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Report from the Tromsø Symposium on the Recommendations to Address Future Management Challenges

Managing the Atlantic salmon in a rapidly changing environment - management challenges and possible responses

Symposium held in Tromsø, Norway
June 3 - 4, 2019
ahead of the North Atlantic Salmon Conservation Organization's (NASCO) Annual Meeting

REPORT FROM THE SYMPOSIUM STEERING COMMITTEE

EXECUTIVE SUMMARY

This executive summary is a short compilation of results from the NASCO International Year of the Salmon Symposium entitled "Managing the Atlantic salmon in a rapidly changing environment - management challenges and possible responses". Two summaries are presented here: the advice for all agencies and organizations who are involved in the conservation and protection of Atlantic salmon; and, recommendations to NASCO.

Summary of Advice for Agencies and Organizations:

1. **Managers and conservation organizations** need to promote strong, healthy, and resilient populations of local wild salmonids in rivers and estuaries in order to reduce the impacts of changing ecosystems. A primary strategy to achieve this is protecting the genetic integrity of stocks, enhanced water quality and habitat protection including improving access for salmon to important habitats, and minimizing human impacts reducing growth and survival in rivers and coastal areas.
2. Salmon management traditionally has focused on managing harvest and artificially stocking rivers to offset salmon mortality or population decline. In the face of a rapidly changing environment, management approaches and decision-making should be broadened to include ecosystem protection of rivers, estuaries and marine environments including water quality, habitat quality and other valued components of the ecosystem.
3. **Aquaculture managers** need to have a strong focus on preventing any escape of farmed salmon from pens and/or consider using sterile salmon within their operations. They should reduce the mortality of wild fish caused by salmon lice and pathogens by implementing stricter disease and parasite control programs. This should be supported by rigorous monitoring and reporting to agencies concerning the prevalence of escapes and disease outbreaks.
4. In light of current knowledge concerning the risk and benefits of stocking, all **agencies, managers and conservation organizations** involved in stocking to artificially supplement populations of any life stage, should adhere to the following principles:
    a. Stocking with hatchery fish of any life stage to augment natural wild Atlantic salmon populations should be an action of last resort, after all other conservation activities have been tried (e.g. optimizing river habitat and water quality), and primarily for preserving endangered populations. If deemed necessary, after carefully evaluating the risks and benefits, stocking should be conducted in a way that minimises or eliminates potential negative effects and maintains genetic integrity and genetic variation of the wild population to the maximum extent possible.
    b. If deemed necessary, stocking should only include the use of local, wild broodfish, emphasize stocking of early life stages, always minimizing time

in captivity, and, balance the number of stocked fish to the number of broodfish and the number of naturally reproducing fish

c. In any stocking program, all hatchery produced fish of any life stage should be tagged in some way to be traceable and the effects of stocking should be evaluated.

5. **Agencies, managers and conservation organizations** considering introductions or managing invasive species should consider the following principles:
    a. Discourage any introduction, intentional or otherwise, of non-native species into salmon rivers;
    b. If established, invasive species should be eradicated where possible, and prevented from spreading when eradication is not feasible;
    c. Work with other organizations to ensure strong and healthy populations of local Atlantic salmon to mitigate the potential impacts of invasive species.
6. To optimize species productivity under future conditions **fisheries managers and conservation organizations** should ensure the highest number of wild smolts in the best condition leave from rivers and near-coastal areas to the ocean.
7. **Fisheries managers and scientists** should continue studies to understand the magnitude and causes of mortality for Atlantic salmon during the marine phase of their life cycle to identify the importance of reduced sea survival due to ocean ecosystem effects versus human impacts in rivers and near-coastal areas and to predict spawner numbers for management. Such research must also include studies in the beginning of the sea migration (i.e. in estuaries and coastal areas).
8. **Fisheries managers and scientists** should continue to meet and to augment the exchange of information and ideas on how salmon management related to biological reference points is done in different regions as a way to encourage greater consistency among the countries in the use of biological reference points, cataloguing habit types and amounts of different habitat. NASCO could facilitate such knowledge exchanges.
9. **Managers, scientists, conservation organizations and governments** should recognise that people are a critical element of the conservation process. Addressing human dimensions requires incorporation of traditional and local knowledge and indigenous perspectives in activities related to salmon science, conservation and management.

Recommendations for NASCO

The IYS Symposium Committee has identified a numbers of areas where NASCO could either start new initiatives, update and modernize existing guidelines, work with the Parties, or facilitate the development and dissemination of information to promote the future conservation of Atlantic salmon:

11. To remain relevant in a period of rapid environmental and social change NASCO needs a renewed strategy to respond to the challenges facing wild Atlantic salmon. To begin this process NASCO should specifically identify strategic activities to deal

with climate change and its cascading effects on salmon and salmon habitat, possibly by updating its 2005 "Strategic Approach for NASCO's 'Next Steps".

