20 December 2007

Report of the External Evaluation Panel on the Salmon Research Program of the Finnish Game and Fisheries Research Institute, Finland

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Executive Summary

An independent Evaluation Panel composed of the three authors of this report met in Helsinki in September 2007 to evaluate the salmon research program of the Finnish Game and Fisheries Research Institute (FGFRI or the "Institute"). The Panel met with many Institute researchers as well as people in management agencies and the fishing community who routinely request scientific information from the Institute. Overall, the Panel was impressed by the high quality of research being conducted, as well as its usefulness in providing advice on a wide range of salmon problems. Not only does salmon research and monitoring at the Institute have a strong applied focus that makes its results directly relevant to answering key management questions, but it is also conducted using the most advanced methods available.

Salmon research topics at the FGFRI include, but are not limited to, (1) scientific evaluation of potential outcomes of proposed management regulations, (2) improving selective fishing technologies, (3) identifying separate salmon stocks in mixed-stock fisheries to reduce the chance of overharvesting the less productive wild stocks, (4) conducting research on freshwater habitats, (5) understanding factors affecting mortality of salmon in nature, including causes of high post-smolt mortality in the ocean, (6) improving survival of hatchery-reared fish, and (7) conducting collaborative research on economic and social indicators related to salmon. In addition, Institute scientists play active and leading roles in the international fisheries community and are also legally mandated to annually report statistics and develop responses to directives and inquiries posed by the European Union and ICES. Sometimes these requests can be very extensive and time consuming. Furthermore, as chairs and members of working groups in international organizations, Institute scientists must report catch information as well as data on the status of Finnish salmon stocks.

Fisheries managers and other "clients" of the Institute's research are receiving high-quality salmon stock assessment advice from scientists at FGFRI. These scientists use sophisticated methods of data collection and analysis to take into account both the complexity of aquatic systems and the large, unavoidable uncertainties inherent in the data. For instance, the Institute's researchers in salmon stock assessment have developed and applied Bayesian statistical methods in collaboration with university researchers to take into account such uncertainties. These methods are recognized internationally as the most advanced techniques available anywhere in applied fisheries science. To their credit, 15 Institute scientists have also continued to increase their knowledge by completing Ph.D. degrees in the last 10 years.

The Institute's salmon research and monitoring work is aimed at providing scientific advice to support well-informed decision making or at creating a necessary and solid foundation on which such high-quality scientific advice is built. There is no extraneous research being conducted. This is a very critical point during the coming period of financial restraint. To maintain the high level of advice from the FGFRI, any reductions in the Institute's research budget must be offset by increased contributions from funding partners in other institutions, countries, and industries. If this is not done, then the Ministry of Agriculture and Forestry, the EU, ICES, user groups, and other "clients" must be prepared for a reduction in the amount and quality of scientific advice from the Institute, as well as longer delays in responding to requests for advice.

We use an example to illustrate how past research at FGFRI has contributed to changes in management regulations that have directly created social and economic benefits for the people of

Finland. This example is from the wild salmon populations of the Tornionjoki and Simojoki, both of which drain into the Baltic Sea near the border with Sweden and which were previously at very low abundance. Research at FGFRI and in Sweden on these populations and on fisheries in the Baltic led to new national regulatory measures. That research also stimulated the International Baltic Sea Fishery Commission to create the "Baltic Salmon Action Plan (SAP)", which recommended stricter international fishing regulations. This combination of new regulations in turn led to a remarkable recovery in abundance of those wild salmon populations in the late 1990s and a recovery in catches. Essentially, the greater abundance of survivors enabled the Tornionjoki and Simojoki populations to rebound quickly when favorable environmental conditions occurred during that period. Without such science-informed changes to fishing regulations on mixed salmon populations, the total salmon fisheries catch in the Baltic would likely be much less than it is today.

Although the Panel concluded that FGFRI's salmon research is very high in quality and reflects the needs of managers and other stakeholders, we make 24 recommendations to further improve salmon research and to suggest ways in which the funding of research at FGFRI can be shared by other groups and institutions. Among other things, these recommendations emphasize the need to continue long-term research programs on critical questions and on important salmon populations, to more broadly apply new methods of analysis with which the Institute already has some experience, and to help decision makers by quantifying the trade-offs among user groups that are implied by different management options. Several other recommendations reflect the difficult financial environment that the Finnish government faces in the future by suggesting ways in which funding of FGFRI research programs could be shared with universities, hydro-electric power companies, and salmon user groups. Such partnerships will help ensure that the salmon populations of Finland continue to produce substantial benefits to people in all regions of Finland.

