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Interim Report of the Working Group on the Effectiveness of Recovery Actions for Atlantic Salmon (WGERAAS)

12–16 May 2014

ICES Headquarters, Copenhagen, Denmark

ICES
International Council for the Exploration of the Sea
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Executive Summary

The Working Group on Effectiveness of Recovery Actions for Atlantic Salmon (WGERAAS) was established in 2012 in response to a question to ICES Working Group on North Atlantic Salmon (WGNAS) by the North Atlantic Salmon Conservation Organisation (NASCO). The NASCO question resulted in a new ToR for WGNAS: "provide a review of examples of successes and failures in wild salmon restoration and rehabilitation and develop a classification of activities which could be recommended under various conditions or threats to the persistence of populations". WGERAAS was established to answer this WGNAS ToR.

After the first meetings of the WGERAAS in 2013 (Belfast, Northern Ireland, and Swansea, Wales) WGERAAS met again at ICES Headquarters in Copenhagen, Denmark, in May 2014.

At the 2013 meetings the Working Group decided that the development of a 'classification system' for rebuilding and recovery actions for Atlantic salmon (ToR a) would be best achieved by the development of a river-specific database; 'Database on Effectiveness of Recovery Actions for Atlantic salmon' (DBERAAS). This database lists all salmon rivers in the North Atlantic and contains information on conservation status, population stressors, and undertaken recovery actions. An analysis of the completed database, which fully completed would comprise of 2690 rivers, allows for a North Atlantic wide assessment of conservation status and an overview and detailed analysis of population stressors, recovery and rebuilding actions, and the effects of recovery and rebuilding actions across varying spatial scales.

To further highlight the results from the database detailed case studies are compiled and presented on a number of rivers, providing 'on-the-ground' examples of the effects of stressors and the results of recovery and rebuilding actions.

At the 2014 WGERAAS meeting a fully completed DBERAAS was not yet available. To demonstrate the potential of a fully populated database it was decided to present an analysis of a partially completed database using data from rivers that were the focus of peer-reviewed or grey literature studies of recovery or rebuilding actions. The results from the analysis showed the excellent potential of a complete DBERAAS for assessment of conservation status, analysis of population stressors, and recovery and rebuilding actions, and the effects of recovery and rebuilding actions across varying spatial scales.

In addition eight case studies of recovery and rebuilding actions on salmon populations experiencing various stressors were presented and discussed. These were proven to be very useful in providing more detail on the effects of recovery and rebuilding actions on salmon populations experiencing specific population stressors.

WGERAAS aims to meet again in May 2015. A report on the activities of WGERAAS in 2014 will be presented at the Working Group Atlantic Salmon (WGNAS) in March 2015, Moncton, Canada.

1 Administrative Details

Working Group name

Working Group on the Effectiveness of Recovery Actions for Atlantic Salmon

Year of Appointment

2013

Reporting year within current cycle (1, 2 or 3)

2

Chair(s)

Dennis Ensing, UK (Northern Ireland)

Meeting venue

ICES Headquarters, Copenhagen, Denmark

Meeting dates

12-16/05/2014

Introduction

The Working Group on Effectiveness of Recovery Actions for Atlantic Salmon (WGERAAS) was established in 2012 in response to a question to ICES Working Group on North Atlantic Salmon (WGNAS) by the North Atlantic Salmon Conservation Organisation (NASCO). The NASCO question resulted in a new ToR for WGNAS: "provide a review of examples of successes and failures in wild salmon restoration and rehabilitation and develop a classification of activities which could be recommended under various conditions or threats to the persistence of populations". WGERAAS was established to answer this WGNAS TOR.

The ToRs for WGERAAS are as follows:

a) 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;

b) populate the system by collecting data on recovery / re-building programs for Atlantic salmon populations from around the North Atlantic;

c) summarize the resulting data set to determine the conditions under which various recovery / re-building actions are successful and when they are not;

d) provide recommendations on appropriate recovery / rebuilding actions for Atlantic salmon given threats to populations, status and life history.

To date there have been three meeting of the WGERAAS. The first meeting of the WGERAAS occurred in February 2013 in Belfast, Northern Ireland. A follow-up meeting of a WGERAAS Database Sub Group occurred in Swansea, Wales in June 2013. The third meeting of the WGERAAS occurred at ICES Headquarters in Copenhagen Denmark in May 2014. The participant list is provided in Annex 1.

At the first meeting the Working Group decided that the development of a 'classification system' for rebuilding and recovery actions for Atlantic salmon would be best achieved by the development of a river-specific database. This database lists all salmon rivers in the North Atlantic and contains information on conservation status, population stressors, and undertaken recovery actions. An analysis of the completed database, which fully completed would comprise of 2690 rivers, allows for a North Atlantic wide assessment of conservation status and an overview and detailed analysis of population stressors, recovery and rebuilding actions, and the effects of recovery and rebuilding actions across varying spatial scales.

To further highlight the results from the database detailed case studies are compiled and presented on a number of rivers, providing 'on-the-ground' examples of the effects of stressors and the results of recovery and rebuilding actions.

For this interim report a completed database was unfortunately not yet available. To demonstrate the potential of a fully populated database it was decided at the 2nd WGERAAS meeting in Copenhagen in May 2014 to present in the WGERAAS interim report an analysis of a partially filled in database using data from rivers that were the focus of peer-reviewed or grey literature studies of recovery or rebuilding actions. It needs to emphasise here that this partially filled in database comes with several caveats. First of all the small number of entries are not representative of the entire North Atlantic salmon stock. These specific rivers were chosen because data was readily available on conservation status, population stressors, and recovery and rebuilding efforts. Secondly the database entries are biased towards the North East Atlantic Committee (NEAC) area because of a lack of available suitable studies from the North Atlantic Committee (NAC) area. In the final version of the database the aim is to present a complete overview of the whole North Atlantic without any bias towards a specific area or as a result from the (un)availability of data in the literature on specific rivers. Nevertheless the Working Group is of the opinion that the analysis presented here is a good example of the potential of the database to address the TORs successfully.

Another issue that needs to be raised in this section is the incomplete number of case studies in this interim report. The aim is to present case studies in order to highlight specific cases involving a range of population stressors, discuss varying results of recovery and rebuilding actions, covering the entire North Atlantic area. The case studies presented and discussed in this interim report do not cover the entire range of population stressors and outcomes of recovery actions, nor do they cover the entire North Atlantic area comprehensively. For instance only two studies from the NAC area are presented in this interim report, compared to nine from the NEAC area. The aim for the final report is to present a more balanced suite of case studies with equal representation from NAC and NEAC areas.

2 Terms of Reference

2.1 ToR a: 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

To address ToR a, it was decided that a database needed to be developed and populated that would provide river-specific information to support the development of a classification system for recovery/re-building programs for Atlantic salmon. The database template was developed which included descriptive information for each Atlantic salmon river (name, location, ID) as well as general categories of information such as population status, threats to populations (i.e. Stressors), life history characteristics, actions taken to re-build populations (i.e. Recovery actions), program goals and metrics for evaluating the success. Definitions for these categories and how they are assessed are provided below.

- **Threats to populations (i.e. Stressor)** – an agent or event that causes a demographic impact on the population. See table 2.1.1 for a list of stressors.
- **Population status** – categorical measure of a population productivity against CL attainment based on adult monitoring/catch data, juvenile abundance measures, other stock status indicators or expert opinion.
- **Life history attributes** – this assessment was not segregated by individual population life history attributes given the difficulty in accomplishing the assessment for the population as a whole
- **Actions taken to re-build populations (i.e. Recovery action)** – an action aimed to relieve or reverse the demographic impact of one or multiple stressors on the population. See table 2.1.2 for a list of recovery actions.
- **Program goals** – description of the overarching goals of the recovery actions
- **Metrics for evaluating the success** – In an effort to reduce the workload associated with populating the database, a description of what metrics were used to assess the effect of the recovery action were not included, as the provided data are assumed to represent the best available information as provided by the regional experts. Metrics are presented within individual case studies (ToR c).

Atlantic salmon rivers listed in the NASCO Rivers database and in the HELCOM Baltic river database were combined to form a new database designed for WGERAAS called 'Database on Effectiveness of Recovery Actions for Atlantic salmon' (DBERAAS). For each individual river the impact of 12 stressors needs to be assessed (Table 2.1.1), taking into account the stressor impact definitions (Table 2.1.2). Also required is an assessment of the benefits of 11 recovery/rebuilding actions (Table 2.1.3), taking into account the given recovery/rebuilding benefit definitions (Table 2.1.4). The recovery/rebuilding actions benefits are assessed against Conservation Limit attainment. The Working Group considered and discussed at length the various metrics against which the effects of recovery and rebuilding actions could be measured, and finally settled on using Conservation Limit attainment. The main reason behind the choice for CL attainment was that NASCO, who defines CL as the spawning stock level that produces maximum sustainable yield, requires that stocks are maintained above their CL. Thus, CL attainment is the ultimate goal for all recovery and rebuilding actions for Atlantic salmon, and therefore an appropriate reference point to measure of the effects of recovery and restoration actions against.

The population status (Table 2.1.5) before the recovery/rebuilding actions commenced needs to be selected for each population entered in DBERAAS. In addition the program goal needs to be identified from the list provided (Table 2.1.6).

A complete list of all DBERAAS entry categories is given below.

NASCO River ID	
Helcom River ID	
Party	
Country	
Region/Province	
River name	
E/W	
Decimal latitude	
Decimal longitude	
Population status	
Recovery action?	
Program goals	
Stressor 1	Pollution
Stressor 2	Barriers
Stressor 3	Water Regulation
Stressor 4	Exploitation
Stressor 5	Aquaculture
Stressor 6	Habitat Degradation
Stressor 7	Diseases/Parasites
Stressor 8	Climate Change
Stressor 9	Invasives
Stressor 10	Stocking
Stressor 11	Predators
Stressor 12	Other
Action 1	Stocking
Action 2	Improved connectivity
Action 3	Habitat restoration
Action 4	Improved water quality
Action 5	Reduction fishing mortality
Action 6	Predator control
Action 7	Invasive species
Action 8	Farmed fish removal
Action 9	Flow management
Action 10	Parasite/disease control
Action 11	Other
Comments stressors	
Comments actions	
Name assessor	

When completed the DBERAAS can be used to assess the conservation status of Atlantic salmon populations, assess the prevalence of population stressors, assess the application of recovery and rebuilding actions, and assess the efficacy of recovery and rebuilding actions on a North Atlantic scale. In addition the possibility also exists to do this on smaller spatial scales such as Northern NEAC, Southern NEAC, and NAC, and compare differences between regions.

An illustration of what information a fully populated DBERAAS could provide is given in section 2 on ToR c.

Table 2.1.1. The 12 stressors (i.e. threats to populations) against which populations will be assessed in DBERAAS.

1. Pollution (organic and chemical pollution, incl. acidification)
2. Barriers (in-river obstructions; e.g. dams, weirs)
3. Water Regulation (e.g. abstraction, hydro-regulation)
4. Exploitation (e.g. legal & illegal fishing)
5. Aquaculture (e.g. escapees, sediments, sea lice)
6. Habitat degradation (e.g. gravel extraction, siltation)
7. Diseases/parasites (e.g. furunculosis, gyrodactylus, UDN)
8. Climate change (e.g. extreme water temperatures, marine mortality induced by climate change)
9. Invasives (non-native invasive flora and fauna)
10. Stocking (stocking of Atlantic salmon having negative impact on population)
11. Predators (predation during any stage of lifecycle; e.g. cormorants, pike, trout, seals, dolphins, otters)
12. Other (incl. noise pollution, light pollution, shipping, etc.

Table 2.1.2. The five options in DBERAAS to assess the impact of the stressors and their definitions.

