://www.dcenr.gov.ie/Natural/Inland+Fisheries+Division/Inland+Fisheries+Division.htm

In 2008, the responsibilities for inland fisheries including the governance of salmon fisheries was transferred to a new department *i.e.* the Department of Communications, Energy and Natural Resources, (now called the Department of Communications, Climate Action and the Environment, DCCAE).

Government policy is to conserve the inland fisheries resource through effective corporate governance of the agencies operating under the aegis of the Department and to facilitate exploitation of the resource on an equitable and sustainable basis.

The Governments strategic objectives are to:

- Ensure the effective conservation, primarily through Inland Fisheries Ireland and the Loughs Agency, of inland fish habitats and stocks.
- Deliver effective legislative and regulatory framework and value for money management for the inland fisheries sector.

International Obligations

In the provision of advice the IFI and the DCCAE must also consider Ireland's international obligations regarding catch advice and attainment of Conservation Limits. Some of these are outlined below.

The North Atlantic Salmon Conservation Organisation (NASCO)

Ireland, as part of the EU, is also a signatory to the NASCO Convention. The primary management objective of NASCO is:

> *'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'.*

In 1998, the North Atlantic Salmon Conservation Organisation (NASCO, 1998) to which the EU is a Contracting Party on behalf of member States, adopted the "precautionary approach" to fisheries management (as outlined in FAO, 1995, 1996). The NASCO Agreement on the Adoption of the Precautionary approach states, that:

'an objective for the management of salmon fisheries is to provide the diversity and abundance of salmon stocks'

or in other words to maintain both the productive capacity and diversity of salmon stocks. NASCO provides interpretation of how this is to be achieved. 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, fishery management actions, habitat improvements and stock enhancement) be developed for stocks that are below Conservation Limits.

In 2008, NASCO indicated that the recent Irish salmon management procedures

" fully comply with NASCOs agreements and guidelines."

The International Council for the Exploration of the Sea (ICES)

The ICES Working Group on North Atlantic salmon (WGNAS) provides scientific advice to NASCO for the management of fisheries in the North Atlantic with particular reference to the mixed stock fisheries of West Greenland and the Faroe Islands. Eastern Atlantic salmon stocks are assessed for the North-East Atlantic Commission (NEAC) as a northern stock complex and southern stock complex. Irish wild salmon stocks are included as part of the southern complex, along with stocks in rivers in France, Iceland (south-west), the UK (England & Wales), UK (Northern Ireland) and UK (Scotland).

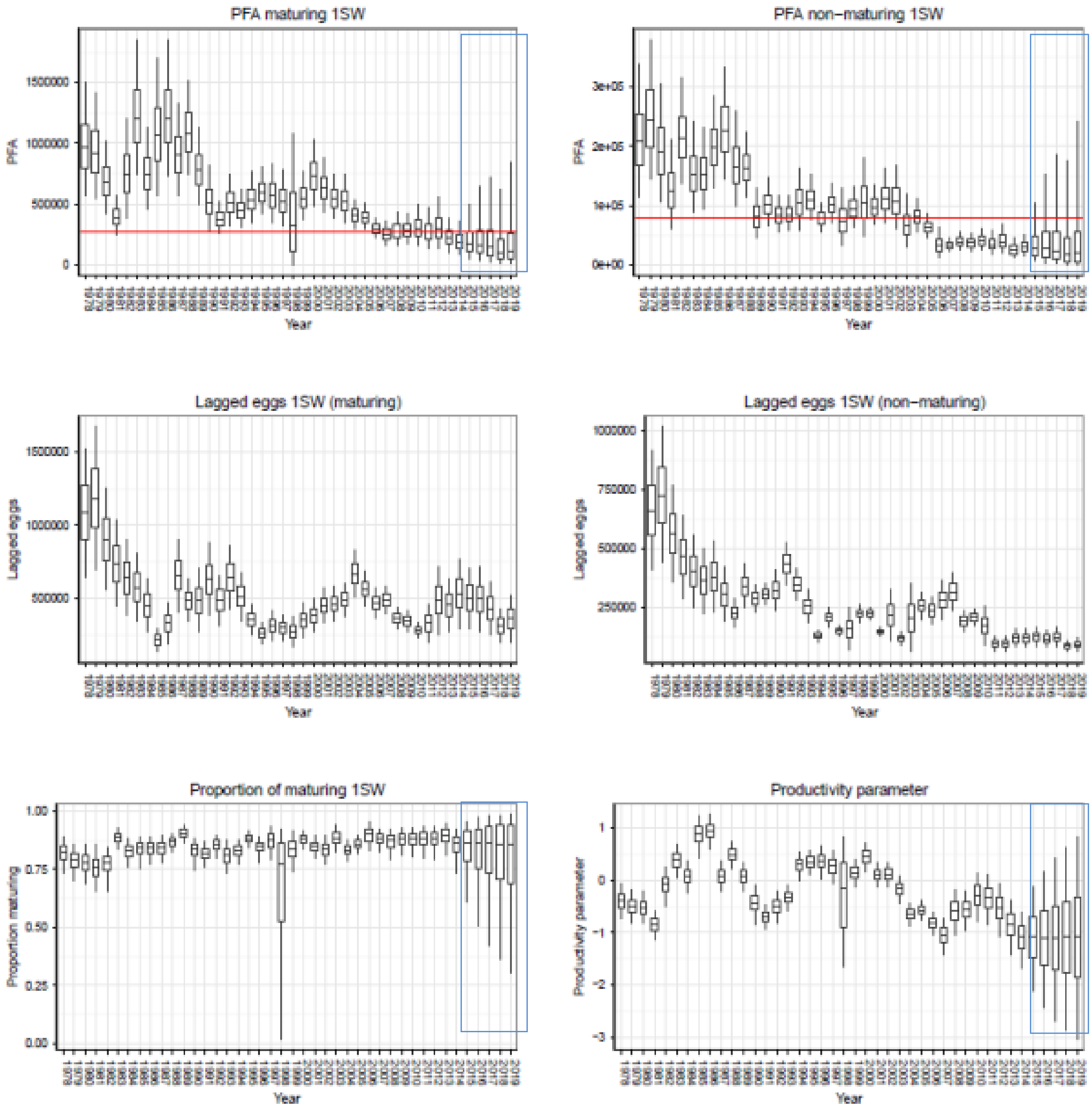
In 2016 ICES provided assessments of the NEAC stock status to NASCO for 2016 to 2019 and advised that:

"When the MSY approach is applied, fishing should only take place on salmon from rivers where stocks have been shown to be at full reproductive capacity. Furthermore, because of the different status of individual stocks within stock complexes, mixed-stock fisheries present particular threats. The management of a fishery should ideally be based upon the individual status of all stocks exploited in the fishery"(NASCO 2016; CNL(16)9).

The assessments included model forecasts for the southern stock complex and its constituent countries, including Ireland, of maturing and non-maturing Pre-Fisheries Abundance (PFA), 1SW and MSW Lagged Eggs, the proportion of PFA maturing and productivity parameter (Figure 1 and Table 1). For Ireland the report indicates that the median maturing and non-maturing PFAs are both below the SER for 2015 to 2019 with only the upper 95th Bayesian credibility intervals (BCIs) predicted to marginally exceed the SER in 2016 and 2017 for maturing PFA. The proportion maturing remains high, at *c*. 0.88 (ICES 2016).

ICES 2016 advice to NASCO included a review of current state of stock complexes, and with reference to the southern stock complex (incorporating Irish river stocks) noted that:

"The 1SW spawning stock has been at risk of suffering reduced reproductive capacity or suffering reduced reproductive capacity for most of the time-series (Figure 2). *In contrast, the MSW stock was at full reproductive capacity for most of the time-series until 1996. After this point, however, the MSW stock has been either at risk of suffering reduced reproductive capacity or suffering reduced reproductive capacity in almost every year. In 2015, the MSW stock complexwas suffering reduced reproductive capacity and the 1SW stock complex was at risk of suffering reduced reproductive capacity."* (NASCO 2016; CNL(16)9).



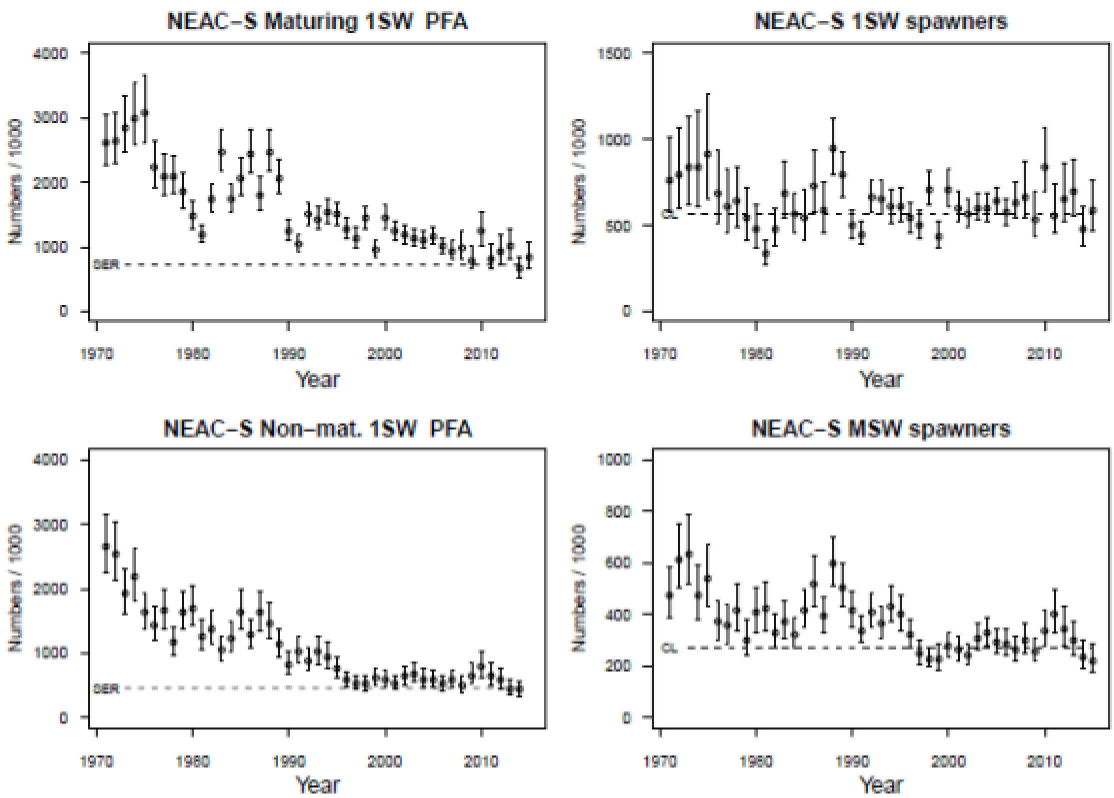
(**Figure 1**). Ireland: PFA maturing and non-maturing, lagged eggs from 1SW and MSW, proportion 1SW maturing, and the productivity parameter values for PFA years 1978 to 2019. For PFAs, proportion maturing and productivity parameter for the last five years (2015 to 2019) are forecasts (as indicated by blue rectangles). The dashed horizontal lines in the upper panels are the age-specific SER values. Box and whiskers show the 5th, 25th, 50th, 75th and 95th BCIs. (ICES 2016).

(Table 1). Probabilities that the forecast PFA for 1SW maturing and 1SW non-maturing fish will be greater than the age specific Spawner Escapement Reserves (SERs) for the PFA years 2015 to 2019 for Ireland.

Ireland		
Spawner Escapement Reserve (SER):	**269,344**	**78,490**
	Probabilities of PFA exceeding SER	
PFA Year	**Maturing**	**Non-Maturing**
2015	0.251	0.097
2016	0.274	0.157
2017	0.261	0.175
2018	0.186	0.144
2019	0.234	0.187

The advice also notes for both the southern and northern European stock complexes that:

> *"Nominal catches and estimated exploitation rates have been decreasing over the time period in Northern and Southern NEAC areas. Despite management measures aimed at reducing exploitation in recent years, there has been little improvement in the status of stocks over time. This is mainly a consequence of continuing poor survival in the marine environment."* (NASCO 2016, CNL (16)9).



(**Figure 2**). Estimated PFA (left panels) and spawning escapement (right panels) with 90% confidence limits, for maturing 1SW (1SW spawners) and non-maturing 1SW (MSW spawners) salmon in southern NEAC (NEAC – S) stock complex (ICES 2016).

A complete summary of ICES (2016) advice to NASCO (ICES CM 2016/ACOM:10) is provided in Appendix II.

The EU Habitats Directive

Council Directive 92/43/EEC (on the conservation of natural habitats and of wild flora and fauna) indicates 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 favourable conservation status in their natural range".*

The North Atlantic salmon (*Salmo salar* L.) has been included as one of the species covered by the Directive. From an Irish perspective, there are currently 40 Irish salmon rivers or their tributaries in SAC's where salmon have a qualifying interest under the Habitats Directive (Appendix III). However, in applying the Directive consideration must be given to all of the populations and not just specifically to these 40 rivers.

The conservation status of a species means the sum of the influences acting on the species concerned that may affect the long-term distribution and abundance of its populations within its territory (also defined) and this *conservation status* will be taken as 'favourable' when:

- population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats
- the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future
- there is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis…"

While not formally an "appropriate assessment" as required under the Habitats Directive, the assessment by the SSC relating to attainment of Conservation Limits can inform on the first of the three criteria above, while informed inferences can made regarding the latter two criteria in this regard. The Directive specifically allows for provision to be made for management measures for salmon, if their conservation status so warrants, including the prohibition of certain means of capture or killing, whilst providing for the possibility of derogations on certain conditions.

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 was submitted in 2007 to the Commission (as part of Irelands reporting requirements under Article 17 of the European Councils Directive) and states that :

"The salmon population in Ireland has declined by 75% in recent years and although salmon still occur in 143 Irish rivers, only 43 of these have healthy populations". (Anon. 2008)

Factors leading to this decline were described in the 2007 report such as reduced marine survival (probably as a result of climate change), poor river water quality (resulting from factors such as inadequate sewage treatment, agricultural enrichment, acidification, erosion and siltation), forestry related pressures and over-fishing. Concerns related to factors causing mortality at sea, such as diseases, parasites and marine pollution were noted. Although the range where salmon were to be found was classified as good, the population size was considered bad, habitat condition was considered poor with future prospects also considered poor. The overall classification for the Atlantic salmon in Ireland was therefore described as “Bad”.

The analysis carried out by the SSCS in 2015 for 2016 indicates that the number of rivers with “healthy populations” on the basis of attainment of Conservation Limits is now 48.

In the second Article 17 report on the status of Irish salmon stocks (Anon 2013) submitted as a requirement under the Habitats Directive in 2013, factors considered as threats to salmon populations are described. These include factors such as agricultural intensification, diffuse pollution to surface waters (resulting from factors such as inadequate sewage treatment, agricultural enrichment, acidification, erosion and siltation), forestry related pressures, pressures related to intensive fish farming and peat extraction, and poaching. Concerns were expressed about the poor levels of marine survival; despite the removal of the drift net fishery from Irish coastal waters in 2006 salmon numbers have not increased. The range where salmon were found was classified as favourable, the population size was considered stable, habitat condition was considered favourable with future prospects considered stable. The overall classification for the Atlantic salmon in Ireland was therefore described as “Stable”, an improvement on the 2007 overall classification of “Bad” status. It was noted that this current period of stability has to be set against the context of a long trend of population decline.

Conservation Limits and Scientific Advice

It is clear from the Government’s strategy and international advice that the *conservation* of salmon stocks is the primary consideration and that there is an aspiration to ensure that national and international obligations are being met. However, in order to provide advice on conservation, it is necessary to establish a conservation “reference point” or “Conservation Limit” which can be measured and used to assess the status of stocks. The following concepts were used by the SSC when considering a Conservation Limit for Irish salmon stocks and for use in the provision of precautionary catch advice.

The Salmon Management Task Force (Anon., 1996) provided the following advice regarding conservation of stocks:

- *Salmon Management will be based on the premise that there is a definable number of spawners for a given river*
- *Sustainable exploitation can take place if there is a surplus of fish over spawning requirements*

The Task Force proposed the application of a Total Allowable Catch (TAC) to allow sufficient fish to spawn to meet these “spawning requirements”.

In 1998, the North Atlantic Salmon Conservation Organisation (NASCO, 1998) adopted the precautionary approach to fisheries management (as outlined in FAO, 1995, 1996). Central to this was the agreement that management measures should be aimed at maintaining all salmon stocks in the NASCO Convention Area above pre-agreed Conservation Limits. The Conservation Limit for Atlantic salmon is defined by NASCO as:

> *"the spawning stock level that produces long term average maximum sustainable yield as derived from the adult to adult stock and recruitment relationship".*

Both the Salmon Management Task Force and NASCO describe a biological reference point, as a point which can be used to assess if salmon stocks are reproducing in sufficient quantities to generate the next generation of salmon. Salmon home to their natal river to spawn and as the number of spawning fish increases, then the number of juveniles increases and also the number of migrating smolts increases. This generally means that the number of adults returning in the following year as 1 sea-winter salmon (or grilse) or in subsequent years as multi-sea winter salmon (2 sea-winter, 3 sea-winter *etc.*) also increases. These older and larger fish usually return in the springtime and are often referred to as spring salmon. However, in some larger rivers (such as the Boyne, Nore, Suir, etc) multi-sea-winter salmon may return primarily in summer and autumn.

There is a limit to the number of juvenile salmon any river can support however, due to competition for food and space. The addition of more spawning salmon can reach a point where they are not contributing to additional production of juveniles or additional smolt output. In this regard, there is a surplus of spawning fish and these can be harvested in a sustainable manner. As each river holds a unique spawning population, which has evolved to survive best in that rivers environment, and there is little straying of salmon from one river to another, a Conservation Limit (CL) of the number of spawning salmon appropriate for each individual river can be calculated.

As both the Salmon Management Task Force advice and the NASCO definition are compatible, the reference point chosen by the SSC to establish the status of individual stocks is the maximum sustainable yield or MSY as described by ICES (2005).

This point can be clearly identified from Stock and Recruitment curves, which are used extensively in fisheries science and fisheries management. ICES in particular has stressed that this is a Limit Reference Point *i.e.* it sets a boundary that defines safe biological limits within which the stock can produce a long term maximum sustainable yield. It therefore delimits the constraints within which the management strategy must operate to maintain a sustainable resource. Individual salmon stocks may well exceed this limit but should not be allowed to fall below the Conservation Limit (ICES 2005). Given the poor returns and low marine survival which prevail currently the SSC advice therefore is to meet the Conservation Limit in the shortest possible time period rather than over a protracted time period. The exception here would be the major impounded rivers i.e. Erne, Lee, Shannon, Liffey, where due to the specific problems associated with fish passage in these rivers, plans may require improvement in fish passage and restoration of individual tributaries upstream of the impoundments on a phased basis, initially taking into account freshwater quality.

Ideally river specific stock and recruitment analysis would be the most accurate way to determine river specific Conservation Limits (Crozier *et al.,* 2004). The acquisition of these relationships is, however, resource intensive as they require a long time scale to cover many generations and a wide range of stock levels. Typical relationships are based on multiple years of stock and recruitment data. It will, for the foreseeable future, be necessary to transport CLs from data-rich rivers to data-poor rivers (Prévost *et al*., 2004). To this end a “Bayesian” hierarchical modelling framework has been developed to transport stock and recruitment information between rivers and to set Conservation Limits accordingly (Crozier *et al.,* 2004, Ó Maoiléidigh *et al.,* 2004). It is important to note that wetted area and latitude are the only common parameters for all rivers (Irish rivers and European index rivers) available to the SSC for these analyses (and most other European rivers). More refined models based on available spawning habitat, river gradient or quality etc. will require that these measures are available for both the subject rivers and the monitored rivers and at present this is not the case. Standardised surveys will be required for this in the future.

Establishment of Conservation Limits for all Irish salmon rivers.
Statistical techniques were developed within the context of the EU funded concerted action i.e. SALMODEL (A co-ordinated approach to the development of a scientific basis for management of wild salmon in the North-East Atlantic, Crozier *et al.,* 2004).

Conservation limits (CLs) were updated in 2012 for calculation of 2013 catch advice and advice in future years. This was undertaken for a number of reasons:

- to update reference rivers providing stock-recruitment indices to a more Irish orientated set in light of new Irish river counter data.
- to ensure that CLs are based on up-to-date, river specific biological information, (e.g. river specific salmon weight rather than national averages).
- in light of updated river wetted areas.

Prior to the 2012 analyses for 2013, the Bayesian Hierarchical Stock and Recruitment Analysis (BHSRA) model was developed for a set of 13 stock and recruitment data series from monitored salmon rivers located in the Northeast Atlantic. For the 2012 analyses for the 2013 season the index rivers were updated, to a more Irish based series comprising 22 rivers, of which 17 are in the island of Ireland, four in the England/Wales (UK) and one in Scotland (UK) (White *et al*, 2016). The time series of spawner – recruits for each river was updated and the model re-run. This yields a set of predicted stock and recruitment parameters for new rivers, provided information is available on the size of the river (in this case accessible habitat or wetted area is used) and on the rivers latitude.

Details of the BHSRA model specification are given in Prevost et al., (2003) and their application to Irish rivers in Ó Maoiléidigh *et al.,* 2004 and White *et al.* 2016. A summary description and the updated reference rivers are presented in Appendix IV.

The ratio of 1SW to MSW fish, the individual weights of fish in each sea age category (1SW & MSW) and their associated fecundities was determined for each river-specific salmon population based on the most recent biological information available. For the 2012-2013 analyses and subsequent years river-specific values were applied. Prior to the 2012 these values were estimated, and set nationally based upon best available information. From 2006 to 2011 salmon in each system were grouped by weight < 4kg or > 4kg. Where data for > 100 fish in each weight category were available river-specific data were used in the forecast model. For rivers with smaller catches (<100 fish) national averages were applied. More detail of the updated CL calculations are given in Appendix VI. A summary is provided in the table 2 below.

Table 2: Summary of data inputs to SSCS model prior to 2012 and after 2012 for 2013 advice.

Conservation Limits	Old Model Data input (up to 2012)	New Model Data Input (for 2013 advice)	Advantage
Wetted Area	Based on groundthruthing from rivers in Mayo only - Published by CFB in 2003	Groundtruthing based on larger sample and other improvements to original approach - peer review publication (McGinnity *et al*. 2011).	Porvides more accurate wetted areas
Age Composition	Assumed single values for most rivers of 93% 1SW and 7% 2SW. For a selected 16 rivers age split based on assuming all fish entering between January and May were "spring" or MSW salmon	Values have been calculated for all rivers individually where rod catch is more than 100 fish. Split is based on weight derived from national catch database or run timing where appropriate and based on local and expert review by IFI	Age composition data are now more reflective of individual rivers
Egg Deposition	Single value applied to all rivers of 3,400 per female 1SW and 8,000 egs 2SW from hatchery stripping	Estimate calculated from a revised national dataset (de Eyto et al 2015) and applied to new weight and age composition data for individual rivers from catch database based on 5 year average. 1SW fecundity average = 3,057, 2SW fecundity = 6,184	Provides the mean and estimates of variation around the mean for individual rivers rather than fixed values
Sex Ratio	Bases on local observations and fixed at 60% male	No change	No change
Monitored rivers used to ransport Stock and Recruitment parameters	Based on 13 Stock and Recruitment series from monitored rivers in the North Atlantic including 4 Irish rivers	New data from 13 Irish rivers with counters and previous Irish rivers data updated. (White et al. 2016). Rivers in extreme latitudes removed.	Provides a more accurate estinmate of Irish Stock and Recruitment parameters and a more appropriate relationship between salmon productivity and latitude for Irish rivers specifically
Transport of Stock and Recruitment	Mean egg deposition/msq used	Median egg deposition used	More statistically robust and represent the underlying data and variation more accurately
Catch Advice	**Old Model data Input**	**New Model data Input**	**Advantage**
Estimates of Total Returns	Based on the mean of the most recent five years catch raised by the estimated exploitation rates or counter data, in a Monte-carlo simulation to predict probabl returns for the next year.	No change	No change
Estimates of Returns by Age Class	Assumed single values for most rivers of 93% 1SW and 7% 2SW. For a selected 16 rivers age split based on assuming all fish entering between January and May were "spring" or MSW salmon	Values have been calculated for all rivers individually where rod catch is more than 100 fish. Split is based on weight derived from national catch database or run timing where appropriate and based on local and expert review by IFI	Estimates of returning salmon can be split more accurately and therefore surpluses/deficits can be calculated to provide advice for management of stock components
Calculation of surpluse/Deficits	Fixed values used for CLs and the catch option providing a 75% chance that the CL will be met based on the predicted estimated returns is advised	Variation in both returns and the CLs are incorporated in the risk analysis i.e. predicted CLs are used and the catch option providing a 75% chance that the CL will be met based on predicted returns is used	This provides a more realistic risk analysys as possible variation in most of the biological parameters has been incorported

Defining Mixed Stock Fisheries and Catch Advice

The migratory behaviour of the Atlantic salmon presents many opportunities for their interception, and a wide range of fisheries have developed, operating in rivers, estuaries, coastal waters and the open ocean. Two contemporary definitions for mixed stock salmon fisheries are given below:

1. From Potter and Ó Maoiléidigh (2006)
   "…MSFs might be defined as any fisheries operating outside estuary limits. The majority of fisheries operating outside river estuaries are known to take salmon from more than one river stock, while within estuary limits, it is unusual (where data are available) for fisheries not to be taking predominantly fish from a single river. This conforms to ICES (2005) advice which states that fisheries in estuaries and rivers are more likely to fulfil the requirement of targeting stocks that have been shown to be within precautionary limits".
2. From NASCO 1998, The North Atlantic Salmon Conservation Organisation (NASCO) has defined mixed stock fishing as:
   "any fishery exploiting a significant number of salmon from two or more river stocks".

Any definition should be related to the primary fishery management objective, which is to maintain river stocks above precautionary limits. In 2006, the Standing Scientific Committee (Anon. 2006) provided the following advice to the National Salmon Commission:

- The overall exploitation in most districts should be immediately reduced, so that Conservation Limits can be consistently met.
- Furthermore, due to the different status of individual stocks within the stock complex, mixed stock fisheries present particular threats to the status of these individual stocks.
- Thus, the most precautionary way to meet national and international objectives is to operate fisheries on river stocks that are shown to be within precautionary limits *i.e.* those stocks which are exceeding their Conservation Limits.
- Fisheries operated in estuaries and rivers are more likely to fulfil these requirements.

The Irish Government committed to aligning with scientific advice in 2006 and essentially closed the Irish marine mixed stock salmon fishery (principally drift nets and some coastal draft nets), thus implementing NASCO and ICES recommendations and complying with the Habitats Directive. The Government also recognised that compliance with scientific advice from 2007 onwards would mean hardship for commercial fishermen and vulnerable coastal communities. Accordingly, the Government appointed an Independent Group to examine all the implications of aligning with scientific advice for commercial fishermen salmon fishing. The Independent Group reported to the Minister in October 2007 and a hardship scheme was introduced for the fishermen affected by the Government decision to move towards single stock salmon fishing only (Collins *et al*, 2006).

The SSCS catch advice provided in 2006 remains in place and advises that fisheries should only be targeted on river stocks shown to be above CL. Commercial fisheries operating in estuaries should only take place if all contributing river stocks are meeting conservation limits. Where fisheries operate on more than one stock, the SSCS provide advice on simultaneous attainment of meeting CL for each contributing stock.

Assessment Methodology for 2016 Catch Advice

There was no change in principle to the methodology used to provide catch advice in 2015 for the 2016 season. A summary of the approach is shown below in Figure 3. In-river or estuarine measures of abundance are used (*i.e.* fish counter data and rod/net catch data) to provide a primary measure of spawning stocks and attainment of Conservation Limits. For the 2012 analyses for 2013 advice, river specific Conservation Limits were updated and these updated CL's will apply in future years. Updates are detailed in the relevant sections below.

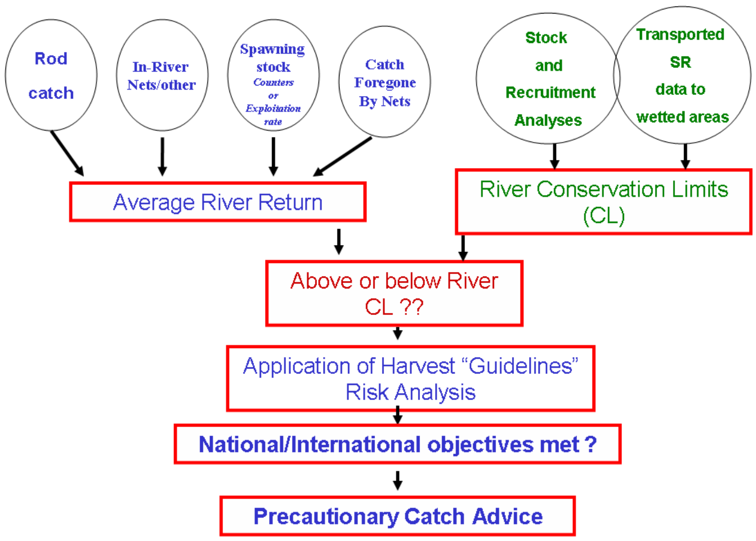


Figure 3. The Scientific Process for catch advice from 2006 to present.