The Panel's specific recommendations for the Institute are as follows. Detailed background information and justification for each recommendation are provided later in this document (see the "Complete Panel Report").

Recommendations for research

1. Continue conducting research on wild salmon populations to understand their dynamics and thereby improve scientific advice on this most important segment of salmon fisheries.

2. Maintain research aimed at understanding the relative importance of different causes of post-smolt mortality of wild as well as hatchery fish in both the Baltic Sea and North Atlantic Ocean.

3. Conduct research to improve strategies for the production and release of smolts.

4. If fisheries managers are going to restore freshwater habitats for salmon and/or improve access to streams by building fish ladders or by-passes around dams (for example), then FGFRI scientists should help by designing such actions so that they are implemented in an experimentally designed manner.

5. Apply a comprehensive Bayesian modelling approach to another complex issue in the salmon life-cycle, the "M74 salmon-mortality syndrome".

6. We strongly recommend that the long-term biological sampling programs for salmon on the rivers Tornionjoki and Teno be continued.

7. Investigate how costs of particular research programs could be shared with other countries, EU institutions, hydroelectric power companies, universities, non-profit conservation organizations, and various stakeholders, including fishermen.

8. Increase efforts to find out what has been done elsewhere in the world in salmon situations similar to those faced in Finland.

9. Given the potential for cuts to the FGFRI budgets, scientists should conduct analyses now to determine how the quality and the types of their scientific advice to managers and stakeholders might be affected by particular cuts to specific research programs.

10. Extend the genetically-based stock-identification work to apply to all Baltic salmon stocks (and also anadromous trout, if possible), as well as the rivers Teno and Näätämö that drain into the North Atlantic.

11. We encourage scientists at FGFRI to continue to publish their research in high-quality journals, to present papers at international conferences, and to obtain a Ph.D. degree if they do not yet have one.

12. Descriptions of current research projects in the Institute and past findings need to be communicated more effectively and more widely than at present.

13. As part of their normal analyses, FGFRI scientists should help decision makers by quantifying, where possible, the unavoidable tradeoffs between indicators of different management objectives.

14. FGFRI scientists must conduct research to enable Finland to comply with the European Union's WFD (Water Framework Directive).

15. Consider doing more research on sea trout.

16. Expand the application of Bayesian methods of analysis.

17. Extend the research on fish stocking, but seek funding from non-government sources.

18. Continue stream-habitat research, but rely more heavily on universities on this topic.

19. Continue research on the M74 syndrome and expand research on environmental toxins.

20. Continue genetic research, but rely more heavily on universities on this topic.

21. Maintain as a high priority the research on technical regulations for salmon fisheries management.

22. Explore new salmon fishing technologies in collaborations largely funded by fishermen.

23. Encourage interdisciplinary research with other partners.

24. Continue applying expertise in international settings.

Conclusion

We expect that the excellent research being conducted by salmon researchers at FGFRI will continue to be needed as managers, fish harvesters, and international organizations deal with conflicting demands on freshwater resources, maintenance of productive wild salmon populations, restoration of depleted populations, and allocation of salmon catches among user groups (among other problems). By following the 24 recommendations that we make here, we anticipate that the salmon research programs of the FGFRI will continue to increase scientific knowledge and ensure that user groups and decision makers are well informed. We hope that with the support of the Finnish government, the Institute will also be able to meet the challenge of potential budget constraints by developing creative ways to share funding for its research and the resulting scientific advice with other institutions and groups that benefit from that knowledge.

Complete Panel Report

Purpose of the External Review

This External Review of salmon fisheries research at the Finnish Game and Fisheries Research Institute (FGFRI) in Helsinki was conducted at the request of Dr. Petri Suuronen, Research Director. The purpose of the review is best described by quoting the background document provided by FGFRI to the external reviewers:

> "With the generally declining (governmental) research funding it is necessary to allocate these research resources into right purposes and to use best possible research methodologies and approaches. This evaluation is conducted to obtain an independent opinion about the quality and relevance of our work in salmon research and monitoring, and to have an external opinion where to go in our salmon research. It is hoped that this evaluation will help the Fisheries Research Unit to optimally focus its future research activities on the most relevant issues and at the same to further improve the quality of its research and advisory work."

How the Review Was Conducted

The three members of the External Review Panel (henceforth, simply called the "Panel") are listed on the title page of this report. On 1 July 2007, the Panel received a draft background document "Salmon research and monitoring in the Finnish Game and Fisheries Research Institute: Background information for the international evaluation in 2007". Panelists were requested to ask the Institute for additional information to add to this document. We did so, and after the document was revised, the Panel then received the final 50-page background document on 31 August 2007.