• **Very strong impact.** A recognised stressor having a sustained and very significant impact on key life stages or habitats which affects the entire population, and whose impact - if removed - is likely to result in a full population recovery within the context of the prevailing climatic conditions.
• **Strong impact.** A recognised stressor having a sustained and significant impact on key life stages or habitats which affects the entire population, and whose impact - if removed - is likely to result in a substantial recovery within the context of the prevailing climatic conditions.
• **Moderate impact.** A recognised stressor having a intermittent or moderate impact on non-key stages or habitats on a localised scale, and whose impact - if removed - is likely to result in some increase in the abundance of the population within the context of the prevailing climatic conditions.
• **Low impact.** A recognised stressor having an occasional or low impact on non-key stages or habitats on a localised scale, and whose impact - if removed - is not likely to result in a detectable increase on the abundance of the population within the context of the prevailing climatic conditions.

Table 2.1.3.The 11 recovery/rebuilding actions listed in DBERAAS.

1. Stocking (introduction of hatchery origin Atlantic salmon)
2. Improved connectivity (e.g. fish passes, weir removal)
3. Habitat restoration (e.g. riparian vegetation, gravel beds)
4. Improved water quality (e.g. water treatment plants)
5. Reduction fishing mortality (e.g. legal actions, quotas, anti-poaching measures)
6. Diseases/parasite control (e.g. furunculosis, gyrodactylus, UDN)
7. Predator control (e.g. culling of predators)
8. Invasive species control (e.g. culling/removal of invasive flora or fauna, legislation)
9. Farmed fish escapes removal
10. Flow management (e.g. reduction in water abstraction, stricter control of hydro-regulation)
11. Others (e.g. reduction in shipping traffic, removing sources of light or noise pollution, etc.)

Table 2.1.4. DBERAAS population recovery benefits categories and definitions.

• **Very High benefit.** An action having a sustained and very substantial benefit on key life stages or habitats, which affects the entire population, and which helps achieve full population recovery within the context of prevailing climatic conditions
• **High benefit.** An action having a sustained and substantial benefit on key life stages or habitats, which affects the entire population, and which helps achieve a substantial population recovery within the context of prevailing climatic conditions
• **Moderate benefit.** An action having an intermittent or moderate benefit on non-key life stages or habitats, which affects parts of the population, and which helps achieve a moderate population recovery within the context of prevailing climatic conditions
• **Low benefit.** An action having an intermittent or small benefit on non-key life stages or habitats, which affects parts of the population, and which helps achieve some population recovery within the context of prevailing climatic conditions
• **Nil benefit.** An action having no detectable benefit on this population within the context of prevailing climatic conditions

Table 2.1.5. DBERAAS population status category options for database entry and definitions.

• **Full Population**. According to adult monitoring/catch data, juvenile abundance measures, other stock status indicators or expert opinion suggest, greater than 100% of Conservation Limit (CL) has been met.
• **Substantial Population**. According to adult monitoring/catch data, juvenile abundance measures, other stock status indicators or expert opinion suggest, 75% and 100% of CL has been met.
• **Moderate Population**. According to adult monitoring/catch data, juvenile abundance measures, other stock status indicators or expert opinion suggest, 50% and 75% of CL has been met.
• **Low Population**. According to adult monitoring/catch data, juvenile abundance measures, other stock status indicators or expert opinion, between 25% and 50% of CL has been met.
• **Very Low Population**. According to adult monitoring/catch data, juvenile abundance measures, other stock status indicators or expert opinion, 25% or less of CL has been met.

• **Extirpated**. According to adult monitoring/catch data, juvenile abundance measures, other stock status indicators or expert opinion this population has been extirpated.

• **Unknown**. Population status unknown.

Table 2.1.6. DBERAAS program goal categories and definitions.

• **Re-establish.** Recovery actions are being implemented to re-establish a population that has been shown to be extirpated. Once a population is re-established, it would then be considered within the 'Recovery' category.

• **Recovery.** Recovery actions are being implemented to recover a population that is at low abundance, may or may not be dependent on hatchery inputs and may or may not be threatened with extinction if current population trends continue into the future. Once a population is recovered, it would then be considered within the Rebuild category.

• **Rebuild.** Recovery actions are being implemented to increase the abundance of a self sustaining population of salmon to meet or exceed its CL. As a guideline, a program considered within the Rebuild category should be at >25% of CL.

• **Fishery.** Recovery actions are implemented to provided **recreational and/or commercial fishing** opportunities. There is no expectation of increased natural reproduction as a result of the actions being implemented (e.g. ranching programs).

2.1.1 Climate change

The stressor 'climate change' is a special case that warrants this section of its own where the peculiarities of this stressor are presented and discussed.

Climate change is (together with 'stocking') unique in the list of stressors here because it is the only stressor without a corresponding recovery/restoration action. This is because there is no realistic direct action available to mitigate for this stressor (i.e. one cannot just reverse climate change).

Climate change manifests itself as a stressor in Atlantic salmon populations mainly as decreased marine survival (Friedland *et al.*, 2014). This increased marine mortality is probably a result of issues with feeding in the marine environment (Beaugrand & Reid, 2012; Mills *et al.*, 2013) or changes in seaward migration timing of smolts (Kennedy & Crozier, 2010; Russell *et al.*, 2012). Other temperature and flow effects could also (theoretically) increase mortality in the freshwater phases of the Atlantic salmon's lifecycle (Jonsson & Jonsson, 2009).

Climate change can in certain cases be such a strong driver of decreased marine survival that it is solely responsible for limiting productivity of certain salmon stocks, completely swamping the effects other stressors might have on the population. Low to very low marine survival as a result of climate change appear to be affecting southern stocks more compared to more northern stocks (Chaput, 2012; Friedland *et al.*, 2014). This trend is also apparent in the DBERAAS entries and case studies presented in this study, as well as long term dataseries on marine survival in various Atlantic salmon stocks (ICES, 2013).

As a result salmon stocks that experience very strong decreases in marine survival as a result of climate change have virtually no chance of successful stock restoration or rebuilding until the situation in the marine environment changes to allow for better marine survival. As will be discussed later in this document this does not mean that no restoration actions should be undertaken in such rivers, but that management and stakeholders should be aware of the limited effects of not being able to mitigate for the strongest stressor acting on the stock.

2.2 ToR b: populate the system by collecting data on recovery/ rebuilding programs for Atlantic salmon populations from around the North Atlantic

ToR b is addressed by populating the DBERAAS described in the section above on ToR a. The results from the db summarization will be highlighted by presenting detailed case studies on recovery/rebuilding actions for Atlantic salmon. These case studies will follow a standardized format and will generally consist of well documented and data-rich examples of recovery/ rebuilding projects. This will provide more in-depth information on various recovery/ rebuilding actions; what stressors are present, to what extent these stressors impact on the population, and how beneficial recovery/rebuilding actions taken have been in these cases. Eight examples of such case studies are presented in section 2.2.1.

2.2.1 DBERAAS

As the fully completed DBERAAS was not available for the second WGERAAS meeting in Copenhagen 2014 an interim version was constructed using WGERAAS case study information to illustrate the potential of the full DB when completed. The temporary database consisted of entries from a few countries and specific studies of Atlantic salmon recovery/rebuilding programs that data were available. These specific case studies were presented one of the following related meetings:

- 2013 WGERAAS meeting (Belfast, UK)
- 2013 Atlantic Salmon Trust/IBIS Workshop on stocking (Scotland, UK)
- 2014 Atlantic Salmon Federation workshop entitled What Works? A Workshop on Wild Atlantic Salmon Recovery Programs (Saint Andrews, Canada)
- 2014 WGERAAS meeting (Copenhagen, Denmark)

A total of 67 entries were provided for the interim database. A summary of the results was prepared and is presented in section 2.3.2.

2.2.2 Case studies

Dennys River, USA

Helcom or NASCO River ID number: NASCO 130

River Catchment size (km^2): ~342

Starting and end year of project: 2001–2007

Situation before restoration: Estimates of returning Atlantic salmon to the Dennys River in the late 1960s through early 1980s were between 50 and 500 adults annually (Beland 1996). In the years immediately preceding this study, returns were at 10 fish or below per year (USASAC 2014).

Main stressors on population: Very strong: Climate change (i.e. marine survival), Moderate: Pollution, Aquaculture, Habitat Degradation, Invasives, Predators.

Actions taken: stocking of 50K 1+ Dennys River strain smolts annually, 2001–2005.

Metrics used to evaluate success: adult counts.

Assessment before project: adult monitoring.

Project Aims: Annual returns of 60–120 fish as predicted from contemporary returns rates for other Maine smolt stocking programs.

Actions taken in more detail:

- A variety of other restoration activities have been undertaken on the Dennys River including improving connectivity, a variety of habitat restoration projects, improvements to water quality to address cultural oligotrophication
- Annual stocking of juveniles from the mid 1990-present (USASAC 2014):
    - Approximately 50K Dennys River strain 1+ smolts (2001 onwards)
    - Approximately 29K Dennys River strain parr
    - Approximately 142K Dennys River strain fry

Assessment during project:

- Annual counts of returning adults
- Ultrasonic telemetry monitoring of 1+ hatchery smolt migration through freshwater, estuarine and nearshore environs

Adjustments to goals during project: The goals of the projected were not adjusted during the effort as the approved restoration plan outlined a five-year stocking effort of 50K 1+ smolts annually.

Project success: The project was not successful. Total adult returns to the Dennys River from 2002–2007 were 22 fish (Figure 2.2.1, USASAC 2014). Of these, 18 were from the smolt stocking and 4 were from fry stocking or natural rearing. In a single year, 2005, there were zero returns to the Dennys River. Expected returns based on contemporary returns rates for other Maine smolt stocking programs were 300–600 total adult returns (60–120 per year).

Project evaluation: The smolt stocking effort was not successful in increasing adult returns to the Dennys River by the predicted amount. Concurrent ultrasonic telemetry investigations revealed that high proportions of the tagged smolts were not successfully making it to the open ocean environment (Figure 2.2.2). It was estimated that approximately between 35–90% of the smolts died before reaching the open ocean with the majority of the mortalities occurring with the estuarine and nearshore zones.

Although the causal mechanisms for the lack of adult returns from the smolt stocking program have not been identified, a number of factors may have contributed to the poor performance of the stocked smolts. The broodstock for the hatchery population are Dennys River origin fish, but this population's adaptive ability may be compromised due to recent population bottlenecks, introgression from aquaculture escapees and/or broodstock selection biases. Environmental challenges related to the Denny's river being a small coastal river, the highly energetic estuarine and nearshore environments, the changing seasonal cues due to earlier snowmelt and runoff (Dudley and Hodgkins 2002) and decreases in marine productivity for many North American Stocks (Mills *et al.* 2013) as well as shifting predator-prey dynamics as a consequence of past natural resource management actions and changing climate may have also contributed.

References

Beland K.F. 1996. The relation between red counts and Atlantic salmon (Salmo salar) parr populations in the Dennys River, Maine. Canadian Journal of Fisheries and Aquatic Sciences 53: 513-519.

Dudley R. W., and Hodgkins, G. A., 2002, Trends in streamflow, river ice, and snowpack for coastal river basins in Maine during the 20th century: U.S. Geological Survey Water-Resources Investigations Report 02-4245, 26 p.

Mills, K. E., Pershing, A., Sheehan, T. F. and Mountain, D. 2013. Climate and ecosystem linkages explain widespread declines in North American Atlantic salmon populations. Global Change Biology. 19: 3046-3061.