12. Given the advances that have been made in the last 15 years in understanding genetic effects of artificial population supplementation, i.e. stocking, and given the conclusions of the 2017 NASCO "special session on Understanding the Risks and Benefits of Hatchery and Stocking Activities to Wild Atlantic Salmon Populations", NASCO should immediately update its 2004 "Guidelines on the Use of Stock Rebuilding Programmes in the Context of the Precautionary Management of Salmon Stocks" with reference to the summary of advice given above (No. 4).
13. Given the importance of habitat and water quality conservation as a key strategy to conserve salmon into the future, NASCO should update its 2010 "Guidelines for the Protection, Restoration and Enhancement of Atlantic Salmon Habitat". Updated guidelines should not only consider the physical environment and include estuaries but should also seek to optimize water quality by considering the chemical and biological quality (e.g. toxic substances, diffuse agricultural pollution, persistent organic pollutants) as well as availability and distribution of prey in the future.
14. Given the advances in the understanding of human dimensions and the importance of incorporating indigenous and local knowledge into salmon conservation, NASCO should update and modernize its 2004 "Guidelines for Incorporating Social and Economic Factors in Decisions under the Precautionary Approach". This update should include recent advances in human dimensions and the incorporation of traditional and local knowledge and indigenous perspectives.
15. Recognizing the importance of salmon to indigenous peoples and the role that indigenous peoples play in salmon conservation, NASCO should improve the participation of indigenous people in NASCO.
16. NASCO should continue efforts, begun under the International Year of the Salmon, to raise global awareness about the status of wild Atlantic salmon, the threats they face, potential solutions, and actions that can be taken.
17. NASCO should facilitate co-operation between Parties when there is a need for international collaboration to prevent or reduce the threat to salmon stocks from invasive species.
18. Given the continued impacts of domestic salmon farming on wild salmon, NASCO should strengthen compliance to the agreed international goals of "100% farmed fish to be retained in all production facilities and, 100% of farms to have effective sea lice management such that there is no increase in sea lice loads or lice-induced mortality of wild salmonids attributable to the farms". This is as stated in the 2009 "Guidance on Best Management Practices to Address Impacts of Sea Lice and Escaped Farmed Salmon".
19. NASCO should establish a new goal to prevent the spread of disease pathogens from fish farms to wild fish consistent with the existing goals on containment and sea lice in the 2009 "Guidance on Best Management Practices to Address Impacts

of Sea Lice and Escaped Farmed Salmon", and the 2016 "Theme-based Special Session: Addressing Impacts of Salmon Farming on Wild Atlantic Salmon".

20. Given the need to identify the importance of reduced sea survival due to ocean ecosystem effects versus human impacts in rivers and near-coastal areas and to predict spawner numbers for management, NASCO should support and continue to encourage research on mortality for Atlantic salmon at the beginning and the end of the marine phase of their life cycle in estuaries and near-coastal areas as well as on the high seas.
21. Given the success of this Symposium and the positive feedback the Committee has received from participants, NASCO should consider hosting similar events in the future.

Introduction

To mark the International Year of the Salmon, a two-day symposium titled *Managing the Atlantic salmon in a rapidly changing environment - management challenges and possible responses* was held ahead of the 36th Annual Meeting of the North Atlantic Salmon Conservation Organization (NASCO). The focus was on challenges facing the Atlantic salmon and possible responses that can help conserve Atlantic salmon. Speakers were invited based on a program developed by the symposium steering committee, and a broad call for posters was distributed widely. Attendance at the symposium was open to all.

The symposium was structured under two main themes: 1) climate change and state of the salmon, with scientific overviews being provided on these subjects, and 2) management challenges and solutions.

Speakers and poster presenters were managers, scientists, representatives of non-governmental organizations, and representatives of indigenous peoples from Norway and Canada. Presenters were provided with a topic and asked to provide an overview from their perspective, their views on the management challenges, and potential responses.

This report presents the conclusions and advice of the Symposium Steering Committee based on the oral and poster presentations of the symposium, and on the discussion with the audience at the end of the symposium. The report includes the Committee's recommendations to NASCO and advice to not only agencies responsible for managing Atlantic salmon, but also to other environmental agencies or organizations whose decisions or activities influence or impact salmon and their ecosystems. A more extensive symposium proceedings containing all manuscripts provided by the speakers and copies of the poster presentations will be published at a later date.

In this report, the issues outlined in the presentations are structured according to the themes of the symposium: 1) impacts of climate change; 2) impacts of salmon farming; 3) limitations of stocking; 4), impacts of invasive alien species;5) the importance of freshwater habitat and water quality; 6) the relatively unknown marine phase of the Atlantic salmon life cycle; 7) the use of biological reference points in management; and 8) and human dimensions. We provide a summary of conclusions and advice for each theme. We conclude with some recommendations on NASCO's role and the changes managers need to consider for effective salmon conservation in a changing world. [Note: throughout this report we refer to fisheries managers or managers. This term is broadly defined for the purposes of this report and includes not only agencies who are directly responsible for managing fish or fish harvest, but also includes other environmental agencies or organizations whose decisions or activities influence or impact salmon and their ecosystems.]

Atlantic salmon in a changing climate

CLIMATE ALTERATION IS CHANGING SALMON ECOSYSTEMS

Climate change is having a major impact on Atlantic salmon in freshwater and at sea, directly through changes in temperature, water flow and other abiotic factors, and indirectly through ecosystem changes such as food availability. Alterations to the climate in the northern hemisphere are expected to affect freshwater systems more strongly than the marine environment because temperature increases over land are expected to exceed those over ocean surfaces, and because the hydrology of rivers (flows and temperatures) is changing concurrently. Additionally, ocean temperatures are rising, and the impacts on marine ecosystems inhabited by Atlantic salmon are also of great concern.

Higher temperatures and increased hydrological variability are predicted to affect all components of freshwater systems. Precipitation is expected to increase, with "wet" areas typically becoming wetter, but with increased variability such that the risk of both floods and droughts will increase. In northern Europe and North America, climate change is projected to result in warmer, drier summers and milder, wetter winters with more precipitation falling as rain and less as snow, a decrease in ice covered periods, and more frequent periods with extreme weather events. We may expect to see many rivers experience extreme low flows (low water levels) during summer with higher water temperatures, which is a potentially lethal combination for salmon.