The Panel then met in Helsinki and had extensive question-and-answer sessions with some of the Institute's scientists (all day on Sunday the 23rd of September) and various "clients" of the Institute's research (on the 24th and 25th of September). These "clients" included Mr. Orian Bondestam (Senior Officer with the Department of Fisheries and Game in the Ministry of Agriculture and Forestry), Mr. Jari Leskinen (Fishing Biologist with the Employment and Economic Development Centre for Lapland, Rovaniemi), and Mr. Sakari Seppälä (Chief of City Planning in Kotka and member of an active group of salmon anglers). "Clients" from other groups were invited but could not attend. One of us (Randall Peterman) also met with scientists at the Institute's field station on the Teno River in Utsjoki to obtain a first-hand look at research there.

The three Panelists then met late on the 25th of September 2007 to discuss and draft an initial outline of ideas for this Report. The Panelists also received numerous publications from Institute scientists. Subsequent to that meeting, the Panel received from Dr. Petri Suuronen, Fisheries Research Director at the FGFRI, an additional document dated 15 October 2007 that provided further background on activities of the Institute's fisheries staff. Over the next two months, the Panelists reviewed this material and wrote the conclusions and recommendations given below. Here, the Fisheries Research Unit of the Finnish Game and Fisheries Research Institute will be referred to interchangeably as either the FGFRI or simply "the Institute".

Background comments

The Panel concluded that scientific research on salmon at the Institute covers an impressive array of fields and is generally of very high quality. This conclusion is based on the Institute's use of methods that are internationally recognized as being at the leading edge of techniques available anywhere in the world. Research and monitoring topics range from population dynamics and scientific evaluation of potential outcomes of proposed management regulations, to improving selective fishing technologies, stock identification in mixed-stock fisheries, research on freshwater habitats, stocking of hatchery-reared fish, identifying causes of high post-smolt mortality of salmon, and conducting collaborative research on economic and social indicators related to salmon. In addition, Institute scientists play active and leading roles in the international fisheries community through contributions to the North Atlantic Salmon Conservation Organization (NASCO), the European Union (EU) Commission, the Baltic Sea Regional Advisory Council (BS RAC), and the International Council for the Exploration of the Sea (ICES) and its working groups such as the Baltic Salmon and Trout Assessment Working Group (WGBAST) and the Working Group on North Atlantic salmon (WGNAS). In fact, due to their reputation for conducting high-quality research, Finnish salmon scientists often lead fisheries working groups. For instance, the two out of three most recent Chairs of the ICES Baltic Salmon and Trout Assessment Working Group were FGFRI scientists. As well, Institute scientists are legally mandated to annually report statistics and develop responses to directives and inquiries posed by the EU. As chairs and members of ICES working groups, Institute scientists have to report catch information as well as other data on salmon stock status to the Working Groups. Sometimes those requests can be very extensive and time consuming.

Fisheries scientists at the Institute are also conducting research of excellent quality that is directly relevant to management problems. The quality of this work and the Institute's goal of continuous improvement is demonstrated by several factors. First, the Institute's research is mainly published in peer reviewed scientific journals, many of which are among the top-quality fisheries journals in the world (e.g., the Canadian Journal of Fisheries and Aquatic Sciences). Second, advanced methods of analysis are required because good scientific advice relevant to fisheries managers must take account of complexity of aquatic systems and large, unavoidable uncertainties inherent in data. The Institute's researchers in stock assessment developed and applied Bayesian statistical methods in collaboration with university researchers. Those methods are recognized internationally as the most advanced methods available in applied fisheries science for taking such uncertainties into account. Thus, fisheries managers and other "clients" of the Institute's research results are getting the most sophisticated salmon stock assessment advice possible from scientists at FGFRI. Third, 15 Institute scientists have completed their Ph.D. degrees in the last 10 years, which reflects an extensive effort to improve their scientific knowledge.

Not only does the fisheries research at the Institute reflect the most advanced methods available, but it has a strong focus on applied research that is directly relevant to answering key management questions. In other words, there does not appear to be any "frivolous" research; it is aimed at providing good scientific advice for well-informed decision making. This is a very critical point during this period of financial constraint. Any proposed reductions in research budget to the Institute must be offset by increased contributions from partners in other institutions, countries, and industries, or, if this is not done, then the Ministry of Agriculture and Forestry, the EU, ICES, and other "clients" must be prepared for a reduction in the amount and

quality of scientific advice from the Institute and longer delays in responding to requests for advice from FGFRI scientists.