USASAC (U. S. Atlantic Salmon Assessment Committee. 2014. Annual Report of the U.S Atlantic Salmon Assessment Committee: Report no. 26 - 2013 Activities. February 24-27, 2014. Old Lyme, Connecticut. 149 p. www.nefsc.noaa.gov/USASAC/

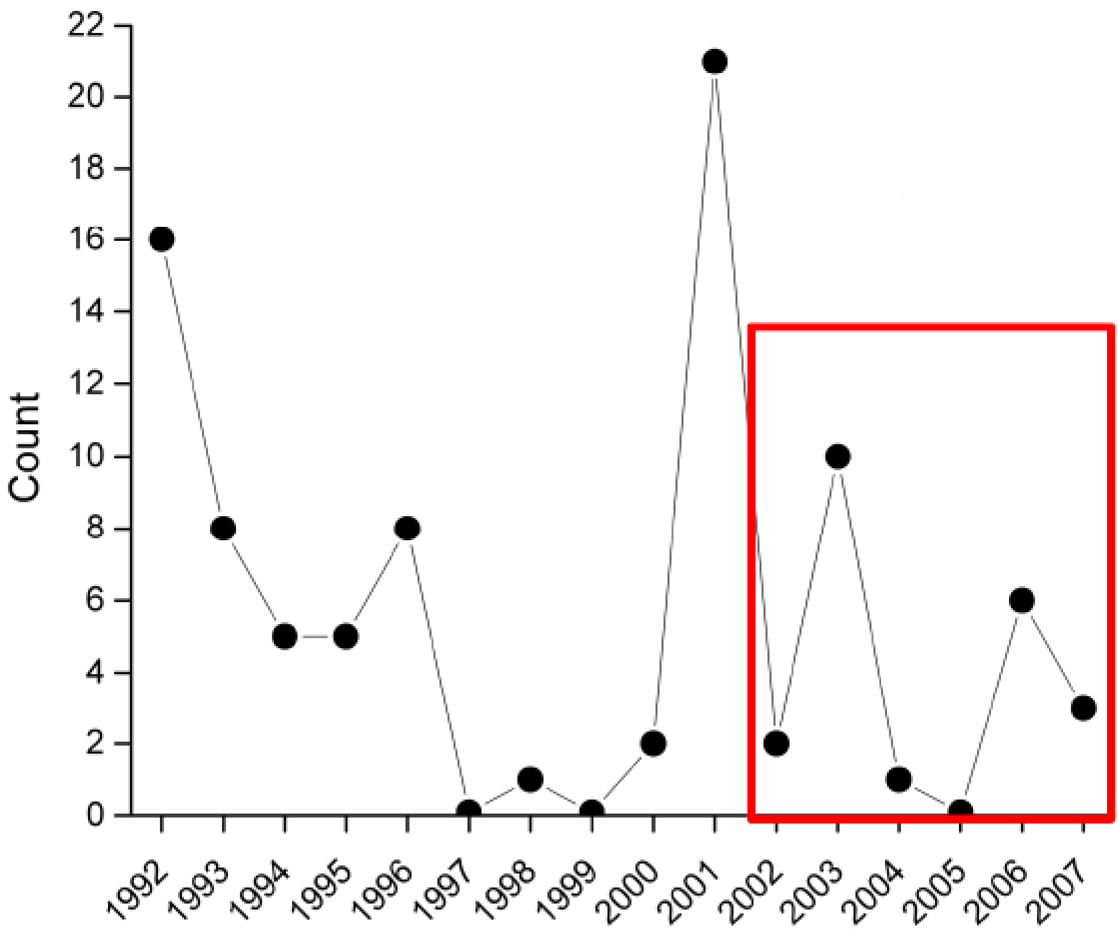

Figure 2.2.1. Adult returns to the Dennys River, 1992–2007. Of the 22 returns record from 2002–2007, 18 originated from the smolt stocking program.

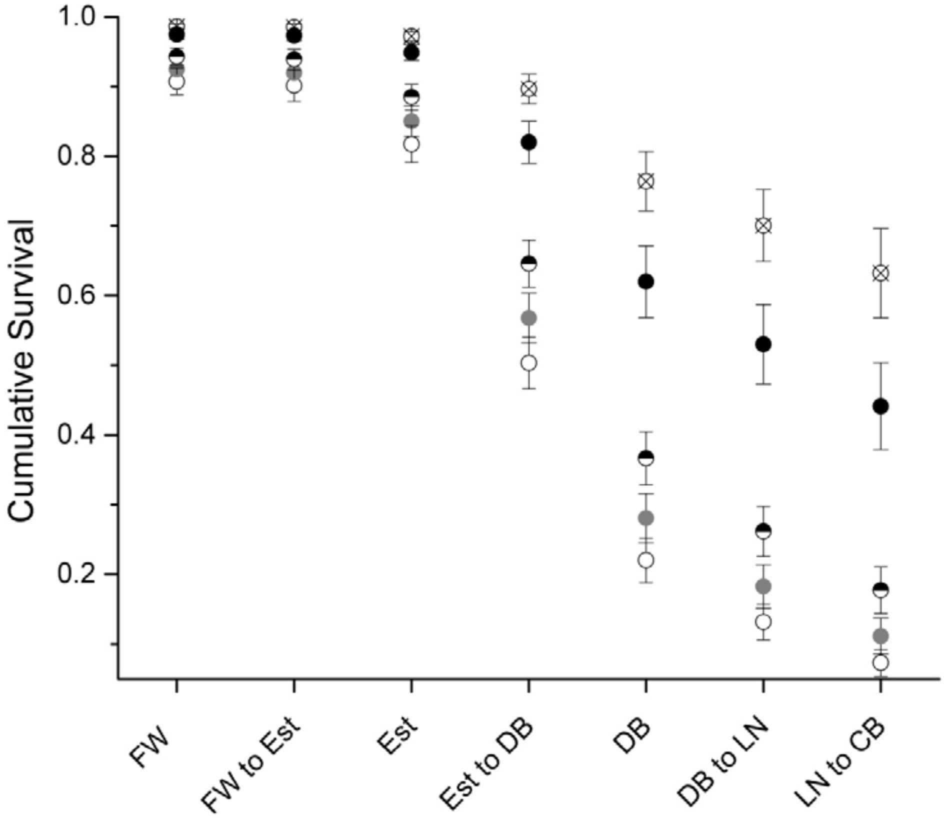

Figure 2.2.2. Cumulative survival 2001–2005 (2001 – solid circle, 2002 – open circle with X, 2003 – gray, 2004 – open circle and 2005 half solid black half open circle) through freshwater (FW and FW to Est), estuarine (Est and Est to DB) and nearshore (DB, DB to LN, LN to CB) environs.

River Mandalselva, Norway

Helcom or NASCO River ID number: NASCO 4845

River Catchment size (km2): ~1.880

Starting and end year of project: 1997 – present

Situation before restoration: stock lost due to acidification.

Main stressors on population: Pollution (acidification: low pHs and high concentrations of inorganic aluminium), barriers (hydroelectric power generation).

Actions taken: Water quality improvement (liming), stocking.

Metrics used to evaluate success: mean juvenile salmon densities.

Assessment before project: Assessment of stock status (electro-fishing for juvenile salmon) and water quality. River Mandalselva is also severely affected by hydroelectric power generation by the creation of obstacles to adult migration through stretches of low water flow and passage through dams, reduced rearing areas for younger fish, fluctuating water levels, and the descent of smolts through tunnels in which turbines have been installed.

Project aims: Re-establish a self-sustaining Atlantic salmon population above CL.

Actions taken in more detail:

- Substantial improvement of water quality in the whole catchment by full-scale liming since 1997
- Stocking in the period 1996–2005 with roe: 689 500; fry: 702 913; smolts: 31 123

Assessment during project:

- Annual assessment of mean juvenile salmon densities by electro-fishing at 18 sites over 8 years

Adjustments to goals during project: none

Project success: the benefit of recovery action is high (Figure 1), CL was exceeded in the last 6 of 8 years, showing a substantial recovery. In recent years, major reductions in fossil fuel emissions have improved water quality in previously acidified waters (Skjelkvåle *et al.*, 2003; 2005). However, water quality in unlimited reaches is still inadequate for the survival of smolts of Atlantic salmon (see Kroglund *et al.*, 2008). River Mandalselva (like other rivers in southern Norway) therefore still need to be limed to sustain healthy populations of Atlantic salmon and probably will continue to be needed for many years to come. The benefit of the recovery action can therefore also seen to be moderate as it is not truly sustained.

Project evaluation: Parr densities remained low during the first 3–5 years after the start of liming. For formerly lost and reduced salmon stocks, 3 and 5 years of liming, respectively, was needed to obtain a significant increase in parr densities (both $p < 0.05$). Annual rod catches of adult salmon increased significantly after liming started, reaching about 45 t after 10 years of treatment in 13 rivers including river Mandalselva. This is 11%–12% of the current total catch of Atlantic salmon in all Norwegian rivers. It was concluded that liming thus makes an important contribution to the restoration of salmon in formerly acidified rivers (Hesthagen *et al.*, 2011).

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Skjelkvåle, B.L., Evans, L., Larssen, T., Hindar, A., & Raddum, G. (2003): Recovery from acidification in European surface waters: a view to the future. Ambio, 32: 170–175.

Skjelkvåle, B.L., Stoddard, J.L., Jeffries, D.S., Tørseth, K., Høgåsen, T., Bowman, J., Mannio, J., Monteith, D.T., Mosello, R., Rogora, M., Rzychon, D., Vesely, J., Wieting, J., Wilander, A., & Worsztynowicz, A. (2005): Regional scale evidence for improvements in surface water chemistry 1990–2001. Environ. Pollut. 137(1): 165–176.

Tuloma River, Russian Federation

Helcom or NASCO River ID number: NASCO 51

River Catchment size (km^2): ~21140

Starting and end year of project: 1936 –present

Situation before restoration: With construction of the Lower Tuloma Dam in 1936 at the tidal extent of the river, and the larger Upper Tuloma Dam in 1965, both for hydro-electric power generation, salmon migration routes were interrupted. A fish ladder in the Lower Tuloma Dam provides passage over the dam, however, no salmon can ascend over the Upper Tuloma Dam. The Upper Tuloma Dam was constructed with a Borland lift fish pass, which was closed after five years of operation due to low numbers of salmon using it. The Padun Falls in the largest spawning tributary below the Upper Tuloma Dam was an obstacle for migrating salmon.

Main stressors on population: Barriers.

Actions taken: Maintained good connectivity in the lower part of the river by making the Lower Tuloma Dam passable for salmon, improved connectivity by construction the Pecha fish pass on the Pecha River which offers the largest spawning and nursery grounds for salmon below the Upper Tuloma Dam.

Metrics used to evaluate success: adult counts.

Assessment before project: feasibility study, adequate nursery habitat available in the Pecha River, problems with the impassable Upper Tuloma Dam.

Project Aims: to maintain the Atlantic salmon population in the Tuloma River system at the historical level.

Actions taken in more detail:

- <u>The Lower Tuloma fish pass.</u> The Lower Tuloma Dam was completed in 1936 and was located at the head of the Kola bay (Figure 1). About 50 km of the former main stem of the Tuloma River has become a part the Lower Tuloma Reservoir. The height of the Lower Tuloma Dam ranges tidally from 16 m to 20 m. A fish ladder was constructed at the same time as the dam and had a fish trap at its upstream exit;
- <u>The Upper Tuloma fish pass.</u> The Upper Tuloma Dam was completed in 1965 and was located just above the Lower Tuloma Reservoir (Figure 3). The dam height is 63 m with the reservoir surface level varying by 5.5 m under normal operating conditions. A Borland lift fish pass was constructed at the same time as the dam, but it was closed after 5 years due to low numbers of ascending fish;
- <u>The Pecha River fish pass</u>. The Padun Falls is located in the Pecha River about 1 km upstream of the Lower Tuloma Reservoir, and has a head drop of around 3.5 m depending upon the river conditions. A fish pass was constructed here at the same time as the Upper Tuloma Dam however it did not function as effectively as expected and was replaced by the efficient Pecha fish pass in 1991.

Assessment during project:

- Annual counts of returning adults at the Lower Tuloma fish pass
- Electrofishing surveys to establish juvenile densities in the Pecha River

Adjustments to goals during project: The project objective has been to maintain a salmon population in the Tuloma River system at the historical level through natural reproduction in the spawning tributaries below the Upper Tuloma Dam. An additional goal of bringing Atlantic salmon above the Upper Tuloma Dam has been formulated recently. This could be achieved by transportation of adult fish trapped at the Lower Tuloma fish pass via road to the Upper Tuloma reservoir.

Project success: The project has succeeded in maintaining the Atlantic salmon population in the River Tuloma at the historical level. The numbers of adult salmon ascending the river in 1965–2012 have been at the same level as before the construction of the Upper Tuloma Dam in 1965 (Figure 4). There have been no long-term upward or downward trends in adult returns over the period.

Project evaluation: The project has reached its initial goals. Current issues are: continuing operation of the Lower Tuloma fish pass, adjustment in the spillway at the Lower Tuloma Dam. Additional issue is: bringing adult fish above the Upper Tuloma Dam.