With the operation of fisheries restricted to estuaries and rivers from 2007, the assessment is now focussed primarily on estimating individual river returns from catch data, counter data (if available) and ranges of rod catch exploitation rates derived from observed values in Irish rivers in recent years.

A more comprehensive description of the data used and the assessment in 2016 for the 2017 fishery is provided in the relevant sections below.

Information and data

Every effort is made to obtain relevant data and monitor the performance of stocks (attainment of Conservation Limits) at the river level and consequently to assess the status of individual riverine stocks. Several sources of information are used in this process.

Commercial catch data – Despite the closure of the mixed stock fisheries, the catch statistics derived from the estuarine commercial fisheries (draft nets & snap nets) will remain an important source of quantitative information if fished, particularly in determining the overall size of the returning stock and the attainment of river Conservation Limits. Following implementation of the wild salmon and sea trout tagging scheme which commenced in 2001 (Ó Maoiléidigh *et al.*, 2001; Anon 2004), the catch data are derived from the logbook returns of commercial fishermen. Reporting rates are at 100% from this fishery.

Rod catch data – The reported rod catch from the wild salmon and sea trout tagging scheme (Anon. 2003 to 2010) was adjusted to take into account the numbers of fish that have been caught by anglers who have not returned their logbook. The adjustment follows Small (1991). In some instances, directly reported rod catches from IFI Regional Fisheries officers or rod catch data from managed fisheries (private owners who maintain reliable records), provided these have been vouched for by IFI officers, have also been used. Logbook returns are increasing in recent years and reached a return rate of 74% in 2013, 71% in 2014 and 71% in 2015.

Total traps and counters – Data are available from 32 counters (see below) and salmon traps including the national and international salmon research and monitoring facility on the Burrishoole River in Mayo, which provides a direct measure of the total adult returns and smolt migrations annually. Similarly, data from an adult salmon trap on the Erriff river (Ballinakill District) are available annually.

Values for October to December were extrapolated from the mean of the previous five years where appropriate. Any further information received which indicated changes to previous catch or counter estimates were incorporated where indicated by IFI.

Fish counter data are provided by IFI (or ESB/Marine Institute) in the case of the Liffey in Dublin and some private fishery owners. In total, counts from 33 fish counters were used in 2016 assessments for 2017 advice, an increase of 12 counters on the 2011 – 2012 assessment. These are the: *Dee and Fane (Dundalk), Boyne (Drogheda), Lower Liffey (Dublin), Upper Liffey US Leixlip (Dublin), Upper Lee (Cork), Blackwater (Kerry), Waterville/Currane (Kerry), Maine (Kerry), Feale (Limerick), Fergus, Inagh, Mulkear and Maigue (Limerick), Shannon Upstream Ardnacrusha/Parteen (Limerick), Corrib and Dunkellin (Galway), Boulisce, Casla (Connemara), Ballynahinch (Connemara), Owenglin (Ballinakill), Dawros (Ballinakill), Culfin (Ballinakill), Erriff (Ballinakill), Bunowen (Ballinakill), Srahmore/Burrishoole traps (Bangor), Owenduff/ Glenamong (Bangor), Owenmore (Bangor), Carrowmore (Bangor), Ballysadare (Sligo), Erne and Eske (Ballyshannon) and Eany (Ballyshannon).*

The following approach has been adopted in interpreting the count data and utilising these to measure the attainment of Conservation Limit:

- Fish are initially separated into salmon & sea trout by signal strength generated by the fish passing the counting electrodes and video images.
- A process of validation of the numbers of salmon and sea trout is carried out during the year whereby a proportion of the counter data (usually 15-20%) is examined in relation to contemporaneous video footage (resistivity counters) or self generated infra-red images (infra-red counters).
- The initial numbers of salmon and sea trout are corrected after video verification and this correction factor is applied to the remainder of the data.

- It is assumed that all of the downstream counts up to the end of May represent out-migrating kelts *i.e.* fish ascending the river in the previous year (except for the Corrib, Lee, Shannon and Erne counters).
- The downstream count from June to December is then subtracted from the upstream count in the same period, correcting for fish counted upstream but which may then come back downstream.
- The estimated upstream run of fish from the counter is corrected to include salmon caught and killed downstream of the counter and excludes salmon caught and killed above the counter.
- Raising factors may be applied to those counters where the possibility of fish moving over the weir without being counted has been reported, the recorded count is raised by a further percentage depending on observations. However, it is essential that these observations are based on assessments carried out by local fisheries authorities or the agencies involved in salmon stock assessment. The Dee, Boyne, Corrib and Slaney counts are raised by a factor of two to allow for the partial nature of these counts. These values will be improved following ongoing counter validation work by Inland Fisheries Ireland and the Marine Institute.
- In the case of the River Slaney where the proportion of MSW salmon to grilse is much higher than most other rivers in Ireland, a specific analysis was carried out which allows the numbers of grilse and MSW salmon to be allocated over the season with greater precision than in previous assessments based on scale analyses. Where counters are used the Conservation Limit relates to the area above the counter. In the event that the count is above or below CL, it is assumed that the overall stock is above or below CL.

<u>National Coded Wire Tagging and Tag Recovery</u> – This programme provides an index of marine survival over a long time period and information on exploitation rates in marine and freshwater fisheries. Despite the closure of the mixed stock fisheries in 2007, information from this programme will continue to inform on marine survival rates and exploitation in some estuarine and rod fisheries and more importantly indicates whether fluctuations in the numbers of returning adults are as a result of management measures or changes in factors occurring outside of management control i.e. environmental/climate changes.

Catchment wide electro-fishing – Information on juvenile abundance indices derived from electro-fishing surveys carried out annually by IFI are examined to indicate stock status. This information is used primarily where new information has not been available for rod catches. A summary of the 2016 programme is provided in Appendix VIII.

<u>Status of individual rivers relative to Conservation Limits</u>

In line with international advice on salmon stocks, the SSCS advise that the best way to meet national and international objectives of conserving salmon stocks in all salmon rivers is to allow fisheries only in rivers or the estuary of that river, where there is a greater probability of targeting only the stocks originating from these rivers (*i.e.* single stock fisheries). The SSCS also advise that fisheries should take place only on stocks that are shown to be meeting their Conservation Limit with the catch restricted to the estimated surplus above Conservation Limit. This advice follows from International best practice as advised by ICES and NASCO.

The main objective of the SSC advice therefore, is to ensure that there are sufficient spawning salmon remaining after commercial and recreational fisheries to meet the required Conservation Limit for that river. In order to do this, the number of salmon which will be available before the fishery takes place must be "forecast" for each river annually, based on the average returns in recent years (usually the most recent 5 years provided sufficient information is available). The information required for this forecast is derived from commercial catch data, from extrapolation of rod catch information using exploitation rates or from estimates based on fish counter information.

Estimating the total catch in each river

As stated previously the catch data for draft nets, other commercial engines (snap nets) and rods, derive from mandatory fishing logbooks or from vouched information supplied by the IFI directly. The forecast model requires the inclusion of the fish taken by the commercial fisheries in the estuaries of each river if present.

Estimating the returns of adult salmon in each river using rod exploitation rates

Rod exploitation rates derive from observed exploitation rate values from fish counters or traps on Irish rivers and supported by information from the scientific literature and the National Coded Wire tagging and Tag Recovery Programme. Exploitation by angling on grilse stocks varies but is generally between 10% and 30% of the total river stock available (Milner *et al.*, 2001). These authors quote mean values of 19% for UK rivers, while values for specific Irish grilse (1SW salmon) fisheries have been estimated for the River Erriff at 19% between 1986 and 2000 (Gargan *et al.*, 2001), and 15% for the Burrishoole between 1970 and 2000 (Whelan *et al.*, 2001). Estimates of angling exploitation on multi-sea winter stocks are generally higher than those reported for grilse (Solomon and Potter 1992) and this has also been observed from Irish fish counter data. In 2008, the SSCS evaluated all existing information on individual rod fisheries made available by IFI, including field observations of fisheries which have known high or low intensity, to derive more precise estimates of the likely rod exploitation rate on a river by river basis.

Provided the catch in a river is known, the total stock can be estimated by extrapolation using an appropriate exploitation rate in the fishery *e.g.*:

> *If the rod catch of salmon was 150 fish and the exploitation rate in the fishery was 10%, then the total stock of salmon available to generate this catch would be estimated as the catch raised by the exploitation rate:*
>
> *Catch / Exploitation rate * 100*
>
> *In this case 150 / 10 * 100 = 1,500 salmon.*

For most rivers, the specific exploitation rates are not known and therefore a range of values is applied within which the true value is expected to be. Further, as there is now specific rod exploitation data for Irish rivers with fish counters, it has been possible to allocate all rivers into specific groups representing heavily fished (higher exploitation rate) to lightly fished rivers (low exploitation rate) based on field observations. This restricts the overall range of values being used to a more likely range rather than applying the entire range of values observed. Table VI-1 in Appendix VI provides the exploitation rate range used for each river.

Provision of Harvest Guidelines

Once estimates of average spawners, average catch, and river specific Conservation Limit have been derived, harvest options are provided with the associated probability of meeting Conservation Limits. Where estimates were available for both a counter or trap) and a rod catch, the values for the counter are used.

Following the procedure used by ICES for the provision of catch advice for West Greenland, the harvest option that provides a 0.75 probability level (or 75% chance) of meeting the Conservation Limit for a given stock is recommended. Where there is no harvest option which will provide a 75% chance of meeting the Conservation Limit, then there is no surplus of fish to support a harvest (commercial or rod).

Examples of the data used for the models and probability of meeting the Conservation Limit at various catch options are provided in Appendix VII:

- Examples where catch and exploitation rates are used to establish stock status relative to conservation limits:
  - River Easky (Ballina district) meeting CL with a surplus of 863 fish.
  - Owenwee/Bleclare river (Ballinakill district) below CL with a deficit of 36 fish.
- Examples where counter data are used to establish stock status relative to CL:
  - Cashla River (Connemara district) meeting CL with a surplus of 446 fish.
  - Blackwater River (Kerry district) .below CL with a deficit 3 fish.

It should be noted in these examples that as the harvest increases, the probability or chance of meeting the required Conservation Limit decreases.

Given the uncertainty in the data and the use of a risk analysis to allow for some of this uncertainty, a further limitation is applied to the recruit per spawner index of each river. The SSC currently apply a maximum recruit per spawner value to the abundance outputs derived from the risk assessment of 3 i.e. for every one spawner three recruits may be produced. This is considered to reflect better the overall status of salmon stocks both nationally and internationally.

An objective of the catch advice from the SSCS is to ensure that harvest fisheries only take place on river stocks meeting and exceeding Conservation Limits. The means to achieve this objective is to allow only harvest fisheries, which can specifically target single stocks, which are meeting their Conservation Limits. Where a fishery comprises of more than one stock, the risk analysis is based on the simultaneous attainment of CL for all contributing stocks. For the 2017 advice, only Killary harbour (Bundorragha and Erriff stocks) and the Castlemaine harbour area (Maine, Laune and Caragh river stocks) were considered as true mixed stock fisheries. The fisheries in the common estuary of the Owenmore, Carrowmore and Owenduff were reviewed by the SSC for the 2013 advice and considered to be made up of discrete fisheries with

only a small degree of mixing. Separate advice was provided on each stock in this instance.
Mixed stock fisheries will always present greater risks than when stocks are exploited separately however, because of uncertainties or variability in the proportion of the catch originating from the weaker of the stocks. This is particularly true when there are large differences in the relative numbers of fish in each stock as it may be difficult to estimate the impacts on the smaller stocks. Therefore, to avoid intercepting fish from other rivers, particularly those which are not meeting Conservation Limits, the advice of the SSCS is to operate all fisheries within the estuary of the river stock for which the catch advice is being given and not a common bay or estuary where several rivers stocks may be present. Careful consideration must be made of local topography, fishing practices, number of contributing stocks and their status and the ability to discriminate the contributing stocks and manage the fishery effectively.

In a number of rivers the Conservation Limit will be achieved by the contributions of both 1SW (grilse) and MSW (spring fish). There is conservation of biodiversity and fisheries development value in identifying and protecting both life history types. It is important for the fisheries management to be able to determine how much of the Conservation Limit is likely to be met by either MSW or 1SW fish and to regulate fisheries for both components separately. More information is required on the proportions of each component of the stock being exploited and the timing of their entry into estuaries and freshwater.

The SSCS have provided advice on 1SW and MSW separately where a significant early run component has been identified and can be managed separately on the assumption that all fish counted or caught before 31st May are considered to be MSW fish (except for the Slaney where in-season data are available on proportions of 1SW and MSW salmon).

Overview of Status of Stocks and Precautionary Catch Advice for 2017

Changes from 2016 catch advice procedure for the 2017 catch advice
Changes to the approach used for 2017 compared to previous years are outlined in sections below. Although new Conservation Limits were applied in 2013 and the basis for the risk assessment was modified, few changes applied to the actual catch advice procedure for the 2017 season. The present system of updating previous years catch data to reflect official logbook returns was maintained (unless indicated otherwise by local inspectors), while the catch data for the most recent year was based on local inspectors estimates. Data from fish counters were updated for the previous year to include October to December values if available, while provisional counts for the current year were based on estimates to October. Values for October to December were extrapolated from the mean of the previous five years where appropriate. Any further information received, which indicated changes to previous catch or counter estimates, were incorporated where indicated by IFI.

Therefore, counting each of the combined rivers above as one stock, catch advice for the 2017 season is provided for 141 separate rivers and additionally advice is also given separately for the upper Liffey and upper Lee. Furthermore, separate assessments are made on 16 rivers for the early running 2SW component of the stock in question.

Of these:

- 31 rivers have counter data (includes rivers with large hydro-electric impoundments)
- 2 rivers have trap data (Burrishoole and Erriff).

Details of the catch advice for 2017 provided by the Standing Scientific Committee on Salmon in Ireland are given in Tables 1 through to 6:

SSCS Catch Advice for 2017

Generally, the Standing Scientific Committee advises that:

- Harvest of salmon should only be allowed on stocks from rivers where there is a surplus above the Conservation Limit identified and that no more than this surplus should be harvested *i.e.* those rivers detailed in Table 3 and 4.
- Harvest fisheries should not take place on stocks from rivers without an identifiable surplus above the Conservation Limit *i.e.* those rivers identified in Tables 5, 6 & 7.
- No harvest fisheries should take place on those stocks from 54 rivers where rod catch data have not been available since 2006 to assess salmon stock status (Table 9). SSCS advise that these rivers remain closed to harvest until such time as additional information becomes available to assess the status of these stocks relative to their Conservation Limits. Of these rivers, where electro-fishing information is available to show that the SSCS threshold has been achieved, these rivers can be open for catch & release.

Owing to the different status of individual stocks within the stock complex, mixed stock fisheries present particular threats to stock status (ICES 2014, Appendix II). The objective of the catch advice from the SSCS is to ensure that harvest fisheries only take place on river stocks meeting and exceeding Conservation Limits. The means to achieve this objective is to allow only harvest fisheries which can specifically target single stocks which are meeting their Conservation Limits. The SSCS strongly advise that all fisheries should operate only on the target stock as close to the river mouth or within the river to achieve this.

Even where all exploited stocks in a common estuary are meeting their Conservation Limits, mixed stock fisheries introduce greater uncertainty into predicting the effects of management measures and pose a greater threat to small stocks or populations, especially if these are of low relative productivity and/or subject to high exploitation. As the number of stocks (or populations) increases, the number of fish that must be released from the fisheries in order to meet Conservation Limits must also increase. When the number of populations is too large, it may be impossible to ensure a high probability of the simultaneous achievement of spawner requirements in each individual unit. The overall objective should be to achieve a flexible but sustainable fishery without compromising conservation goals by fishing only single stocks salmon stocks which are shown to have a harvestable surplus over the Conservation Limit. The best way to achieve this is to fish within the river or as close to the river as possible (i.e. the estuary of that river).

The Standing Scientific Committee have been providing catch advice for use by the Department of Communications Energy and Natural Resources (now Dept of Communications, Climate Action & Environment) since 2002 and with specific catch advice for individual rivers since 2007. Over this period the CLs and the assessments for some smaller rivers entering into larger estuaries have been combined leading to changes in the overall number of separate "rivers" for which catch advice is provided. Since 2009 (Figure 4) the number of rivers open for a harvest fishery (either rod and line or estuarine/riverine fishing engines) has remained relatively stable.

The stock status and catch advice for the 2017 fishery is that:

- 44 rivers have an advised harvestable surplus as they are exceeding their Conservation Limits (Table 3).
- A further 27 rivers, may be opened on a catch and release only basis, subject to IFI management criteria based on having a high probability of achieving 65% of their CL or exceeding the qualifying fry threshold of > 17 fry (0+) per 5 min electrofishing (multiple site catchment average) (Table 8).
- In addition 72 rivers are (a) failing to meet 65% of their CL or (b) recent data to determine their CL attainment status are lacking. Where there is a lack of data, or where catchment-wide electro-fishing surveys indicate juvenile abundance below the SSCS fry threshold, the SSCS assumes that these rivers are failing to meet CL (Tables 5 & 9).

There are 16 rivers for which there are significant fisheries on the MSW (spring salmon) component of the stock and a separate assessment is made. Of these:

- 12 have an advised harvestable surplus as they are exceeding their Conservation Limits (Table 4).

- Three rivers (Table 6) may be opened on a catch and release only basis subject to IFI management criteria.as they are they have a high probability of achieving 65% of their CL or exceeding the minimum fry threshold in catchment wide electrofishing,
- One river is not meeting >65% CL and not exceeding the catchment wide electro-fishing salmon fry threshold

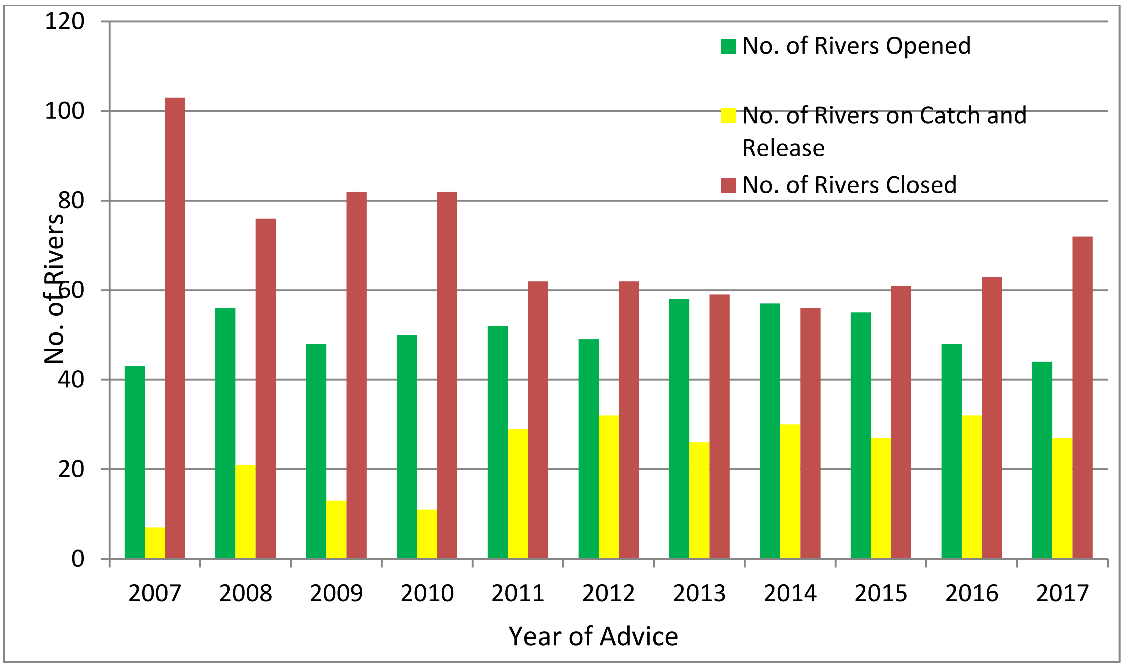


Figure 4. Summary of status of stocks and scientific catch advice provided between 2007 and 2017.

Amongst the stocks being assessed are 54 river stocks (Table 9) where no rod catch data has been available since 2006 and the most recent annual average rod catch (2002-2006) has been less than 10 salmon, making a direct assessment difficult. Although these are insignificant fisheries (accounting for less than 0.5% of the total national rod catch when combined), their stocks are important as spawning populations in their own right, which must be maintained as constituent elements of biodiversity, as required under the EU Habitats Directive. Because there is no recent means of direct salmon stock assessment on these rivers, the SSCS have not provided an assessment of CL attainment on these rivers for the 2017 advice. The SSCS advise that these rivers should remain closed until additional information is made available to assess stock status relative to their Conservation Limits.

Of the 141 rivers being assessed by the SSCS, there are currently 40 rivers or river tributaries in SACs where salmon have a qualifying interest under the EU Habitats directive. Of these, only 21 are above their CL (Appendix III). In addition, there are stocks in four major rivers used for hydro power which have been assessed as being below their conservation limits above the impoundments i.e. Upper Liffey (Dublin), Upper Lee (Cork), Upper Shannon (Limerick) and the River Erne (Table 7) and following the scientific advice already provided for other rivers, there should be no harvest fisheries on wild salmon in these specific rivers. It is also recognised however, that the release of hatchery reared salmon has resulted in fishery opportunities within these rivers for these stocks. Restoration programmes should therefore be given precedence until such time as significant improvements to the generation of self-sustaining runs of salmon above these impoundments has been made within the context of agreed restoration plans.

Table 3. Rivers with a forecasted surplus above the required Conservation Limit for 2017. This is the catch option which provides a 75% chance that Conservation Limit will be met. (Note: 1SW and 2SW combined unless otherwise noted in italics).

District	**River**	**CL**	**Surplus**	**Proportion**
				CL Achieved
Dundalk	Glyde	1856	175	1.09
Lismore	Blackwater, Glenshelane, Finisk	12024	5670	1.47
Cork	Lower Lee (Cork)	1898	1819	1.96
Cork	Bandon	1631	797	1.49
Cork	Argideen	467	143	1.31
Cork	1SW Ilen	678	355	1.52
Cork	Mealagh	96	191	3.00
Cork	Owvane	372	412	2.11
Cork	Coomhola	310	43	1.14
Cork	Glengarriff	166	332	3.00
Kerry	Croanshagh	274	157	1.57
Kerry	Sheen	624	1001	2.60
Kerry	Roughty	1539	117	1.08
Kerry	Sneem	347	695	3.00
Kerry	1SW Waterville	119	168	2.21
Kerry	Inney	629	53	1.08
Kerry	Ferta	224	109	1.49
Kerry	1SW Caragh	395	789	3.00
Kerry	1SW Laune and Cottoners	2072	3636	2.76
Kerry	Maine	1181	272	1.23
Kerry	Owenmore	105	211	3.00
	Common Embayment Castlemaine	4743	3713	
Limerick	1SW Feale, Galey and Brick	2847	773	1.27
Galway	Corrib	7572	5470	1.72
Connemara	Cashla	421	230	1.55
Connemara	Ballynahinch	834	829	1.99
Ballinakill	Owenglin	423	205	1.49
Ballinakill	Dawros	493	454	1.92
Ballinakill	Culfin	136	271	3.00
Ballinakill	Erriff	1383	114	1.08
Ballinakill	1SW Bundorragha	95	190	3.00
Ballinakill	Bunowen	462	310	1.67
Ballinakill	*Common Embayment Killary*	1627	180	
Bangor	1 SW Newport R. (Lough Beltra)	507	231	1.46
Bangor	1SW Owenduff (Glenamong)	712	803	2.13
Bangor	1SW Carrowmore	232	464	3.00
Ballina	Moy	16730	14925	1.89

Ballina	Easky	1399	374	1.27
Sligo	Ballysadare	6363	3350	1.53
Sligo	1 SW Garvogue (Bonnet)	2543	409	1.16
Sligo	Drumcliff	510	90	1.18
Ballyshannon	1 SW Drowes	1059	2119	3.00
Letterkenny	Owenea and Owentocker	1690	320	1.19
Letterkenny	1SW Gweebarra	611	112	1.18
Letterkenny	Gweedore (Crolly R.)	342	156	1.46
Letterkenny	Clady	345	195	1.57

Table 4. Rivers meeting Conservation Limits and estimated surplus and proportion of CL achieved for MSW stocks only in 2017. (Total surplus for these rivers = 1SW & MSW surplus combined).

District	River	CL	Surplus	Proportion CL achieved
Cork	Ilen	212	162	1.77
Kerry	Waterville	83	62	1.74
Kerry	Caragh	280	559	3.00
Kerry	Laune	815	924	2.13
Limerick	Feale	864	181	1.21
Ballinakill	Bundorragha	70	114	2.63
Bangor	Newport	366	185	1.50
Bangor	Owenduff	402	176	1.44
Bangor	Carrowmore	122	243	3.00
Sligo	Garvogue	289	323	2.12
Ballyshannon	Drowes	426	426	2.00
Letterkenny	Gweebarra	116	97	1.84

Table 5. Rivers below Conservation Limits in 2017 and the estimated deficits and proportion of CL achieved for 1SW and MSW stocks combined unless otherwise indicated.

District	**River**	**CL**	**Deficit**	**Prop CL achieved**
Dundalk	Castletown	1449	-1255	0.13
Dundalk	Fane	1177	-516	0.56
Dundalk	1SW Dee	945	-778	0.18
Drogheda	Boyne	10239	-7989	0.22
Dublin	Lower Liffey Inc Rye	1703	-1017	0.40
Dublin	Upper Liffey US Lexlip	5383	-5084	0.06
Wexford	Owenavorragh	945	-738	0.22
Wexford	1SW Slaney counter	915	-770	0.16
Wexford	1SW Slaney rod	915	-509	0.44
Waterford	Barrow and Pollmounty	11737	-9589	0.18
Waterford	Nore	10464	-3104	0.70
Waterford	Suir, Clodiagh, Lingaun, Blkwater	14048	-2966	0.79
Waterford	Colligan	423	-217	0.49
Lismore	Bride	1567	-388	0.75
Cork	Owennacurra	293	-228	0.22
Cork	Adrigole	167	-46	0.72
Kerry	Cloonee	61	-35	0.43
Kerry	Blackwater	437	-285	0.35
Kerry	Behy	177	-97	0.45
Kerry	Owenascaul	181	-110	0.39
Limerick	Maigue	4632	-4449	0.25
Limerick	Upper Shannon (Above Parteen)	49638	-47156	0.05
Limerick	Mulkear	4214	-700	0.83
Limerick	Fergus	1188	-554	0.53
Galway	Owenboliska R (Spiddal)	598	-410	0.31
Connemara	Screebe	151	-8	0.95
Ballinakill	Carrownisky	365	-165	0.55
Ballinakill	Owenwee (Belclare)	374	-53	0.86
Bangor	Srahmore (Burrishoole)	614	-238	0.61
Bangor	Owenmore	2073	-852	0.59
Bangor	Glenamoy	623	-79	0.87
Ballyshannon	Duff	1066	-30	0.97
Ballyshannon	Erne	16586	-14462	0.13
Ballyshannon	Eske	731	-283	0.61
Ballyshannon	Eany	1312	-570	0.57
Ballyshannon	Oily	629	-269	0.57
Ballyshannon	Bungosteen	373	-258	0.31
Ballyshannon	Glen	1197	-98	0.92
Ballyshannon	Owenwee (Yellow R)	183	-75	0.59
Letterkenny	Tullaghobegly	223	-83	0.63

Letterkenny	Ray	435	-187	0.57
Letterkenny	1SW Lackagh	236	-18	0.92
Letterkenny	1SW Leannan	516	-266	0.48
Letterkenny	Crana	1074	-281	0.74

Table 6. Rivers below Conservation Limits and estimated deficits and proportion of CL achieved for MSW stocks only in 2017. (Total deficit for these rivers = 1SW & MSW deficits combined).

District		CL	Surplus	Proportion CL achieved
Dundalk	Dee	715	-589	0.18
Wexford	Slaney Counter	2749	-2088	0.24
Wexford	Slaney Rod	2749	-1343	0.51
Letterkenny	Lackagh	278	-38	0.86
Letterkenny	Leannan	1199	-1074	0.10

Table 7. Status of salmon stocks above rivers impounded for hydro-electric schemes

	Wetted Area u/s of	CL	Average Salmon Count
River	Hydro Station M²		2012-2016
Upper Liffey	2,308,361	5,389	337
Upper Lee	2,370,000	2,789	533
Shannon	30,895,619	49,638	1376
Erne	6,457,264	16,586	2278

Table 8. Rivers open for catch & release based on meeting >65% CL management threshold or meeting SSCS electro-fishing threshold (>17 salmon fry/ 5 min catchment wide average).