It is also useful to illustrate how past research at FGFRI has contributed to changes in management regulations that have directly created social and economic benefits to the people of Finland. The first example is from the wild salmon populations of the Tornionjoki and Simojoki, both of which drain into the Baltic near the border with Sweden. The Tornionjoki is the major producer of salmon smolts to the Baltic stock of Atlantic salmon found in this area and thus these populations are very important components of the total salmon catch in the Baltic. Of outstanding importance is the estimation of the annual wild smolt production in the Tornionjoki, which has created a time series of data that helps managers to understand and predict problems with the returning parental stock. During the last decades, both salmon populations were at low abundance, with the Simojoki population being close to extinction. Research at FGFRI and in Sweden on these populations and fisheries in the Baltic led to new national regulatory measures. That research also stimulated the International Baltic Sea fishery Commission to create the "Baltic Salmon Action Plan (SAP)", which recommended stricter international fishing regulations. Those regulations in turn led to a remarkable recovery in abundance of those wild salmon populations in the late 1990s. The greater abundance of survivors enabled the Tornionjoki and Simojoki populations to rebound quickly when favorable environmental conditions occurred during that period. Without such science-informed changes to fishing regulations on mixed salmon populations, the total salmon fisheries catch in the Baltic would likely be much less than it is today, particularly given the recent poor survival rate of hatchery-reared smolts and post-smolts in coastal areas. A second example of the value of past research at the Institute is work on identification of origin of stocks of salmon, based both on scale analyses and genetics. That work contributed to adjustments in the timing and location of mixed-stock fisheries. Those adjustments have reduced the interception of certain salmon populations and enabled more of those fish to reach coastal and in-river fishing areas. The Teno system in the north is a third example of this direct link between FGFRI research and changes in management regulations. This river with all its tributaries support many wild salmon populations, and presently the total recorded salmon catches in this system are the highest in the Atlantic. One notable point with the wild salmon population in the River Teno is that no hatchery-produced fish has been released in the system. Extensive research efforts in this river system have led to considerable new information which will benefit the management of salmon. For example, the time series on parr densities over many years has given insight into the factors that affect the production of juveniles, as well as the genetic sub-structure of the Teno stock. The latter information enabled development of the first conservation limit estimates. Extremely few studies on salmon stocks related to genetic structure and juvenile production exist in catchments relatively unaffected by humans. These studies will be very important for the future understanding of salmon management where conservation is one important target.

Recommendations for research

In the remaining sections of this report, we make 24 specific recommendations. Each recommendation below is addressed to members of the Institute and is followed by a brief justification of our reasoning. We are confident that most of our recommendations are based on a sound understanding of the Institute's salmon research and monitoring programs.

1. Continue conducting research on wild salmon populations to understand their dynamics and thereby improve scientific advice on this most important segment of salmon fisheries.

Justification: Commercial salmon fisheries in the Gulf of Finland, the Bothnian Sea, and Bothnian Bay are now almost totally reliant on productive wild salmon populations. Post-smolt marine survival of hatchery-reared fish has decreased substantially since 2000 and these reared fish now contribute a minority of fish caught; most are wild salmon. Therefore, there is considerable potential for improving economic and social benefits to the people of Finland by increasing the emphasis on research and management actions on wild salmon populations.

2. Maintain research aimed at understanding the relative importance of different causes of post-smolt mortality of wild as well as hatchery fish in both the Baltic Sea and North Atlantic Ocean.

Justification: The overall goal of this recommendation is to help increase the survival rates in the ocean of post-smolt salmon from both wild and hatchery stocks. Well-justified management decisions to achieve that goal require sound scientific advice. A fundamental foundation for such high-quality advice is research that considers evidence about alternative hypotheses that might possibly explain changes observed in the past. For example, there currently are debates about the causes of low survival rates of salmon post-smolts in the ocean. Some people believe that unfavorable oceanic conditions have led to poor survival. Others believe that increasing predation by seals is to blame. However, only a rigorous scientific research program, such as is usually carried out by FGFRI scientists, will be able to provide sound conclusions about the relative importance of these and other factors in the low survival rate of salmon observed recently. It is also worth noting that the SALSEA (Salmon at Sea) research program has now been approved by the EU. The main purpose of this research program is to enhance the knowledge about salmon in the ocean and to understand the causes of the reduced marine survival of Atlantic salmon. Finnish scientists participate in this project. Note that such research is also of interest to other countries in the ICES region who are not partners in the program. Therefore, expenses could justifiably be shared with them.