The increase of atmospheric greenhouse gases through human activities leaves more carbon dioxide in the ocean and more energy in the climate system; 25-30% of the anthropogenic carbon dioxide emissions are stored in the ocean, and about 93% of the excess heat is taken up by the ocean. This leads to oceanic changes that have the potential to influence and threaten marine ecosystems. Upper ocean warming increases the vertical stratification of the water column and could lead to reduced nutrient supply into the sunlit zone. Warming also contributes to the observed decrease of global marine oxygen concentrations and is expected to lead to a decrease in the North Atlantic water circulation between 30% and 50% prior to 2100. The increasing concentration of dissolved carbon dioxide in the ocean leads to acidification, which in the long-term has the potential to affect the entire food chain. Oceanic changes are not uniform around the globe. Depending on the strength of the continued emissions of greenhouse gases, climate alterations of ecosystems will evolve, enlarging the oceanic trends already observed, although regional ecosystems may show more or less impacts than in the ocean itself.

IMPACTS ON ATLANTIC SALMON

Scientists are projecting that conditions for Atlantic salmon may deteriorate, both in freshwater and at sea due to climate change. The vulnerability of salmonids in a rapidly warming environment is a known concern but with some uncertainty as to how well

salmonids will be able to adapt. Although salmonids have some capacity to respond and potentially adapt to variations in the environmental conditions, there are limits to these capacities, especially over short time periods.

The predicted changes to river hydrology will likely influence the population dynamics of Atlantic salmon. The average annual water flow in many regions is expected to increase, which will increase river wetted area and thereby increase the habitat available for juveniles. However, the in-year flow pattern will be variable, with high flows in autumn and winter, and periods of very low flows in summer. Future periods of low river flow during summers are, therefore, a potential bottleneck for Atlantic salmon production.

Salmon are ectotherms, and as such, the water temperature directly controls their physiology and metabolism. During spawning, eggs are laid in the gravel and the timing of hatching and how fast the fry consumes the nutrients from the yolk sack before it emerges from the gravel is controlled by water temperature. With increased water temperatures, this process will be more rapid, and the fry will emerge from the gravel earlier, which may lead to a disconnect between the timing of fry emergence and food availability. When temperatures increase, the growth of juvenile salmon in the river will generally speed up, and they may reach smolt size earlier. Studies have shown that smolt age has decreased in the past decades, as water temperatures have increased.

The warmer temperatures earlier in spring appears to have influenced migration timing, with smolts migrating to the ocean earlier in the year. There is concern that the changed ocean environmental conditions are creating a mismatch between timing of smolt sea entry and favorable conditions at sea. Migratory fishes are particularly vulnerable to warming environments as the transitions between habitats are finely tuned to specific environmental cues. The success of these transition periods has consequences for subsequent life stage survival.

Climate alteration has already imposed changes for Atlantic salmon. Water temperatures in many rivers are expected to exceed the upper thermal tolerance limit for salmonids, and during the summer, many populations are already encountering water temperatures near or exceeding experimental lethal limits. In most areas where salmon reside in water with warmer water temperatures (southern Europe), suitable cold-water refuges have been found. It is expected that cold water refuges will become increasingly more important as more rivers experience extreme temperature events.

Energy depletion at high temperatures before spawning has been shown to be greater in small salmon compared to large salmon, suggesting that smaller individuals may be more impacted by high temperatures. If so, one may expect long-term phenotypic change in salmon populations experiencing high temperatures.

Historically, research on climate effects in freshwater has focused directly on factors such as changes in water temperature and flow, while research in the marine phase has been

focused on indices and correlations of growth with water temperatures. Marine ecosystems have changed in response to climate change over the past hundred years, which may have influenced the food supply for Atlantic salmon in the marine phase. The spatial distribution of food and high-productive areas may also change, which may impact the ocean migration routes and distribution of Atlantic salmon.

CHANGING CLIMATE EFFECTS AMPLIFIES OTHER STRESSORS

As the ecosystems and habitats of Atlantic salmon change due to the effects of the changing climate, there are cascading effects and negative feedback loops that are only now being identified. Some human activities will amplify the stress caused by climate change and impact the resilience of salmon and the ability to adapt to changing environments. This additional stress may in turn reduce the ability of salmon to respond to cumulative impact of other stressors.

Other known stressors of high concern have been identified in relation to climate alteration and include:

- Genetic introgression of farmed salmon and uncontrolled stocking impose an extra load on the process of adaptation and may reduce the ability of Atlantic salmon to adapt to rapid environmental changes;
- Atlantic salmon will experience temperatures that are outside the optimal range, which in turn may affect immunological and physiological functions necessary to combat diseases. This applies to both wild and farmed Atlantic salmon. Wild Atlantic salmon may be negatively impacted both in their natural habitats as well as by pathogen transmission from fish farms;
- With an increase in water temperatures, new species may invade Atlantic salmon rivers, and other native species or introduced species may increase in abundance. This may lead to additional competition for resources, increased predation, or other ecological effects. With new fish species, risks of new viruses, bacteria, protozoans and multicellular parasites increase. Additionally, a warming ocean and other climate change impacts may influence the likelihood of pink salmon being established in Northern Europe.

CONCLUSIONS – CHANGING CLIMATE

- Most future challenges for the Atlantic salmon under current climate change scenarios cannot be predicted. NASCO can best prepare for the future by ensuring that Parties preserve healthy and resilient Atlantic salmon populations with the genetic diversity that exists today.
- Climate change has already changed ecosystems and habitats and consequently have put wild salmonids under pressure, which render them more vulnerable to other stressors.