District	River	CL	Deficit	Prop CL	Electro-fishing Mean No. fry/5 min
				Achieved	Average
Dundalk	Castletown	1449	-1255	0.13	21
Dundalk	Fane	1177	-516	0.56	19
Dundalk	1SW Dee	945	-778	0.18	17
Drogheda	Boyne	10239	-7989	0.22	19
Dublin	Lower Liffey Inc Rye	1703	-1017	0.40	20
Waterford	Barrow and Pollmounty	11737	-9589	0.18	27
Waterford	Nore	10464	-3104	0.70	
Waterford	Suir	14048	-2966	0.79	
Lismore	Bride	1567	-388	0.75	
Cork	Adrigole	167	-46	0.72	
Kerry	Cloonee	61	-35	0.43	25
Kerry	Blackwater	437	-285	0.35	19

Kerry	Owenascaul	181	-110	0.39	19
Limerick	Mulkear	4214	-700	0.83	
Connemara	Screebe	151	-8	0.95	
Ballinakill	Carrownisky	365	-165	0.55	19
Ballinakill	Owenwee (Belclare)	374	-53	0.86	
Bangor	Owenmore	2073	-852	0.59	28
Ballina	Glenamoy	623	-79	0.87	
Ballyshannon	Duff	1066	-30	0.97	
Ballyshannon	Eany	1312	-570	0.57	20
Ballyshannon	Oily	629	-269	0.57	20
Ballyshannon	Bungosteen	373	-258	0.31	21
Letterkenny	Glen	1197	-98	0.92	
Letterkenny	1SW Lackagh	236	-18	0.92	
Letterkenny	1SW Leannan	516	-266	0.48	18
Letterkenny	Crana	1074	-281	0.74	

Table 9. Rivers where no rod catch data available since 2006, with exceedance of catchment wide electro-fishing (CWEF) threshold indicated.

District	River	CL	Meeting CWEF Threshold (Value)
Dundalk	Flurry	427	No (11.1)
Dublin	Dargle	734	No (3.9)
Dublin	Vartry	274	No (7.9)
Wexford	Avoca	3945	No (7.3)
Waterford	Corock R	836	Yes (21.3)
Waterford	Owenduff	300	No (8.7)
Waterford	Mahon	443	No (5.6)
Waterford	Tay	319	No (4.4)
Lismore	Lickey	148	No (13.3)
Lismore	Tourig	118	No (9.4)
Lismore	Womanagh	368	No (8.9)
Kerry	Kealincha	128	No (0.0)
Kerry	Lough Fada	88	No (2.4)
Kerry	Owenshagh	304	No (5.5)
Kerry	Finnihy	143	No (4.30
Kerry	Owenreagh	87	No (4.6)
Kerry	Emlaghmore	68	No (1.7)
Kerry	Carhan	88	No (10.1)
Kerry	Emlagh	137	No (5.1)
Kerry	Milltown	87	No (15.9)
Kerry	Feohanagh	161	No (10.6)
Kerry	Lee	507	No (0.7)
Limerick	Deel	2823	No (0.7)
Limerick	Doonbeg	525	No (15.3)

Limerick	Annageeragh	321	No (5.5)
Limerick	Inagh	1096	No (4.4)
Limerick	Owenagarney	630	No (13.5)
Limerick	Aughyvackeen	223	No (1.0)
Limerick	Skivaleen	458	No (13.7)
Galway	Aille (Galway)	105	No Data
Galway	Clarinbridge	487	No (7.2)
Galway	Knock	132	No (12.5)
Connemara	L.Na Furnace	71	No (0.0)
Bangor	Owengarve R.	227	No (4.1)
Bangor	Muingnabo	336	No (1.3)
Ballina	Ballinglen	411	No (9.3)
Ballina	Cloonaghmore	1323	No (14.6)
Ballina	Brusna	1096	No (11.2)
Ballina	Leaffony	241	No (4.9)
Sligo	Grange	339	No (4.5)
Ballyshannon	Abbey	333	Yes (17.7)
Ballyshannon	Ballintra (Murvagh R).	548	No (13.9)
Ballyshannon	Laghy	448	No (11.5)
Letterkenny	Bracky	200	No (14.9)
Letterkenny	Owenamarve	205	No (2.5)
Letterkenny	Glenna	215	No (8.1)
Letterkenny	Swilly	1105	No (10.7)
Letterkenny	Isle (Burn)	521	No (2.1)
Letterkenny	Mill	312	No (0.0)
Letterkenny	Clonmany	443	No (9.1)
Letterkenny	Straid	184	No (0.1)
Letterkenny	Donagh	429	No (2.5)
Letterkenny	Glenagannon	377	No (9.3)
Letterkenny	Culoort	252	No (2.0)

Mixed Stock Commercial Fisheries Advice

The objective of the catch advice from the SSCS is to ensure that harvest fisheries operate only - in estuaries where stocks in contributing systems meet and exceed Conservation Limits. There are potentially three mixed stock commercial fisheries operating in estuaries.

Killary Harbour

In the case of the Killary Harbour (Ballinakill) fishery, there are two contributing stocks (Delphi and Erriff) both of which are meeting and exceeding their Conservation Limits in 2017 (Table 1). The SSCS provide advice on the Killary common embayment based on the CL being met on both rivers simultaneously.

Tullaghan Bay

The draft net fishery operating in Tullaghan Bay, Bangor District, exploits stocks from the Owenmore, Owenduff and Carrowmore systems, Following a review of this fishery in 2012, the SSCS determined that the main bulk of the catch was made within the estuaries of the individual rivers, so individual catch options were provided rather than a combined common embayment catch option as in previous years. There is a small overlapping fishery which takes some stock from each river but a local arrangement for the quota for this fishery was determined by IFI for 2013. For the 2015 SSCS advice, one of these river stocks, the Owenmore was below conservation limit and no TAC was provided for the Tullaghan bay fishery or the Owenmore river in 2015. This is also the case for the 2017 advice. The Owenduff river had a substantial surplus and a TAC was allocated to the Owenduff estuary in 2015, 2016 & 2017.

Up to 2010, these were the only such mixed stock fishery situations where advice was provided by the SSCS as in other estuaries there was:

- more than three contributing stocks
  and/or
- one or all of the contributing rivers were failing to meet Conservation Limits
  or
- given the disproportionate size of the contributing stocks, a potential mixed stock fishery would pose a threat to the attainment of Conservation Limits immediately or in the future.

<u>Castlemaine Harbour</u>
In 2010, the Minister of State at the Department of Communications, Energy & Natural Resources requested advice on how a commercial salmon fishery could be operated on stocks in Castlemaine Harbour in a sustainable manner, maximizing the opportunities for commercial fishing whilst ensuring that stocks are not overexploited. In this context, a pilot fishery was operated in Castlemaine Harbour in 2010 to determine the composition of the various stocks in the fishery. The results indicated that at least 94% of the catch in the fishery comprised salmon stocks from rivers entering Castlemaine Harbour (Laune, Caragh and Maine). All three rivers have been above CL since 2011 and a mixed stock fishery has operated since that time. The SSCS provides advice annually on this common embayment fishery based on all three rivers simultaneously achieving their conservation limits.

<u>Recent Trends in Salmon Stock Status</u>

Since 2007, the SSCS have provided scientific advice on an individual river basis regarding salmon stock status. While scientific advice will continue to be presented on an individual river basis, data from fish counters is combined below in order to provide an overview of trends in salmon stock status nationally.

<u>Fish counter time series</u>

The number of counters installed and used in SSCS stock assessments has increased since river specific advice began. The analysis below is based on data from 28-30 of a possible 32 fish counters with a reasonable time series of data. The counter time series runs from 2002 to the present year with the number of counters increasing from 9 to 30. Corrected average yearly fish counts can be calculated using a general linear model (GLM) to show annual trend across the available counters. This provides a benchmarked comparison of how annual salmon returns have varied in this time period. Figure 5 below shows variation in the mean values for numbers of salmon counted through counters from 2002 to 2015, peaking in 2007 which coincided with the closure of offshore drift netting. The linear trend between 2002 and 2014 was fairly stable, however, there has been a marked decline in the linear trend since 2007, with 2014 being the lowest in the time series.

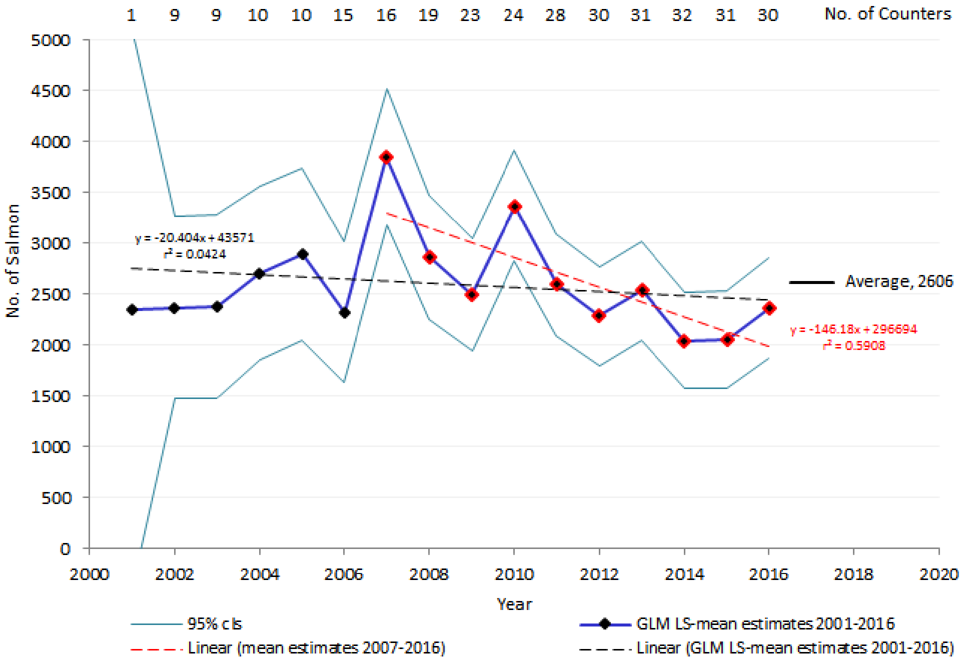


Figure 5. Marginal GLM LS-mean standardized number of salmon counted through counters operated between 2002 and 2016 (±. 95% cls - thin blue lines). The number of counters is shown at the top. The linear trend over the full time period (black dashed line), and between 2007 and the present (red dashed line) are also indicated. Note that the drift net fishery ceased at the end of the 2006 season. The average over the entire time series is also indicated. (Standardized means are calculated as marginal, least squared, means through a Generalised Linear Model).

While a slight upturn in the mean counter value for 2016 was shown, this point is the 4th lowest in the time series and the overall trend (and last 9 year trend) shows a persistent decline. Overall, 22 of 31 counters estimates are below their mean counts, with 9 falling below the lower 95%cl of their proceeding time series, (Fig. 6).

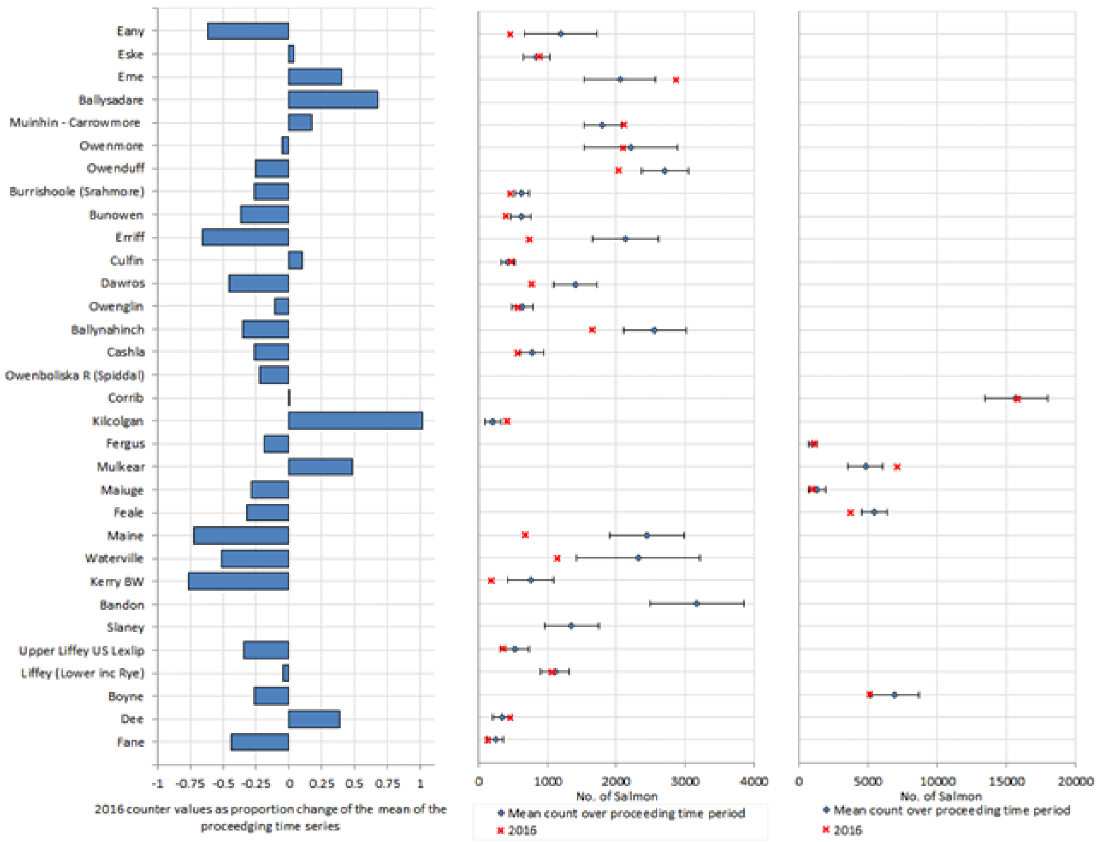


Figure 6. The proportional change in the salmon count in 2016 compared to previous multi-annual means (left panel), and mean salmon counts (± 95% cls) with 2016 value indicated (red X) (middle and right panel – note the different axes scales).

<u>Time series of National salmon returns and estimates of salmon spawners relative to the attainment of CL</u>

<u>One Sea Winter Returns & Spawners</u>

ICES has provided an estimate of national salmon returns and spawners for all countries in the North Atlantic, (ICES 2016). In the case of Ireland, 1SW returns were above CL from 1970 until 2006 and from 2008 to 2013, but have fell below this level in 2014 (lowest value in the time series) and again in 2015 (Fig 7). Spawners have been at or below CL for 19 of the 45 years. In most recent years, post the cessation of the drift net fishery, the national CL has been met or exceeded in all but three years, 2009, 2014 and 2015.

<u>Multi Sea Winter Returns & Spawners</u>

National MSW returns exceeded CL until 1991 (Fig 7) after which values fluctuated around the CL until 2005. Since then, salmon returns of MSW have been well below CL. While the management aim is to ensure that MSW spawners are above CL after any fishery takes place, this has only been achieved once since 1988.

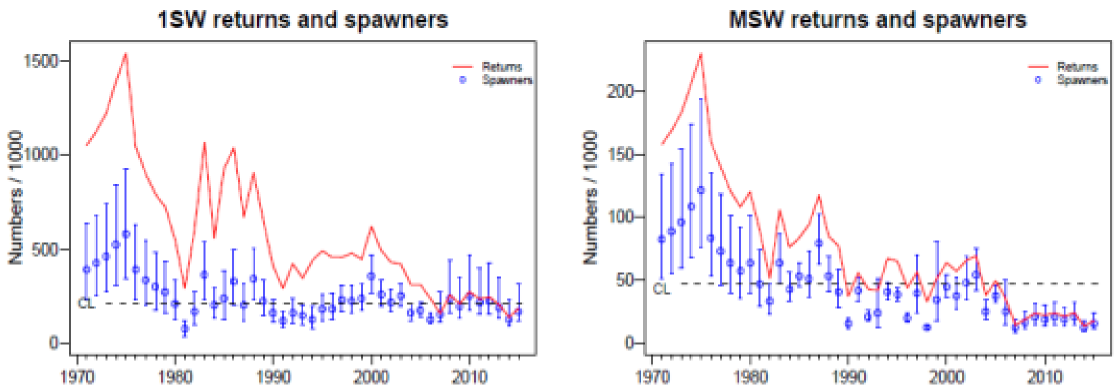


Figure 7. Estimated return of salmon to Ireland prior to homewater fisheries (solid line) and spawners (points including 95% confidence intervals) relative to National Conservation Limits (dashed line). Source ICES 2016.

<u>Advice for Stock Rebuilding</u>

The terms of reference of the SSCS are outlined earlier in this report. One of these relates to salmon stocks below CL.

> *"In cases where stocks are determined to be below the conservation limits the Committee shall advise the level to which catches should be reduced or other measures adopted on a fishery basis in order to ensure a high degree of probability of meeting the conservation limits".*

Other measures to be adopted can relate to stock rebuilding programmes for salmon stocks below CL. In 1998, NASCO adopted the "precautionary approach" to fisheries management. The NASCO Agreement on the Adoption of the Precautionary approach states, that:

‘*an objective for the management of salmon fisheries is to provide the diversity and abundance of salmon stocks’*

or in other words to maintain both the productive capacity and diversity of salmon stocks. NASCO provides interpretation of how this is to be achieved. Management measures should be aimed at maintaining all stocks above their Conservation Limits by the use of management targets. The precautionary approach is an integrated approach that requires, *inter alia,* that stock rebuilding programmes (including as appropriate, fishery management actions, habitat improvements and stock enhancement) be developed for stocks that are below Conservation Limits.

NASCO developed Guidelines on the Use of Stock Rebuilding Programmes (SRP) in the Context of the Precautionary Management of Salmon Stocks in 2004, CNL(04)55. An SRP is an array of management measures, possibly including habitat restoration/improvement, exploitation control and stocking, which is designed to restore a salmon stock above its conservation limit. The nature and extent of the programme will depend upon the status of the stock and the pressures that it is facing. NASCO guidelines on stock rebuilding programmes notes, that while the short-term response to a stock failing to exceed its conservation limit may be to reduce or eliminate exploitation, there will generally be a need to develop a programme to evaluate and address the causes of the stock decline. In more serious situations, there may be a need for a comprehensive programme of research and management, involving a wide range of management actions undertaken by a number of user groups.

NASCO’s SRP guidelines were developed to *inter alia* provide a link between several other guidance documents developed by NASCO in relation to the application of the Precautionary Approach, including the Decision Structure for the Management of Salmon Fisheries, and the Plan of Action for the Protection and Restoration of Atlantic Salmon Habitats. Since the SRP Guidelines were adopted, NASCO has adopted Guidelines for the Management of Salmon Fisheries, CNL(09)43, Guidelines for the Protection, Restoration and Enhancement of Salmon Habitat, CNL(10)51, and 'Guidance on Best Management Practices to Address Impacts of Sea Lice and Escaped Farmed Salmon on Wild Salmon Stocks', SLG(09)5, which contain elements relevant to stock rebuilding.

Ireland was required to submit an Implementation Plan (IP) to NASCO covering the period 2013 – 2018 to demonstrate what actions are being taken to implement NASCO Resolutions, Agreements and Guidelines. Among the information to be provided are the main threats to wild salmon and challenges for management in relation to fisheries, to estuarine and freshwater habitat, and to aquaculture, introductions and transfers, and transgenics. The IP sets out what actions are planned to address each of the above threats and challenges in the five year period to 2018.

Each year Ireland is required to submit an Annual Progress Report (APR) to NASCO providing information on progress against actions in Irelands Implementation Plan relating to management of salmon fisheries, habitat protection and restoration and aquaculture and related activities as well as available information on monitoring the effectiveness of those actions and their enforcement. In addition, details of any significant changes to the status of stocks and any changes to the Implementation Plan are included in the report. The Implementation Plan sets out how actions are proposed to address stock rebuilding of salmon stocks below CL and the Annual Progress Report details progress being made to achieve these objectives.

ICES is also addressing the issue of stock rebuilding of salmon across all North Atlantic salmon countries. The ICES Working Group on Effectiveness of Recovery Actions for Atlantic Salmon (WGERAAS) met twice in 2014 and in 2015, and is reviewing and evaluating the effectiveness of the many salmon recovery and rebuilding programmes that have been implemented in the past. This investigation will enable successful approaches, and their situations, to be highlighted and recommendations based upon this for future works to be made. The group has four Terms of Reference, to:

- Develop a classification system for recovery / re-building programs for Atlantic salmon, including threats to populations, population status, life history attributes, actions taken to re-build populations, program goals, and metrics for evaluating the success of re-building programs;
- Populate the system by collecting data on recovery / re-building programs for Atlantic salmon populations from around the North Atlantic;
- Summarize the resulting data set to determine the conditions under which various recovery / re-building actions are successful and when they are not;
- Provide recommendations on appropriate recovery / rebuilding actions for Atlantic salmon given threats to populations, status and life history.

The findings of this group will be provided to NASCO and reported on to its members by 2016.

Other Factors Affecting Stock Rebuilding Programmes for Irish Salmon Stocks

Closure of marine mixed stock fisheries for salmon and even complete closure of some salmon rivers to harvest fisheries may not ensure that all rivers will meet or exceed Conservation Limits in the short term. There are several identifiable problems militating against immediate recovery and this must be taken into account for future management over and above management of fisheries. In some instances, such as climate changes leading to poorer marine survival of salmon, it may not be possible to tackle the specific problems directly. Some of these specific problems are outlined below.

Marine Survival

Although there has been considerable fluctuation, estimates of marine survival prior to 1996 for wild stocks were generally higher compared to more recent years with survival rates in excess of 15% in many years (*i.e.* 15 adult returns to the coast for every 100 smolts migrating, Figure 8).

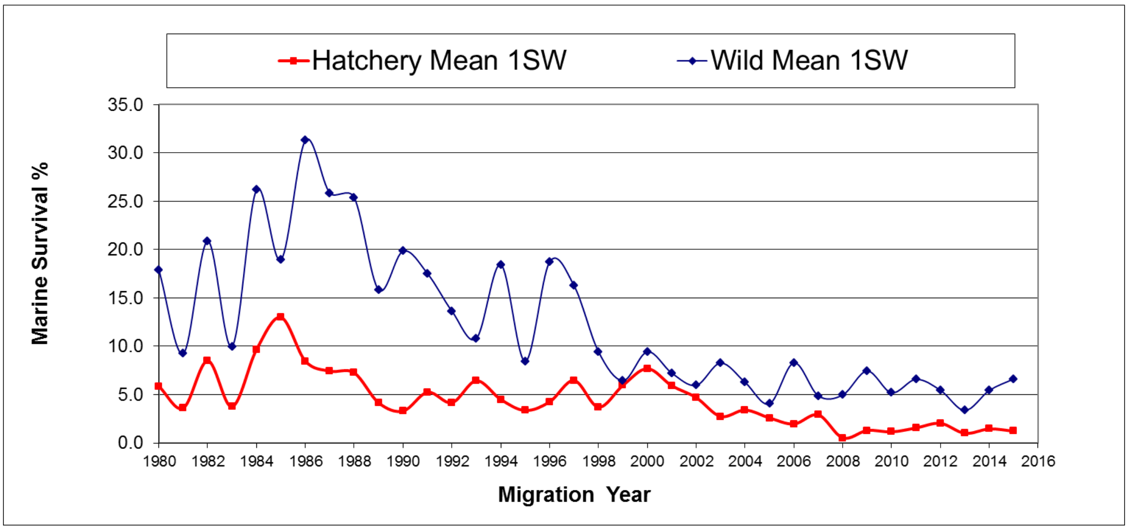


Figure 8. Marine survival (from smolt release to return to the coast) for wild and hatchery salmon.

The current estimates which are amongst the lowest in the time series suggest that based on recent years just over 5% of the wild smolts that go to sea from Irish rivers are surviving (*i.e.* 5 adults returning for every 100 smolts migrating). Survival rates from hatchery fish are lower than for wild fish. The decline in hatchery salmon survival has become more apparent since 2003 and recent values are the lowest in the time series.

Marine survival is influenced by many factors (Figure 9). While the main focus of this report is on fisheries and fisheries effects, there are real concerns relating to factors causing mortality at sea such as predation by seals, diseases and parasites, estuarine pollution *etc.* However, there is insufficient empirical information to allow anything other than general advice to be given on these at this stage *i.e.* the more the effects each individual factor can be reduced the more salmon will return to our coasts and rivers. Clearly more directed investigations need to be carried out on these other factors.

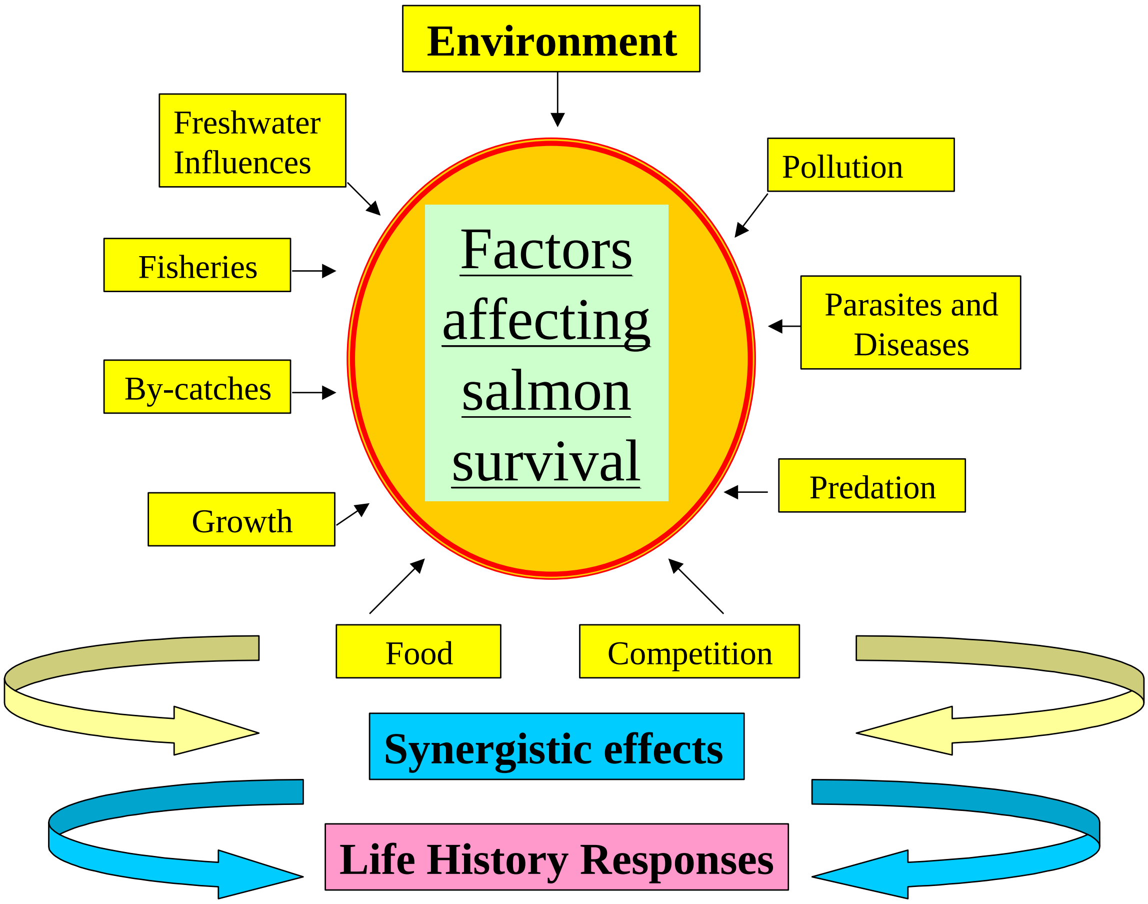


Figure 9. The factors which individually and synergistically affect the marine survival of salmon and which cause significant changes to life history responses such as population structure, fitness and size.

Requirements for future assessments

There are 143 separate 1SW stocks (including upstream of rivers with large hydro-dams, Liffey, Shannon, Erne and Lee) and 16 MSW stocks for which the SSC provide the status of stocks relative to the attainment of biologically based Conservation Limits. Amongst the stocks being assessed are 58, mostly small, river stocks where rod catch data have not been available since 2006 or the most recent annual average rod catch has been less than 10 salmon, making a direct assessment difficult. Therefore, for assessment purposes, these rivers are assumed to be failing to meet Conservation Limits. Although these are insignificant fisheries, their stocks are important as spawning populations in their own right which must be maintained for biodiversity as required under the EU Habitats Directive. As there is no recent stock assessment on these rivers, the SSCS has not provided an assessment of CL attainment on these rivers since 2015. The Standing Scientific Committee advise that additional information should be made available to assess stock status relative to their Conservation Limits for these small rivers.