3. Conduct research to improve strategies for the production and release of smolts.

Justification: The intention here is to reverse the recently observed decrease in marine survival rates of hatchery-reared smolts. The smolt production in hatcheries started in the early 1950s when there was a need to compensate for the loss of wild salmon and sea trout production when watersheds were used to generate hydro-electric power. Methods for such hatchery production of salmon smolts mainly started, and were refined, in Sweden. During the last decade the smolt production in controlled environments in hatcheries has undergone a dramatic change, with new feed, feeding techniques, tank designs, etc. This has resulted in relatively large smolts being released at present from Swedish and Finnish hatcheries. The production of smolt-sized juveniles after just one-year of growth in northern hatcheries has thus increased substantially. Research on smolt production in hatcheries that target questions related to the importance of size, early sexual maturation among smolts (males) and the timing of migration is essential to understand why hatchery-smolts today do not survive well after release. For instance, we have limited understanding of how improved growth in hatcheries will affect the seasonal timing of migration of juveniles once they are in the ocean. The hatchery component in the mixed-stock fishery of salmon in the Baltic is very important for the economy of coastal/sea fishermen in all Baltic countries. More information on this topic is provided below under recommendation 16.

4. If fisheries managers are going to restore freshwater habitats for salmon and/or improve access to streams by building fish ladders or by-passes around dams (for example), then FGFRI scientists should help by designing such actions so that they are implemented in an experimentally designed manner. Some FGFRI scientists already have developed expertise with such designs (e.g., before/after-control/impact designs) and they should be able to provide advice to managers and others who are considering such actions.

Justification: Despite the best of intentions, fisheries managers around the world commonly face situations in which new management actions have been implemented that have unexpected and undesirable results. For instance, increasing early-lifestage survival rates of some North American salmon populations through hatchery rearing and controlled flows in spawning areas indirectly led to overfishing of less productive wild populations that were caught in the same mixed-stock fisheries that targeted the more productive hatchery-reared populations. Such counterintuitive outcomes result from incomplete understanding of the dynamics of human and aquatic systems. In many other cases where management actions have been taken, it is difficult to rigorously determine the effectiveness of those actions because other factors changed at the same time (e.g., environmental conditions, composition of gear-types in the fishing fleet, fishing effort, between-year variation in timing of spawner returns and migration routes in the coastal areas, etc.). Thus, the interpretation of any observed changes in target indicators such as catch or abundance of juveniles or spawners is confounded by those changes in other factors that were not under the control of managers.

The most effective way to rigorously conclude whether some management action worked as planned is to carry out some small-scale trial (where possible) and if successful, implement the action on a larger scale in the context of a well-designed experiment. That means either having "control" situations that operate under the old conditions and "treatment" situations that use the new actions (e.g., fish ladders), or "contrasting treatment" designs that apply different levels of the action (e.g., changing water flows over fish ladders by 20%, 50%, and 80% in each of three places or periods). Good data on the system prior to, as well as after, implementation of any new actions is also essential. The widely used before/after-control/impact (BACI) designs are directly applicable in this type of situation, and it is clear to the Panel that FGFRI scientists have experience with using such designs.

5. Apply a comprehensive Bayesian modelling approach to another complex issue in the salmon life-cycle, the "M74 salmon-mortality syndrome". This M74 syndrome results in very poor survival of yolk-sac fry in fresh water, but its causes are unclear. The Bayesian modelling approach that FGFRI scientists used recently on salmon spawner and adult recruit data appears to be a very promising method to synthesize into one framework of analysis the complexities and large uncertainties about causes of the M74 syndrome. The purpose of this research should be to create a method for forecasting (with clear probability intervals) the M74 levels about 2 years in advance so that appropriate management actions can be taken to reduce effects of the syndrome. This work could either be conducted by focusing only on M74, or by adding it to the existing Bayesian modelling framework on salmon life-cycle population dynamics. Furthermore, as more becomes understood about post-smolt mortality, its components could also be added to the Bayesian framework that explicitly models the effects of numerous uncertainties.

Justification: Although effects of the M74 syndrome are relatively small at present, they were very large in the past, resulting in extremely low return rates of adult salmon. This problem

may reappear in the future, as it has unexpectedly done elsewhere. The cause of the M74 problem is not clearly understood due to many complexities and uncertainties. Time series data are available on the occurrence of the syndrome both from Finland and Sweden. It has been suggested that a diet dominated by sprat during the winter feeding of salmon in the main Basin is a causal factor for the syndrome observed on returning adults in northern rivers. Because sprat is the dominant prey for salmon only in limited areas of the Baltic, spatial distributions and migration routes of salmon may thus be important keys to understanding the M74 phenomenon. Nevertheless, there are many other hypotheses about factors affecting M74, and none of them has been clearly implicated as the cause of this syndrome. Because the potential economic and biological costs are so high, it is important to make efforts to improve the chance of predicting the future occurrences of the M74 problem. It would be beneficial to collaborate with both university and government scientists in countries that are working on similar problems (e.g., Sweden and Canada).