- Climate change will likely have a greater impact on Atlantic salmon in the southern distribution range due to increased river water temperatures and reduced flows. Water temperatures in summer periods are already close to the lethal limit in many southern regions. Currently, the northern populations have more scope for acclimation because current river temperatures are lower and well below the lethal limits.
- Global responses, beyond fisheries management, are needed to reduce climate heating and its impacts by reducing carbon dioxide emissions. Nevertheless, fish managers should consider the need to incorporate more flexibility and more perspectives into decision making around harvests.
- To maximize resilience in salmonid populations in the face of rapid environmental change, it is vital to maintain the genetic diversity and complex life histories (*e.g.*, proportion of small and large salmon, multiple sea-age) of wild populations by ensuring natural reproduction and avoiding selective fishing.
- Genetic introgression from escaped farmed salmon from aquaculture farms can reduce the ability of Atlantic salmon to adapt to climate change. Measures to prevent further escape or using sterile salmon in aquaculture will help Atlantic salmon populations to maintain resilience to rapid environmental changes.
- The artificial stocking of natural populations to augment abundance does not have the support of many in the scientific community as it is increasingly being shown that stocking negatively impacts the genetic variation and ability of Atlantic salmon to adapt to environmental change. If stocking is deemed necessary to preserve endangered populations, it should be conducted in a way that maintains genetic integrity and genetic variation.
- Maintaining or increasing cold water refuges as well as access to those habitats is an important strategy and was raised in several symposium presentations.
- Managing Atlantic salmon to meet the challenges posed by a warming ocean is a difficult task. Approaches that promote diverse populations to produce the maximum number of high quality wild smolts migrating to the ocean should be supported.
- Impacts of a changing climate have both local and global impacts, and populations in different regions will respond differently. Consequently, there is need for data from long-term monitoring programs to continually evaluate productivity estimates for both fresh and marine waters.

ADVICE – CHANGING CLIMATE

- Managers and conservation organizations need to promote strong, healthy, and resilient populations of local wild salmonids in rivers and estuaries in order to reduce the impacts of changing ecosystems. A primary strategy to achieve this is protecting the genetic integrity of stocks, enhanced water quality and habitat protection including improving access for salmon to important habitats, and

minimizing human impacts reducing growth and survival in rivers and coastal areas.

- Salmon management traditionally has focused on managing harvest and artificially stocking rivers to offset salmon mortality or population decline. In the face of a rapidly changing environment, management approaches and decision-making should be broadened to include ecosystem protection of rivers, estuaries and marine environments including water quality, habitat quality and other valued components of the ecosystem.

Impacts of salmon farming

Domestic Atlantic salmon are farmed in pens in coastal areas in many jurisdictions of NASCO. The distribution and production of salmon farming in the marine environment is projected to continue to increase. The numbers and tonnage of farmed salmon in aquaculture facilities in the North Atlantic are now far larger, by orders of magnitude, than wild salmon. Just one aquaculture sea site may for instance contain more farmed salmon than the annual pre-fishery abundance of wild Atlantic salmon returning to all of Norway.

Fish farming has had some of the greatest impacts on wild Atlantic salmon populations in several areas of their distribution. These impacts include mixing of escaped farmed and wild salmon during spawning, salmon lice infestations, and pathogen transmission and infectious diseases. The impacts of salmon farming, escaped domestic salmon, and lice and other pathogens were extensively covered at the 2017 Theme-based Special Session of the NASCO Council.

IMPACTS OF ESCAPED FARMED SALMON

Wild Atlantic salmon are genetically adapted to their local environment, the prerequisites for which are genetic variation and restricted gene flow of mal-adapted genotypes that break down the genetic integrity of natural populations. Due to intentional and unintentional domestication selection, farmed salmon is genetically different from its wild origin, and less adapted to the natural environment, particularly a rapidly changing natural environment. Genetic introgression of escaped domestic farmed salmon, therefore, represents a real threat to the viability of many wild salmon populations, as it breaks down local genetic adaptation by introgression of mal-adapted genotypes and changes important life history traits in impacted wild salmon populations.

Although only a small fraction of farmed salmon escape from their net pens, they can make up a large proportion of the salmon at the spawning grounds in rivers. For instance, in Norway, among 225 populations analysed so far, about two-thirds have been changed genetically due to genetic introgression from domestic farmed salmon.

The breakdown of genetic integrity and loss of genetic variation due to genetic introgression of escaped domestic farmed salmon adds to the effects of ecosystem alteration due to a changing climate - and is posing additional challenges to the viability of wild Atlantic salmon populations now and into the future.

PATHOGEN TRANSMISSION AND INFECTIOUS DISEASES

Large-scale intensive farming of domestic Atlantic salmon in open net cages in concentrated areas suffers similar challenges to intensive animal farming on land such as higher incidence of disease caused by parasites and pathogens. Within the fish farming industry, this has resulted in the emergence of several infectious diseases and widespread sea lice outbreaks. Pathogen and parasite exchange between wild and domestic farmed Atlantic salmon is a threat to wild Atlantic salmon populations in areas with open net pen farming.

CONCLUSIONS – IMPACTS OF SALMON FARMING

- Impacts of fish farming have become the greatest threats to wild Atlantic salmon in several areas of their distribution due to impacts of escaped farmed salmon, salmon lice and pathogens causing diseases.
- Infectious disease and pathogen incidence and parasite exchange between wild and domestic farmed Atlantic salmon are real threats to wild salmon in regions where salmon fish farming is conducted. However, our understanding of the impacts from pathogens and diseases is incomplete, and there is a risk that the impacts are underestimated.

ADVICE – IMPACTS OF SALMON FARMING

- **Aquaculture managers** need to have a strong focus on preventing any escape of farmed salmon from pens and/or consider using sterile salmon within their operations. They should reduce the mortality of wild fish caused by salmon lice and pathogens by implementing stricter disease and parasite control programs. This should be supported by rigorous monitoring and reporting to agencies concerning the prevalence of escapes and disease outbreaks.