From a fisheries management perspective and for the purposes of ongoing assessment and provision of catch advice, the remaining rivers support more significant fisheries requiring assessment and specific catch advice and it is possible to provide an assessment based on counters (32) or traps (2) currently in operation, with the remaining stocks being assessed based on an average rod catch and a range of exploitation rates derived from the rivers with fish counters and literature sources. Amongst these, there are the four major rivers (Shannon, Erne, Lee and Liffey) with hydro-electrical power generating impoundments where programmes to rehabilitate or restore some wild stocks are required. If a fishery can proceed, it will be possible to provide ongoing assessments based on the following:

- The existing counters.
- Rod catch.
- Any new counters to be installed.

In the absence of a fishery or counter an alternative assessment for future years will be required based on at least one of the following:

Primary Assessment data for stock assessment:

- Adult counts from fish counter installations (including both main stems and/or tributaries).
- Adult stock indices from existing traps.
- Rod catch data including catch and release.
- Mark recapture assessments.

Data required for stock status indices:

- Juvenile assessment surveys benchmarked against indices of total stock from index rivers.
- Redd count surveys benchmarked against other indices of total stock for index rivers.
- Indices of population size, which could be developed in the future, include effective population size (N_e) and number of breeders (N_b), which are based on genetic data.

Changes to assessments in future years

New developments in the provision of catch advice for international and homewater fisheries have been reported in the context of ICES and EU 7th Framework programmes (ECOKNOWS). The main goals of these programmes are to develop life-history forecast models including production at all life stages of salmon life history. The approaches will allow more data to be included in assessments and underlying assumptions to be tested and validated. It is envisaged that the new approaches for the provision of Irish catch advice will be developed within the next three years.

Until such time as new methods become available the existing forecast model based on fisheries data or count data will be applied using the currently derived conservation limits for the next 5 year period. Data will continue to be updated and where appropriate improved to provide catch advice.

The SSCS examined rod exploitation rates on rivers with counters in 2008 to derive estimates of the likely range of exploitation by anglers on salmon stocks. Since then, new counters have been installed on many rivers and a time series of rod exploitation has been generated on a range of rivers nationally. The SSCS intend to review available data on rod exploitation rates and refine the rod exploitation rates currently being used to provide estimates of salmon stock status.

Conclusions

Despite the considerable reductions in catches, following the closure of the mixed stock fishery at sea in 2007, only 50% of Irelands 89 assessed salmon rivers are currently estimated to be meeting biologically based Conservation Limits. While 27 more rivers could open for catch and release angling as assessments indicate relatively high juvenile densities or the stocks are meeting >65% of CL, it is clear the overall proportion of rivers with good population status is low. Fish counters provide the most direct assessment of salmon stock status in rivers. The number of counters installed and used in SSCS stock assessments has increased from 9 in 2002 to 33 in 2016. There has been variation in the mean count since 2002, with highest numbers recorded in 2007 coinciding with the closure of offshore drift netting. However, there has been a marked decline in salmon counts subsequently with 2014 and 2015 being the two lowest values in the entire time series. A minor improvement was seen in the 2016 counter data. These counter data can be considered as an index for other rivers nationally and probably reflects the national trend.

Based on ICES advice, 1SW returns to Ireland before fisheries take place were above CL from 1970 to 2006, below CL since 2014 and fluctuated around CL in the intervening period. However, following exploitation, spawners have been at or below CL for 19 of the 45 years in the time series. In the most recent years, post the cessation of the drift net fishery, the national CL has been met or exceeded in all but three years , 2009, 2014 and 2015. National MSW returns exceeded CL until 1991 after which values fluctuated around the CL until 2005. Since then, salmon returns of MSW have been well below CL. While the management aim is to ensure that MSW spawners are above CL after any fishery takes place, this has only been achieved once since 1988.

Marine survival values in the past 5 years are amongst the lowest recorded since the coded wire tagging programme commenced in 1980. Changes in oceanic conditions leading to poor recruitment of salmon have been implicated by the North Atlantic Salmon Conservation Organisation (NASCO) following international investigations into the decline of salmon stocks (e.g. SALSEA Merge). Recent stock forecasts from the International Council for the Exploration of the Seas (ICES) for stocks in the southern range of the North East Atlantic, indicate that this low stock situation will prevail at least until 2018. Given the current poor survival, the expectation of large catches is unrealistic at present and priority should be given to conservation objectives rather than catch increases until there is a noticeable improvement in stock abundance.

In this regard, the ongoing management policy of adopting the scientific advice to only allow exploitation on stocks above conservation limit is central to aid the recovery of salmon stocks nationally. With this policy in place, any improvement in marine survival would be reflected in greater numbers of rivers achieving conservation limit. This will contribute to meeting ICES & NASCO advice of providing for the diversity and abundance of salmon stocks.

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Appendix I. Members of the Standing Scientific Committee on Salmon (SSCS) 2000 to 2016

Dr. P. Gargan, (Chair) - Inland Fisheries Ireland
Dr. P. Boylan – The Loughs Agency
Dr. N. Connolly (to 2001) – Coastal Research Centre, University College, Cork
Dr. W. Crozier – (to 2015) Agri-food & Biosciences Institute for N. Ireland (AFBINI)
Dr. D. Doherty (from 2008) – Electricity Supply Board
Ms. M. Dromey (to 2005) – National Parks and Wildlife Service
Dr. E. de Eyto (from 2007) – Marine Institute
B. Kennedy (from 2007) – Environmental Protection Agency
Dr. I. Lawler (from 2007) – Bord Iascaigh Mhara
Dr. D. Lyons (from 2013) National Parks and Wildlife Service
Dr. M. McGarrigle (to 2007) – Environmental Protection Agency
Dr. P. McGinnity – NUI, Cork
Dr. M. Millane (from 2015) Inland Fisheries Ireland
Dr. F. Marnell (from 2005- 2013) – National Parks and Wildlife Service
Dr. V. O'Donovan (to 2007) – Bord Iascaigh Mhara
K. O'Higgins (from 2009) – Inland Fisheries Ireland
Dr. C. O'Keeffe (to 2002) – National Parks and Wildlife Service
Dr. N. Ó Maoiléidigh, Marine Institute
Dr. W. Roche (from 2007) – Inland Fisheries Ireland
Dr. S. Shephard (from 2015) Inland Fisheries Ireland
Dr. J. White (from 2009) – Marine Institute

APPENDIX II. ICES Advice May 2016

ECOREGION North Atlantic
STOCK Atlantic salmon from the Northeast Atlantic

10.2.1 Summary of the advice for fishing seasons 2016/2017 to 2018/2019

In 2015, ICES advised that there were no mixed-stock fisheries options on the NEAC stock complexes at the Faroes for the fishing seasons 2015/2016 to 2017/2018 (ICES, 2015). NASCO subsequently agreed a multi-annual (3-year) regulatory measure for the Faroes fishery stipulating no catch for these seasons. The measure for 2016/2017 and 2017/2018 was predicated on the application of a Framework of Indicators (FWI) to provide an annual check that there had been no substantive change in the forecasts of abundance. Application of the FWI in January 2016 suggested that the forecast for the Northern NEAC multi-sea winter stock complex may have been underestimated. This, therefore, signalled a full reassessment in 2016.

ICES advises that when the MSY approach is applied, fishing should only take place on salmon from rivers where stocks have been shown to be at full reproductive capacity. Furthermore, because of the different status of individual stocks within stock complexes, mixed-stock fisheries present particular threats. The management of a fishery should ideally be based on the individual status of all stocks exploited in the fishery.

In the absence of any fisheries in the fishing seasons 2016/2017 to 2018/2019, there is a less than 95% probability of meeting the conservation limits (CLs) for the two age groups (potential 1-sea-winter (1SW) and multi-sea-winter (MSW) spawners) of the Southern NEAC stock complex. Therefore, in the absence of specific management objectives, ICES advises that there are no mixed-stock fisheries options on the NEAC complexes at the Faroes in the fishing seasons 2016/2017 to 2018/2019. In the absence of any fisheries in these seasons, the probabilities of individual countries meeting their CLs range from 17% to 99% for maturing 1SW salmon and 14% to 100% for salmon maturing as MSW. Some of the management units are exploited at very low levels; however, in the absence of a management decision on which units should be included in the catch options analysis, all management units are currently included.

The FWI previously developed has been updated in support of the multiyear catch advice and the potential approval of multiyear regulatory measures for the Faroes. This updated format can be applied at the beginning of 2017, with the returns or return rate data for 2016, to evaluate the appropriateness of the advice for 2017/2018, and again at the beginning of 2018, with the returns or return rate data for 2017, to evaluate the appropriateness of the advice for 2018/2019.

10.2.2 NASCO has asked ICES to describe key events of the 2015 fisheries

No fishery for salmon has been prosecuted at the Faroes since 2000. No significant changes in gear type used were reported in the NEAC area in 2015. The NEAC area has seen a general reduction in catches since the 1980s (Figure 10.2.2.1). This reflects the decline in fishing effort as a consequence of management measures, as well as a reduction in the size of stocks. The nominal catch for 2015 (1091 t) was above that in 2014 (954 t), but remained among the lowest in the time-series in both areas. The catch in Southern NEAC, which constituted around two-thirds of the total NEAC catch in the early 1970s, has been lower than that in Northern NEAC since 1999 (Figure 10.2.2.1).

2015 nominal catch	Southern NEAC reported	Northern NEAC reported	Faroes	Total reported catch	Unreported catch
	226 t	865 t	0 t	1091 t	298 t

1SW salmon constituted 63% of the total catch in Northern NEAC in 2015 (Figure 10.2.2.2). For the Southern NEAC countries, the overall percentage of 1SW fish in the catch in 2015 was estimated at 52%. In both areas, 1SW fish have generally constituted a smaller proportion of the catch in the last decade than earlier in the time-series. There is considerable variability in the proportions among individual countries (Figure 10.2.2.2).

The contribution of escaped farmed salmon to national catches in the NEAC area in 2015 was again generally low in most countries, with the exception of Norway, Iceland, and Sweden, and is similar to the values that have been reported in previous years. Estimates of farmed fish in Norwegian angling catches were in the lower range of observed values in the time-series (5%), while the proportion of farmed salmon estimated in Norwegian rivers in the autumn was the lowest in the time-series (provisionally estimated at 10%).

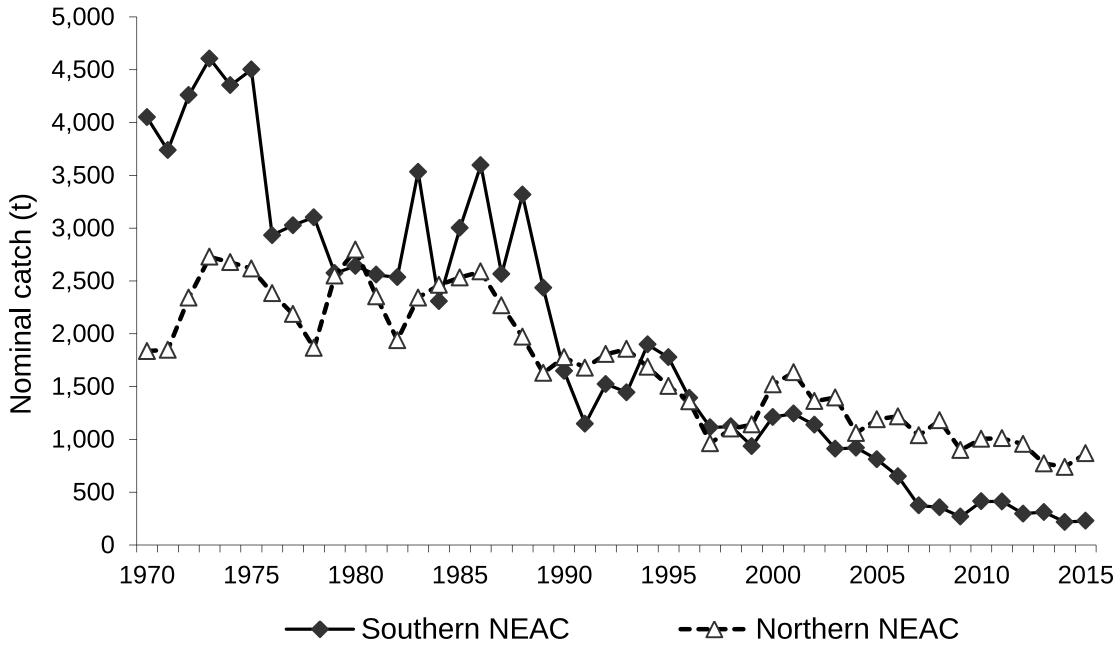

Figure 10.2.2.1 Nominal catches of salmon in the Southern NEAC and Northern NEAC areas (1971–2015).

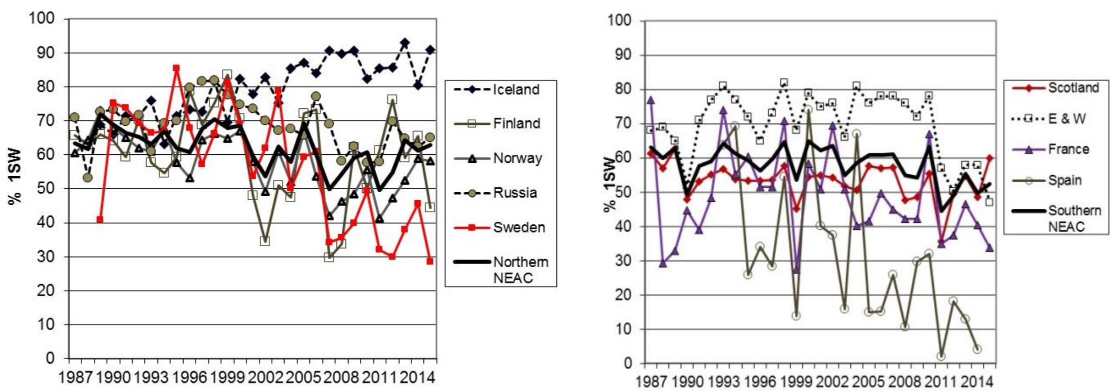

Figure 10.2.2.2 Percentage of 1SW salmon in the reported catch for Northern NEAC countries (left panel) and Southern NEAC countries (right panel). Solid bold line denotes mean value from catches in all countries within the complex.

10.2.4 NASCO has asked ICES to describe the status of the stocks

National stocks within the NEAC area are combined into two groupings for the provision of management advice for the distant-water fisheries at West Greenland and the Faroes. The Northern group consists of: Russia, Finland, Norway, Sweden, and the northeastern regions of Iceland. The Southern group consists of: UK (Scotland), UK (England and Wales), UK (Northern Ireland), Ireland, France, and the southwestern regions of Iceland.

Recruitment, expressed as pre-fishery abundance (PFA; split by maturing and non-maturing 1SW salmon, at 1 January of the first winter at sea) is estimated by stock complex (Northern NEAC and Southern NEAC), and individual country, and interpreted relative to the spawner escapement reserve (SER).

PFAs of both maturing 1SW and non-maturing 1SW salmon for Northern NEAC show a general decline over the time period (since 1983), with the decline being more marked in the maturing 1SW stock (Figure 10.2.4.1). Both stock complexes have, however, been at full reproductive capacity prior to the commencement of distant-water fisheries (i.e. meeting the SER with at least 95% probability) throughout the time-series. PFA of maturing 1SW and of non-maturing 1SW salmon for Southern NEAC demonstrate broadly similar declining trends over the time period (since 1971). Both stock complexes were at full reproductive capacity prior to the commencement of distant-water fisheries throughout the early part of the time-series. However, in around half of the years since the mid-1990s, the non-maturing 1SW stock has been at risk of suffering reduced reproductive capacity before any fisheries took place. The maturing 1SW stock, on the other hand, was first assessed as being at risk of suffering reduced reproductive capacity in 2009, and has been at risk of suffering reduced reproductive capacity or suffering reduced reproductive capacity in around half of the years since then.

1SW spawners in the Northern NEAC stock complex have been at full reproductive capacity (i.e. meeting the CL with at least 95% probability) throughout the time-series, albeit at reduced levels since 2007 (Figure 10.2.4.1). MSW spawners, on the other hand, while generally remaining at full reproductive capacity, have spent limited periods at risk of suffering reduced reproductive capacity, most recently in 2007. Since 2000, MSW spawners have generally been above values in the early part of the time-series. Both 1SW and MSW stock complexes were at full reproductive capacity in 2015.

Declines in spawner numbers are evident for both 1SW and MSW salmon in the Southern NEAC stock complex. The 1SW spawning stock has been at risk of suffering reduced reproductive capacity or suffering reduced reproductive capacity for most of the time-series. In contrast, the MSW stock was at full reproductive capacity for most of the time-series until 1996. After this point, however, the MSW stock has been either at risk of suffering reduced reproductive capacity or suffering reduced reproductive capacity in almost every year. In 2015, the MSW stock complex was suffering reduced reproductive capacity and the 1SW stock complex was at risk of suffering reduced reproductive capacity.

Nominal catches (Figure 10.2.2.1) and estimated exploitation rates (Figure 10.2.4.2) have been decreasing over the time period in Northern and Southern NEAC areas. Despite management measures aimed at reducing exploitation in recent years, there has been little improvement in the status of stocks over time. This is mainly a consequence of continuing poor survival in the marine environment.

There has been an overall declining trend since 1980 in the return rates (marine survival) of both wild and hatchery-origin smolts to 1SW returns for both Northern and Southern NEAC areas (Figure 10.2.4.3). Results from these analyses are consistent with the information on estimated returns and spawners as derived from the PFA model, and suggest that returns are strongly influenced by factors in the marine environment. The declining trend is not evident for the 2SW wild components in either area, or for hatchery-origin smolts to 2SW in Northern NEAC (no data are available for hatchery-origin 2SW return rates for Southern NEAC).

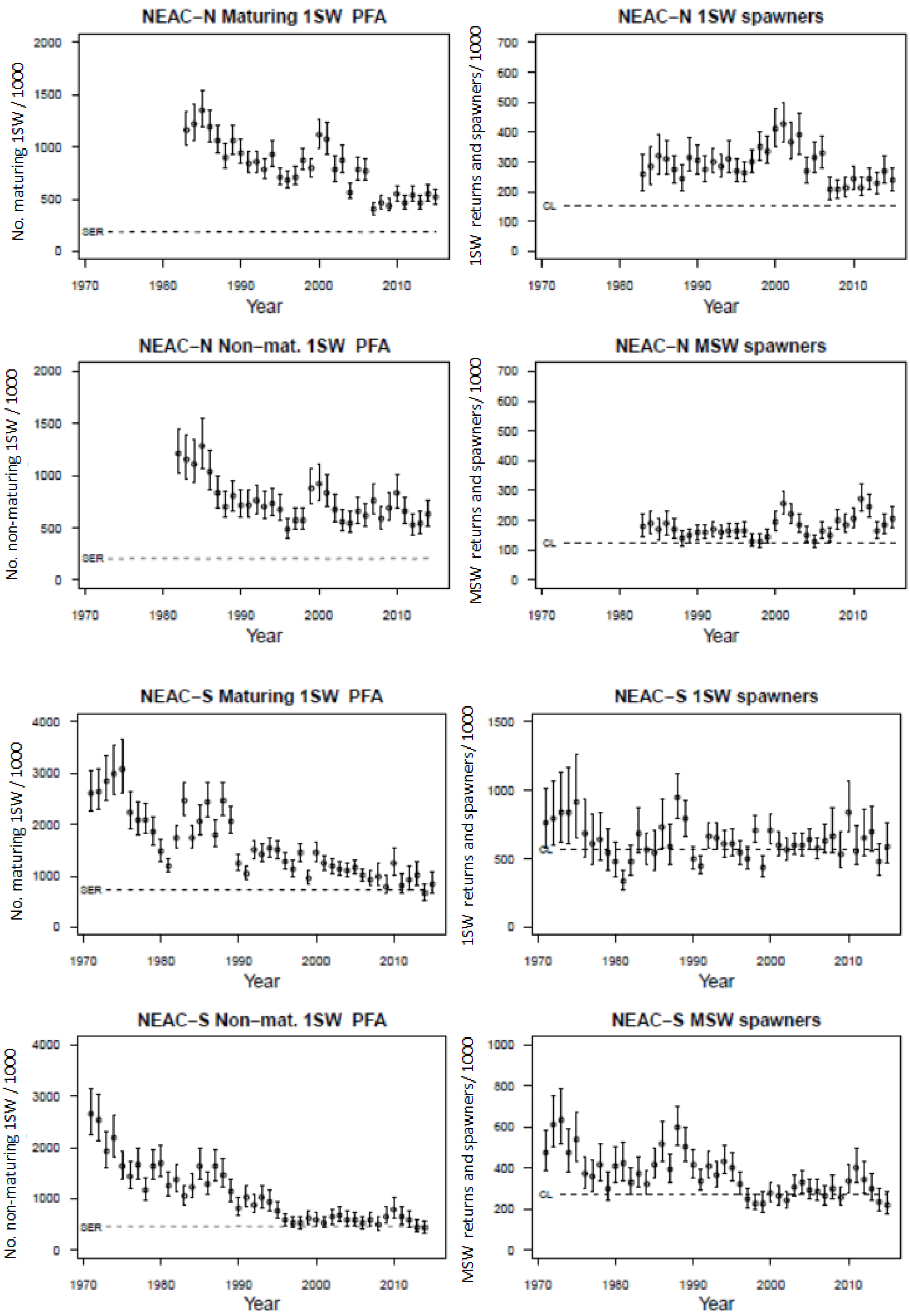

Figure 10.2.4.1 Pre-fishery abundance (PFA – recruits; left panels) and spawners (right panels), with 90% confidence limits, for maturing 1SW (spawning as 1SW) and non-maturing 1SW (spawning as MSW) salmon in Northern Europe (NEAC-N) and Southern Europe (NEAC-S). The dashed horizontal lines in the left panels are the spawning escapement reserve (SER) values, and in the right panels the conservation limit (CL) values.

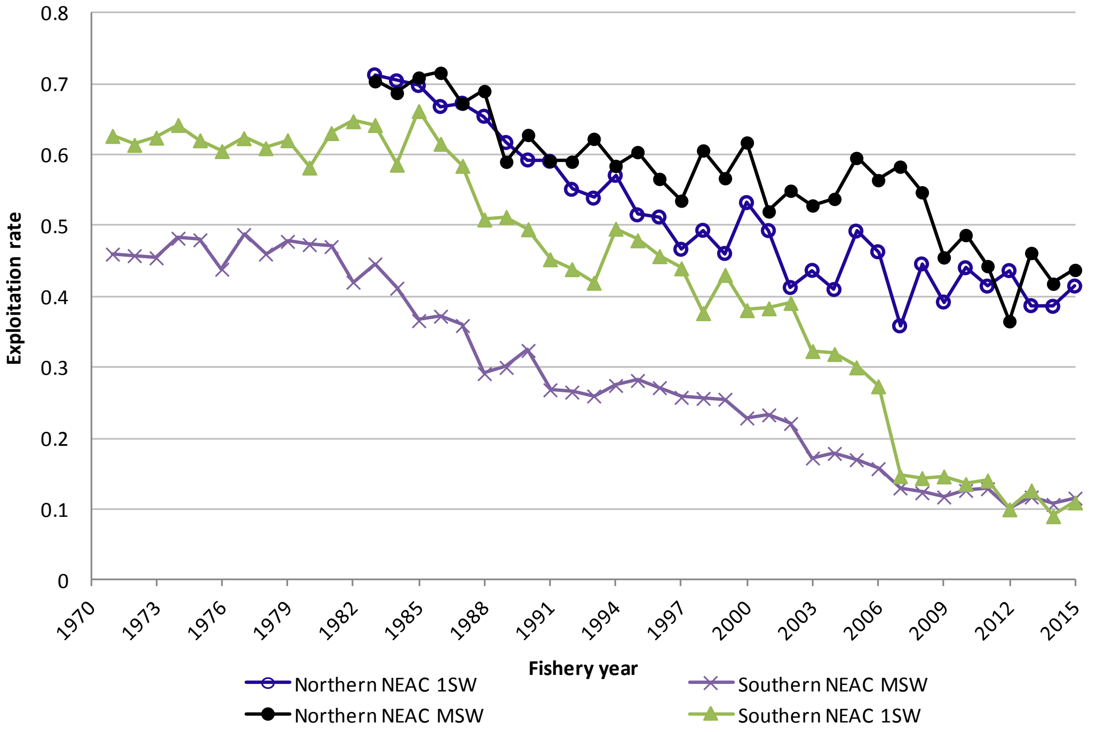

Figure 10.2.4.2 Exploitation rates of wild 1SW and MSW salmon in home water fisheries in the Northern (1983–2015) and Southern (1971–2015) NEAC areas.

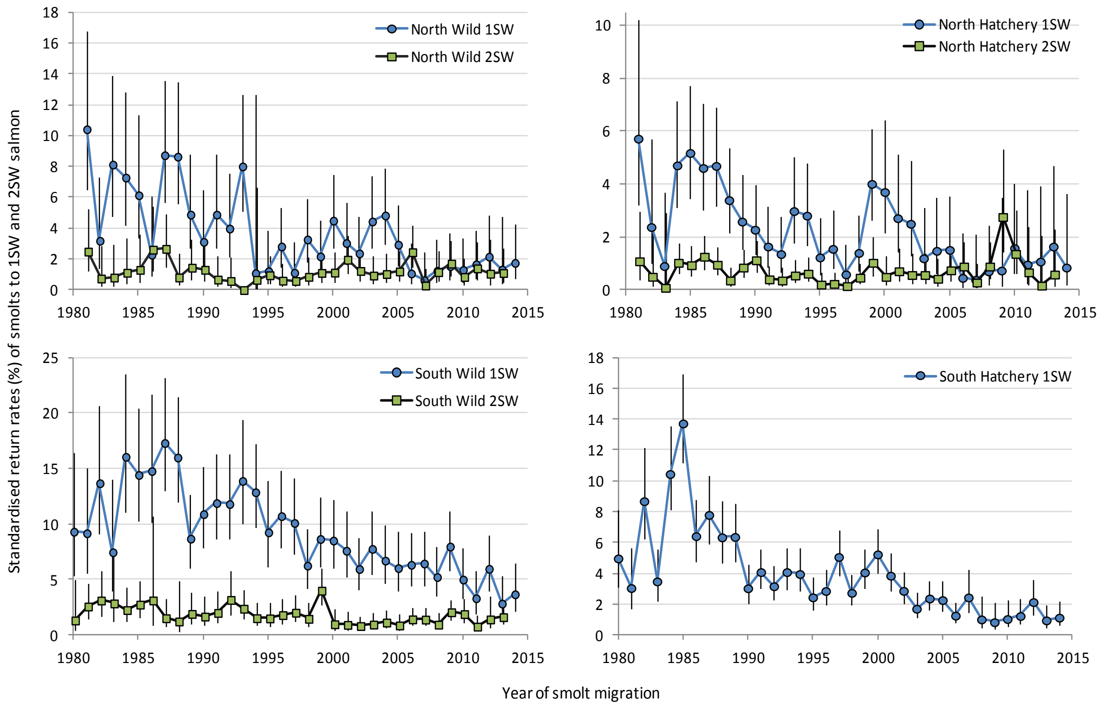

Figure 10.2.4.3 Standardized mean annual survival indices (%) of wild (left panels) and hatchery-origin (right panels) smolts to 1SW and 2SW adult salmon to Northern (top panels) and Southern (bottom panels) NEAC areas. The standardized values are derived from a general linear model analysis of rivers in a region. Note differences in scales of *y*-axes among panels. The *x*-axis denotes the smolt migration year.

10.2.6 NASCO has asked ICES to provide catch options or alternative management advice for the 2016/2017 to 2018/2019 fishing seasons, with an assessment of risks relative to the objective of exceeding stock conservation limits, or pre-defined NASCO Management Objectives, and advise on the implications of these options for stock rebuilding

PFA forecasts until 2019 for the Southern and Northern NEAC complexes were developed within a Bayesian model framework (Figures 10.2.6.1–10.2.6.2). Probabilities of meeting CLs are higher in the Northern than in the Southern complex and are generally higher for Northern countries than Southern countries.

MSY approach

ICES considers that to be consistent with the MSY and the precautionary approach, fisheries should only take place on salmon from stocks that can be shown to be at full reproductive capacity. Due to the different status of individual stocks, mixed-stock fisheries present particular threats.

No specific risk level has so far been agreed by NASCO for the provision of catch advice for the Faroes fishery; in the absence of this, ICES uses a 95% probability of meeting individual conservation limits, which can be applied at the level of the European stock complexes (two areas and two age classes) and the NEAC countries (ten countries and two age classes). In the absence of any fisheries in 2016/2017 to 2018/2019, there is less than 95% probability of meeting the CLs for the two Southern NEAC complexes (potential 1SW and MSW spawners). There is also less than a 95% probability of many individual countries meeting their CLs for 1SW or MSW fish in the absence of any fisheries. Therefore, in the absence of specific management objectives, ICES advises that there are no mixed-stock fisheries options on the NEAC complexes/countries at the Faroes in 2016/2017 to 2018/2019.