6. We strongly recommend that the long-term biological sampling programs for salmon on the rivers Tornionjoki and Teno be continued. Such long-term series are rare but are essential for rigorously identifying the major sources of future changes in survival rates and abundance, and for determining whether they arise mainly in fresh water or the ocean. Such results will thus help identify what can be done to correct for problems. These long-term data sets on the rivers Tornionjoki and Teno are also crucial for advising managers on allowable harvest rates, times and places for fishery openings, types of fishing gear to allow, potential productivity, etc.

Justification: The value of these long-term programs is now becoming clear. Information on salmon from the Teno, one of the most important salmon rivers emptying into the Atlantic, was sparse until Finnish scientists started to collect and publish information on salmon life history in this river. Due to the flexibility in life history strategies and geographical variation of salmon, studies at these northern latitudes near the distribution limit of the species are very important, and will add more knowledge about Atlantic salmon in general, and about their response to climatic change in particular. To study the abundance of juvenile salmon, an annual monitoring program has been carried out for over 25 years using electro-fishing at the same time and locations each year. This work was conducted in parts of the main stem of the Teno and some of its tributaries. This has given information on parr densities and has thus indicated changes in juvenile abundance. Institute scientists have started to use a combination of field data and habitat models to define reference levels for habitat conditions required by juvenile salmon. They have also extended the study of juvenile abundance to include adult salmon. Catch statistics and data on angling effort have also been collected from the fisheries on the Teno. Together with analyses of scale samples and other biological information, these linked freshwater and marine research projects have provided a significant advancement in the understanding of the salmon in that region. This research has also shown that Teno salmon have a very complicated age structure, which has been shown in Alaska to be an important feature that permits groups of salmon populations to remain productive in the presence of changes in climate. Furthermore, recent analyses of the data has indicated the potential of using the time series from the juvenile monitoring and catches of 1 and 2 SW salmon of the same cohort to forecast salmon runs.

Earlier in this report under "Background comments", we mentioned the importance of the long-term research on juvenile salmon abundances on Tornionjoki. Rather than repeat the demonstrated value of that research program here, we will merely emphasize that, like the long-

term program on the Teno, the management and understanding of Tornionjoki salmon have benefited considerably from that research and it should be continued.

7. Investigate how costs of particular research programs could be shared between FGFRI and other countries, EU institutions, hydroelectric power companies, universities, non-profit conservation organizations, and various stakeholders, including those who buy fishing licenses (the last source is analogous to the system in the United States where a portion of the cost of each fishing license goes into a fund for research). Such cost-sharing could be done through strategically and creatively designed collaborative research projects. One example could be where boat-time could be donated by fishing groups. Appropriate senior Finnish government officials should also be encouraged to discuss the benefits of sharing the costs of research on border rivers with governments from other countries (Norway and Sweden).

Justification: At present, costs are not shared equitably with Sweden and Norway, which benefit from salmon from rivers bordering Finland. FGFRI is currently paying most research costs on Teno River Atlantic salmon in the north, which has Europe's largest wild Atlantic salmon population. Although people in Norway benefit from this healthy population, Norway currently provides little funding to support FGFRI research. A similar situation exists for the Tornionjoki, where Finland conducts most of the research and yet Sweden also benefits. Thus, in both cases of these border rivers, Finland is taking the major responsibility for funding and conducting research.

A potential cost-sharing opportunity, this time within Finland, deals with the so-called "compensatory releases" of hatchery-reared juvenile Atlantic salmon, which are carried out annually to at least partially compensate for the detrimental effects of hydro-electric dams on wild salmon populations. It is therefore reasonable to expect that the hydro-electric power companies should pay most of the costs of FGFRI's research and monitoring projects conducted in support of those smolt releases. However, the hydro companies currently pay very little of these costs. Under the "Justification" section of Recommendation 8 below, we give some examples of cases elsewhere in which hydro-electric power companies fund such efforts.

We also recommend that strategically planned and creative collaborative research projects be created to address co-management of salmonids stocks in the Gulf of Bothnia area because Finland and Sweden are the only two nations controlling the major migratory stocks in this region (both wild and hatchery salmon and sea trout). As well, since Sweden and Finland together have a responsibility for the future of the salmonid production in the Tornionjoki and related river and coastal fisheries, it would be beneficial if, through bilateral negotiations, both countries could agree to pay on an equal basis for the basic salmon research used in the management process of this important stock.