Stocking

The deliberate release of hatchery produced salmon as a means to enhance salmon stocks has a long history and is practiced worldwide. Due to evidence of potential negative genetic consequences of stocking, the motivation for stocking Atlantic salmon has gradually shifted from enhancing population size for recreational fishing towards preservation of endangered populations. Hatchery and stocking activities have been covered in an earlier Theme-based Special Session of the NASCO Council in 2017.

Potential genetic consequences of stocking include:

- reduction of effective population size and loss of genetic variation due to a disproportionally large contribution of stocked individuals from a limited number of broodfish;
- breakdown of local genetic adaptation from the use of non-local broodfish;
- unintentional domestication selection of hatchery produced fish; and,
- epigenetic effects from the rearing of fish under artificial hatchery conditions.

ADVICE - STOCKING

- In light of current knowledge concerning the risk and benefits of stocking, all **agencies, managers and conservation organizations** involved in stocking to artificially supplement populations of any life stage, should adhere to the following principles:
    - Stocking with hatchery fish of any life stage to augment natural wild Atlantic salmon populations should be an action of last resort, after all other conservation activities have been tried (e.g. optimizing river habitat and water quality), and primarily for preserving endangered populations. If deemed necessary, after carefully evaluating the risks and benefits, stocking should be conducted in a way that minimises or eliminates potential negative effects and maintains genetic integrity and genetic variation of the wild population to the maximum extent possible.
    - If deemed necessary, stocking should only include the use of local, wild broodfish, emphasize stocking of early life stages, always minimizing time in captivity, and, balance the number of stocked fish to the number of broodfish and the number of naturally reproducing fish
    - In any stocking program, all hatchery produced fish of any life stage should be tagged in some way to be traceable and the effects of stocking should be evaluated.

Impacts of invasive alien species

Invasive alien species are non-native species that have become established outside their native range because they have arrived there deliberately or accidentally by human activity - and that are negatively impacting native biodiversity and ecosystem services. The International Union for the Conservation of Nature (IUCN) asserts that the spread of invasive alien species is the second most significant threat to global biodiversity, after habitat loss.

Throughout the range of Atlantic salmon, there are a number of introduced species, both fishes and other organisms, which may impact Atlantic salmon as competitors, predators, vectors of new pathogens that may cause diseases, or plants that alter aquatic habitats. Examples are Northern pike (*Esox lucius*), rainbow trout (*Oncorhynchus mykiss*), pink salmon (*O. gorbuscha*), Eurasian minnow (*Phoxinus phoxinus*), bullhead (*Cottus gobio*), Japanese knotweed (*Fallopia japonica*) and *Gyrodactylus salaris*. The impacts of many of

these alien species have not been studied and consequently are not well known. However, there is one alien invasive species, the parasite *Gyrodactylus salaris*, which has been studied due to its impact in northern European rivers.

G. salaris is a parasite that causes high mortality of juveniles in Atlantic salmon populations not adapted to the parasite. It has been one of the major threats to Atlantic salmon in Norway after it was introduced, but the parasite has been successfully eradicated from many rivers, and only seven of the fifty infected rivers are still infected. However, spreading of the parasite continues in Russia and on the Swedish west coast.

Other species in the same genus as Atlantic salmon can also be invasive alien species. Pink salmon is a salmonid native to the Pacific Ocean. Deliberate releases of pink salmon into rivers in north-west Russia have resulted in self-reproducing populations. In 2017, pink salmon were documented along coasts and in rivers in many countries in the North Atlantic. Based on present knowledge, it is difficult to predict the potential impact of invasive pink salmon on native salmonids, ecosystems and ecosystem services, but there is clearly a potential risk for negative impacts. As long as there is successful reproduction of pink salmon in rivers in northwest Russia and Northern Norway, every year there will be a pool of potential invaders in the Barents Sea and the Northeast Atlantic, with a risk of spreading and establishment in new areas under favourable conditions.

CONCLUSIONS – INVASIVE ALIEN SPECIES

- Invasive alien species have the potential to negatively impact Atlantic salmon. Knowledge of the ecological consequences or impacts of biological invasions is often gained after the introduced alien species have become well established. Once established, the impacts of alien invasive species can be severe and often expensive to reverse. This points towards a need for greater surveillance to identify new invasions as soon as possible to allow early mitigation and reversal if possible.
- Management measures available to reduce potential impacts of invasive pink salmon are to hinder pink salmon from entering the rivers, to catch as many pink salmon as possible before they can spawn or try to destroy their spawning redds before hatching. Such management measures involve a significant effort and possible negative consequences for native fauna.
- Mitigation measures to reduce the risk of establishment and negative impacts of pink salmon must be implemented through coordinated efforts over larger areas to achieve any long-term effect. Hence, mitigation efforts may only be efficient if regional and international collaboration and co-ordination to reduce pink salmon abundance can be achieved.

ADVICE – INVASIVE ALIEN SPECIES

- **Agencies, managers and conservation organizations** considering introductions or managing invasive species should consider the following principles:
    - Discourage any introduction, intentional or otherwise, of non-native species into salmon rivers;

- If established, invasive species should be eradicated where possible, and prevented from spreading when eradication is not feasible;
- Work with other organizations to ensure strong and healthy populations of local Atlantic salmon to mitigate the potential impacts of invasive species.

Freshwater habitat and water quality

Migration barriers, loss of rearing and spawning habitat and poor water quality have contributed to population declines and extirpations in large parts of the Atlantic salmon's range. Providing free passage for juveniles from their nursery grounds to the sea and for returning adults to reach their spawning grounds is necessary to support Atlantic salmon populations. The availability of suitable habitat and good water quality control the production of wild salmon from freshwater, both in terms of abundance and quality of individual fish, which impacts their subsequent sea survival.