Additional considerations

ICES emphasizes that the national stock CLs discussed above are not appropriate for the management of home-water fisheries, particularly where these exploit separate river stocks. This is because of the relative imprecision of the national CLs and because they will not take account of differences in the status of different river stocks or sub-river populations. Management at finer scales should take account of individual river stock status. Nevertheless, the combined CLs for the main stock groups (national stocks) exploited by the distant-water fisheries can be used to provide general management advice to the distant-water fisheries.

Fisheries on mixed stocks pose particular difficulties for management, when they cannot target only stocks that are at full reproductive capacity. The management of a fishery should ideally be based on the status of all stocks exploited in the fishery. Conservation would be best achieved if fisheries target stocks that have been shown to be at full reproductive capacity. Fisheries in estuaries and, especially, rivers are more likely to meet this requirement.

Data and methods

Input data to estimate the historical PFAs are the catch in numbers of 1SW and MSW salmon in each country, unreported catch levels, and exploitation rates. Uncertainties are accounted for using minimum and maximum ranges for unreported catches and exploitation rates. A natural mortality value of 0.03 (range 0.02 to 0.04) per month is applied during the second year at sea. Data beginning in 1971 are available for most countries. In addition, catches at the Faroes and catches of NEAC-origin salmon at West Greenland are incorporated.

The Bayesian inference and forecast models for the Southern NEAC and Northern NEAC complexes have the same structure and are run independently through “R”. For both Southern and Northern NEAC complexes, PFA forecasts were derived based on lagged spawners and productivity. PFA was forecast from 2016 to 2019 for maturing 1SW salmon and from 2015 to 2019 for non-maturing 1SW salmon (Figures 10.2.6.1–10.2.6.2).

The risk framework was used to evaluate TAC options for the Faroes fishery in the 2016/2017, 2017/2018, and 2018/2019 fishing seasons, based on the NEAC stock complex and national management units. For any TAC option being evaluated, the number of fish that would be caught at Faroes from each management unit is estimated. These values are divided by the Faroes share allocation to estimate the total harvest that can be taken at Faroes and in home-water fisheries combined. The risk analysis then estimates the probability of each management unit achieving its management objectives for each TAC option, assuming that the total estimated harvest is taken.

The large uncertainty in the PFA forecasts (Figures 10.2.6.1 and 10.2.6.2) results in increased risk of not achieving the CLs in the forecasts. As a result, the advice is more cautious regarding fishing opportunities.

Comparison with previous assessment and catch options

The most recent catch advice in 2015 concluded that there were no catch options at the Faroes for 2015/2016 to 2017/2018 (ICES, 2015). The Framework of Indicators (FWI) applied in January 2016 triggered a reassessment, as the indicators for one of the stock complexes (Northern NEAC MSW salmon) suggested that the previous forecast of PFA may have been underestimated. However, the current assessment and forecast remain unchanged relative to the 2015 advice.

The advice this year is based on the risk assessment framework, as in 2015. This framework directly evaluates the risk (probability) of meeting CLs in the 1SW and MSW Southern and Northern NEAC complexes, and at country level, under different catch scenarios. Managers can choose the risk level which they consider appropriate. ICES considers, however, that to be consistent with the MSY and the precautionary approach, and given that the CLs are considered to be limit reference points to be avoided with high probability, managers should choose a risk level that results in a low chance of failing to meet the CLs. ICES recommends that management decisions be based principally on a 95% probability of attainment of CLs in each stock complex or country individually (ICES, 2013).

Assessment and management area

National stocks are combined into Southern NEAC and Northern NEAC groups. The groups fulfilled an agreed set of criteria for defining stock groups for the provision of management advice (ICES, 2005). At that time, consideration of the level of exploitation of national stocks resulted in the advice for the Faroes fishery (both 1SW and MSW) being based on all NEAC area stocks, and the advice for the West Greenland fishery being based on the Southern NEAC non-maturing 1SW stock only.

ICES (2010, 2011, 2012) previously emphasized the problem of basing a risk assessment and catch advice for the Faroes fishery on management units comprising large numbers of river stocks. In providing catch advice at the age and stock complex or country levels for Northern and Southern NEAC areas, consideration needs to be given to the recent performance of the stocks within individual countries. At present, insufficient data are available to assess performance of individual stocks in all countries in the NEAC area. In some instances, river-specific CLs are in the process of being developed.

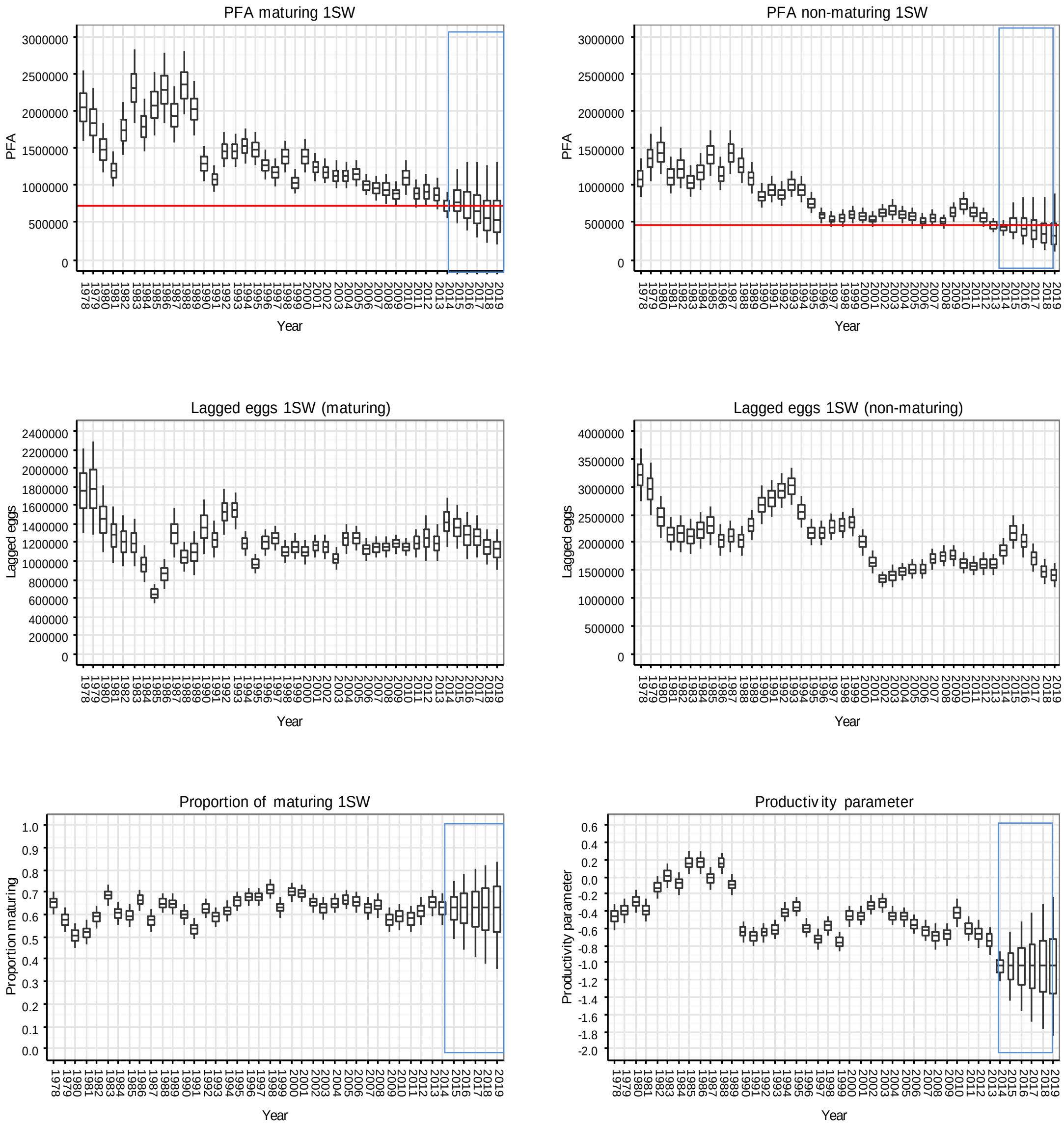

Figure 10.2.6.1 Southern NEAC PFA for maturing (top left) and non-maturing (top right) 1SW fish, lagged eggs, productivity parameter, and proportion maturing as 1SW. The last five years are forecasts (indicated by rectangles). The horizontal lines in the upper panels are the SER values. Box and whiskers show the 5th, 25th, 50th, 75th, and 95th percentiles of the estimated or forecast distribution.

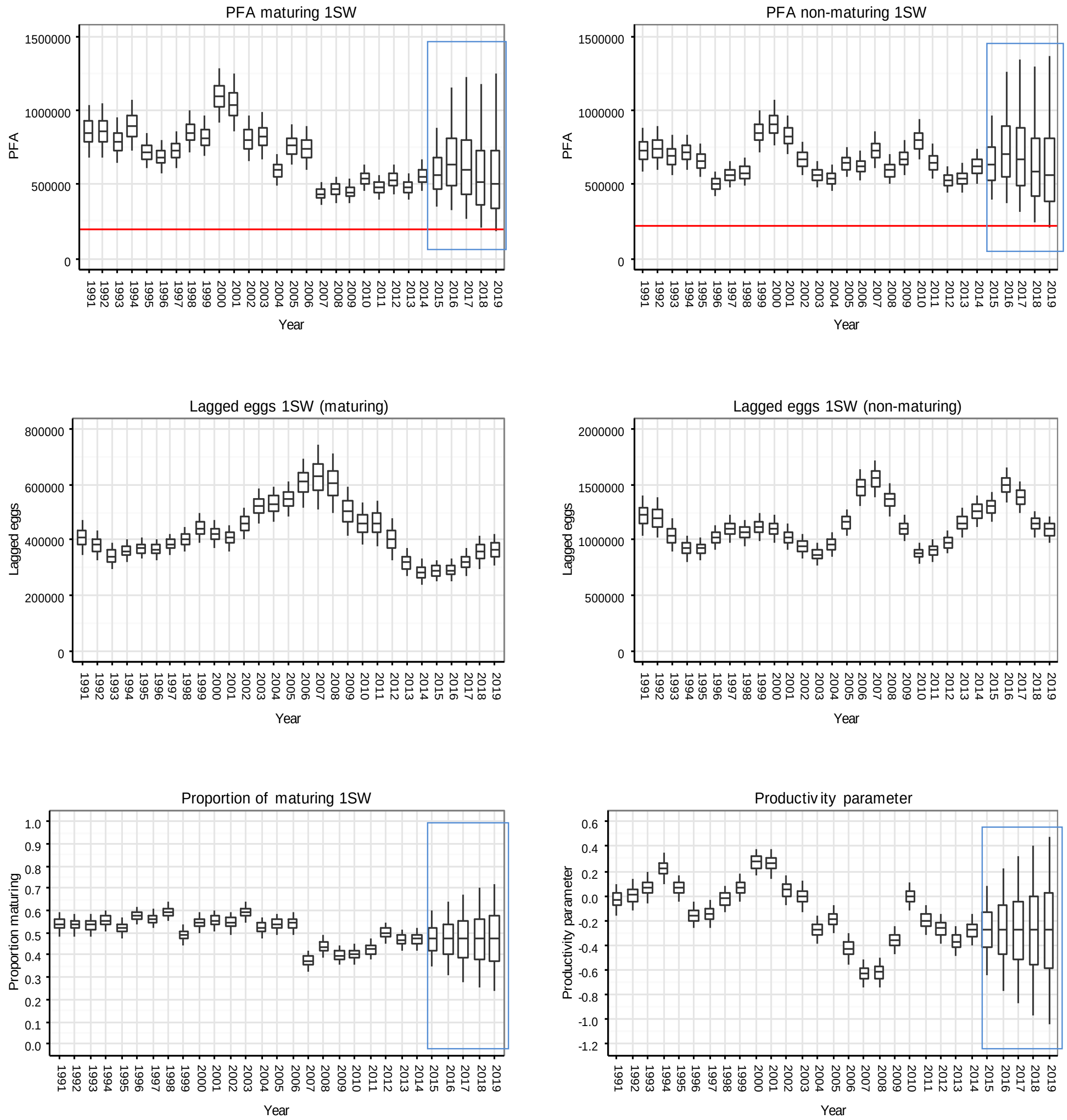

Figure 10.2.6.2 Northern NEAC PFA for maturing (top left) and non-maturing (top right) 1SW fish, lagged eggs, productivity parameter, and proportion maturing as 1SW. The last five years are forecasts (indicated by rectangles). The horizontal lines in the upper panels are the SER values. Box and whiskers show the 5th, 25th, 50th, 75th, and 95th percentiles of the estimated or forecast distribution.

Appendix III. Rivers assessed by the SSCS where salmon have a qualifying interest in Special Areas of Conservation (EU Habitats Directive) and status relative to Conservation Limit in 2016

District	River	Above / Below CL in 2016	SAC
Drogheda	Boyne	Below	River Boyne and River Blackwater SAC
Wexford	Slaney	Below	Slaney River Valley SAC
Waterford	Barrow	Below	River Barrow and River Nore SAC
Waterford	Nore	Below	River Barrow and River Nore SAC
Waterford	Suir	Below	Lower River Suir SAC
Lismore	Blackwater	Above	Blackwater River (Cork/Waterford) SAC
Kerry	Mealagh	Above	Killarney Nat Park, Macgillycuddy's Reeks & Caragh R. Cat SAC
Kerry	Kerry Blkwater	Below	Blackwater River (Kerry) SAC
Kerry	Emlagh	Below	Castlemaine Harbour SAC
Kerry	Owenascaul	Below	Castlemaine Harbour SAC
Kerry	Owenreagh	Below	Killarney Nat Park, Macgillycuddy's Reeks & Caragh R Cat SAC
Kerry	Caragh	Above	Killarney Nat Park, Macgillycuddy's Reeks & Caragh R Cat SAC
Kerry	Ferta	Above	Killarney Nat Park, Macgillycuddy's Reeks & Caragh R Cat SAC
Limerick	Shannon	Below	Lower River Shannon SAC
Galway	Owenboliska	Below	Connemara Bog Complex SAC
Galway	Corrib	Above	Lough Corrib SAC
Galway	Corrib	Above	Maumturk Mountains
Connemara	Cashla	Above	Connemara Bog Complex SAC
Ballinakill	Culfin	Above	The Twelve Bens/Garraun Complex SAC
Ballinakill	Dawros	Above	The Twelve Bens/Garraun Complex SAC
Ballinakill	Bundorragh	Above	Mweelrea/Sheeffry/Erriff Complex SAC
Ballinakill	Bunowen	Above	Mweelrea/Sheeffry/Erriff Complex SAC
Ballinakill	Carrownisky	Below	Mweelrea/Sheeffry/Erriff Complex SAC
Ballinakill	Erriff	Above	Mweelrea/Sheeffry/Erriff Complex SAC
Bangor	Srahmore	Below	Owenduff/Nephin Complex SAC
Bangor	Owenduff	Above	Mweelrea/Sheeffry/Erriff Complex SAC
Bangor	Owenmore	Below	Mweelrea/Sheeffry/Erriff Complex SAC
Bangor	Glenamoy	Above	Glenamoy Bog Complex SAC
Bangor	Muingnabo	Below	Glenamoy Bog Complex SAC
Bangor	Newport	Above	Newport River SAC
Ballina	Moy	Above	River Moy SAC
Sligo	Garavogue	Above	Lough Gill SAC
Sligo	Ballysadare	Above	Unshin River SAC
Ballyshannon	Eske	Below	Lough Eske and Ardnamona Wood SAC
Ballyshannon	Glen	Above	Cloghernagore Bog and Glenveagh National Park SAC
Ballyshannon	Drowes	Above	Lough Melvin SAC
Letterkenny	Leannan	Below	Leannan River SAC
Letterkenny	Gweebarra	Above	West Of Ardara/Maas Road SAC
Letterkenny	Owenea	Above	West Of Ardara/Maas Road SAC
Letterkenny	Owennamarve	Below	Cloghernagore Bog and Glenveagh National Park SAC
Letterkenny	Clady	Above	Lough Eske and Ardnamona Wood SAC

Appendix IV. Transporting Biological Reference Points (BRPs): the Bayesian Hierarchical Stock and Recruitment Analysis (BHSRA)

Prior to the 2012 analyses for 2013, the Bayesian analysis of this hierarchical model was developed from a set of 13 stock and recruitment data series from monitored salmon rivers located in the Northeast Atlantic. For the 2012 analyses for the 2013 season the index rivers were updated, to a more Irish based series comprising 22 rivers, of which 17 are in the island of Ireland, four in the UK and one in Scotland. The time series of spawner – recruits for each river was updated and the model re-run. This yields a set of predicted stock and recruitment parameters for new rivers, provided information is available on the size of the river (in this case usable habitat or wetted area is used) and on the rivers latitude.

The following description of the model used to transport Biological Reference Points (in this instance stock and recruitment parameters) from monitored rivers to rivers without these data is extracted from several sources:

Crozier, W. W., Potter, E. C. E., Prévost, E., Schon, P–J., and Ó Maoiléidigh, N. 2003. A co-ordinated approach towards the development of a scientific basis for management of wild Atlantic salmon in the north-east Atlantic (SALMODEL – Scientific Report Contract QLK5–1999–01546 to EU Concerted Action Quality of Life and Management of Living Resources). Queen's University of Belfast, Belfast. 431 pp.

Prévost, E., Parent, E., Crozier, W., Davidson, I., Dumas, J., Gudbergsson, G., Hindar, K., McGinnity, P., MacLean, J., and Sættem, L. M. 2003. Setting biological reference points for Atlantic salmon stocks: transfer of information from data-rich to sparse-data situations by Bayesian hierarchical modelling. e ICES Journal of Marine Science, 60: 1177-1193.

McGinnity, P., Gargan, P., Roche W., Mills, P., and McGarrigle M. 2003. Quantification of the freshwater salmon habitat asset in Ireland using data interpreted in a GIS platform. Irish Freshwater Fisheries Ecology and Management Series, Central Fisheries Board, Dublin, 3. 131 pp.

Ó Maoiléidigh, N., McGinnity, P., Prévost, E., Potter, E. C. E., Gargan, P., Crozier, W. W., Mills, P., and Roche, W. 2004. Application of pre-fishery abundance modelling and Bayesian hierarchical stock and recruitment analysis to the provision of precautionary catch advice for Irish salmon (Salmo salar L.) fisheries. e ICES Journal of Marine Science, 61:1370-1378.

White J, Maoiléidigh NÓ, Gargan P, de Eyto E, Chaput G, Roche W, McGinnity P, Crozier WW, Boylan P, Doherty D, O'higgins K. Incorporating natural variability in biological reference points and population dynamics into management of Atlantic salmon (Salmo salar L.) stocks returning to home waters. ICES Journal of Marine Science: Journal du Conseil. 2016 Jun 1;73(6):1513-24.

For a more complete description of the techniques, models and underlying assumptions readers are advised to consult these primary texts.

Introduction

The analysis of stock and recruitment (SR) data is the most widely used approach for deriving BRPs for Atlantic salmon (*Salmo salar*) (Prévost and Chaput 2001). SR data are routinely collected on monitored rivers. On these rivers, adult returns, spawning escapement and sometimes smolt production are estimated yearly. Potter (2001) reviewed the various approaches currently applied for determining BRPs from SR data. They fall into two categories: the classical parametric SR models and alternative non-parametric approaches. Walters and Korman (2001) give a full and critical exposure of the procedures relying on the classical SR models. Such an extensive review does not exist for non-parametric approaches, but Potter (2001) provides a clear presentation of the various options proposed and used for stock assessment at ICES. Despite their many pitfalls, the classical SR models have the great advantage over non-parametric approaches that they offer a formal framework to account for sources of uncertainty in the derivation of BRPs. Walters and Korman (2001) advocate the use of the Bayesian approach for uncertainty assessment: our knowledge/uncertainty about BRPs should be reflected by probability distributions given the SR data in hand.

There are several hundreds of salmon stocks across the North East Atlantic area, each having its own characteristics with regard to SR relationships. However, resources to collect SR data are limited and there are only a limited number of monitored rivers. Suitable SR series (both in terms of length and reliability of observations) are available for about 15 monitored rivers. Extrapolation of knowledge gained from monitored rivers to rivers for which SR data are not available is therefore required. This extrapolation process is also called transport of BRPs.

SR information from the monitored rivers can be used to set BRPs for all the North East Atlantic salmon rivers while accounting for the major sources of uncertainty. Until recently, this issue was essentially addressed in practice by extrapolating the BRPs determined from a single river SR series to an entire region or country while accounting for the variations of size between rivers. When SR data are available from several rivers which are considered to be representative of an assemblage of rivers, the question can be asked as to what can be inferred about the nature of the SR relationship for any new river of the assemblage based on data from the sampled rivers. There are two nested sources of uncertainty in this situation. The first level of uncertainty is associated with the fact that there is relevant SR information available from a limited number of rivers within the assemblage of rivers. The second level of uncertainty relates to the limited number of SR observations available within each river. Bayesian meta-analysis using hierarchical modelling (Bayesian Hierarchical Analysis) provides a framework for integrating these two levels of uncertainty. It incorporates the nested structure of the uncertainty to derive a probability distribution of BRPs for a river with no SR data. Prévost *et al.* (2001) illustrated this approach with a case study on the salmon rivers of Québec. Crozier *et al* (2003) further applied and extended it to the rivers in the North East Atlantic area and Ó Maoiléidigh *et al.* considered the specific application of this approach in an Irish context.

Bayesian approaches are now widely applied in fish population and fisheries dynamics studies (Punt and Hilborn 1997; McAllister and Kirkwood 1998). It is also an active field of investigation in itself. Bayesian reasoning aims at making inferences about any unknown quantity of interest (*U*) conditionally on observed data (*D*). It considers probabilities as comparative degrees of belief. Although not specific to it, the bayesian approach requires the initial setting of a probability model representing our prior understanding of the process giving rise to the data. From this prior setting, posterior inferences are derived conditionally on the data using Bayes theorem:

$$P(U|D) = P(U)P(D|U)/P(D) \propto P(U)P(D|U)$$

Setting up a Bayesian Hierarchical Stock and Recruitment Model

To make inferences from data in a Bayesian framework, a probabilistic (*i.e.* stochastic) model representing the prior understanding of the process generating the observed data must be set. The data are Stock and Recruitment (SR) observations. Standard SR models such as a Ricker curve with lognormal random errors (Walters and Korman 2001) can be use to represent the link between the stock and the subsequent recruitment within any single river. Such a single river SR model is controlled by a few parameters, which are either Biological Reference Points (BRPs) or from which BRPs can be computed. Let θ_i denote the SR parameters vector of the river *i*. In this case, inferences based on the data from the monitored rivers about the other rivers of the NEAC area are of special interest. The model must therefore specify the link between salmon rivers irrespective of whether SR data are available for them. The idea that all salmon rivers belong to a common family or an assemblage of rivers is translated by considering them as issuing from a single probability distribution. More precisely, it is the θ_i's which are seen as realizations from a common probability distribution. This probability distribution is itself controlled by parameters, also called hyper-parameters. Denoting Θ the vector of hyper-parameters.

The conditioning structure corresponding to this general setting can be represented by a Directed Acyclic Graph (DAG; Figure 1). It is a hierarchical setting because:

- the distribution of the recruitment for any given level of stock is controlled by the θ_i parameters,
- the distribution the θ_i parameters is controlled by the Θ hyper-parameters.

This hierarchical structure organizes the transfer of information brought by the monitored rivers SR data towards the other rivers. The SR data from the monitored rivers improve the information about the θ_i's. This information gained about the θ_i's allows improvements in turn in the information about Θ. This information gained on Θ provides insight into the SR parameters of any new river for which no SR data are available.

The hierarchical setting is midway between a complete pooling of SR data sets and the independent treatment of each single river SR series. Complete pooling of SR data sets relies on the assumption that there is a unique SR relationship common to all rivers, *i.e.*, $\theta_i = \theta_j$ for any $i \neq j$. This is certainly an oversimplifying assumption. Conversely, full independence between rivers would mean there is nothing to learn from the monitored rivers about the SR relationship of the other rivers. This is not sensible either and contradictory to the very essence of monitored rivers projects. By considering the θ_i's as realizations from a common probability distribution it acknowledges that they can be different between rivers while at the same time they are not fully unrelated. This intermediary assumption allows the transfer of information between rivers. Any increase in information about a θ_i consequentially provides information about the probability distribution of the θ_i's, thus bringing information about any θ_j $j \neq i$. The Bayesian treatment of a hierarchical model allows the data to used to learn from the monitored rivers.

Implicit but crucial to the above concepts is the hypothesis of exchangeability of the rivers with regards to their SR parameters. This is a common assumption when little is known about the differences between units (Gelman *et al.* 1995). In this case it means that, apart from the SR data, there is no insight provided into the phenomena causing variations in the SR relationship among rivers. In terms of modelling, exchangeability translates into independent identical distribution (iid) of the θ_i's. If covariates informative about the variations in θ_i's are available, then exchangeability can still be assumed, conditionally on the covariate. It must be stressed that, in practice, it is not enough to know that a given variable influences the SR relationship (from some experimental or detailed single site studies). To be able to take advantage of this knowledge it must be possible to measure the covariates on every river of interest, *e.g.*, all the salmon rivers in the North East Atlantic area, and also model the nature of the link between the covariates and the θ_i's. It is clear that these two conditions shall limit the number of covariates which can be used in practice, especially if inferences are to be made for many rivers for which there is little known. The basic concept and model are presented below in Figure 1.

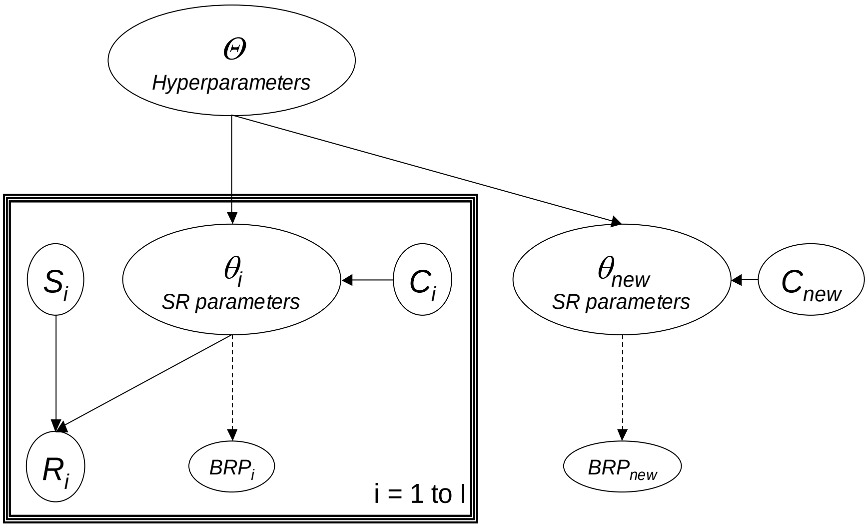

Figure IV.1. The conditioning structure of the BHSRA as represented in a Directed Acyclic Graph (DAG). Nodes (ellipses) are random variables. The plain arrows represent stochastic links, *i.e.* the distribution of a child node depends on its parents. Dashed arrows represent deterministic links, *i.e.* the BRPs are functions of the θ_i's. S_i and R_i are the series of observed stock and recruitment for the monitored river *i*. C_i is a vector of explanatory covariate of the θ_i's. The frame means there are *I* monitored rivers with SR data. The "*new*" subscript index refers to any river with no SR data but belonging to the family from which the monitored rivers are a representative sample.

Treating the rivers as exchangeable in their SR parameters implies that the monitored rivers are a representative sample from the broad family, *e.g.* the North East Atlantic area or Irish rivers specifically, about which inferences are required to be made. The principles presented and discussed above are the fundamentals of the joint treatment of several SR series, called a Bayesian Hierarchical SR Analysis (BHSRA). Such an approach does not, in itself, solve all the problems encountered in the analysis of SR data. BHSRA is, however, a step forward from the previous approach for setting and transporting BRPs in Atlantic salmon. It sets a consistent framework for learning from monitored rivers SR data, while previous practices essentially relied on the unrealistic premise that there is a common SR relationship across broad regions. Ample room is left for improvement in the single river SR modelling, but this approach now provides a hierarchical setting which can accommodate any new SR model for (Bayesian) learning from monitored rivers.