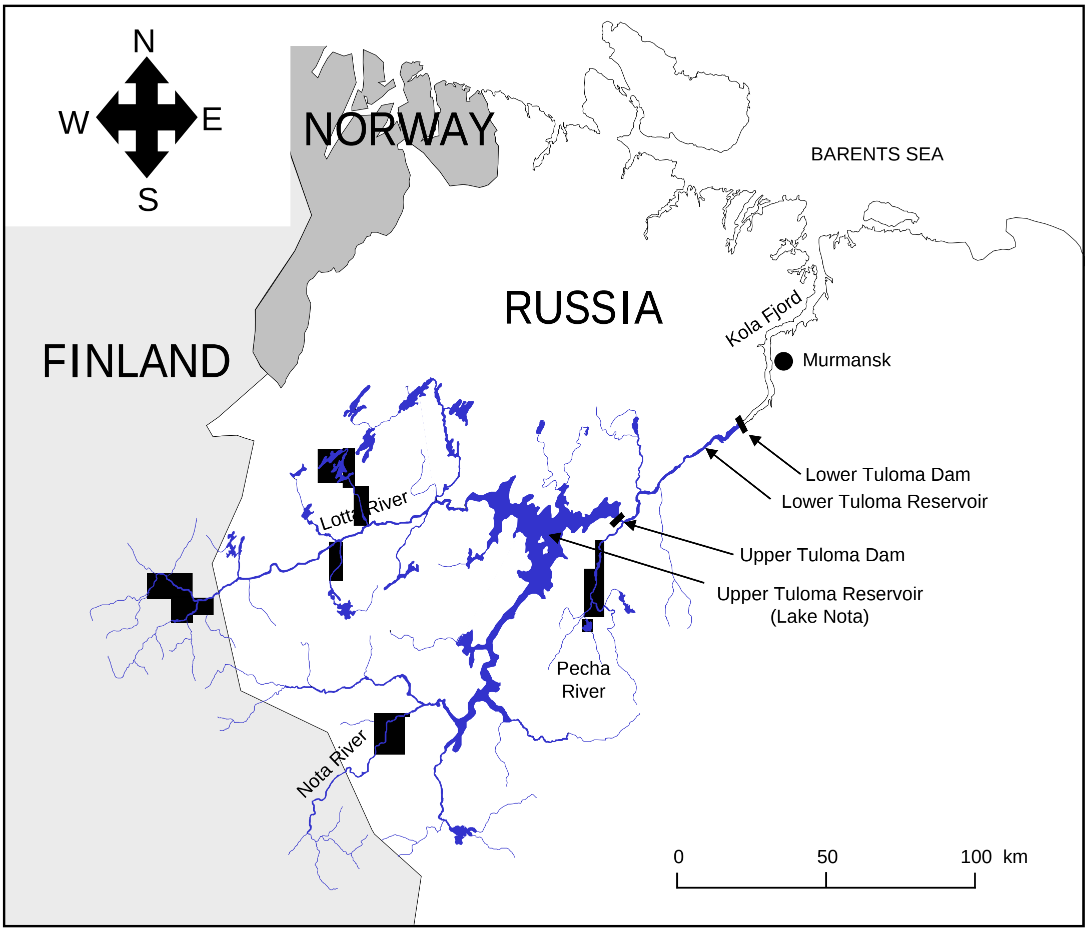

Figure 2.2.3. Tuloma River System (Tuloma River Project. Technical Feasibility of Migration Routes. 2000. Report No. 1014. EU Tacis Programme).

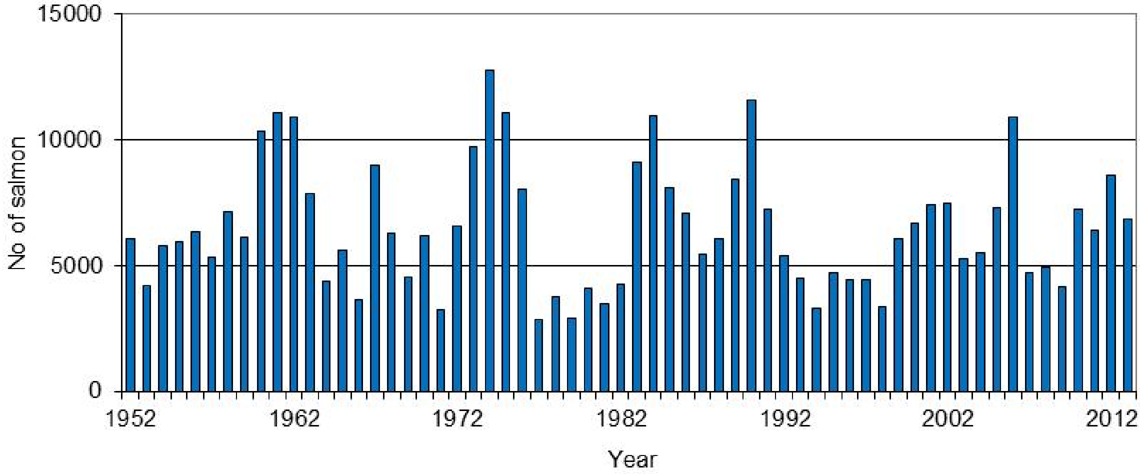

Figure 2.2.4. Number of adult salmon assended the Lower Tuloma fish pass in 1952–2012. (ICES North Atlantic Salmon Working Group Working Paper 2014/15).

West River, Canada

Helcom or NASCO River ID number: NASCO 2692

River Catchment size (km^2): ~262

Starting and end year of project: 2005 – present

Situation before restoration: Abundance of Atlantic salmon populations in the Southern Upland region of Nova Scotia has been in decline for more than two decades. A recent Recovery Potential Assessment (Lecis *et al.*) for the Southern Upland (DFO 2013) noted that river acidification has significantly contributed to reduced abundance or extirpation of populations from many rivers in the region during the last century. The Southern Upland Atlantic Salmon RPA identified acidification, altered hydrology, invasive fish species, habitat fragmentation due to dams and culverts and illegal fishing and poaching as the freshwater threats with the highest overall level of concern, and salmonid aquaculture and marine ecosystem changes as the threats with the highest overall level of concern in the estuarine and marine environment (Bowlby et. al. 2014).

The West River, Sheet Harbour is one of approximately 25 known rivers within the Southern Upland region to have a remnant population of Atlantic salmon. Juvenile densities are low (Halfyard 2007, Bowlby et. al. 2013) and well below reference values thought to reflect freshwater productivity of healthy populations. The river has been shown to be acidified to the point which is detrimental to salmon and is also subject to a number of other stressors such as habitat degradation and barrier construction associated with historical logging.

Main stressors on population: Pollution (acidification), climate change (marine survival).

Actions taken: Improved water quality (Acid mitigation program; i.e. liming).

Metrics used to evaluate success: Water chemistry, primary/secondary productivity, and juvenile and smolt Atlantic salmon abundance estimates.

Assessment before project: Water chemistry, primary/secondary productivity, and juvenile salmon monitoring.

Project Aims: The primary goal was to increase the freshwater survival, and consequently production, of Atlantic salmon (Halfyard 2007). Other goals were to increase the likelihood of population persistence, to monitor efficacy of lime dosing and associated biological response, and to demonstrate the efficacy of using lime dosing as part of a larger conservation effort (NSSA 2013).

Actions taken in more detail: Installation of a Kemira Kemwater lime doser ~30 km from the head of tide to provide automated dose to control the pH of river water at a pH of approximately 5.5 (Halfyard 2007). A pH above 5.5 has been shown to significantly reduce acid-related mortality in Atlantic salmon (Lacroix and Knox 2005).

A number of other restoration activities were ongoing within the watershed including:

- Watershed habitat planning, mapping and enhancement
- Supportive rearing
- Kelt reconditioning
- Smolt and sea trout research

Assessment during project: water chemistry, primary/secondary productivity, juvenile and smolt salmon monitoring.

Adjustments to goals during project: unknown.

Project success: No adult salmon abundance monitoring was conducted in conjunction with the project, so an assessment of adult return rates is not possible. The project was successful at improving water chemistry, and monitoring suggests a biological response for invertebrates and smolt production (Halfyard 2007, NSSA 2013).

Project evaluation: Adult salmon monitoring was not conducted for this project, so it is not possible to determine whether there was a significant response in adult returns associated with these mitigation initiatives. However, the population is thought to remain at low abundance.

The West River Sheet Harbour Acid Mitigation Program resulted in improvements in the freshwater environment. The primary goal of the West River, Sheet Harbour, Acid Rain Mitigation Project is to increase the freshwater survival, and consequently production, of Atlantic salmon (Halfyard 2007). The analysis of monitoring results indicate that the acid rain mitigation project coupled with other initiatives, such as supportive rearing and kelt reconditioning, provides some evidence of a positive biological response in smolt production when compared to the control site and to other smolt trends within Atlantic Canada and the USA (NSSA 2013).

During the recent RPA for Southern Upland Atlantic Salmon, population viability analyses for two of the larger populations remaining in the Southern Upland indicated that relatively small increases in either freshwater productivity or at-sea survival are expected to decrease extinction probabilities (Gibson and Bowlby 2013). It was further noted that larger changes in at-sea survival are required to restore populations to levels above conservation requirements.

Not all stressors (or at least all the major stressors) for the West River Sheet Harbour salmon population were addressed via this recovery action or other ongoing recovery actions. For any recovery effort to be successful at restoring populations above conservation requirements all stressors to the population should be identified and the magnitude of their effect on the productivity of the salmon population should be understood. At a minimum, the duration of time since this recovery project began coupled with low marine survival were not sufficient to allow increases in juvenile production to result in an adult population size that meets or exceeds the conservation requirement. A more complete understanding of the factors driving marine mortality will a) further allow researchers and managers to accurately set and communicate objectives and goals for recovery efforts and b) further allow for evaluation of recovery to reduce the stressor's impact on the salmon population's productivity.

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River Tyne, UK (England & Wales)

Helcom or NASCO River ID number: NASCO 448

River Catchment size (km^2): 2936 km^2

Starting and end year of project: not specific project start date, water quality improvements in 1960s with closure of industrial plant and hatchery started in 1979.

Situation before restoration: Historically, the River Tyne supported substantial runs of salmon and sea trout. However, during the first half of the 20th century there was a dramatic decline in numbers of fish due mainly to a reduction in estuarine water quality as a result of industrial and urban sewage pollution. Records continue to show catches of a few hundred salmon in most years through the 1930s, but after World War II virtually no fish were reported. Zero catches were recorded in 1951 and 1959.

Main stressors on population: Pollution, exploitation, habitat degradation.

Actions taken: Improvements water quality, stocking.

Metrics used to evaluate success: Rod catch data,,routine juvenile monitoring surveys. A specific investigation to evaluate the contribution of hatchery-reared fish to the recovery was based on an analysis of tag returns from a major coded wire micro-tagging programme (1983–2000).

Assessment before project: Catch data.

Project Aims: Recovery of salmon stock.

Actions taken in more detail:

- 160 000 0+ and 1+ salmon parr stocked annually, numbers stocked have often exceeded this level with up to 600 000 parr being stocked in some years (Milner *et al.*, 2004, 2008); the majority of the stocked fish were 0+ parr.
- Between 1983 and 2000, batches of the stocked salmon parr were marked with coded wire microtags (CWTs). Only 1+ parr were tagged.

Assessment during project:

Detailed assessment of CWT recoveries was achieved through both active screening of catches and voluntary returns. Rod catches and juvenile survey data are also available.

Adjustments to goals during project: Not applicable.

Project success: The River Tyne stock has recovered rapidly with an average rod catch over the last 10 years of almost 4000 salmon (3,968) (Figure 5). The River Tyne is also one of relatively few rivers in UK (England & Wales) which currently exceeds its conservation limits (CL) on a regular basis and which is classified as ‘Not at Risk’ against the management objective of meeting the CL in four years out of five, on average. As such, the recovery of the Tyne stock can be considered a success.