The removal of dams and other physical barriers to salmon movement is now a well established conservation activity to improve and re-open habitat in salmon rivers. This activity requires much interaction and support from local communities in order to be successful. Moving forward, it is necessary to re-focus on restoration of watersheds and healthy ecosystems (rather than focusing on a single species that may be locally extirpated, like Atlantic salmon). This may resonate more strongly with local people and is key for building relationships with other stakeholders.

CONCLUSIONS – FRESHWATER HABITAT AND WATER QUALITY

In addition to discussing physical barrier removal, and warming water temperature effects, many presenters at the Symposium referred to the importance of improving or maintaining habitat quality and water quality as a front-line defense to mitigate the compounding effects of climate alteration on ecosystems and Atlantic salmon. While many in the scientific community are focused on understanding at-sea mortality, it is also important to identify smolt and post-smolt fitness as a potential concern and potential contributor to salmon declines. The quality of habitat and water in rivers including food availability mis-match and sub-lethal chronic impacts from other river stressors are areas that should be investigated to assist fisheries managers in developing appropriate protection measures.

Some other conclusions from this Symposium include:

- There is significant potential for further mitigation measures related to hydropower production, other river regulations and habitat alterations, and poor water quality throughout the distribution area of Atlantic salmon, which can

greatly increase production of Atlantic salmon, and improve quality of juveniles leaving freshwater, which in turn will help increase their sea survival.
- Restoration projects that require altering the landscape (e.g., dam removal) require addressing social concerns through a strong education, outreach, and engagement program and must be sensitive to local values and aspirations.

ADVICE – FRESHWATER HABITAT AND WATER QUALITY

- To optimize species productivity under future conditions **fisheries managers and conservation organizations** should ensure the highest number of wild smolts in the best condition leave from rivers and near-coastal areas to the ocean.

The marine phase of the Atlantic salmon

Atlantic salmon marine survival rates are variable across time and space. Atlantic salmon populations have declined over large parts of the distribution area during the last decades, and one of the reasons is reduced survival during their marine feeding and adult maturation migration. This could be a cyclic phenomenon, and salmon productivity could increase again; however, human induced climate change has also been implicated. As temperatures continue to increase over the next century, the outlook for Atlantic salmon in the North Atlantic is expected to be challenging.

Marine mortality rates vary geographically and seasonally and are typically more variable than freshwater survival. Marine mortality rates have a large influence on the number of salmon returning for spawning. It is assumed that the majority of marine mortality occurs during the first year at sea, but for multi-sea-winter stocks mortality during the second year can also be high. Marine survival rates are impacted by climate and ecosystem changes in the sea and by human activities in coastal areas such as aquaculture and power production. Also, the condition and quality of the smolts when leaving freshwater will impact marine survival.

The ability to identify and mitigate direct human-induced threats to salmon productivity across its marine range is generally available. However, natural mortality and mortality arising from indirect human activity (i.e., climate change) remains an intractable problem due to lack of information on the marine phase of the salmon, the size of the habitat, and the complexity of the ecosystem. This lack of information is one of the biggest problems we face in predicting the fate of Atlantic salmon in the longer term.

CONCLUSIONS – MARINE LIFE OF ATLANTIC SALMON

- At present, it is not possible to identify and implement management actions directly to counteract salmon declines due to climate and ecosystem changes in the ocean. The best management option in situations with reduced marine survival is to optimize species productivity under future conditions by supporting

approaches that promote production of a maximum number of high quality wild smolts from the rivers and near-coastal areas to the ocean.

- Reduced marine survival is, in many areas, partly due to stresses caused by human activities such as aquaculture and other activities in coastal areas, which can be mitigated by proper management measures.
- There is a need to increase knowledge on the migration routes and distribution areas in the marine phase, and on which factors that are impacting the marine growth and mortality. Such knowledge can help researchers identify importance of reduced sea survival versus human impacts and to predict annual returns of spawners for management, which at present is not possible due to lack of knowledge on marine mortality. These are complex research questions, which require data from large geographical areas and long-term research programs. Facilitating large, collaborative research programs will help improve this knowledge base.
- When recording marine survival from salmon that are leaving their natal rivers, it is important to collect data such that mortality due to impacts of smolt quality from human activities in the near-coastal areas can be distinguished from mortality that is a result of ecosystem and climate changes in the ocean.
- With declining Atlantic salmon populations, mortality from predation seems to be increasingly in focus. It is important that managers facilitate studies where the ultimate reasons for mortality are identified. Simply showing that a smolt is eaten by a predator does not necessarily mean that predation is the ultimate mortality factor. Predation may often be the end point of post-smolts in the sea, even though the ultimate reason for mortality may be one or several other factors. For instance, a post-smolt with a deadly infestation of salmon lice will likely be eaten by a predator before it dies from salmon lice. This fish would have eventually died from the lice infestation even in the absence of predators.
- Data collected by long term monitoring programs on all life stages of the species across its entire freshwater and marine range can be used by researchers to measure, compare and contrast population trends and are the essential ingredients for river and region specific informed management. These datasets will also be essential to retrospectively assess the impacts of a changing climate to forecast future impacts. Managers should encourage the continuation and possible expansion of such long term monitoring programs.

ADVICE – MARINE LIFE OF ATLANTIC SALMON

- **Fisheries managers and scientists** should continue studies to understand the magnitude and causes of mortality for Atlantic salmon during the marine phase of their life cycle to identify the importance of reduced sea survival due to ocean ecosystem effects versus human impacts in rivers and near-coastal areas and to predict spawner numbers for management. Such research must also include studies in the beginning of the sea migration (i.e. in estuaries and coastal areas).

Management according to biological reference points

Fisheries managers in different countries have used varying methods to establish conservation limits and evaluate whether conservation limits and management targets are met and developed. In the last two decades, there has been a trend in fisheries management, including the management of Atlantic salmon, to have a better biological foundation for determining conservation objectives based on species needs and capacity to sustain harvest.