Introduction of Covariates – Wetted Area and Latitude

The BHSRA as used for the transport of SR parameters to Irish rivers is detailed below (Figure 2). Among the many covariates to explain differences between rivers in their SR parameters, river size is the most evident. It would be irrelevant to set escapement reference points irrespective to the size of the rivers considered. Indeed, the size of a stock is constrained by the size of its river of origin because of the specificities of the riverine Atlantic salmon ecology. For instance, individuals have a territorial behaviour at the juvenile stage and during spawning, and compete for limited spatial resources (Elliott, 2001). Prévost *et al.* (2001) reviewed the many ways of assessing river size as a limiting factor for salmon production. Currently, the riverine wetted surface area accessible to salmon appears to be the "smallest common denominator" which can be used across the North East Atlantic area. This measurement is readily available for Irish rivers (McGinnity *et al.*, 2005) by means of Geographical Information Systems (GIS) applications. More refined measures of river size, incorporating information about the habitat quality within the wetted area, have been proposed. The methods, however, vary among regions and rivers and in the vast majority of rivers the data requirements cannot currently be achieved.

Given the very limited information available on the bulk of the NEAC salmon rivers, geographical location is probably the only variable readily accessible for explaining variations in SR parameters among rivers. Latitude has been investigated because it influences the ecology of Atlantic salmon. For instance, it is well known that mean smolt age increases with latitude (Metcalfe and Thorpe 1990). Koenings *et al.* (1993) also found a positive latitudinal gradient for smolt-to-adult survival in sockeye salmon (*Oncorhynchus nerka*).

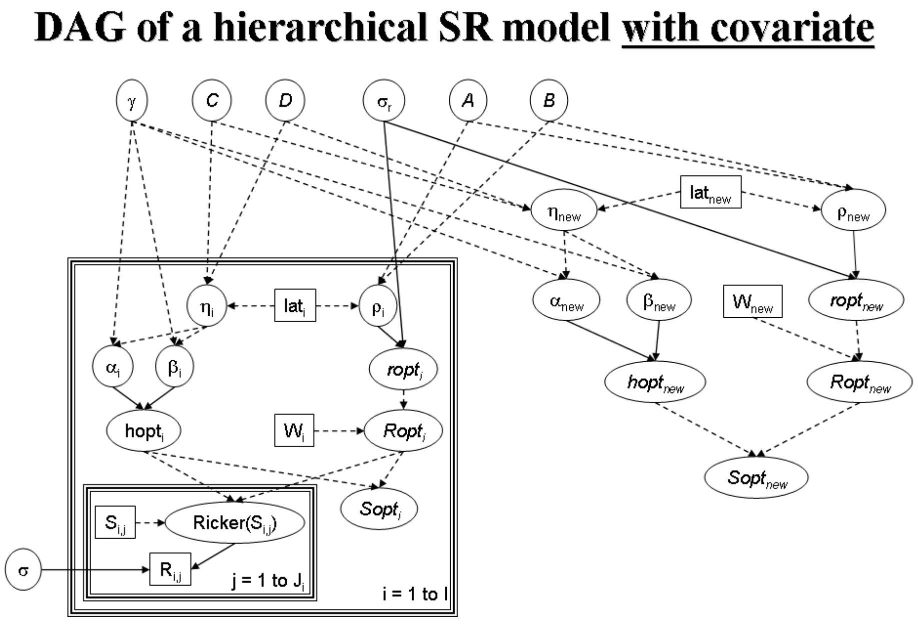

Figure IV.2. DAG of the hierarchical SR model with covariates used to transport stock and recruitment parameters to Irish rivers. The same graphical conventions are applied as in Figure 1. Naming of the nodes are explained below.

Brief explanation of terms used in the DAG.

$R_{i,j} \sim lognormal(log(Ricker(S_{i,j}), \sigma)$

Ricker$(S_{i,j}) = (exp(h_{opt}i)/(1 - h_{opt}i))\ S_{i,j}\ exp(-((h_{opt}i/((1 - h_{opt}i)R_{opt}i))S_{i,j})$

where:
$R_{i,j}$ is the recruitment of the cohort born in year *j* from the river *i*,
$S_{i,j}$ is spawning stock of year *j-1* from the river *i*,

$Ricker(S_{i,j})$ is the value of a Ricker function with parameters ($h_{opt}i$, $R_{opt}i$) at $S_{i,j}$,
σ is the standard deviation of the normal distribution of $log(R_{i,j})$, whose mean is $log(Ricker(S_{i,j}))$,
$h_{opt}i$ is the exploitation rate at MSY for the river *i*,
$R_{opt}i$ is the value of the Ricker function at MSY for the river *i*.

Any other SR related parameter or BRP can be calculated from $h_{opt}i$ and $R_{opt}i$. NASCO recommended the use of the stock level that maximizes the long-term average surplus (MSY) as the standard Conservation Limit (CL; Potter 2001).

Denoting $S_{opt}i$ this BRP for the river *i*:
$S_{opt}i = (1 - h_{opt}i)R_{opt}i$

At the upper level, the parameters of the Ricker function are assumed to be different between rivers, but drawn from a common probability distribution:
$R_{opt}i \sim lognormal(A, B)$
$h_{opt}i \sim beta\ (C,D)$

where:
A□ and *B* are the mean and standard deviation of the normal distribution of $log(R_{opt}i)$.
C and D are the parameters of the beta distribution of $h_{opt}i$,

The basic model formulation above was improved by the use of additional co-variables, which would be informative about SR related parameters. In this case it is obvious that the river size must be most influential on $R_{opt}i$, *i.e.* the bigger the river the higher should $R_{opt}i$ be.

This can be translated into replacing assumption:
$R_{opt}i \sim lognormal(A, B)$ above
by:
$R_{opt}i = r_{opt}i\ WA_i$

where:
WA_i is the wetted area accessible to salmon (m^2).
$ropt_i$ is the egg recruitment rate per m^2 of riverine wetted area accessible to salmon at MSY
lat_i is the latitudinal location of river i.
ρ_i is the mean of the $log(ropt_i)$ distribution and is a linear function of latitude.

α_i and β_i is the beta distribution assigned to $hopt_i$ (which varies between 0 and 1).
η_i is the mean of the beta distribution or

$\alpha_i / (\alpha_i + \beta_i)$

γ is a scale parameter directly connected to the “sample size” of the beta distribution

The “new” subscript denotes the posterior distributions of all the parameters for any new river based on the posterior distributions of the monitored rivers.

Data available to apply the BHSRA to monitored rivers

Prior to 2012 Egg-to-egg Stock-Recruitment (SR) time series from 13 European rivers were used in the analysis, from: two French rivers, three UK, three Northern Ireland, two Scottish, one from Norway. one from Iceland and one from Ireland. To give a more Irish – centric analysis, and in light of newly available data from counters on Irish rivers, the input data was re-worked to 22 rivers, and the analysis re-run. Rivers, their latitude and wetted areas and the number of SR observations are detailed in Table IV-1 and Figure IV-1.

Egg-to-egg SR series can be obtained from monitored rivers, *i.e.* any river where at least the adult returns and the fisheries are surveyed. Rivers colonized mainly by sea trout and holding a comparatively small salmon population were not considered. Biological data, *i.e.* sex ratio and average fecundity per female, were used to express spawning escapement in eggs. Recruitment can also be derived from adult returns. Information on the age composition of the returns allows derivation of adult returns per spawning year, *i.e.* homewater recruitment. Data on sex ratios and fecundity of females were used to express recruitment in eggs.

Table IV.1. Stock-Recruitment index rivers, latitudes, wetted areas and number of observations.

Index rivers:	Country	Latitude (decimal degrees N)	Wetted Area (ha)	Number of SR Obs
Bandon	Ireland	51.74	136.04	4
Waterville Curraune	Ireland	51.84	20.16	4
Lismore (Munster) Blackwater	Ireland	51.91	888.25	4
Kerry Blackwater	Ireland	51.91	27.61	3
Feale	Ireland	52.34	211.81	4
Slaney	Ireland	52.60	321.93	4
Liffey	Ireland	53.20	233.78	4
Casla	Ireland	53.34	17.62	3
Screebe Trap	Ireland	53.44	6.19	6
Erriff	Ireland	53.67	54.04	21
Dee	Ireland	53.84	94.68	3
Burrishoole	Ireland	53.99	12.77	26
Ballysadare	Ireland	54.12	214.72	3
Eany	Ireland	54.71	45.75	3
Bush	UK (N. Ireland)	55.00	84.55	21
Faughan	UK (N. Ireland)	55.00	88.24	11
Mourne	UK (N. Ireland)	55.00	1036.06	13
Frome	UK (England)	50.50	87.64	20
Tamar	UK (England)	50.58	292.57	13
Dee	UK (England)	53.00	617.00	15
Lune	UK (England)	54.50	423.00	18
North Esk	UK (Scotland)	57.00	210.00	16

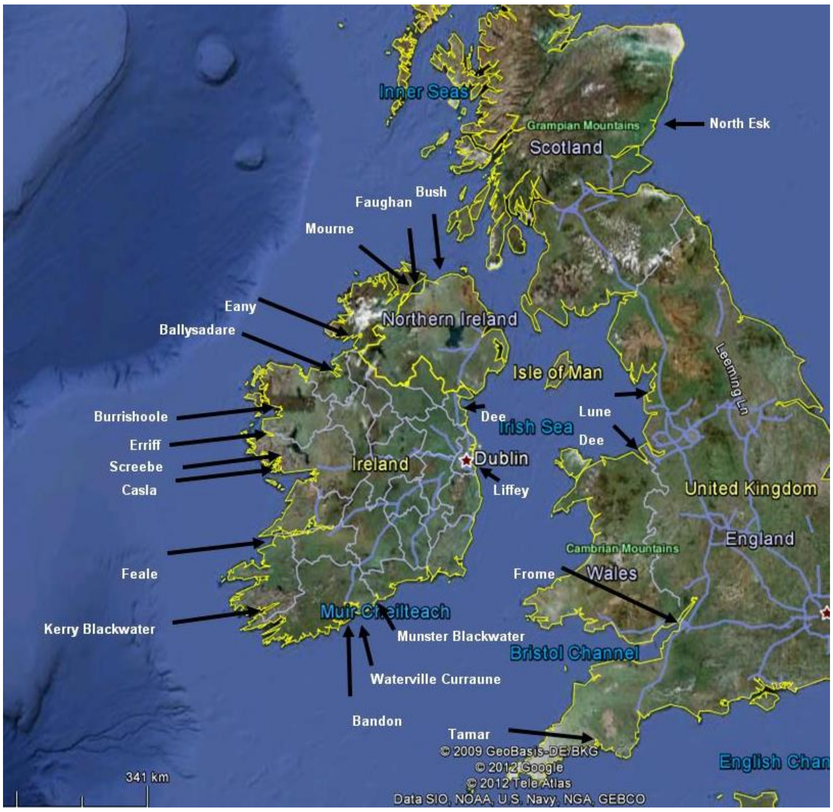

Figure IV. 3. Locations of rivers used for the provision of stock and recruitment parameters for BHSRA.

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Appendix V. Calculation of river specific Conservation Limits

The process of calculating river conservation limits is displayed in figure V-1 and detailed below.

Step 1. Fecundity:
The IFI Wild Salmon and Sea Trout tagging scheme itemises Salmon rod catch and weights by River and catch date, providing the most contemporary data set on salmon populations available. Six recent years of this data (2006 and 2011) were used to detail river specific variability in salmon populations. River catch weights were split at 4kg to initially differentiate between 1SW and MSW groups. For rivers where greater than 100 fish above 4kg, and below 4kg, were reported over the time period, river specific values were used. Where fewer than 100 fish > or < 4kg were reported the national average values were used. From these bimodal weight data sets, normal frequency distributions were constructed from the means and standard deviations of the fish greater than and less than 4kg (Elliott, 1977; Fowler and Cohen, 1990) describing the weight ranges of 1SW and MSW fish for each river population. From these the 10th percentile, 50th percentile (median) and 90th percentile weights were taken as the range in weights (example in Figure V-2).

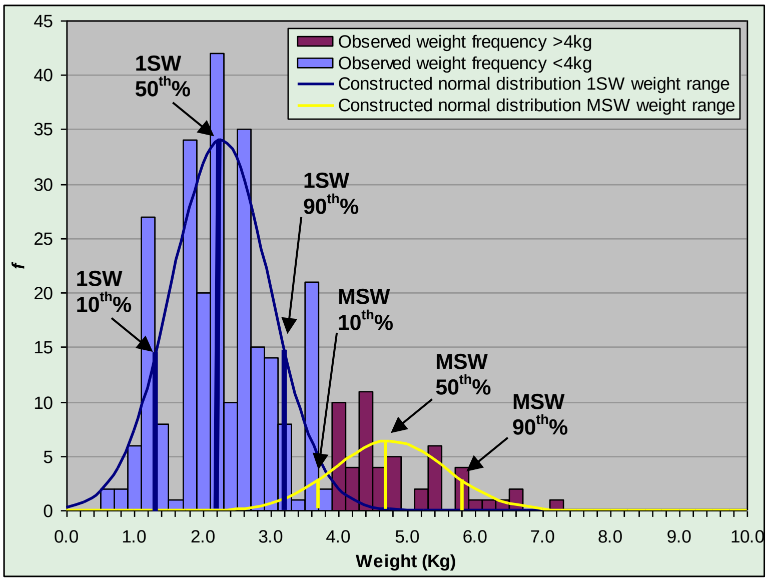


Figure V-2. Example of river specific observed weight frequency ranges and constructed normal distribution weight ranges of 1SW and MSW based upon initial weight splits of less than and greater then 4kg respectively. 10th, 50th and 90th percentile weights of each age group indicated.

The weight to fecundity relationship was established from 336 wild fish stripped by hatcheries between 1992 and 2011 (de Eyto et al. 2015). The linear relationship between recorded fish weights and number of stripped eggs was found to be significant (Figure V-3). The resulting linear regression relationship provides means to calculate fecundity in number of eggs from fish weights:

$$\text{No. of eggs} = 1250.83*(\text{Weight kg}) + 505.56$$

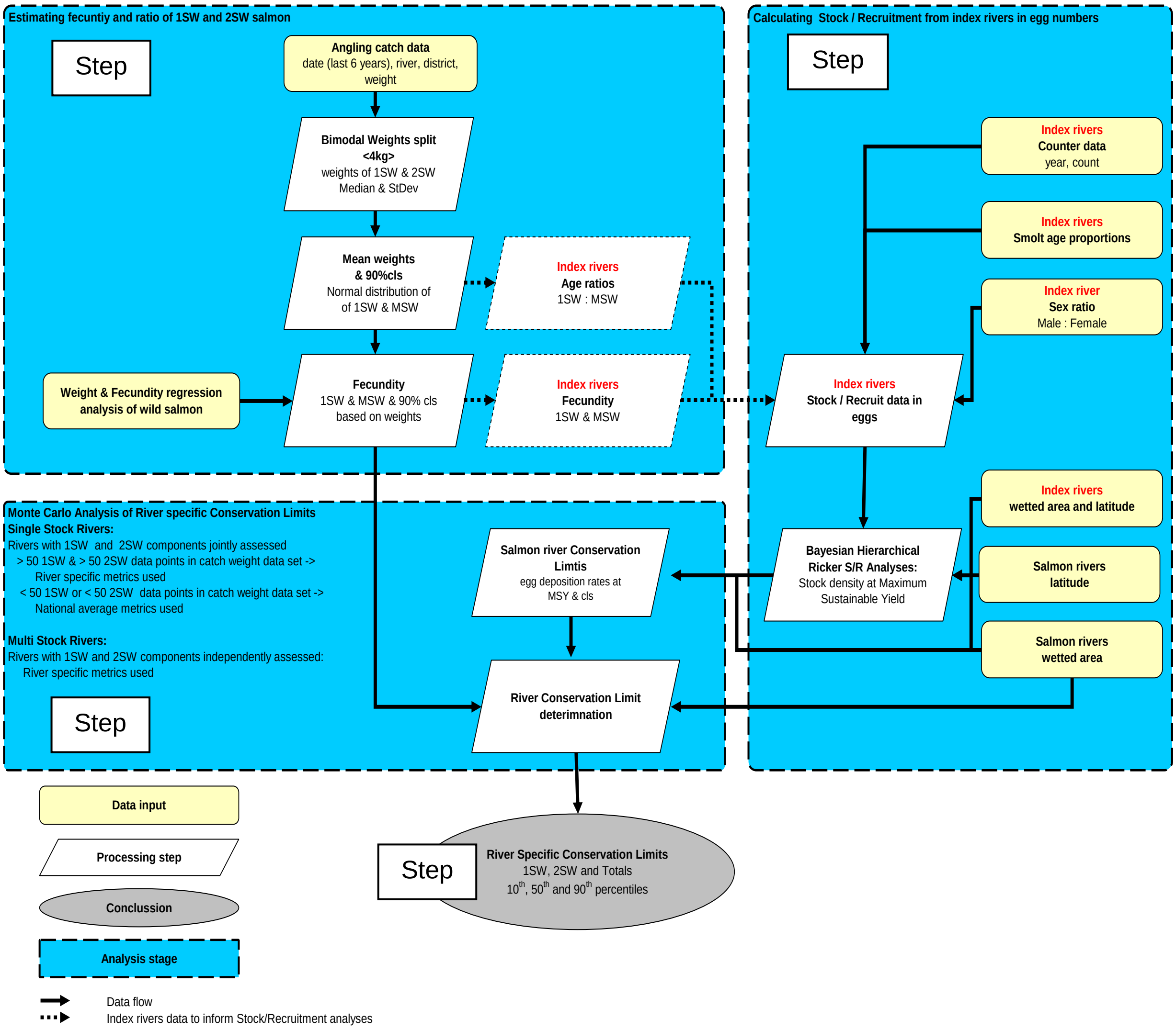


Figure V-1. Diagrammatic display of information flow in estimation of river specific conservation limits.

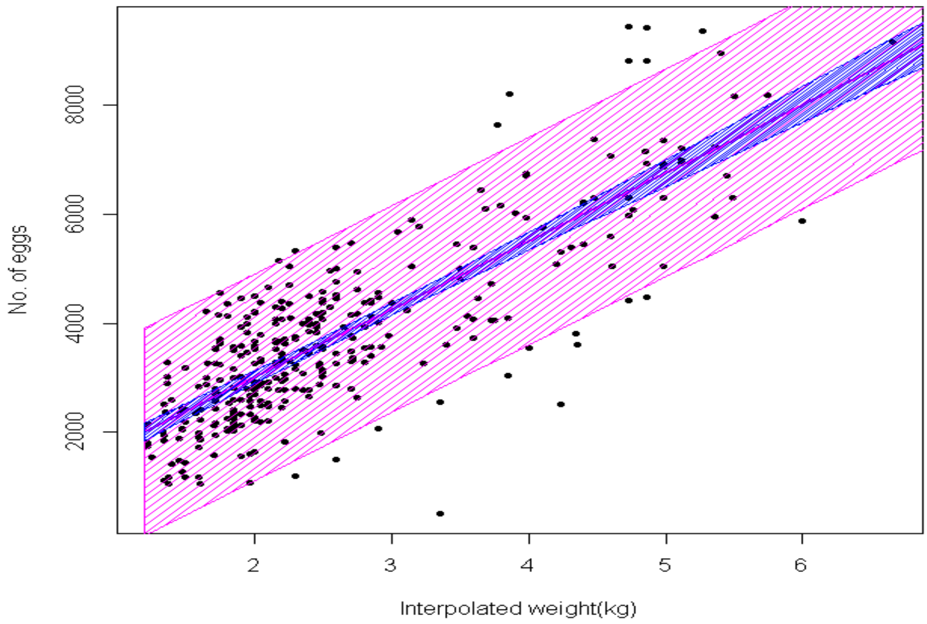


Figure V-3. Stripped number of eggs in Irish wild salmon, 1992 - 2011, against weight (kg) of fish. Fitted line is calculated from the model. Pink are = 95% prediction intervals, blue area = 95% confidence intervals. n=336

Age Ratio, 1SW:MSW fish

The number of fish over 4kg and below 4kg for each river was used to construct binomial frequency distributions (Elliott, 1977; Fowler & Cohen, 1990) of the ratio of 1SW to MSW fish for each river. From these the 10^{th} percentile, 50^{th} percentile (median) and 90^{th} percentile were taken as the ranges in the ratios of 1SW:MSW fish for each river n (Figure V-4).

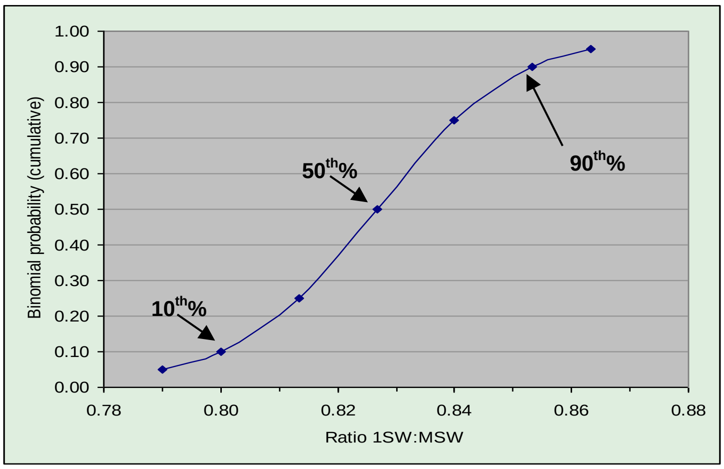


Figure V-4. Cumulative Binomial frequency distribution of the ratio of 1SW salmon in a river based upon the count of fish below 4kg and total number of recorded as caught in a river in catch statistics. MSW ratios are the inverse, hence 0.83 1SW: 0.17 MSW. 10^{th}, 50^{th} and 90^{th} percentiles indicated.

Step 2. Calculating Stock/ Recruitment from index rivers

The Bayesian Hierarchical Stock and Recruitment Analysis (BHSRA) of index rivers, and transport of Biological reference points to other rivers, gives a required egg deposition rate per metre squared, specific to each river and the necessary quantity defining each rivers conservation limit (Appendix IV). These calculations are based upon index river data, and associated smolt ages, age ratios and fecundities. Specific data were used where available for these from counter/ trap monitoring station records or up to date scientific monitoring. Where no such data existed the river specific rod catch data set were used to provide them.

Egg deposition rates at Maximum Sustainable Yield
Variability in the egg deposition rates at Maximum Sustainable Yield (MSY), as part of the output from the BHSRA were also taken at the 10th percentile, 50th (median) and 90th percentiles of the river specific range (Figure V-5). These approximate negative binomial frequency distributions and are appropriate for describing the culmed (also known as contagious) distribution (Elliott, 1977) of dispersal of salmon redds and eggs in streams and rivers (after Armstrong et al., 2003 and Bardonnet & Baglinière 2000).

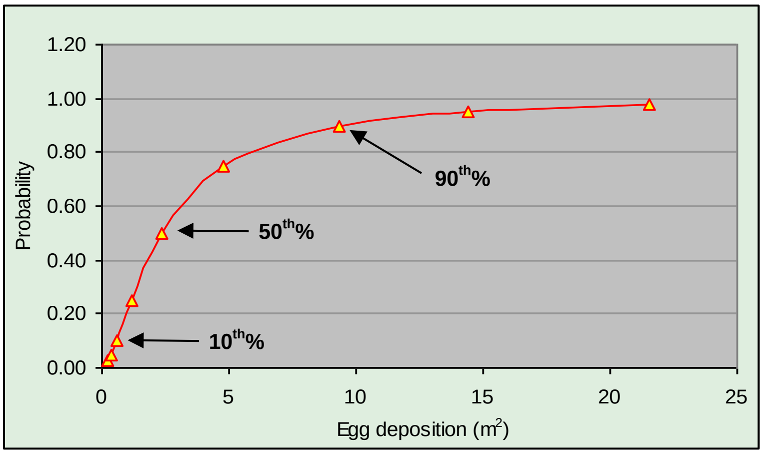


Figure V-5. Cumulative frequency egg deposition rate from BHSRA. 10th, 50th and 90th percentiles indicated.

Wetted areas:
Following the 2012 season the wetted areas of rivers was updated. Prior to 2012 these were computed from statistically combined parameters: the length of upstream river, upstream catchment area, stream order, and local gradient interpolated from aerial photography within a GIS platform according to McGinnity *et al.*, (2003). This approach was updated for the 2013 assessment, incorporating a national database of 1767 individual river width reference measurements, from 340 reaches according to McGinnity (2012) who identified that:

The best model to predict wetted width of rivers included two explanatory variables: upstream catchment area and Shreve index (Table 1). These two variables explained 88% of the variation in the wetted width measured in the field using:

$$\log_{10}(\text{Wetted width} + 1) = 0.22734 + 0.20045 (\log_{10} \text{catchment area}) + 0.25939(\log_{10} \text{Shreve index})$$

Table 1. Best fit model (ANOVA) explaining the response variable, Log_{10} (wetted width + 1), using multiple linear regression of explanatory GIS-derived variables

	d.f.	Sum Square	Mean Square	F	P
Log_{10} Catchment Area	1	29.67	29.67	2223.13	<0.0001
Log_{10} Shreve	1	1.82	1.82	136.10	<0.0001
Residuals	321	4.28	0.01		
Adj. R^2 = 0.88; F = 1180 (2, 321 d.f.); P < 0.0001					

	Estimate	SE	t-value	P
Coefficients				
Intercept	0.22734	0.01721	13.21	<0.0001
Log_{10} Catchment Area	0.20045	0.01891	10.60	<0.0001
Log_{10} Shreve	0.25939	0.02224	11.67	<0.0001

These updated wetted areas were applied in the BHSRA the model specification (as described presented in Appendix IV) with regard to the index rivers, all other Irish salmon rivers for which stock-recruitment indices were derived by the BHSRA and in raising the results to river specific CLs.

Step 3. Monte Carlo Analysis of CLs

The salmon conservation limits, in eggs per m^2 at MSY are raised to the wetted area of each river to give the total necessary egg deposition for each river, *i.e*. the rivers conservation limits. These values are calculated as number of eggs, and then converted to numbers of fish. Calculations to establish the conservation limits in numbers of fish are based upon:

- proportion of 1SW and MSW fish
- fecundity of 1SW and MSW fish

Variation around ratios of 1SW: MSW, their fecundities and egg deposition requirements were incorporated in Monte Carlo analysis. Ranges were truncated to triangular distributions taking the 10th percentile and 90th percentile as upper and lower limits and the 50th percentile (median) as the most likely, to derive total river conservation limits and their 1SW and MSW components, where:

Conservation Limit in total number of eggs =

(Prop. 1SW * Prop. Female * 1SW Fecundity * X) + (Prop. 2SW * Prop. Female * 2SW Fecundity * X)

Where the proportion of females to males in 1SW fish is taken as 0.6:0.4 and in MSW as 0.85:0.15 and X is the relative value of number of fish, which is subsequently split by the ratio of 1SW to 2SW to give the conservation limit of each, and summed to give the total river conservation limits against which returns are compared.

Step 4. River specific Conservation Limits

The Monte Carlo analyses also provides confidence bounds around mid point CL estimates, which were subsequently incorporated into the catch advice assessment methodology. The 50th percentile (median value) is implemented as the most likely values and the 10th and 90th percentiles as minimum and maximum values in triangular distributions in the risk analysis leading to provision of catch advice (Appendix VI).

This approach recognises and incorporates appropriate biology and ecology variability in salmon river populations in order to take it into consideration when establishing surplus and deficits in returning river specific salmon stocks. By estimating salmon fecundities and 1SW:MSW ratios from greater than 100 records of fish, empirically recognised as most probably of 1SW and MSW origin by splitting data sets at 4kg, from the most up-to-date catch statistics, this approach provides substantial, relevant and reliable, quantitative information on a river by river basis. While for rivers with smaller catches, national average values are implemented to ensure that the most probable ranges in variability are incorporated.

References:

Armstrong J.D., Kemp P.S., Kennedy G.J.A., Ladle M. and Milner N.J. (2003). Habitat requirements of Atlantic salmon and brown trout in rivers and streams. *Fisheries Research;*62*:*143-170*.*

Bardonnet A. and Baglinière J. L. (2000). Freshwater habitat of Atlantic salmon *(*Salmo salar*)*. Canadian Journal of Fisheries and Aquatic Sciences*;* 57*:*497-506*.*

de Eyto E, White J, Boylan P, Clarke B, Cotter D, Doherty D, Gargan P, Kennedy R, McGinnity P, O'Maoiléidigh N, O'Higgins K. (in press). The fecundity of wild Irish Atlantic salmon *Salmo salar* L. and its application for stock assessment purposes.

Elliott JM, (1977). Some methods for the statistical analysis of samples of benthic invertebrates. 2nd edn. Freshwater Biological Association, Scientific Publication

Fowler, J. and L. Cohen, 1990. Practical Statistics for Field Biology. 1st Edn., Open University Press, Philadelphia, USA., ISBN: 0-335-09207-1, pp: 240.

McGinnity P, de Eyto E, Gilbey J, Gargan P, Roche W, Stafford T, McGarrigle M, Ó Maoiléidigh N, Mills P. (2012). A predictive model for estimating river habitat area using GIS derived catchment and river variables. Fisheries Management and Ecology 19:69-77.