8. Increase efforts to find out what has been done elsewhere in the world in salmon situations similar to those faced in Finland. For example, what has been learned in other regions about improving survival rates of hatchery-reared juvenile salmon and about increasing the support and collaboration of hydro-electric power companies? Answers to these questions might make the Institute's research more cost-effective.

Justification: As mentioned near the start of this report, the External Review Panel was impressed by the high quality and rigor of research at the Institute, which meets the highest international standards. Nevertheless, the Panel recommends that Institute scientists seek to learn more from what has been done by fisheries scientists and managers elsewhere to solve some of

the problems that FGFRI faces. This can be done either through personal contacts or more extensive review of publications. Several examples illustrate this point.

a. Survival rates of juvenile chum salmon (*Oncorhynchus keta*) released from hatcheries in Japan were very poor in the 1950s and 1960s when such programs were relatively new. However, through intensive research and experimentation, Japanese scientists were able to greatly increase survival rates of the juveniles and therefore also increase catches from a given number of released juveniles. Subsequent experiments in western North America and with Atlantic salmon in the Atlantic and the Baltic also showed that the size and time at release of juvenile hatchery-reared salmon can greatly affect their survival rates in the ocean. These cases may still be relevant to salmon in the Baltic; indeed, Finnish scientists are already using some of that knowledge. It is worth continuing to keep up on the non-Finnish research on this topic.

b. Similarly, research on wild salmon in the North Pacific and the North Atlantic Oceans shows that there can be decade-long periods in which favorable oceanographic conditions increase marine survival rates (e.g., Alaskan sockeye (*O. nerka*) and pink salmon (*O. gorbuscha*) in the late 1970s and early 1980s and Atlantic salmon (*Salmo salar*) in the 1970s) or unfavorable conditions that drastically reduce those survival rates (e.g., Canadian coho salmon (*O. kisutch*) in the 1990s and Atlantic salmon in the 1990s). Knowledge of such "background context" of post-smolt survival rates of wild salmon is essential for properly interpreting results from studies of survival rates of hatchery-reared salmon in Finland.

c. Everywhere that salmon exist in the world, there are conflicts between people who wish to maintain or rebuild wild salmon populations and those who wish to use rivers for other purposes such as hydroelectric power dams. The situation in Finland is the same. However, a partial solution for such conflicts in Finland can be learned from examples in North America. There, growing public interest in environmental issues has increased pressure on hydroelectric power companies to financially support activities to compensate for their dams or to reduce their impacts on wild salmon populations. One notable example is from the Bonneville Power Administration in the northwestern United States. There, by law, a small percentage of its revenue from electricity sales amounting to tens of millions of dollars per year goes into salmon-favorable actions such as (1) building screens to guide downstream-migrating juveniles around turbine intakes, and (2) increasing water flows (and decreasing hydropower revenue) during periods of downstream or upstream migration of salmon to make flows more similar to those in a natural river. A similar situation also exists in British Columbia, Canada, where the provincial government requires the main hydro-electric power company (BC Hydro) to contribute millions of dollars toward maintaining environmentally sound freshwater habitats. These are "win-win" examples because both the salmon and power companies benefit (the latter because they create an improved public image as environmentally and socially responsible corporate citizens). These North American companies' extensive public relations efforts reflect the importance that they place on this benefit of having a good public image.

d. There are many users of waterways. They range from salmon and other aquatic species to recreational users, fishermen, native people, sources of drinking water, hydroelectric power companies, and other industries. There are thus many different perspectives on what should be done with former or current salmon-producing rivers. These different objectives have been most successfully addressed through "multi-stakeholder" consultations, whereby plans are developed and discussed through many meetings with interested groups of people. One prominent example of the success of this approach is the "Water Use Planning" process conducted by BC Hydro in British Columbia. Over several years, water-use plans were developed for 23 different locations

in British Columbia. All plans aimed to find a better balance among competing uses of fresh water. Through extensive involvement of all interested people, greater awareness of costs and benefits were produced than existed previously, permitting development of more informed water-use plans.

e. The EU Water Framework Directive (WFD) is one of several public policies focusing on heavily human-modified waterways and aiming to achieve good ecological potential or good ecological status in flow-regulated waters (also see recommendation 14 below). This framework could be used to put additional pressure on other users of the running waters in Finland (i.e., hydro-power companies) and encourage them to be economically responsible for the future survival of migratory stocks by improving flow rates at critical times for salmon. This is clearly the situation in Sweden, where the hydro-power industry by law (old water laws) has to compensate for the loss of wild fish production by producing hatchery smolts, by installing fish-ladders, etc. However, from a Swedish standpoint, it is relatively unclear at present how the EU WFD will be used to safeguard the future of migratory stocks in heavily human-modified waters.