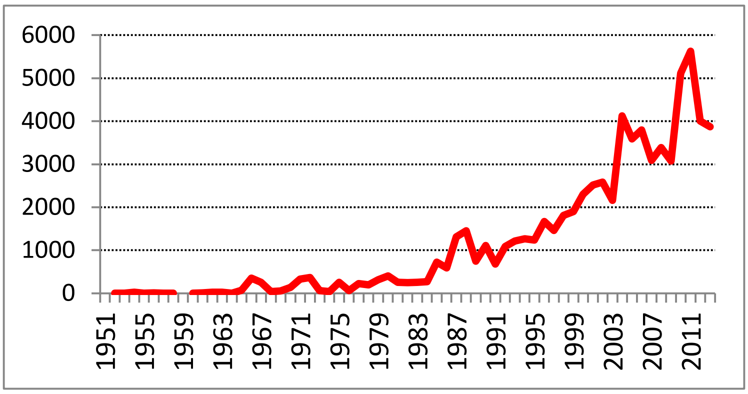

Figure 2.2.5. Declared rod catch of salmon on the River Tyne, 1951–2013.

In terms of the salmon stocking programme, the first returns of adult fish from hatchery-reared parr were in 1980. Hatchery returns peaked between 1984 and 1987, when these were estimated to contribute up to 274 fish (best estimate; range 128–566) to the rod catch annually and 2 084 fish (best estimate; range 975–4 515) to the spawning escapement. Percentage returns of stocked parr to the coast and to the river declined since the start of the programme, due to reductions in marine survival. Estimates of the long term (1980–2000) weighted returns to the coast and river were 0.6% (range 0.5–0.8%) and 0.3% (range 0.1–0.6%) respectively (Figure 6). Over the same time the weighted contributions to the Tyne rod catch was estimated at 6% (range 3–14%); later estimates (post-1995) were lower.

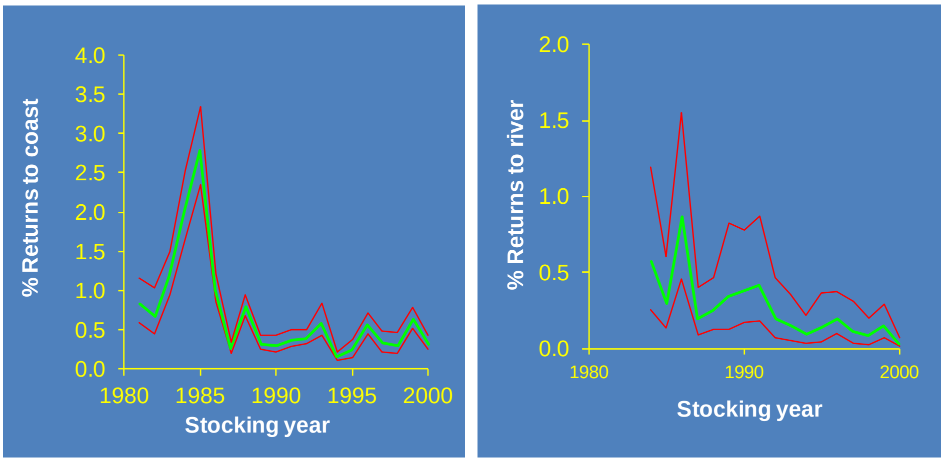

Figure 2.2.6. Estimated return rates of stocked Tyne salmon to: a) the coast, pre-North east Coast fishery, and b) the river pre-rod fishery. Upper middle and lower lines are MAX, BEST and MIN estimates, respectively [see Milner *et al.*, 2004 for further details].

In the early years of the stocking programme, contributions of hatchery fish to the run and escapement were higher because the natural recovery was in its early stages. Best estimates of annual % hatchery contribution to the rod catch ranged between 22 and 42% between 1983 and 1986 (Figure 7). These estimates are based on first returns; it has not been possible to assess potential contribution of stocked fish to later generations.

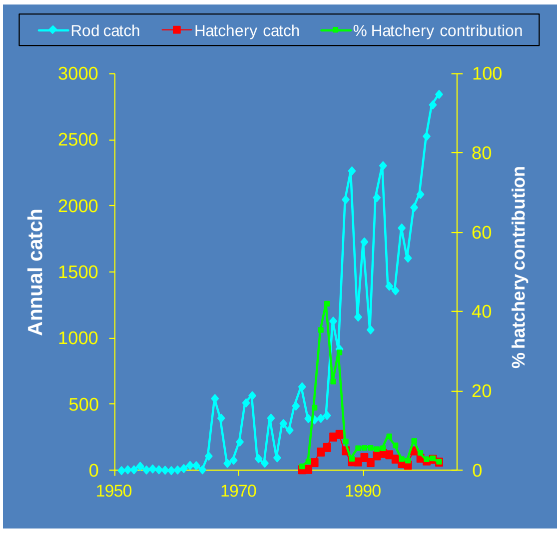

Figure 2.2.6. Annual Tyne salmon rod catch [corrected for underreporting – see Milner *et al.*, 2004], estimates of hatchery derived salmon in the rod catch and the % hatchery contribution.

Project evaluation: The Tyne recovery has been a success. However, natural recovery was the dominant process following the clean-up of the estuary, thereby removing this barrier to smolt and adult migration. The contribution from stocking is thought to have accelerated and stabilised stock recovery in its early stages when water quality improvements were still inconsistent.

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River Gave of Pau, France

NASCO River ID : NASCO 780

River Catchment size (km2): 2710

Starting and end year of project: 1983 –present. A priority since 2004.

Situation before restoration: Strong decrease in 1917 after building of 2 dams in lower part of the river. Second important regression in 1958 due to the building of Artix-Pardies dam, without fishway and totally no-passable by fish: no more access to the main spawning area. Loss of functionality in lower stretches during the second half of 20th century. Previous barriers in lower part (downstream of Orthez) have never extirpated the population. The population has alsways been exploited.

Main stressors on population: Barriers, Exploitation, Pollution.

- Barriers: N =55 (29 hydroelectric power plants, storage and run-of-the-river stations), cumulative head around 125 m. 37 barrages on main river, cum. head of 105 m (of which 15 downstream the best production areas), others on tributaries Few fish reach the best spawning grounds (upstream of Nay, 1010 km up the confluence with river Adour). Issues with flow fluctuations and lack of attractive water in by-passed stretches leading to delay in migration
- Exploitation: essentially by net in estuary and coast exerted on mixed stock composed by Nives, Oloron and pau populations Pau)
- Habitat degradation: gravel extraction in salmon habitat in the 1950s, stopped in the 1980s. Main river is classified as a "heavily modified water body"
- Pollution: issues with industrial discharge in lower part and domestic waste in middle and upper reaches

Actions taken: Improved connectivity, stocking

- Connectivity restoration: 42 fishways built mainly in 1980s and 1990s on main stem and one tributary, giving theoretically free access to all the main stem from the mid 1990s onwards at an estimated cost of 12 Millions €. Many by-pass facilities exist but some of which have low efficiency. In practical terms the high numbers of dams and several poor facilities for fish passage are still a problem
- Stocking: fair effort since middle of years 2000, with 500 000 fish yearly (coming from wild strains and F1) . 0.15 M€ per year these last years

Metrics used to evaluate success: juvenile counts, adult counts, monitoring of exploitation, passage, and fry survival.

Assessment before project: No real feasibility study undertaken. Many barriers exist on the river but of limited size (compared with rivers Garonne or Dordogne for example). Good quantity nursery habitat available and a healthy potential donor population in the geographically close river Gave d'Oloron.

Project Aims: Re-establish a self-sustaining salmon population of 1000–2000 returning adults per year (which is the estimated potential level of the population, once all obstacles removed).

Actions taken in more detail:

- Making weirs passable, facilitating access to middle part of river by constructing 42 fishways potentially making more than 200 km accessible. Many by-pass facilities however are not efficient
- Installation of video-counter at the ninth obstacle (Artix) to monitor upstream fish movements
- Stocking of juveniles : mainly since 2004, with Gave d'Oloron stock
- Juvenile abundance surveys

Assessment during project:

- Fish passage: the 15 lower dams allow passage for only 35% of expected run (telemetry studies by ONEMA during 5 years)
- Exploitation: catch supposed to be around 35% of stock
- Reproduction: redd counting from 2011: low natural reproduction is observed
- Survival of released fish 5 to 10 times better with late releases than with early ones ('late' refers to after snow melt flow)
- Stocking efficiency study comparing wild and hatchery origin adult fish by otolith Sr: Ca methodology (Figure 2.2.8 showing returning adult numbers and stocked fish per stage)

- Stocking:
  - Fed fry mainly, coming from local spawners from early 90s (discontinued stocking non-native strains as was done previously).
  - 40 000 fish annually before 2004, more than 500 000 after 2003
  - Early stocking in april and may, on main river and tributary Ouzom; late release since 2 years

- Returns:
  - Clear increase: 100–200 fish before 2005; 350–600 fish from 2005 to 2012.
  - Mainly 1SW fish before 2006 but 30% of returning adults are MSW after 2006.
  - Possible explanation: increased stocking from 2004, limited but increasing natural spawning contribution as a result of recent improvement of fish passage on two weirs in lower part of the river (Casteltarbe (2000) and Baigts (2001)).
  - Return rate (rough proxi): 0,057% to 0, 57 per 1000 stocked juveniles. More accurate return rate estimations will be available from 2014.

Adjustments to goals during project: No real change of goal except small increase of initial aim of 1500–2500 fish per year, which is the potential level of the population, once all obstacles removed. Achievable if: 1) free passage is fully restored without delay, and 2) exploitation is reduced.

Project success: The project has so far failed to establish a self-sustaining breeding population, but it probably was impossible to achieve in the period and the current effort.

Project evaluation: No attainment of goal. Among causes :

- Impact of dams preventing two-thirds of runs to reach spawning grounds and killing at least 20% of smolt production; 30 to 40% of good quality spawning habitat is only available today (against 70 and 65% on rivers Oloron and Nive)
- Over-exploitation during this rebuilding phase. A third of run is harvested
- Unsuccessful stocking: lack of genetic diversity and sub-optimal timing of release

Possible improvements:

- Stocking:
    - improve genetic quality: increase the number of wild spawners in the broodstock (currently under review)
    - delay fish release after spates and snow melt to improve fry survival
- Fish passage:
    - replace old fishways and build new ones with increased flow. Ten fishways will facilitate 80% of returning adult fish to reach good habitats
    - equip all hydroelectricity plants with good by-pass structures and flows to reduce mortality by one third
- Counting adult fish:
    - plan to build a video-counting facility, furher downstream of current counter, on the fourth dam

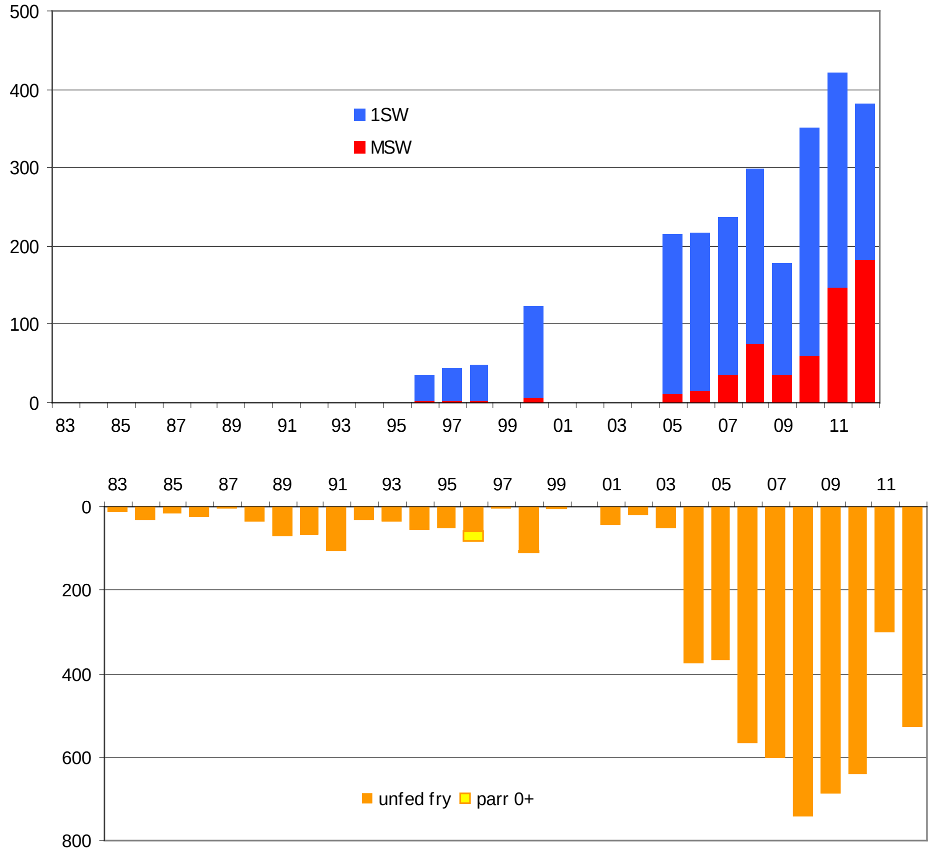

Figure 2.2.8. River Gave de Pau fry stocking (bottom) and adult returns (top). Stocking graph is shifted to the right, for 2 years.