Appendix VI. Derivation of river-specific catch advice for Atlantic salmon fisheries in Ireland for 2014

River-specific fisheries advice is provided for the forthcoming season based on a forecast of the abundance of salmon which will return to each river in that year, comparison of the estimated abundance to the river-specific Conservation Limit, and determination of harvest of salmon which could be made while allowing a high probability (at least 75% recommended) that the Conservation Limit (CL) would be met.

Predicted abundance in each river for the fishing season in question is taken as the average abundance of salmon from each river prior to any national fisheries (recruits) in the most recent 5 years where data (counter, trap or rod catch) are available.

River-specific recruitment of salmon is estimated as follows:

- Estimates of spawners and returns in most rivers have been updated since 2006 and are based on an extrapolation of rod catch figures using specific exploitation rate bands identified from rivers with counters (Appendix VI-1).
- For rivers with counter data, the spawners from the counter monitoring are used rather than rod catch and extrapolation using rod exploitation rate data.
- For rivers with no counters or a rod catch of less than 10 annually, it is assumed that they are meeting 33% of the in-river stocks requirement.
- River specific catches in draft nets and other estuarine fisheries are derived from actual reported catches from carcass tagging and logbooks.
- Total annual abundance for the most recent five year average prior to any national fisheries is the sum of river-specific spawners, river-specific rod catches, river-specific draft net and other estuary catches, and river-specific driftnet catch where present.

Risk analysis leading to the provision of catch advice
The text and methodologies below are derived primarily from:

Crozier, W. W., Potter, E. C. E., Prévost, E., Schon, P–J., and Ó Maoiléidigh, N. 2003. A co-ordinated approach towards the development of a scientific basis for management of wild Atlantic salmon in the north-east Atlantic (SALMODEL – Scientific Report Contract QLK5–1999–01546 to EU Concerted Action Quality of Life and Management of Living Resources). Queen’s University of Belfast, Belfast. 431 pp.

Readers are advised to consult this text for a more complete explanation of methods and formulas used in the calculations.

The use of reference points in fisheries management requires that the probability of achieving the objectives is taken into account. Spawning requirement reference points from stock and recruitment analysis are established on the basis of an egg deposition rate weighted by area measures of freshwater habitat available for juvenile production (see Appendix IV). Because fisheries exploit fish, the egg requirements are translated to the number of salmon required to achieve that egg deposition using the biological characteristics of the stock. This is the approach used to manage some homewater fisheries on both sides of the Atlantic and the high seas fishery of west Greenland.

Fish are discrete units and Atlantic salmon stocks generally consist of relatively small numbers of animals, in the order of 100s to 1000s for most rivers of the north Atlantic. Managing to achieve spawning escapement, reference points must consider the probability of obtaining at least the required number of fish to achieve the egg deposition. Since only females contribute eggs, fisheries should be managed to ensure that the required number of females are available for spawning.

The probability profiles for achieving the spawning requirement objective in a specific year are defined by the stochastic properties of small numbers and additional factors including the size of the river stock (estimated directly from counters/traps or extrapolated from rod exploitation rates) and proportion female in the stock (proportions taken from known proportions in broodstock recovery programmes). In the management of mixed stock fisheries, the aggregation of individual river requirements into a regional objective introduces additional uncertainty to the achievement of the individual river objectives. There are curently two estuary fisheries (Killary harbour, Owenmore/Owenduff common estuary) which exploit stocks from more than one river where advice is provided. The aggregation of spawner requirements into regional requirements changes the probability profiles, which are affected by: the number of rivers which are aggregated, relative size of the rivers, disproportionate productivity rates among the rivers, and the possibility of straying between rivers in the aggregated complex.

Monte Carlo methods for estimating probabilities under binomial and multinomial models

The description of the probability profiles are based on application of the binomial and multinomial distributions of the fate of fish released to spawn. For the single river case, the simplest situation, the fish released to spawn are of two types: males and females. The probability of a given number of females within a specified group of fish is described by the binomial distribution:

$$\Pr(Z = k) = [N! / (k! (N - k)!)]\ p^k (1 - p)^{N-k}$$

where:

Z = number of female fish
N = number of fish in the group, males and females
p = probability that a fish is female (*i.e.* proportion female in the stock)

The binomial distibution has the following properties:

1) For a fixed p, the coefficient of variation decreases as N increases,
2) The variance is greatest when p = 0.5.

For the aggregated stock example, the binomial is extended to the multinomial distribution for which there are more than two possible outcomes (*i.e.* female from river A, male from river A, female from river B, male from river B,…). The probability of a given set of outcomes is given by:

$$\Pr(Z_1=k_1, Z_2=k_2, \ldots Z_M=k_M) = [N! / (k_1!\ k_2! \ldots k_M!)]\ p_1^{k1}\ p_2^{k2} \ldots p_M^{kM}$$

where:

$Z_1, Z_2, \ldots Z_M$ = are outcomes in M stocks
N = number of fish in total
$p_1, p_2, \ldots, p_M$ = proportion female in rivers 1, 2, …, M

For the simple case of one river, exact probabilities of meeting or exceeding the spawner requirements (Pr(Z >= k) can be calculated from the binomial formula for an assumed proportion female (p) and for a given number of fish released to the river (N).

In the more complicated situation in which more than one stock is being considered (and for which the sum of a large number of probabilities must be calculated) or when including annual variations in the biological characteristics of the stock, the probabilities can be conveniently approximated using Monte Carlo techniques.

The spawner requirements are defined on the basis of the number of female fish (S_{optf}) required to achieve the egg requirements at the reference point. The proportion of females in the stock is assumed known (or expected) (p). In the simulation, this female proportion represents the probability of a fish being female. The simulation proceeds as follows (for the single river example):

1. A number (j) is drawn from a random uniform distribution between 0 and 1.
2. If j <= p (proportion female in the stock), then that fish is considered a female and the female counter for that fish is set at 1 ($sex_f = 1$). If j > p, then the fish is considered male and the counter is set to 0 ($sex_f = 0$).
3. Repeat steps 1 and 2 a total of N times (N = number of fish released to the river) using independent random uniform numbers.
4. The total number of females released to the river from step 3 is the sum of sex_f for the N random number assignments.
5. If Σsex_f from step 4 >= S_{optf} , then the spawner requirement has been met (*i.e.* $SpawnerMet_i = 1$, for i = 1 to M simulations).
6. Introduced in 2012 for the 2013 season, ecological/ bogical variability about conservatin limtis (S_{optf}) was introduced to incorporate the range of 1SW:MSW fish, their respective fecundities and variability in egg deposition from stock-recreuitment analyses (Appendix V).
7. Repeat steps 1 to 5 a large number of times (M = 10,000).
8. Calculate the number of times the spawner requirement was met or exceeded (Σ $SpawnerMet_I$ from step 5).
9. Calculate and store the probability of meeting or exceeding the spawner requirement for N releases of fish to the river (P_N)as Σ $SpawnerMet_i$ divided by M (from step 6 and 7).
10. Release N + c fish to the river with c > 0.
11. Repeat steps 1 to 9 until the desired probability of meeting or exceeding the spawner requirement is attained.
12. Estimate the probability of meeting the spawner requirement (P_N, P_{N+c}, …) versus the number of fish released to the river (N, N+c, ….) to describe the probability profile for the specificed conditions (S_{optf}, p).
13. Plot the probability of meeting spawning requirements versus various catch options with the catch option providing at least a 75% probability of meeting the Conservation Limit being advised by the SSC for each fishery.

In all the analyses, a total of 10,000 Monte Carlo simulations were performed for each fixed release of fish to the river(s).

Table VI-1. River Rod Catch Exploitation rates applied for 2017 advice.

		1SW Exploitation rates			MSW Exploitation rates		
District	**River**	**Likely**	**Minimum**	**Maximum**	**Likely**	**Minimum**	**Maximum**
Dundalk	Castletown	0.05	0.01	0.12			
Dundalk	Fane (2015 & 2016)	0.05	0.01	0.12	0.12	0.06	0.27
	Fane (2012 – 2014)	0.15	0.07	0.35	0.12	0.06	0.27
Dundalk	Glyde (2014, 2015, 2016)	0.15	0.07	0.35	0.12	0.06	0.27
	Glyde (2012, 2013)	0.05	0.01	0.12	0.12	0.06	0.27
Wexford	Owenavorragh	0.05	0.01	0.12			
Waterford	Barrow and Pollmounty	0.05	0.01	0.12	0.12	0.06	0.27
Waterford	Nore (2015, 2016)	0.05	0.01	0.12	0.12	0.06	0.27
Waterford	Nore (2012-2014)	0.15	0.7	0.35	0.12	0.06	0.27
Waterford	Suir, Clodiagh, Lingaun & Blackwater (2014 ,2015, 2016)	0.05	0.01	0.12	0.12	0.06	0.27
	Suir, Clodiagh, Lingaun & Blackwater (2012 - 2013)	0.15	0.7	0.35	0.12	0.06	0.27
Waterford	Colligan	0.05	0.01	0.12			
Lismore	Blackwater Glenshelan & Finisk	0.18	0.12	0.26			
Lismore	Bride	0.05	0.01	0.12			
Cork	Owennacurra	0.03	0.01	0.05			
Cork	Lower Lee (Cork) (2015)	0.05	0.01	0.12	0.12	0.06	0.27
Cork	Lower Lee (Cork) (2016, 2012 - 2014)	0.15	0.07	0.35	0.12	0.06	0.27
Cork	Argideen	0.05	0.01	0.12			
Cork	Ilen	0.15	0.07	0.35	0.12	0.06	0.27
Cork	Mealagh	0.05	0.01	0.12			
Cork	Owvane	0.05	0.01	0.12			
Cork	Coomhola	0.15	0.07	0.35			
Cork	Glengarriff	0.05	0.01	0.12			
Cork	Adrigole	0.05	0.01	0.12			
Kerry	Croanshagh (Glanmore R.) (2013-2016)	0.05	0.01	0.12			
	Croanshagh (Glanmore R.) (2012)	0.15	0.7	0.35			
Kerry	Cloonee	0.05	0.01	0.12			
Kerry	Sheen	0.04	0.01	0.10			
Kerry	Roughty	0.10	0.05	0.15			
Kerry	Sneem	0.05	0.01	0.12			
Kerry	Inney	0.15	0.07	0.35			
Kerry	Ferta	0.05	0.01	0.12			
Kerry	Behy	0.05	0.01	0.12			
Kerry	Caragh	0.15	0.07	0.35	0.31	0.15	0.46
Kerry	Laune and Cottoners	0.15	0.07	0.35	0.31	0.15	0.46
Kerry	Owenascaul	0.05	0.01	0.12			
Kerry	Owenmore	0.05	0.01	0.12			
Limerick	Skivaleen	0.05	0.01	0.12			
Connemara	Screebe	0.20	0.12	0.29			
Ballinakill	Owenglin	0.15	0.07	0.35			
Ballinakill	Bundorragha (Wild Rod)	0.15	0.07	0.35	0.31	0.15	0.46
Ballinakill	Carrownisky	0.05	0.01	0.12			
Ballinakill	Owenwee (2013 - 2016)	0.15	0.07	0.35			
	Owenwee (2012)	0.05	0.01	0.12			
Bangor	Newport R. (Lough Beltra)	0.10	0.05	0.12	0.12	0.06	0.27
Bangor	Glenamoy (2015)	0.15	0.07	0.35			
	Glenamoy (2012 – 2014, 2016)	0.05	0.01	0.12			
Ballina	Moy	0.15	0.07	0.35	0.31	0.15	0.46
Ballina	Easky (2012-2015)	0.15	0.07	0.35			
	Easky (2016)	0.05	0.01	0.12			
Sligo	Garvogue (Bonnet)(2013-2016)	0.05	0.01	0.12	0.12	0.06	0.27
	Garvogue (Bonnet) (2012)				0.31	0.15	0.46
Sligo	Drumcliff	0.15	0.07	0.35			
Ballyshannon	Duff	0.15	0.07	0.35			
Ballyshannon	Drowes	0.15	0.07	0.35	0.31	0.15	0.46
Ballyshannon	Oily	0.05	0.01	0.12			
Ballyshannon	Bungosteen	0.05	0.01	0.12			
Ballyshannon	Glen	0.15	0.07	0.35			
Letterkenny	Owenea and Owentocker	0.15	0.07	0.35			
Letterkenny	Gweebarra	0.15	0.07	0.35	0.12	0.06	0.27
Letterkenny	Gweedore (Crolly R.)	0.05	0.01	0.12			
Letterkenny	Clady (2012, 2013)	0.03	0.01	0.05			
	Clady (2014)	0.05	0.01	0.12			

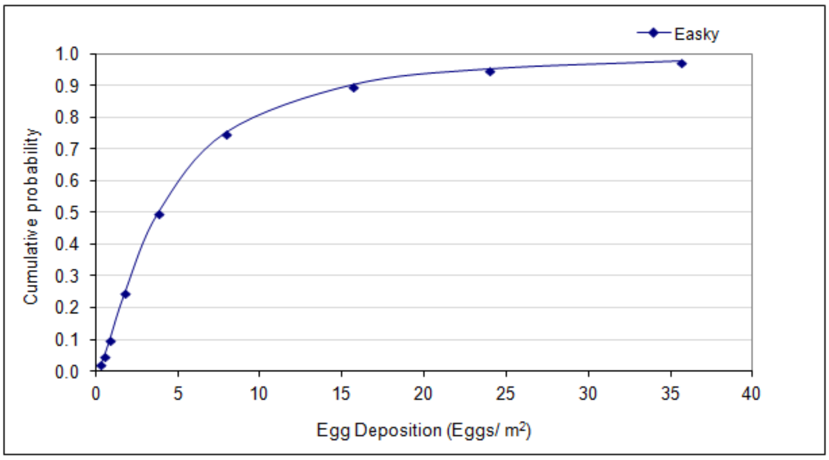
	Clady (2015, 2016)	0.15	0.07	0.35			
Letterkenny	Tullaghobegly (2014-2016)	0.05	0.01	0.12			
	Tullaghobegly (2012,2013)	0.15	0.07	0.35			
Letterkenny	Ray	0.05	0.01	0.12			
Letterkenny	Lackagh	0.15	0.07	0.35	0.12	0.06	0.27
Letterkenny	Leannan	0.15	0.07	0.35	0.12	0.06	0.27
Letterkenny	Crana (2012-2015)	0.15	0.07	0.35			
	Crana (2016)	0.05	0.01	0.12			

Appendix VII. Worked assessment examples

Easky (Ballina):

Example of a river assessment made by angling catch with a surplus

The Bayesian Hierarchical Stock and Recruitment Forecast Analysis (BHSRA) details the egg deposition per m^2 at maximum sustainable yield (MSY) for each river, based upon latitude and wetted area (fluvial accessible area), transported from the MSY point of Ricker stock/recruitment analysis of index rivers. This is equivalent to the conservation limit (CL) in number of eggs per m^2.

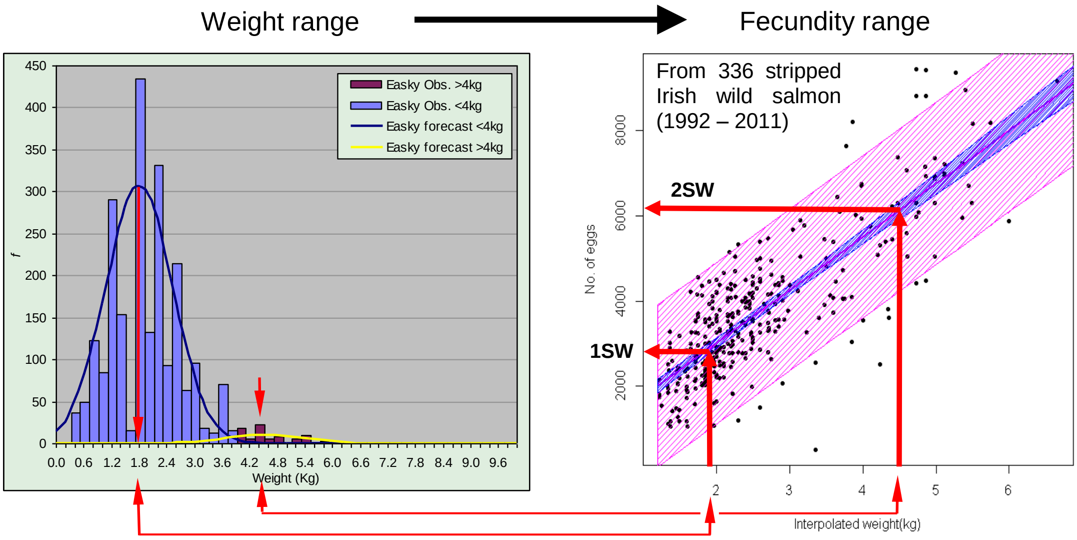


Egg deposition rate /m^2 frequency distribution for the river Easky.

Details for the Easky river and median egg requirements per m^2.

Variable	Value
Wetted area (ha)	53.90
Fluvial accessible area (ha)	46.56
Latitude (Deg N)	54.17
Median (50th percentile) required egg deposition (eggs/m^2)	3.8

The ratio of 1SW:2SW and fecundities of salmon in the river (as eggs per 1SW and 2SW female fish) are calculated from the weight frequency distribution of fish caught in the river (between 2006 and 2011) and a relationship between weight and fecundity developed from wild stripped salmon:



Weight range of 1SW and 2SW salmon in the Easky and associated fecundities.

Median weights of 1SW and 2SW salmon in the Easky and 10th and 90th percentiles.

1SW			2SW		
Median	10th	90th	Median	10th	90th
1.81	0.87	2.75	4.54	3.47	5.61

Median fecundities of 1SW and 2SW salmon in the Easky and 10th and 90th percentiles

1SW			2SW		
Median	10th	90th	Median	10th	90th
2770	1594	3945	6184	4846	7523

Proportion 1SW: 2SW

Median	10th	90th
0.827	0.825	0.828
0.173	0.172	0.175

Proportion females and males in 1SW and 2SW age groups

	1SW	2SW
Proportion female	0.60	0.85
Proportion male	0.40	0.15

The conservation limit (CL) in number of eggs per m^2 is converted into numbers of 1SW, 2SW and total number of salmon, and variability, for the whole river following Equation 1 in a Monte Carlo simulation of 75,000 iterations. The conversion from eggs to fish incorporates: the egg deposition rates at MSY (with variability); the proportion of the stock that are age 1SW (with variability); the proportion of the stock that are age 2SW (with variability); the proportion of each age group that are female; the fecundity of each age group (with variability).

Variability around estimates are incorporated as the 10th and 90th percentiles of the observed ranges, set as minimums and maximums in triangular distributions.

CL in No. of Fish (± 90^{th}%) =

MY (No. of Eggs/m^2) ±90th% /

$$\frac{MSY\ (\text{No. of Eggs}/m^2) \pm 90th\%}{(\text{Sea-Age Prop}_{1SW} \pm 90^{th}\% * \text{Female Prop}_{1SW} * \text{Fecundity}_{1SW} \pm 90^{th}\% + \text{Sea-Age Prop}_{MSW} \pm 90^{th}\% * \text{Female Prop}_{MSW} * \text{Fecundity}_{MSW} \pm 90^{th}\%) * \text{River wetted area}\ (m^2)}$$

Equation 1.

Conservation limits of 1SW, 2SW and total salmon

Sea age	1SW	2SW	Total
	1156	242	1398

Catch Advice

The number of salmon likely to return in the next fishing season is calculated from the most recent 5 year catch.

Angling catch in the river Easky

	2008	2009	2010	2011	2012
Rod catch: Killed	353	257	355	226	268
Rod catch: Catch & Release	152	115	158	118	155

No Commercial catch in the river Easky

	2008	2009	2010	2011	2012
Add catch from Draft net	0	0	0	0	0

The total rod catch is raised using exploitation rate values and added to the commercial catch to provide the estimate of returns prior to homewater fisheries.

Fishing exploitation rate on the river Easky

	Min	Most likely	Max
Exploitation rate	0.07	0.15	0.35

The estimated Recruits (i.e. returns of salmon) must exceed the CL if there is to be an allowable catch. A catch option which provides a high probability that the CL will be attained is advised. If returns are likely to be less than the CL then harvest fishing is not advised.

Easky is estimated to have a 75% probability of attaining its CL with a surplus of 863 fish.

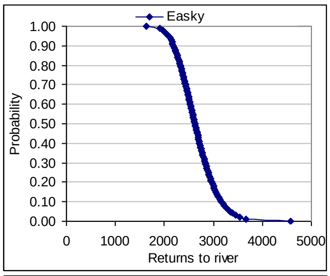
The CL used for Irish rivers are Limit Reference points i.e. stocks should not be allowed to fall below this limit but should be maintained above the limit with a high probability. In the assessment of international salmon fishing quotas, ICES recommends catch options which allow at least a 75% chance that the CLs will be met.

The SSC adopt a similar precautionary risk level when providing catch advice based on a risk assessment which includes the annual variation in RECRUITS and in the estimated CLs (shown in the following figures).

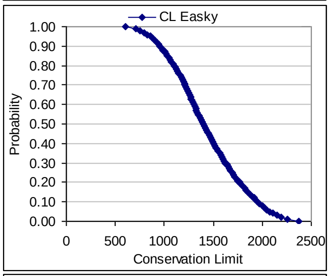
The catch option which provides a 75% chance that the CL will be attained is advised to IFI by the SSC.

Risk plots

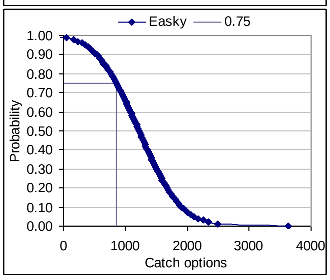
Predicted recruits	**Easky**
Percentiles	
100%	1622
90%	2188
75%	2380
50%	2625
25%	2896
10%	3164
0%	4576



CL	**Easky**
Percentiles	
100%	601
90%	954
75%	1160
50%	1398
25%	1691
10%	1951
0%	2372



Surplus/Deficit	**Easky**
Percentiles	
100%	-626
90%	537
75%	**863**
50%	1226
25%	1588
10%	1914
0%	3642



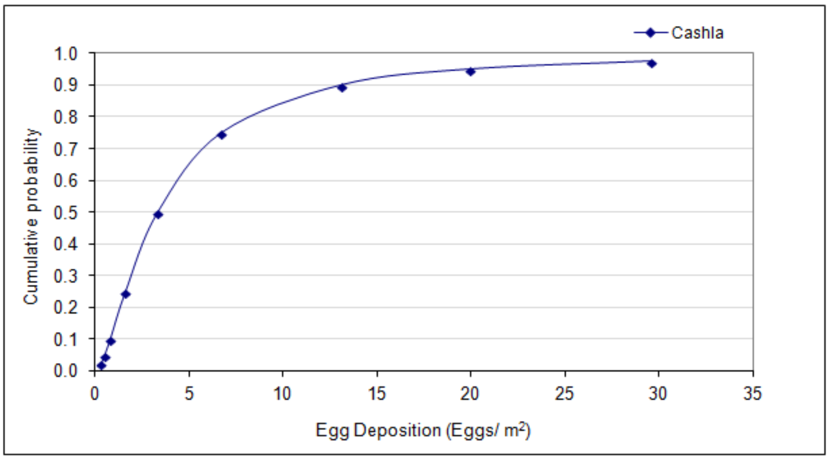
Risk plot for Catch Advice

Percentiles and risk plots of the predicted recruits, conservation limits and resulting surplus/ deficits in relation to a range of catch options for the river Easky. Predicted recruits and CL risk plots are calculated from 50,000 draws in Monte Carlow analysis, with each paired draw compared to calculate the surplus/ deficit risk plot and hence catch advice. Note that the presented risk plots and values for predicted recruits and CLs are the percentiles of their 50,000 draws independently and direct comparison of these do not equate to the surplus/ deficit percentiles, which are the percentiles of the 50,000 comparisons of each of the paired predicted recruit to CL draws.

Cashla (Connemara):

Example of a river assessment made by counter with a surplus

The Bayesian Hierarchical Stock and Recruitment Forecast Analysis (BHSRA) details the egg deposition per m^2 at maximum sustainable yield (MSY) for each river, based upon latitude and wetted area (fluvial accessible area), transported from the MSY point of Ricker stock/recruitment analysis of index rivers. This is equivalent to the conservation limit (CL) in number of eggs per m^2.

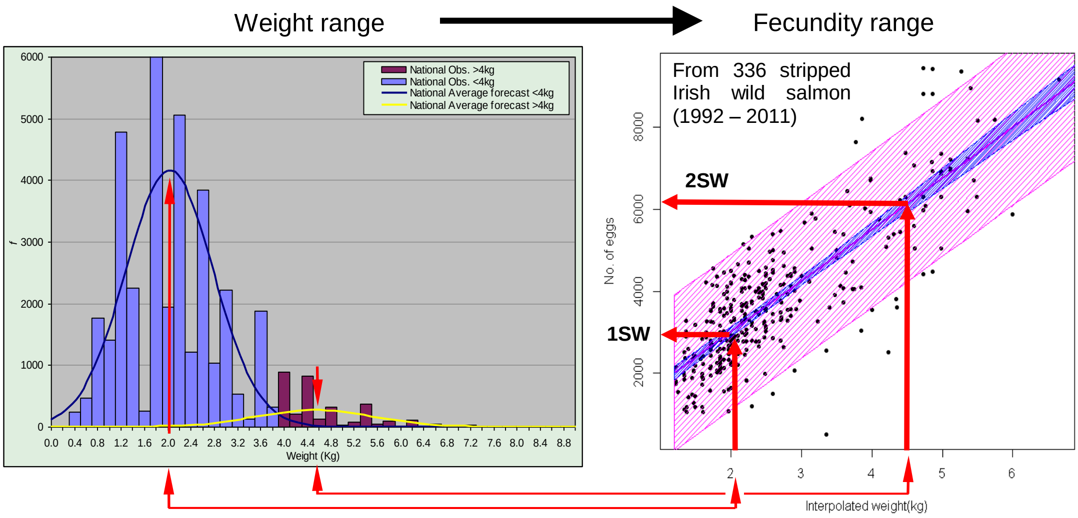


Egg deposition rate /m^2 frequency distribution for the river Cashla.

Details for the Cashla river and median egg requirements per m^2.

Variable	Value
Wetted area (ha)	23.96
Fluvial accessible area (ha)	19.21
Latitude (Deg N)	52.34
Median (50th percentile) required egg deposition (eggs/m^2)	3.32

The National average ratio of 1SW:2SW and fecundities of salmon (as eggs per 1SW and 2SW female fish) are calculated from the weight frequency distribution of fish caught (between 2006 and 2011) and a relationship between weight and fecundity developed from wild stripped salmon:



National average weight range of 1SW and 2SW salmon and associated fecundities applied to the Cashla.

Median weights of 1SW and 2SW salmon (national average) and 10^{th} and 90^{th} percentiles.

1SW			2SW		
Median	10^{th}	90^{th}	Median	10^{th}	90^{th}
2.04	1.07	3.01	4.54	3.27	5.81

Median fecundities of 1SW and 2SW salmon (national average) and 10^{th} and 90^{th} percentiles

1SW			2SW		
Median	10^{th}	90^{th}	Median	10^{th}	90^{th}
3057	1844	4271	6184	4596	7773

Proportion 1SW: 2SW (national average)

Median	10^{th}	90^{th}
0.825	0.827	0.828
0.175	0.172	0.173

Proportion females and males in 1SW and 2SW age groups

	1SW	2SW
Proportion female	0.60	0.85
Proportion male	0.40	0.15

The conservation limit (CL) in number of eggs per m^2 is converted into numbers of 1SW, 2SW and total number of salmon, and variability, for the whole river following Equation 1 in a Monte Carlo simulation of 75,000 iterations. The conversion from eggs to fish incorporates: the egg deposition rates at MSY (with variability); the proportion of the stock that are age 1SW (with variability); the proportion of the stock that are age 2SW (with variability); the proportion of each age group that are female; the fecundity of each age group (with variability).

Variability around estimates are incorporated as the 10^{th} and 90^{th} percentiles of the observed ranges, set as minimums and maximums in triangular distributions.

CL in No. of Fish (± 90^{th}%) =

MSY (No. of Eggs/m^2) ±90th% /

(Sea-Age $Prop_{1SW}$ ±90^{th} % * Female $Prop_{1SW}$ * $Fecundity_{1SW}$ ±90^{th} %

\+ Sea-Age $Prop_{MSW}$ ± 90^{th} % * Female $Prop_{MSW}$ * $Fecundity_{MSW}$ ±90^{th}%)

* River wetted area (m^2)

Equation 1.

Conservation limits of 1SW, 2SW and total salmon.

Sea age	1SW	2SW	Total
	363	74	438

Catch Advice

The number of salmon likely to return in the next fishing season is calculated from the most recent 5year counts.