Using this management approach implies that the scientific information needed to make management decisions is increased. There is a further need in many rivers and regions to increase monitoring and data collection on population abundance, as well as fisheries effort data.

Using biological reference points to establish conservation limits and management targets, fisheries management assessment processes have the potential to become objective and repeatable, with clearly specified management rules. This has provided a common language for managers, fishers, developers, politicians and scientists to discuss and agree on conservation goals and management objectives. Although improvements are happening, the translation of scientific methods and results, due to their complexity, to easily understandable language remains a challenge.

CONCLUSIONS – BIOLOGICAL REFERENCE POINTS

- Fisheries managers should be using biological reference points to provide the scientific foundation for fisheries management decisions.
- There are challenges related to the development of the reference points and to the methods used to assess whether they are reached - and to how the reference points are related to fisheries management and conservation objectives. Information about the methods used in various jurisdictions should to a larger extent be shared between scientists and managers at the international level.
- The use of catch statistics is, in many cases, the basis for monitoring and assessments of populations. Correct reporting of catches and well-functioning reporting systems are essential. Better catch statistics with the establishment of biological reference points are important activities for future management and conservation of Atlantic salmon.

ADVICE – BIOLOGICAL REFERENCE POINTS

- **Fisheries managers and scientists** should continue to meet and to augment the exchange of information and ideas on how salmon management related to biological reference points is done in different regions as a way to encourage greater consistency among the countries in the use of biological reference points, cataloguing habit types and amounts of different habitat. NASCO could facilitate such knowledge exchanges.

Managing salmon is managing people: Human dimensions

Most of the issues facing wild salmon are the result of human activities, either directly (e.g., overfishing; aquaculture; habitat destruction, etc.) or indirectly (e.g., climate change). In many cases, existing scientific knowledge of these issues is sufficient to develop potential solutions. However, as many speakers pointed out, our inability to implement timely and effective solutions is often hampered by socio-economic factors These include conflict of interest, lack of consensus, mistrust, diversity of environmental values and ethics, ineffective governance, failure to consider alternative perspectives (e.g., Indigenous perspectives), and difficulties in motivating governments, communities, and individuals to take appropriate action. Thus, restoration and conservation of Atlantic salmon require attention to the human dimensions from both scientific (i.e., understanding human values, attitudes, and behaviours) and management perspectives (i.e., applying human dimensions knowledge to developing and implementing solutions).

Salmon and people are intricately linked through complex social-ecological systems. The persistence of these systems, and the benefits they bring to humans, depend on these systems being resilient and adaptive. Many of the speakers discussed human dimensions that, if addressed, would help to strengthen the relationship between wild salmon and people and enhance our capacity to develop solutions, address constraints, take action, and increase the resilience and adaptive capacity of social-ecological systems in support of salmon conservation. These include: improving the engagement of stakeholders in decision-making; building relationships and increasing collaboration among stakeholders; improving science communication and outreach; exploring novel governance systems; better engagement of the public in salmon conservation through novel stewardship programs; and systematically building public and political will for conservation initiatives.

Representatives for indigenous people in Canada and Norway spoke at the conference, presenting their challenges, perspectives and solution. The importance and value of incorporating indigenous peoples and their knowledge and perspectives in salmon conservation was emphasized. For example, indigenous peoples' knowledge systems capture generational data that can include detailed observations about changes in environmental conditions, species abundance, and species behaviour. Given limits to government resources for data collection and monitoring, these additional knowledge systems make significant contributions to salmon restoration, conservation, and management. The indigenous perspective that "everything is connected, everything is one" was also discussed. This perspective is consistent with the western concept of social-ecological systems and further emphasizes the importance of embracing the notion that salmon conservation is ultimately a human endeavour that cannot be successful without understanding and incorporating human values, aspirations, and behaviours.

Conclusions – managing salmon is managing people

- Human dimensions are of great importance and need to be increasingly emphasised by managers aiming to conserve, restore and enhance Atlantic salmon populations. There is a need for better involvement of stakeholders and local communities, forums to solve management conflicts, clearer dissemination of scientific knowledge, and sound use of multiple knowledge systems.
- Coordinated and collaborative efforts involving all levels of government, environmental organizations, indigenous groups, academia, and interested members of the public, are needed to mitigate human impacts on salmon populations.
- Improving trust and dialogue is essential in these processes. Forming strong networks based on repeated interaction and collaboration can help to build trust. Many concerns are based on a lack of information, which can be addressed through education and dialogue.
- Direct interaction between humans and salmon is needed to succeed in the conservation of salmon. When the resource is reduced or lost, fisheries are reduced and lost, people lose their connection with salmon, and awareness of the species and its conservation is diminished. Better understanding of the broader social, cultural, and economic value of salmon, and connecting and integrating these values to management and engagement actions, are critical to salmon conservation overall.

Advice – managing salmon is managing people

- Managers, scientists, conservation organizations and governments should recognise that people are a critical element of the conservation process. Addressing human dimensions requires incorporation of traditional and local knowledge and indigenous perspectives in activities related to salmon science, conservation and management.

Conserving salmon in a changing world: Recommendations to NASCO

The objective of NASCO is to conserve, restore, enhance and rationally manage Atlantic salmon through international co-operation taking account of the best available scientific information. NASCO has an important role in bringing together countries, as well as non-governmental organisations, and indigenous peoples to work collaboratively in support of salmon. To have an inter-governmental body where people from governments and organisations meet, and where the Parties are reporting to NASCO, has substantially changed and improved salmon conservation during the last decades.