River Shannon, Erne, Lee and Liffey, Ireland

River Catchment size: See table 2.2.1

Starting and end year of project: Dams built between 1925 and 1960s. Hatcheries built between 1958 and 1970s. The River Shannon rises in the mountains of Cavan, and extends south for almost 160 miles where it enters the Sea at Limerick. The river flows through three large lakes or loughs i.e. Lough Allen, Lough Ree and Lough Derg. While the harnessing of the river for hydro power did not significantly affect the environment for fish life in the upper reaches, it created **an obvious entry and exit problem for salmon.** Upstream passage was facilitated by the installation of fish lifts or ladders. Dams also present problems for juvenile fish travelling downstream. To compensate for this, **fish hatcheries were built to produce juveniles for restocking each year.** This case study examines the outcome of more recent stocking efforts from 1994 to 2007.

Situation before restoration: Prior to 1929, the salmon stock on these rivers was large with significant commercial fisheries operating. Some were particularly noted for the presence of very large multi-sea winter salmon. With the introduction of a hydroelectric power station the return of salmon declined dramatically in most instances.

Main stressors on population: Barriers, climate change, exploitation.

Actions taken: Improved connectivity, stocking.

Metrics used to evaluate success: Assessment of adult returns from restocking activities related to Conservation limit requirement in numbers of adult salmon (Table 2.2.1). The magnitude of the potential returns estimated from these releases has been compared to the individual Conservation Limits for these rivers to gauge, at least in numerical terms the possible contribution these stocking activities might have on the wild stocks. The issue of quality of the returning fish and their ability to perform as well on spawning beds or in survival through subsequent life-history stages compared to wild stocks is not dealt with here.

Assessment before project: Catch data.

Project Aims: Recovery of salmon stock.

Actions taken in more detail: In 1994, the Fisheries Research Centre (and subsequently the Marine Institute from 1996) began collecting records of all of the stocking activities in Ireland in an effort to establish the scale of restocking programmes i.e. the number and size of the rivers being stocked, the numbers and source of any wild fish being removed for broodstock purposes and the possible impacts and effects on wild salmon stocks. Under this programme (ESOPS, Enhancement Stocks – Origin, Progress and Status) all hatchery operators have been requested to supply details of the broodstock captured, eggs produced, and all locations, dates and numbers of progeny at each life stage released into the wild. In this way a comprehensive overview of the stocking activities in Ireland has been produced since 1995.

In order to quantify the returning adults from the various stocking strategies using different life-history stages of Atlantic salmon in Ireland, conversion factors for the survival of eyed ova, unfed fry, fry and parr to the smolt stage are required. These have derived from de Eyto *et al.*, 2007, McGinnity, 1997 and McGinnity (pers. comm). Subsequently, conversion of smolts to adults is based on returns from the Irish National Coded Wire Tagging and Tag Recovery Programme (Ó Maoiléidigh *et al.*, 2001). The conversion factors used are presented in Table 2.2.1. A distinction is made when converting smolts from plantings to adult returns and smolts reared entirely in the hatchery to adult returns. In the former, the survival rates generated in the National CWT programme for "wild" Irish smolts is used which would be considerably higher in most instances than hatchery reared smolts. Similarly, the exploitation rates used for adults derived from the returns of planted smolts is also based on the wild exploitation index on the assumption that the planted progeny will have spent more time in the wild and will subsequently behave more like true wild salmon. This will result in higher overall returns of planted hatchery progeny (eyed ova to parr) than assuming survivals and exploitation rates derived for smolts reared entirely in the hatchery.

The main objective of most restocking programmes in Ireland has generally been to restore depleted salmon stocks. While often significant returns of salmon have been generated from these programmes, the difficulty has been in gauging the long term success of the strategy. This was essentially due to the lack of an acceptable population "benchmark" with which to measure the outcome of the restocking projects.

Assessment during project: Detailed assessment of CWT recoveries was achieved through a National Coded Wire Tagging and Tag Recovery Programme. Both active screening of catches, broodstocks and voluntary returns information were available.

Adjustments to goals during project: Not applicable.

Project success: There are four rivers which have been harnessed for hydro-electrical power generation. Of these the highest estimated return of hatchery fish relative to the Conservation Limit is to the River Lee, with over 10% of the required Conservation Limit being generated (Figure 2.2.9). However, despite consistent restocking this river is estimated to be only meeting 2.2% of its Conservation Limit (based on the runs of wild fish past the fish counter) suggesting that the overall contribution of the hatchery fish is probably much less. Early restocking programmes for the river Erne are likely to have generated up to 40% on average of the returns required to meet the Conservation Limit. However, more recent contributions are estimated to be much lower (less than 5%) and the river is far below its Conservation Limit (only 9.5% of Conservation Limit being attained at the time based on upstream counts). The decline in potential returns is linked to decreasing marine survival. Both the Liffey and Shannon are only generating a small fraction of the Conservation Limit in numbers of salmon (Figure 2.2.9).

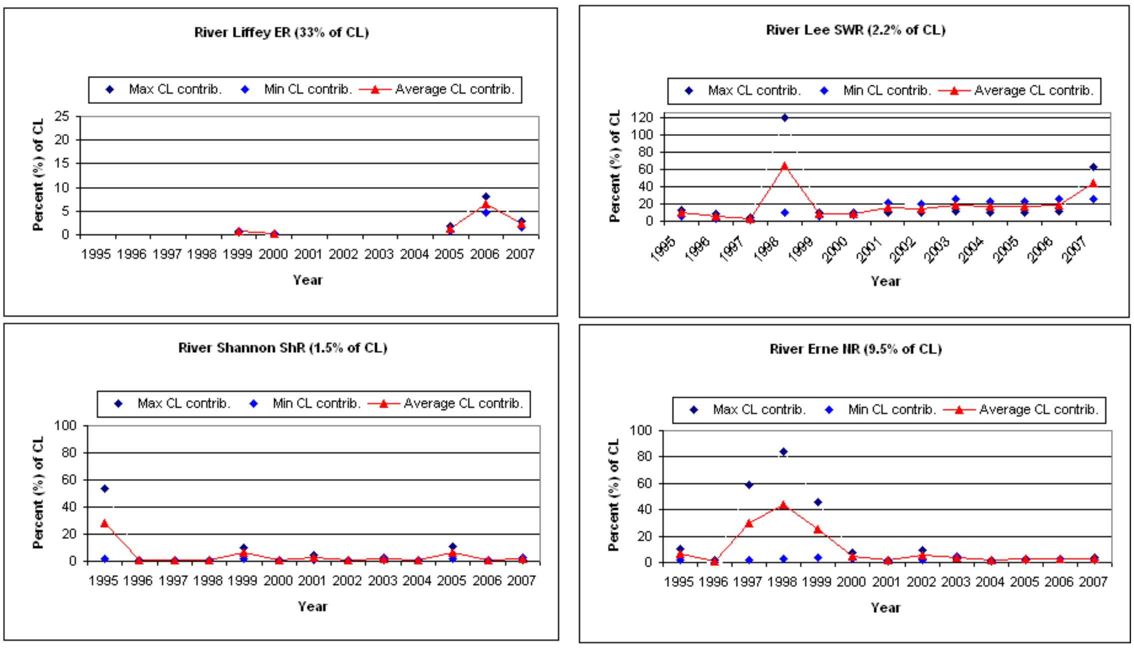

Figure 2.2.9. Estimated potential returns of hatchery reared Atlantic salmon relative to Conservation Limit requirements – Rivers currently below CL and with hydro-electric installations.

Table 2.2.1. Stocks above large rivers impounded for hydro-electric schemes. Counts are average counts for the most recent 5 years with the exception of the Liffey (Islandbridge) which is the most recent 4 years.

River	Wetted Area U/S Dams	Total CL	1SW CL	2SW CL	Average Count
Shannon	30,895,619	49,524	45,909	3,729	707
Erne	6,457,264	16,554	15,345	1,247	1445
Liffey	2,308,361	4,391	4,062	329	1157
Lee	1,923,476	2,789	2,585	210	57

Project evaluation: In general the results suggest that the contribution being made by hatchery reared intervention (in this instance simply in terms of adult numbers being generated) is minimal for rivers with hydro dams as these are still significantly below conservation limits. The objective of establishing self-sustaining runs of salmon in the first instance and the further objective of meeting the required Conservation Limit are unlikely to be fulfilled with the a restocking strategy alone. In fact may limit the re-establishment of small quasi-wild populations which could have established following extensive restocking in earlier years.

On the basis of the present results, it is concluded that extensive stocking programmes undertaken in Ireland over the last thirteen years, particularly for rivers with major hydro-power generating stations have made little real contribution to the productivity of these rivers or to the goals of restoring self-sustaining salmon runs.

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River Rhine (Netherlands, Germany, Luxemburg, France, Switzerland)

Helcom or NASCO River ID number: NASCO 284, 784

River Catchment size (km2): ~185.300

Starting and end year of project: 1987 – present (ongoing)

Situation before restoration: One of the world's largest Salmon populations (> 1 Mio. returners / year in 19th century) extirpated since ~1960.

Main stressors on population: Pollution, barriers, water regulation, habitat degradation, exploitation, climate change, predation, others (shipping).

Actions taken: Water quality improvement, stocking, improved connectivity, reduction of fishing mortality.

Metrics used to evaluate success: adult counts, grilse-MSW-ratio; some regions: also juvenile counts, redd counts.

Assessment before project: feasibility studies (pilot projects); cartography of adequate nursery habitat available in selected tributaries and upper river, potential problems with lack of spawning habitat in some tributaries, impassable weirs in the Upper Rhine and most tributaries.

Project aims: Re-establish a self-sustaining Atlantic salmon population in river Rhine by the year 2020 (formerly year 2000).

Actions taken in more detail:

- Substantial improvement of water quality in the whole catchment (nutrients, heavy metals, residual pollution like PCB etc., micropollutants).
- Making several weirs in tributaries passable, making access to tributaries in the upper part of the main stream (fish-passes Iffezheim and Gambsheim allow access to tributaries up to Strassbourg, fish-pass Strassbourg is under construction and will operate 2015, construction of fish-pass Gerstheim will begin 2015), improvement of existing fish passes in tributaries and in the High Rhine.
- Monitoring intensified; video observations and traps at fish-passes Iffezheim and Gambsheim (river Rhine), Koblenz (river Moselle), Siegburg (river Sieg) & Kostheim (river Main) to monitor ascending adults.
- Stocking of juveniles: approx. 40 Mio. since 1994; 251 950 ova, 7 558 370 YOY and 311 060 farm reared smolts (mostly age 1) between 2009–2013.
- Some stocking material is gained from brood-stocks partly consisting of fish caught as 'naturally spawned' fry and/or stripped returners.
- Reduction of fishing mortality by implementation of fishing regulations (full protection of the species in the whole Rhine river basin, ban zones on "hot spots"), but lack of saturation anti-poaching measures.

Assessment during project:

- Annual counts of returning adults (traps, video-observations, electro-fishing, telemetry and other methods) and estimations (partial counts) of migrating smolts;
- Electro-fishing surveys to establish juvenile densities (stocked and wild fish);
- Redd counts;
- Genetic studies (brood-stock, returners).