Counts on the river Cashla

	2008	2009	2010	2011	2012
Trends in counts	353	257	355	226	268
Add catch killed above counter	20	22	21	47	26

The average of the Counter, along with rod catch and any commercial catch taken provide the estimate of returns prior to homewater fisheries.

No commercial fisheries intercepting Cashla salmon

	2008	2009	2010	2011	2012
Add catch from Draft net	0	0	0	0	0

The estimated Recruits (i.e. returns of salmon) must exceed the CL if there is to be an allowable catch. A catch option which provides a high probability that the CL will be attained is advised. If returns are likely to be less than the CL then harvest fishing is not advised.

Cashla is estimated to have a 75% probability of attaining its CL with a surplus of 446 fish.

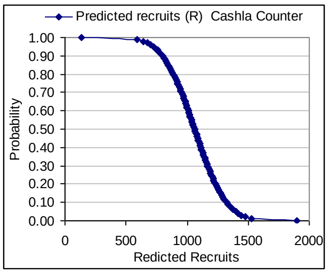
The CL used for Irish rivers are Limit Reference points i.e. stocks should not be allowed to fall below this limit but should be maintained above the limit with a high probability. In the assessment of international salmon fishing quotas, ICES recommends catch options which allow at least a 75% chance that the CLs will be met.

The SSC adopt a similar precautionary risk level when providing catch advice based on a risk assessment <u>which includes the annual variation in RECRUITS and in the estimated CLs</u> (shown in the following figures).

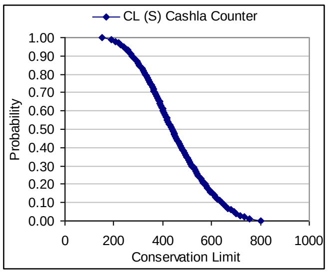
The catch option which provides a 75% chance that the CL will be attained is advised to IFI by the SSC.

Risk plots

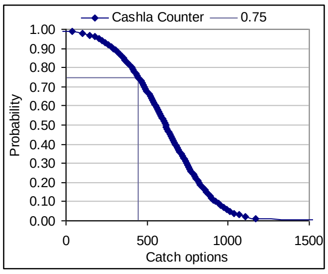
Predicted recruits	Cashla Counter
Percentiles	
100%	139
90%	798
75%	924
50%	1060
25%	1199
10%	1323
0%	1900



CL	Cashla Counter
Percentiles	
100%	152
90%	276
75%	349
50%	438
25%	545
10%	641
0%	804



Surplus/Deficit	Cashla Counter
Percentiles	
100%	-401
90%	294
75%	**446**
50%	614
25%	779
10%	924
0%	1692



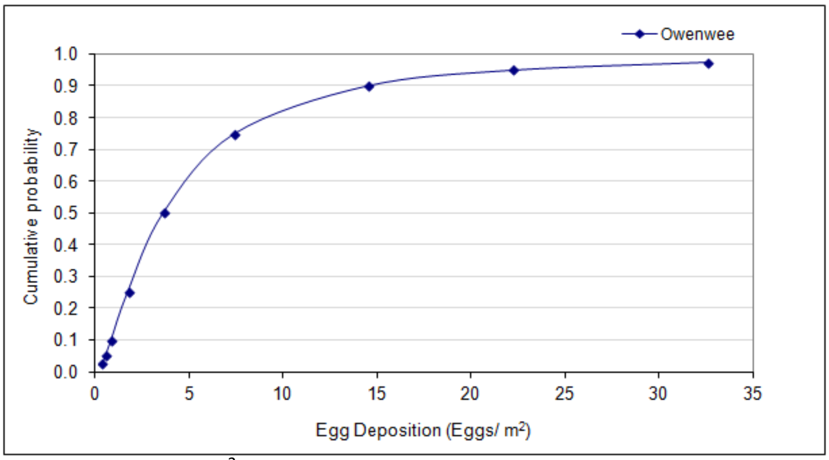
Risk plot for Catch Advice

Percentiles and risk plots of the predicted recruits, conservation limits and resulting surplus/ deficits in relation to a range of catch options for the river Cashla. Predicted recruits and CL risk plots are calculated from 50,000 draws in Monte Carlow analysis, with each paired draw compared to calculate the surplus/ deficit risk plot and hence catch advice. Note that the presented risk plots and values for predicted recruits and CLs are the percentiles of their 50,000 draws independently and direct comparison of these do not equate to the surplus/ deficit percentiles, which are the percentiles of the 50,000 comparisons of each of the paired predicted recruit to CL draws.

Owenwee (Belclare) (Ballinakill)

Example of a river assessment made by angling catch with a deficit

The Bayesian Hierarchical Stock and Recruitment Forecast Analysis (BHSRA) details the egg deposition per m^2 at maximum sustainable yield (MSY) for each river, based upon latitude and wetted area (fluvial accessible area), transported from the MSY point of Ricker stock/recruitment analysis of index rivers. This is equivalent to the conservation limit (CL) in number of eggs per m^2.

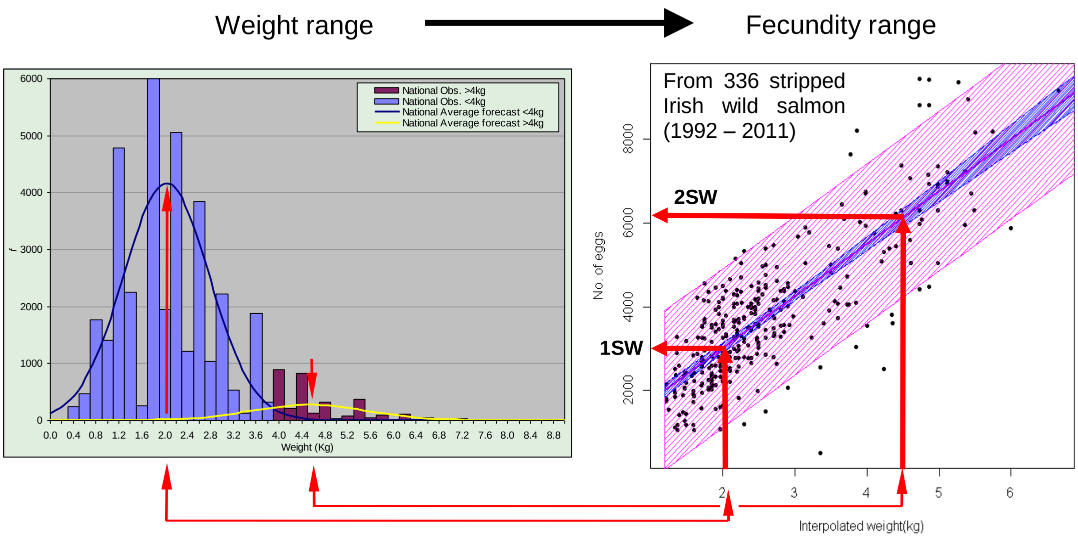


Egg deposition rate /m^2 frequency distribution for the river Owenwee (Belclare)

Details for the Owenwee river and median egg requirements per m^2.

Variable	Value
Wetted area (ha)	17.81
Fluvial accessible area (ha)	14.34
Latitude (Deg N)	53.75
Median (50th percentile) required egg deposition (eggs/m^2)	3.6

The National average ratio of 1SW:2SW and fecundities of salmon (as eggs per 1SW and 2SW female fish) are calculated from the weight frequency distribution of fish caught (between 2006 and 2011) and a relationship between weight and fecundity developed from wild stripped salmon:



National average weight range of 1SW and 2SW salmon and associated fecundities applied to the Owenwee.

Median weights of 1SW and 2SW salmon (national average) and 10th and 90th percentiles.

1SW			2SW		
Median	10th	90th	Median	10th	90th
2.04	1.07	3.01	4.54	3.27	5.81

Median fecundities of 1SW and 2SW salmon (national average) and 10th and 90th percentiles

1SW			2SW		
Median	10th	90th	Median	10th	90th
3057	1844	4271	6184	4596	7773

Proportion 1SW: 2SW (national average)

Median	10th	90th
0.825	0.827	0.828
0.175	0.172	0.173

Proportion females and males in 1SW and 2SW age groups

	1SW	2SW
Proportion female	0.60	0.85
Proportion male	0.40	0.15

The conservation limit (CL) in number of eggs per m^2 is converted into numbers of 1SW, 2SW and total number of salmon, and variability, for the whole river following Equation 1 in a Monte Carlo simulation of 75,000 iterations. The conversion from eggs to fish incorporates: the egg deposition rates at MSY (with variability); the proportion of the stock that are age 1SW (with variability); the proportion of the stock that are age 2SW (with variability); the proportion of each age group that are female; the fecundity of each age group (with variability).

Variability around estimates are incorporated as the 10th and 90th percentiles of the observed ranges, set as minimums and maximums in triangular distributions.

CL in No. of Fish (± 90th%) =

MSY (No. of Eggs/m^2) ±90th% /

(Sea-Age $Prop_{1SW}$ ±90th % * Female $Prop_{1SW}$ * $Fecundity_{1SW}$ ±90th %

\+ Sea-Age $Prop_{MSW}$ ± 90th % * Female $Prop_{MSW}$ * $Fecundity_{MSW}$ ±90th%)

* River wetted area (m^2)

Equation 1.

Conservation limits of 1SW, 2SW and total salmon

Sea Age	1SW	2SW	Total
	309	65	373

Catch Advice

The number of salmon likely to return in the next fishing season is calculated from the most recent 5 year catch.

Angling catch in the river Owenwee

Catch	2008	2009	2010	2011	2012
Rod catch: Killed	0	0	0	6	7
Rod catch: Catch & Release	10	3	24	22	25

Commercial catch in the river Owenwee

	2008	2009	2010	2011	2012
Add catch from Draft net	87	103	0	0	0

The total rod catch is raised using exploitation rate values and added to the commercial catch to provide the estimate of returns prior to homewater fisheries.

Fishing exploitation rate on the river Owenwee

	Min	Most likely	Max
Exploitation rate	0.01	0.05	0.12

The estimated Recruits (i.e. returns of salmon) must exceed the CL if there is to be an allowable catch. A catch option which provides a high probability that the CL will be attained is advised. If returns are likely to be less than the CL then harvest fishing is not advised.

The Owenwee (Belclare) is not estimated to have a surplus of fish with a 75% probability of attaining its CL, with a deficit of 36 fish.

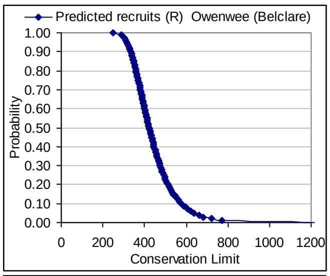
The CL used for Irish rivers are Limit Reference points i.e. stocks should not be allowed to fall below this limit but should be maintained above the limit with a high probability. In the assessment of international salmon fishing quotas, ICES recommends catch options which allow at least a 75% chance that the CLs will be met.

The SSC adopt a similar precautionary risk level when providing catch advice based on a risk assessment which includes the annual variation in RECRUITS and in the estimated CLs (shown in the following figures).

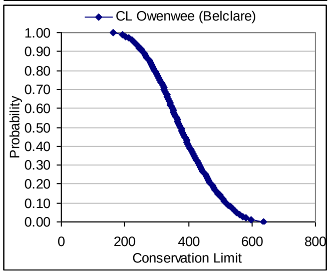
The catch option which provides a 75% chance that the CL will be attained is advised to IFI by the SSC.

Risk plots

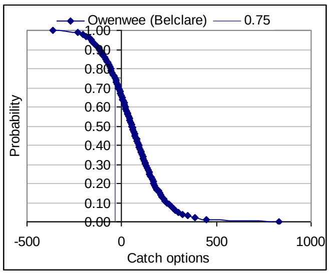
Predicted recruits	**Owenwee (Belclare)**
Percentiles	
100%	249
90%	333
75%	369
50%	422
25%	492
10%	576
0%	1231



CL	**Owenwee (Belclare)**
Percentiles	
100%	162
90%	254
75%	308
50%	373
25%	450
10%	517
0%	634



Surplus/Deficit	**Owenwee (Belclare)**
Percentiles	
100%	-363
90%	-117
75%	**-36**
50%	54
25%	148
10%	238
0%	832



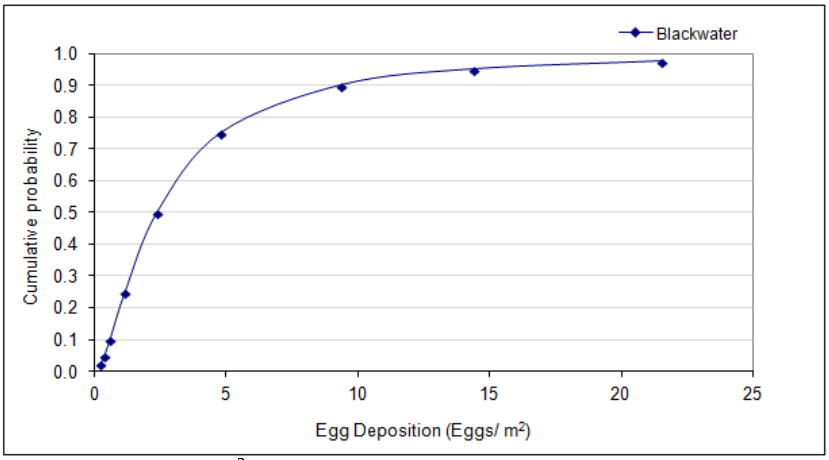
Risk plot for Catch Advice

Percentiles and risk plots of the predicted recruits, conservation limits and resulting surplus/ deficits in relation to a range of catch options for the river Owenwee. Predicted recruits and CL risk plots are calculated from 50,000 draws in Monte Carlow analysis, with each paired draw compared to calculate the surplus/ deficit risk plot and hence catch advice. Note that the presented risk plots and values for predicted recruits and CLs are the percentiles of their 50,000 draws independently and direct comparison of these do not equate to the surplus/ deficit percentiles, which are the percentiles of the 50,000 comparisons of each of the paired predicted recruit to CL draws.

Blackwater (Kerry)

Example of a river assessment made by counter with a deficit

The Bayesian Hierarchical Stock and Recruitment Forecast Analysis (BHSRA) details the egg deposition per m^2 at maximum sustainable yield (MSY) for each river, based upon latitude and wetted area (fluvial accessible area), transported from the MSY point of Ricker stock/recruitment analysis of index rivers. This is equivalent to the conservation limit (CL) in number of eggs per m^2.

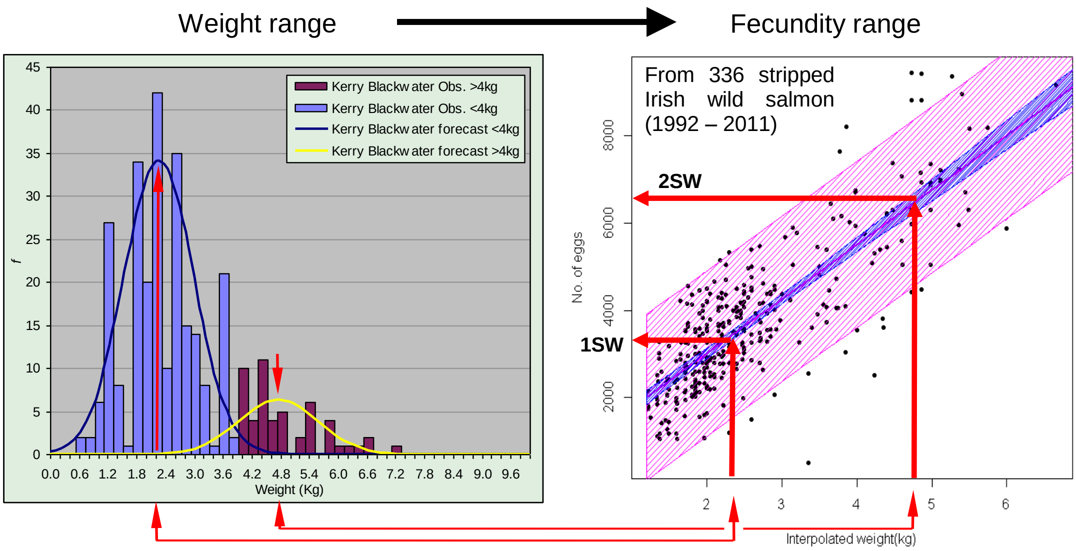


Egg deposition rate /m^2 frequency distribution for the river Blackwater (Kerry)

Details for the Blackwater river and median egg requirements per m^2.

Variable	Value
Wetted area (ha)	36.06
Fluvial accessible area (ha)	29.16
Latitude (Deg N)	27.61
Median required egg deposition (eggs/m^2)	2.36

The ratio of 1SW:2SW and fecundities of salmon in the river (as eggs per 1SW and 2SW female fish) are calculated from the weight frequency distribution of fish caught in the river (between 2006 and 2011) and a relationship between weight and fecundity developed from wild stripped salmon:



Weight range of 1SW and 2SW salmon in the Blackwater and associated fecundities.

Median weights of 1SW and 2SW salmon in the Blackwater and 10th and 90th percentiles.

1SW			2SW		
Median	10th	90th	Median	10th	90th
2.27	1.34	3.20	4.76	3.71	5.81

Median fecundities of 1SW and 2SW salmon in the Cashla and 10th and 90th percentiles

1SW			2SW		
Median	10th	90th	Median	10th	90th
3345	2182	4508	6460	5146	7773

Proportion females and males in 1SW and 2SW age groups

	1SW	2SW
Proportion female	0.60	0.85
Proportion male	0.40	0.15

The conservation limit (CL) in number of eggs per m^2 is converted into numbers of 1SW, 2SW and total number of salmon, and variability, for the whole river following Equation 1 in a Monte Carlo simulation of 75,000 iterations. The conversion from eggs to fish incorporates: the egg deposition rates at MSY (with variability); the proportion of the stock that are age 1SW (with variability); the proportion of the stock that are age 2SW (with variability); the proportion of each age group that are female; the fecundity of each age group (with variability).

Variability around estimates are incorporated as the 10th and 90th percentiles of the observed ranges, set as minimums and maximums in triangular distributions.

CL in No. of Fish (± 90^{th}%) =

MSY (No. of Eggs/m^2) ±90th% /

(Sea-Age $Prop_{1SW}$ ±90^{th} % * Female $Prop_{1SW}$ * $Fecundity_{1SW}$ ±90^{th} %

\+ Sea-Age $Prop_{MSW}$ ± 90^{th} % * Female $Prop_{MSW}$ * $Fecundity_{MSW}$ ±90^{th}%)

* River wetted area (m^2)

Equation 1.

Conservation limits of 1SW, 2SW and total salmon.

	1SW	2SW	Total
Required females	217	63	279
Required males	144	11	156
Total	361	74	435

Catch Advice

The number of salmon likely to return in the next fishing season is calculated from the most recent 5year counts.

Counts on the river Blackwater

	2008	2009	2010	2011	2012
Trends in counts	575	347	1205	914	291
Add catch killed above counter	52	48	35	65	30

The average of the Counter, along with rod catch and any commercial catch taken provide the estimate of returns prior to homewater fisheries.

No commercial fisheries intercepting Blackwater salmon

	2008	2009	2010	2011	2012
Add catch from Draft net	0	0	0	0	0

The estimated Recruits (i.e. returns of salmon) must exceed the CL if there is to be an allowable catch. A catch option which provides a high probability that the CL will be attained is advised. If returns are likely to be less than the CL then harvest fishing is not advised.

The Kerry Blackwater is not estimated to have a surplus of fish with a 75% probability of attaining its CL, with a deficit of 3 fish.

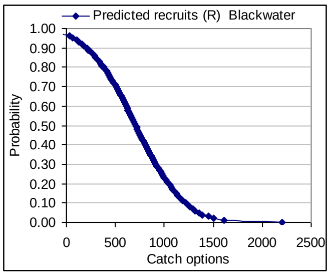
The CL used for Irish rivers are Limit Reference points i.e. stocks should not be allowed to fall below this limit but should be maintained above the limit with a high probability. In the assessment of international salmon fishing quotas, ICES recommends catch options which allow at least a 75% chance that the CLs will be met.

The SSC adopt a similar precautionary risk level when providing catch advice based on a risk assessment which includes the annual variation in RECRUITS and in the estimated CLs (shown in the following figures).

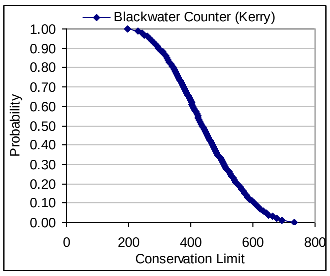
The catch option which provides a 75% chance that the CL will be attained is advised to IFI by the SSC.

Risk plots

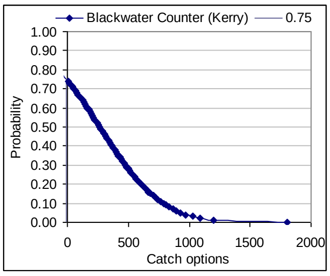
Predicted recruits	**Blackwater Counter**
Percentiles	
100%	-701
90%	212
75%	452
50%	712
25%	979
10%	1219
0%	2211



CL	**Blackwater Counter**
Percentiles	
100%	202
90%	303
75%	365
50%	442
25%	531
10%	608
0%	739



Surplus/Deficit	**Blackwater Counter**
Percentiles	
100%	-1292
90%	-250
75%	-3
50%	270
25%	541
10%	797
0%	1806



Risk plot For Catch Advice

Percentiles and risk plots of the predicted recruits, CLs and resulting surplus/ deficits in relation to a range of catch options for the Kerry Blackwater. Predicted recruits and CL risk plots are calculated from 50,000 draws in Monte Carlow analysis, with each paired draw compared to calculate the surplus/ deficit risk plot and hence catch advice. Note that the presented risk plots and values for predicted recruits and CLs are the percentiles of their 50,000 draws independently and direct comparison of these do not equate to the surplus/ deficit percentiles, which are the percentiles of the 50,000 comparisons of each of the paired predicted recruit to CL draws.

Appendix VIII. Summary results from the Catchment Wide Electro-Fishing Programme in 2016.

Analysis of salmon fry index

In cases where the current Standing Scientific Committee on salmon (SSCS) forecast of returning salmon recruits to a river provides a catch option resulting in less than a 75% chance of the river meeting its Conservation Limit (CL), the SSCS recommend that the river is closed for fishing. As a separate recommendation, Inland Fisheries Ireland (IFI) management advise that if a river is meeting more than 65% of its CL the river can open for Catch and Release (C&R). There are many rivers, typically smaller catchments, where a direct assessment is not possible due to a very low or inconsistent reported angling catch (i.e. less than 10 on average annually). Therefore, advised closures of rivers with very low rod catches, or which have been closed over a period due to the absence of new and alternative information (e.g. fish counter information, redd count or other population indicator), pose a problem for assessing the status of the rivers salmon population and CL attainment over time as there are no new data for updating the forecast and risk analysis method currently employed by the SSC.

A relative index of catchment wide 0+ fry abundance based on a site-specific semi-quantitative electrofishing technique (Crozier and Kennedy, 1994 and Gargan *et al.* 2008) was developed by the SSCS in 2009 and 2010 to provide an alternative method for assessing attainment of Conservation Limits in rivers closed for angling or where there was no counting facility. Electrofishing of juveniles presents an alternative (and fisheries independent) source of population information as the numbers of juveniles should be a good reflection of the number of adults which produced them and the relative productive capacity of that river. This method is based on a relationship between fry abundance (which may be measurable annually) and adult returns for rivers with information on rod catches or counters over a number of years was available. The SSCS advise that assessments should preferentially be based on a recent five year average. Initially results from the catchment wide electro-fishing programme (CWEF) provided an assessment based on a single year of sampling for many rivers but sampling frequency has increased since the programme was initiated in 2007 and more robust assessments are now feasible based on multiple years of data for most rivers.

The method is primarily used for rivers where there is no other index of stock. A small number of catchments are electro-fished annually as index catchments. Currently a catchment wide index of ≥17 salmon fry per 5 minute standardised electrofishing (multiple site catchment average) is used by the SSCS as the threshold value distinguishing systems where the stock is evidently below Conservation Limits, and those rivers exceeding the threshold where it is more likely that the stock is meeting CL.. If the fry index is above the threshold only catch and release fishing in the following year is advised. The information from the C&R fishery, when combined with the other most recent catch data allows a forecast of adult returns to be made in the next fishing season. This provides a safeguard against opening a river prematurely, while still allowing some fishery activity and the subsequent catch data collection..

Catchment-wide electro-fishing is also important in providing managers with information on the distribution and abundance of salmon fry and to identify management issues in a catchment or tributary. The absence or low density of salmon fry may be related to water quality issues, obstructions, or habitat damage and areas of low abundance can be investigated.

During 2016, CWEF was undertaken in 35 catchments to assess abundance and distribution of salmon fry (Figure VII-1). 24 catchments, mostly in the South and East of the country, were surveyed completely but a number of catchments had persistently high water levels throughout the summer preventing the completion of surveys.. A total of 1300 sites were visited. In the first ten years of the programme (2007-2016) 376 catchment surveys in 136 catchments have been undertaken comprising 8,618 site surveys.

CWEF results for catch and release systems have consistently concurred with the forecast model outputs which have been based on available counter, rod catch or other data. All of the CWEF rivers sampled in 2016, that were operating on a catch and release basis (i.e. those predicted to be ≥ 65% CL in 2016), had a CWEF value of ≤ 17 salmon fry over the 2007-2016 period. The SSCS uses combined multi-year CWEF data to provide a conservative appraisal of CWEF fry abundance. For the catchments surveyed in 2016, the salmon fry abundance ranged from an average of zero fry/5min on exploratory catchment surveys of the Owenamallagh and Meennascarty, to a catchment average of 23.38 salmon fry per 5 min on the Croanshagh, an established salmon system. The Erriff recorded an annual catchment wide average of >17 fry. Salmon fry abundance exceeding 15 Sal fry/min was recorded for the Boyne

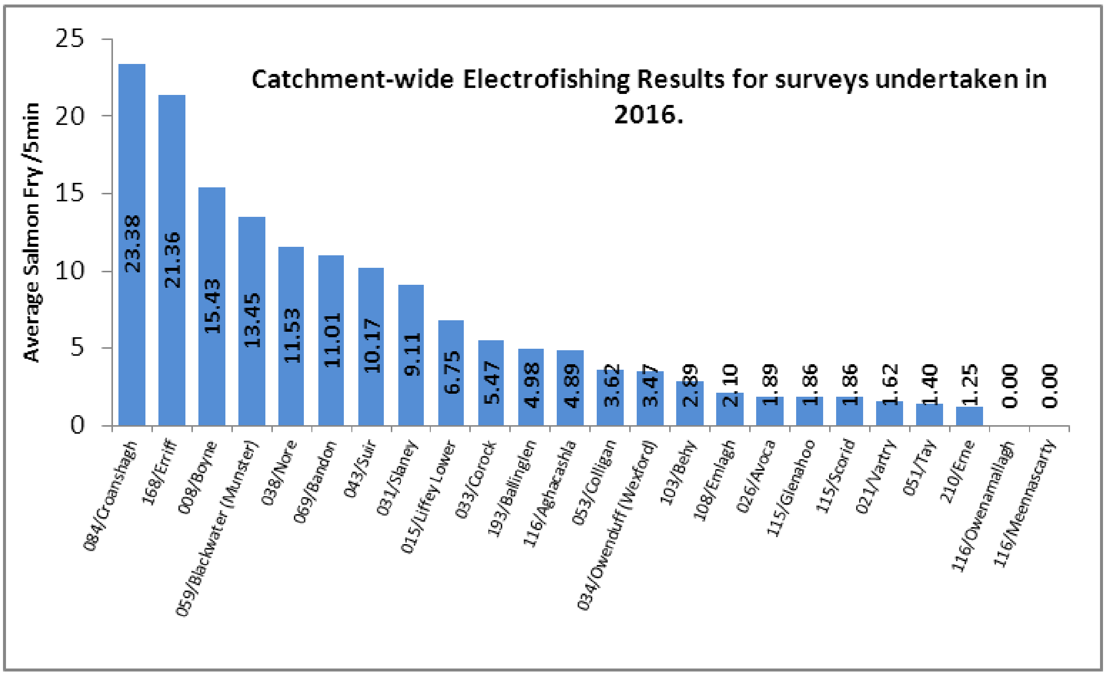


Figure VII -1. Results of catchment wide electro-fishing programme in 2016.

catchment. A large proportion of the sites surveyed this year were on very large catchments- the Boyne, Slaney, Nore, Suir and Munster Blackwater; though all of these catchments had some excellent individual sites the mean CWEF figures for each was ≤ 17 salmon fry per 5 min.

References:

Crozier, W.W. and Kennedy G.J.A (1994). Application of semi-quantitative electro-fishing to juvenile salmonid stock surveys. J. Fish Biol (1994), 45, 159-164.

Gargan, P., Roche, W., Keane, S. and Stafford, T. (2008). Catchment-wide electrofishing Report. Central Fisheries Board, Mobhi Boreen, Dublin 9.