Since its inception, NASCO has broadened its initial focus of limiting fishing on the high seas to developing guidelines or agreements on the precautionary approach; habitat protection and restoration; aquaculture, introductions, transfers and transgenics; stock rebuilding, and relating socio-economic factors to the precautionary approach.

Within that context, the IYS Symposium Committee has identified a numbers of areas where NASCO could either start new initiatives, update and modernize existing guidelines, work with the Parties, or facilitate the development and dissemination of information to promote the future conservation of Atlantic salmon:

1. To remain relevant in a period of rapid environmental and social change NASCO needs a renewed strategy to respond to the challenges facing wild Atlantic salmon. To begin this process NASCO should specifically identify strategic activities to deal with climate change and its cascading effects on salmon and salmon habitat, possibly by updating its 2005 "Strategic Approach for NASCO's 'Next Steps".
2. Given the advances that have been made in the last 15 years in understanding genetic effects of artificial population supplementation, i.e. stocking, and given the conclusions of the 2017 NASCO "special session on Understanding the Risks and Benefits of Hatchery and Stocking Activities to Wild Atlantic Salmon Populations", NASCO should immediately update its 2004 "Guidelines on the Use of Stock Rebuilding Programmes in the Context of the Precautionary Management of Salmon Stocks" with reference to the summary of advice given above (No. 4).
3. Given the importance of habitat and water quality conservation as a key strategy to conserve salmon into the future, NASCO should update its 2010 "Guidelines for the Protection, Restoration and Enhancement of Atlantic Salmon Habitat". Updated guidelines should not only consider the physical environment and include estuaries but should also seek to optimize water quality by considering the chemical and biological quality (e.g. toxic substances, diffuse agricultural pollution, persistent organic pollutants) as well as availability and distribution of prey in the future.
4. Given the advances in the understanding of human dimensions and the importance of incorporating indigenous and local knowledge into salmon conservation, NASCO should update and modernize its 2004 "Guidelines for Incorporating Social and Economic Factors in Decisions under the Precautionary Approach". This update should include recent advances in human dimensions and the incorporation of traditional and local knowledge and indigenous perspectives.
5. Recognizing the importance of salmon to indigenous peoples and the role that indigenous peoples play in salmon conservation, NASCO should improve the participation of indigenous people in NASCO.
6. NASCO should continue efforts, begun under the International Year of the Salmon, to raise global awareness about the status of wild Atlantic salmon, the threats they face, potential solutions, and actions that can be taken.

7. NASCO should facilitate co-operation between Parties when there is a need for international collaboration to prevent or reduce the threat to salmon stocks from invasive species.
8. Given the continued impacts of domestic salmon farming on wild salmon, NASCO should strengthen compliance to the agreed international goals of "100% farmed fish to be retained in all production facilities and, 100% of farms to have effective sea lice management such that there is no increase in sea lice loads or lice-induced mortality of wild salmonids attributable to the farms". This is as stated in the 2009 "Guidance on Best Management Practices to Address Impacts of Sea Lice and Escaped Farmed Salmon".
9. NASCO should establish a new goal to prevent the spread of disease pathogens from fish farms to wild fish consistent with the existing goals on containment and sea lice in the 2009 "Guidance on Best Management Practices to Address Impacts of Sea Lice and Escaped Farmed Salmon", and the 2016 "Theme-based Special Session: Addressing Impacts of Salmon Farming on Wild Atlantic Salmon".
10. Given the need to identify the importance of reduced sea survival due to ocean ecosystem effects versus human impacts in rivers and near-coastal areas and to predict spawner numbers for management, NASCO should support and continue to encourage research on mortality for Atlantic salmon at the beginning and the end of the marine phase of their life cycle in estuaries and near-coastal areas as well as on the high seas.
11. Given the success of this Symposium and the positive feedback the Committee has received from participants, NASCO should consider hosting similar events in the future.

CONCLUSION – CONSERVING SALMON IN A CHANGING WORLD

This Symposium has demonstrated that the effects of climate change on Atlantic salmon are already evident, and that impacts on salmon and their environments will increase into the future. In general, one of the key themes to emerge from the symposium is the need for adaptation – by salmon, people, and institutions. In today's rapidly changing ecological, social, and political environments, it is imperative for NASCO - the world's only international body focused on the conservation and survival of Atlantic salmon - to remain adaptable and engaged in the activities that are necessary to ensure the survival of wild Atlantic salmon. This symposium and the resulting recommendations outlined above are intended to assist NASCO in this regard. Furthermore, the steering committee urges NASCO to engage in an on-going process of self-reflection and evolution to ensure the organization remains a relevant and effective forum for the conservation of wild Atlantic salmon.

ANNEX: SYMPOSIUM STEERING COMMITTEE

The Steering Committee for this Symposium was created by NASCO with the following mandate: '*The Council accepted a proposal from Norway, CNL(17)19 to hold an IYS symposium in conjunction with the 2019 Annual Meeting. The symposium would be entitled 'Managing the Atlantic salmon in a rapidly changing environment – management challenges and possible responses'. The Council agreed that each Party and the NGOs should be asked to nominate one person to serve on the Symposium Steering Committee by the end of August 2017. The Committee should report back prior to the 2018 Annual Meeting. The Committee should develop the programme and make the arrangements for the symposium. This symposium, at a North Atlantic level, is in addition to the major event to launch the IYS*'.

The Committee had its only face-to-face meeting in November 2017 in Trondheim, Norway to begin planning the Symposium. All other planning meetings were done via conference call and video call.

Members of the Steering Committee were:

- Eva Thorstad (Norway)
- Doug Bliss (Canada)
- Kim Damon-Randall (United States)
- Emma Hatfield (NASCO)
- Grant Horsburgh (EU)
- Heidi Hansen (Norway)
- Niall Ó Maoiléidigh (Ireland)
- Steve Sutton (NGO)