Adjustments to goals during project: The time span of the project was extended (year 2000 to 2020) taking into account that the re-introduction of an extinct species and especially the main action to promote it – the restoration of connectivity – is a complex and protracted task. The goal of establishing a self-sustaining breeding population can only be achieved once marine survival improves significantly and factors concerning survival of smolts and adults in the migration corridor (river and/or estuary and/or coastline) are further identified and reduced (e.g. poaching, predation, barrier in the Delta-Rhine).

Project success: The re-introduction of Atlantic salmon in river Rhine proved that water quality and spawning habitats in numeral tributaries are suitable for the species. The selected strains used for stocking (Ätran in the Lower and Middle Rhine, Allier in the Upper and High Rhine) basically manage to make their way from the North Sea to their home waters. Salmon use the installed fish passes and benefit from improved patency in program waters (481 barrage weirs were altered between 2000 and 2013). Accessible habitat is used for spawning in most program waters. However, the project has so far failed to establish a self-sustaining breeding population of

Atlantic salmon in the River Rhine system. Numbers of recorded returning adults experienced a peak when two monitoring-facilities (Iffezheim at the Upper Rhine and Buisdorf near Siegburg at river Sieg, Lower Rhine) started to operate in the year 2000. Another high followed in the year 2007 – the year after the Irish drift net fisheries where closed. Since then the number of recorded adults has declined from ~800 (in 2007) to ~300 (in 2013) individuals. The apparent downward trend in the last six years is attributed to decreasing marine survival, poaching (including by-catch), predation (e.g. cormorants), and probably navigation. Redds and 'naturally spawned' fry have been encountered annually throughout more than 12 years of the project in some tributaries, but numbers are also decreasing significantly. It is expected that at least some returning adults originate from natural reproduction already.

Project evaluation: As stated before, very low marine survival and factors within the migration corridor (poaching, predation, probably navigation) are generally seen as the main causes for the projects not reaching its initial goals. Additional issues preventing achievement of projects goals are: installation of new hydro power plants in program waters, passage problems with some obstructions particularly in low-flow conditions. With current marine survival levels etc. the goal of establishing a self-sustaining breeding population of Atlantic salmon until 2020 does not appear to be within reach and might be 'readjusted'.

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2.3 ToR c: summarize the resulting data set to determine the conditions under which various recovery/ re-building actions are successful and when they are not

2.3.1 DBERAAS

Figures 2.3.1 to 2.3.6 and Tables 2.3.1 and 2.3.2 give an overview of interim DBERAAS. This number of entries is not sufficient to draw final conclusions, but it does illustrate the potential of a fully populated DBERAAS. Despite the low number of entries, hints of regional differences in both the strength of different stressors as well as the effect of recovery actions become apparent.

One of these differences had already been observed in the case studies; the difference in the occurrence and strength of the stressor 'climate change' between NAC/S. NEAC and N. NEAC. In the three NAC entries the effects of climate change are listed as 'very strong' (Figure 2.3.1). In the S. NEAC area climate change effects are listed as 'moderate' in 35 out of 45 entries, with another six 'strong' to 'very strong' (Figure 2.3.3). In sharp contrast the N. NEAC area only lists 'climate change' effects as 'low' in 13 out of 15 entries, with the remaining two as 'nil' (Figure 2.3.5). These preliminary DBERAAS results, combined with data from the case studies suggest that 'climate change' is a stressor that is more pronounced in the southern part of the Atlantic salmon's range.

Another marked difference between areas is the stressor 'predators' which appears to have at least a 'moderate' impact on most populations in the NAC/S. NEAC, but scores 'nil' in all the N. NEAC entries (Figures 2.3.1, 2.3.3, 2.3.5).

The absence of a population where the stressor 'aquaculture' is listed as any more than 'moderate' was also notable. For the combined NEAC areas 'aquaculture' was listed as 'nil' in 47 out of 63 entries. This is could be the effect of a bias in the entries in DBERAAS so far, as examples in the peer-reviewed literature exist where open-cage Atlantic salmon aquaculture is described as a major factor in the decline of wild Atlantic salmon stocks (Hansen & Windsor, 2006; Ford & Myers, 2008). Equally it could be the result of an underestimation of the effects of the stressor aquaculture by scientists responsible for populating DBERAAS.

Several observation could be made on regional differences in the effects of the 'actions' as well. For instance it is very striking to observe that very few actions in the NAC and S. NEAC areas resulted in a 'strong' or 'very strong' effect (Figures. 2.3.2, 2.3.4, 2.3.6). Actions in the N. NEAC area were generally more successful. This could be an effect of the lower impact of the stressor 'climate change' in this area compared to NAC/S. NEAC, and the lower average number of stressors working on populations in the N. NEAC area.

Also very apparent is that by far the most frequently listed action in all areas is 'stocking'. This action is listed in 46 out of 66 entries (Table 2.3.2). Yet only in eight cases is the effect of stocking listed as 'moderate', with no entries for the categories 'high' or 'very high'. This means that in 38 out of 46 cases stocking has a 'nil' or 'low' benefit. This suggests that stocking is generally a very unsuccessful recovery action. This is also apparent from the results of the case studies. Improved water quality, reductions in fishing mortality, and improved connectivity are examples of actions that scored better than stocking with at least some populations experiencing 'high' to 'very high' benefit from these actions.

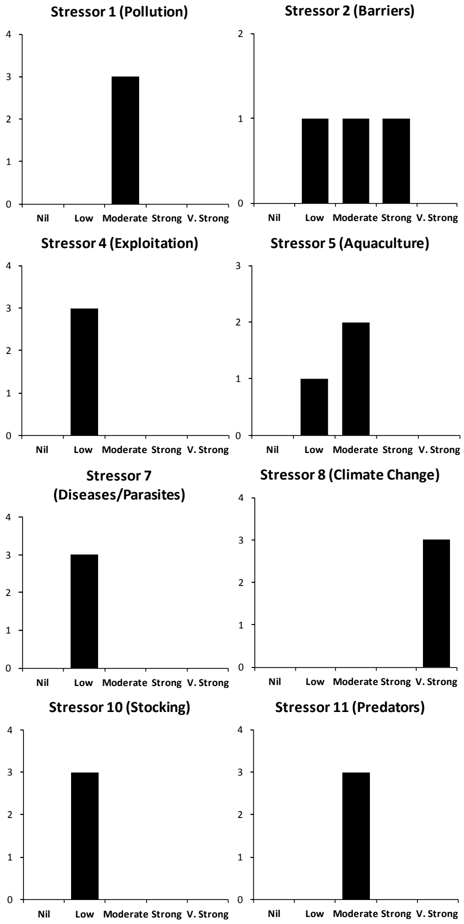

Figure 2.3.1. DBERAAS stressors NAC.

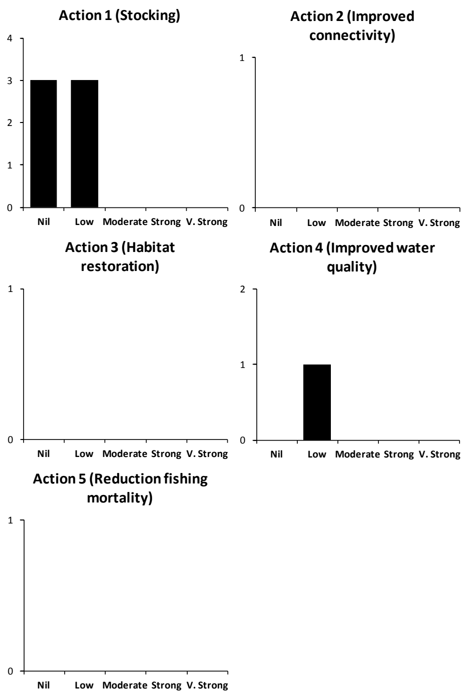

Figure 2.3.2. DBERAAS actions NAC.

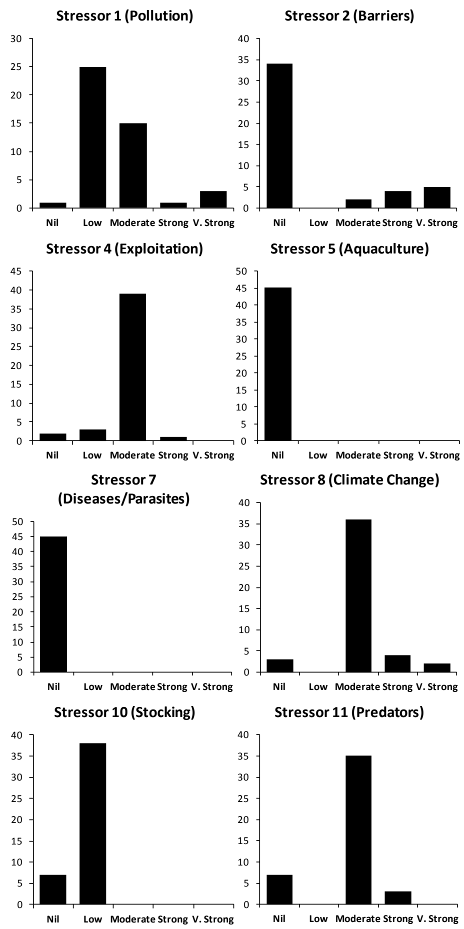

Figure 2.3.3. DBERAAS stressors Southern NEAC.

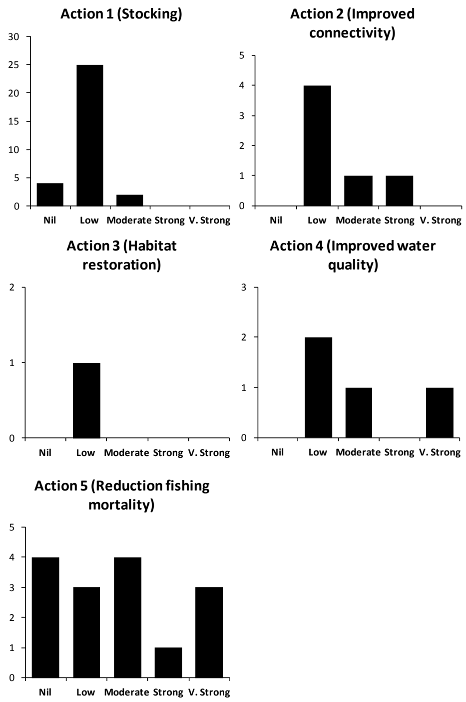

Figure 2.3.4. DBERAAS actions Southern NEAC.

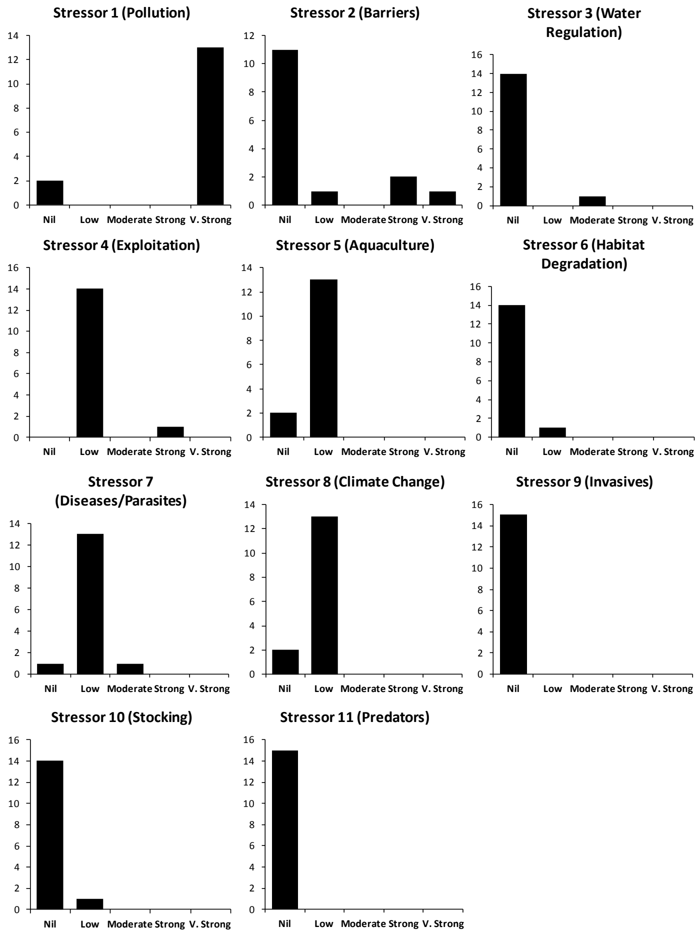

Figure 2.3.5. DBERAAS stressors Northern NEAC.

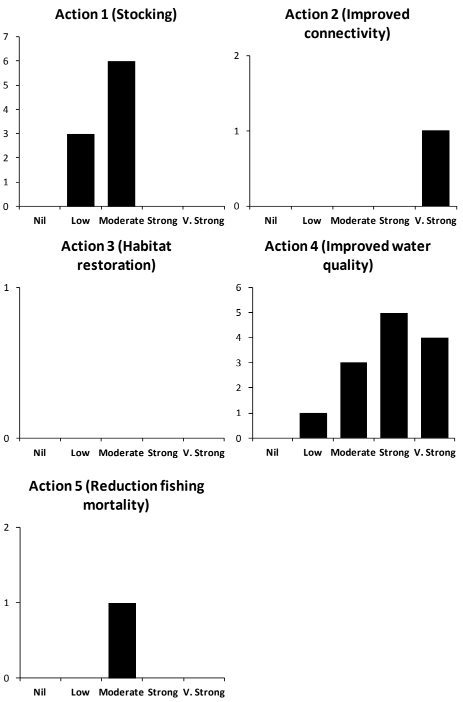

Figure 2.3.6. DBERAAS actions Northern NEAC.

Table 2.3.1. Total of Stressor entries by Stock Complex and Stressor category.

	NAC	S NEAC	N NEAC
Stressor 1 (Pollution)	3	45	15
Stressor 2 (Barriers)	3	45	15
Stressor 3 (Water Regulation)	3	45	15
Stressor 4 (Exploitation)	3	45	15
Stressor 5 (Aquaculture)	3	45	15
Stressor 6 (Habitat Degradation)	3	45	15
Stressor 7 (Diseases/Parasites)	3	45	15
Stressor 8 (Climate Change)	3	45	15
Stressor 9 (Invasives)	3	45	15
Stressor 10 (Stocking)	3	45	15
Stressor 11 (Predators)	3	45	15
Stressor 12 (Other)	-	-	-

Table 2.3.2. Total of Action entries by Stock Complex and Stressor category. 'x' Denotes that no entries were provided for this category.

	NAC	S NEAC	N NEAC
Action 1 (Stocking)	6	31	9
Action 2 (Improved connectivity)	0	6	1
Action 3 (Habitat restoration)	0	1	0
Action 4 (Improved water quality)	1	4	13
Action 5 (Reduction fishing mortality)	0	15	1
Action 6 (Predator control)	x	x	x
Action 7 (Invasive species)	x	x	x
Action 8 (Farmed fish removal)	x	x	x
Action 9 (Flow management)	x	x	x
Action 10 (Other)	x	x	x

2.3.2 Case studies

The case studies provided in this interim report (Section 2.2.2) are examples of well documented recovery actions for Atlantic salmon throughout the range. The aim for the final report is to increase the number of case studies presented and to specifically present case studies on all stressors detailed within the DBERAAS. As an example, 'diseases/parasites' and 'stocking' stresses are not address by any case studies within this interim report.

Even with the low numbers of case studies presented within this interim report (n=8), there is geographic representation across the range of North Atlantic salmon (Northern NEAC (Mandalselva, Tuloma), Southern NEAC (Tyne, Gave de Pau, Shannon/Liffey/Erne/Lee, and Rhine), and NAC (West River, Dennys River)). In addition there is good variation among case studies with regard to the number of stressors acting on the salmon population (varying between one and eight), the number of actions taken (varying between one and four), and the result of the actions taken (varying between nil benefit and high benefit).

Stressors reported in the eight case studies were: Pollution, barriers, water regulation, habitat degradation, exploitation, climate change, predation, aquaculture, invasives, and others (shipping). Most often reported were pollution (6), barriers (5), and habitat degradation/exploitation/climate change (4). Invasives, aquaculture, and others (shipping) were only entered once. Diseases and parasites was not entered as a stressors in any of the case studies presented here, but examples of such cases do exist in the literature and the aim is to include at least one case study in the final report where diseases and parasites is an important stressors on the population.

Recovery actions listed in the case studies were: Stocking, improved connectivity, improved water quality, and reduction in fishing mortality. Stocking was reported in six cases, followed by improvements in water quality (5), and improved connectivity (3). Reductions in fishing mortality was only entered in one case study as a recovery action that was implemented.

The number of stressors reported in case studies (10) is much higher compared to the number of recovery actions (4). For instance the stressor 'habitat degradation' is reported in four out of eight case studies, yet the corresponding recovery action 'habitat degradation' is not mentioned in any case study as an action that was taken. Other common stressors too, like exploitation, are not often countered with the appropriate recovery action, in this case 'reduction in fishing mortality'.

It is clear from the case studies however that not all stressors are, or can be, countered by the appropriate recovery actions. Perhaps herein lays a clue into the failure of many recovery actions.

It has to be noted that the stressor 'climate change' does not have an associated equivalent recovery action because of the obvious lack of an appropriate effective direct recovery action for this global phenomenon (i.e. one cannot just reverse climate change). Such stressors cannot be mitigated for directly and actions like proposed at the Salmon Summit in 2011 in La Rochelle ("increase the output of wild smolts") might be the only measure resulting in some effect that can be taken until such times when marine survival of Atlantic salmon increases again either through adaptation of Atlantic salmon to the changed marine conditions or a change to more favourable conditions for higher survival at sea. From the case studies it appears that the stressor 'climate change' is a major factor in limiting the success of recovery actions in the S. NEAC and southern NAC areas. This has been reported in the peer-reviewed literature too (Gibson *et al.*, 2009; Mills *et al.*, 2013).

Some interesting patterns can be observed when comparing the unsuccessful case studies (nil/low benefit) with the successful ones (high/very high benefit). All successful case studies presented have only experienced one or two stressors, and that the actions taken on these rivers have succeeded in (partially) removing the stressors, resulting in a substantial or full population recovery. Another factor that is shared among the successful case studies is a more northern location compared to the unsuccessful ones. In the N. NEAC and northern parts of the NAC areas the stressor 'climate change', which generally manifest itself as prolonged low marine survival in salmon populations, is virtually absent as a stressor (see Section 2.1.2). In S. NEAC and the southern parts of NAC low marine survival is generally reported as a major factor in the decrease in the number of returning adults in these areas since the 1990s (Chaput, 2012; ICES, 2013).

The case studies suggest that salmon populations experiencing few stressors generally had successful recovery programs. The reverse of this appears also to be the case: rivers experiencing the highest number of stressors are also the ones where success of recovery actions was lowest. It has to be noted that most of these populations are found in the S. NEAC and southern parts of the NAC where, as mentioned above, the stressor 'climate change' has an effect on most populations. Also the S. NEAC and southern parts of the NAC are more densely populated compared to N. NEAC and the northern parts of the NAC and this has an effect on the number of stressors on populations as more populated areas generally also experience more pollution, habitat degradation, and water regulation. The River Rhine case study is a good example of this. The Rhine flows through one of the most densely population areas in the world and as a result the River Rhine salmon experience no less than eight main stressors (Pollution, barriers, water regulation, habitat degradation, exploitation, predation, others (shipping), and climate change). Some of these stressors have been addressed by certain actions (water quality improvement, stocking, improved connectivity, reduction of fishing mortality) with various success. But not all stressors have been addressed, and as a result the outcomes of these actions have so far only had a small benefit on the population. For a high to very high benefit more stressors have to be addressed successfully, which is difficult on a river in a densely populated area, highly modified to accommodate river traffic and regulate flow, and with river management being shared by many different countries.

Pre-project feasibility studies were not conducted in all case studies presented here. Some appear to be an ad-hoc reaction to low numbers of returning adults. Most case studies were adequately assessed and evaluated both during and, if applicable, after the projects were completed.

2.4 ToR d: provide recommendations on appropriate recovery/ rebuilding actions for Atlantic salmon given threats to populations, status and life history

The appropriate recovery/rebuilding actions for Atlantic salmon given here are preliminary as they are based on an incomplete DBERAAS and set of case studies. They do however offer an interesting preview of what the recommendations on the appropriate recovery/ rebuilding actions might be in the final report.

From the case studies it is apparent that not all recovery/ rebuilding programs were based on in-depth studies on specific stressors acting on the salmon population before actions are implemented. Most case studies presented here do report some process of evaluation during, and after the actions have been undertaken to assess the effects of the actions. The case studies presented here are generally the best documented ones, as many case studies that were considered for inclusion in this report were rejected because a general lack of data that could be used to evaluate success or failure. From the DBERAAS it becomes apparent that many recovery/rebuilding projects take the action 'stocking' regardless of the stressors acting on the population. This is not a recommended approach as DBERAAS shows that the effects of stocking are at best classified as 'moderate', and often 'small' or 'nil'.

A clear recommendation would be that recovery/rebuilding actions for Atlantic salmon should consist of a clear and comprehensive plan that start with an in-depth assessment of the stressors that are acting on the population, and preferably an analysis of the strength of the individual stressors and the potential effect that actions will have using for instance a modelling approach. See Gibson *et al.* (2009) for an example of such a study. This will help to achieve a prioritization of stressor(s), determination of most appropriate action(s), and will be a great benefit in determining the chances of success of the recovery-rebuilding project as a whole. Communication of the pre-project study and recovery plan to stakeholder groups should create (more) realistic expectations of the chances of project success as well as provide information on how the plan is evaluated.

A second recommendation, following from the first, would be to consider a realistic aim for the project. Most projects discussed in the case study section aim to restore a salmon population to historical levels, above CL, or similar objectives. Only few report less ambitious aims such as increasing freshwater survival, or small numbers of returning adults. It has to be noted here that DBERAAS does not take these individual project aims into consideration. DBERAAS measures success of an action in the ability to result in population recovery as measured against CL attainment. When pre-project assessment shows that ambitious project aims are impossible to achieve it should be considered to progress with the project under less ambitious aims such as lowering of the population's future extinction risk or to facilitate future recovery actions. Modelling studies estimating the effect of recovery actions in response to changing the impact of certain stressors (Gibson *et al.*, 2009) have shown that in certain situations substantial population recovery under present conditions (i.e. the effects of particular stressors that are impossible to mitigate for severely limit the effects of any recovery action removing other stressors) is impossible. A good example of such a scenario is the effect of the stressor 'climate change' (reduced marine survival. Actions to mitigate against climate change (i.e. low marine survival) in the near term have yet to be developed, however it is likely worthwhile to start recovery actions to tackle the effects of other stressors acting on a population as in future marine survival might improve, and thus past recovery actions could facilitate future population increases. Such as scenario might also apply to populations that experience the negative effects of many stressors simultaneously, such as the case of the River Rhine. It may be impossible to start recovery actions aimed removing all stressors simultaneously, but the removal of each stressor is a step toward full population recovery. Again, communication to stakeholders of the limited effects of some actions because of the ongoing limiting factors caused by remaining stressors should be considered.

A third recommendation is that all stressors on the population need to be removed for the potential of full population recovery. Addressing a subset of the identified stressors may provide benefits and help reduce extinction risks in the short term, but the remaining stressors can severely limit the effects of recovery actions overall. In cases where not all stressors are or can be removed (such as the case with climate change) the result of recovery actions may be limited. With this in mind it would be prudent to recognise the difficulties to achieve more than a low or moderate population recovery under current conditions in the S. NEAC and southern NAC areas.

3 Next steps

The Working Groups aims to complete populating the DBERAAS database in the first quarter of 2015. More case studies will be added during this time as well.

A meeting of WGERAAS at ICES HQ in Copenhagen is suggested for May 2015. At this meeting a final analysis of both case studies and DBERAAS is planned, and drafting of a final report.

The final report should be available in time for the ICES ASC 2015.

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