We expect that FGFRI researchers can benefit from further investigating these and other examples of how various problems that they face have been dealt with elsewhere in the world.

9. Given the potential for cuts to the FGFRI budgets, scientists should conduct analyses now to determine how the quality and the types of their scientific advice to managers and stakeholders might be affected by particular cuts to specific research programs.

Justification: One way to evaluate priorities for research and determine the impacts of potential budget cuts is to conduct some "What if ...?" types of sensitivity analyses. For instance, take the existing biological data set for Tornionjoki salmon and remove the data for every second year. Then re-analyze the new data set in the same way that it has been analyzed in the past. This will clearly indicate which questions asked by managers and stakeholders could still be answered (and with what degree of confidence) and which cannot be answered at all if such a biennial sampling regime were to become necessary due to budget cuts. Similarly, one could reduce the current genetic database (simulating a reduced budget for such research in the future) and then re-analyze it by asking questions about stock identification and appropriate timings and locations of various fisheries. It will become clear which questions will have less clear (or no) answers in the future if such budget cuts were to take place. It would also be of strategic importance to consider sea trout questions in the same way as is done with salmon. The fisheries on sea trout, especially the coastal fishery and the river fishery in the Gulf of Bothnia, will require that both Atlantic salmon and sea trout be abundant. These two species also have about the same life-history. Samples taken in different assessment programs already deal to some extent with both species.

10. Extend the genetically-based stock-identification work to apply to all Baltic salmon stocks (and also anadromous trout, if possible), as well as the rivers Teno and Näätämö that drain into the North Atlantic.

Justification: As noted above, previous stock-identification research at FGFRI has directly influenced improvements management regulations by identifying how the times and locations of allowable fishing should be changed. Opportunities exist to further refine management regulations on salmon populations from other river systems and to differentially harvest hatchery-produced, as opposed to wild salmon in order to encourage recovery of wild populations. It would be beneficial if a stock-specific genetic reference database could be set up

for all salmon and major sea trout stocks from all countries around the Baltic as well as for salmon in the River Teno tributaries. This database could then be used by interested groups of stakeholders. By sampling the catch and analysing the stock composition in major fishery areas along the coast and in the main stem of the rivers, new and alternative management scenarios could be discussed/presented in relation to the actual status of different stocks. However, one issue to consider here is the generally high cost of keeping an excellent genetic lab for doing analysis. The other issue is the fast development of research techniques and analytical tools in this field. It is important that the Institute has skills to ask the right questions on how to use "molecular biology" to solve important management alternatives.

11. We encourage scientists at FGFRI to continue to publish their research in high-quality journals, to present papers at international conferences, and to obtain a Ph.D. degree if they do not yet have one.

Justification: All of these steps help ensure that the latest research methods and ideas are being applied to fisheries problems and that the scientific advice provided by FGFRI scientists to fisheries managers is of the highest quality and reliability. Furthermore, high-quality publications on leading-edge topics increase the chances that FGFRI scientists will obtain substantial outside funding, thereby reducing the financial burden on the Finnish government.

12. Descriptions of current research projects in the Institute and past findings need to be communicated more effectively and more widely than at present.

Justification: FGFRI already produces numerous brochures, pamphlets, magazine articles, and other non-technical publications for the public. It also holds an annual public "Research Days" forum. However, during the interviews with stakeholders from certain rivers, it became clear that there was insufficient communication between the researchers at FGFRI in Helsinki (and elsewhere) and the local communities along important river valleys. On the other hand, people in the Kotka region were very pleased with their communications with the Institute. It would be important in the future to have FGFRI research representatives at meetings on a more local/regional scale so that people along river valleys can, in a more direct way, communicate their needs and thinking with the Institute. We encourage FGFRI to continue to hire, and even broaden the hiring of, local people to undertake surveys, trapping, sampling, etc., because this is another way to maintain a strong research base out in the areas where landowners (fishing-right owners) are present. Of course, such operations have to be done with appropriate training of the local people to ensure quality control of the collected data. This approach is also advantageous because in the future, co-management of salmon/trout fisheries in whole catchments will likely be necessary.

13. As part of their normal analyses, FGFRI scientists should help decision makers by quantifying, where possible, the unavoidable tradeoffs between indicators of different management objectives.

Justification: Complex management objectives that reflect views of multiple stakeholders make decisions difficult for fisheries managers. Some of their uncertainty about choices among management options can be reduced by scientific analyses that will describe how much of one objective's indicator must be traded off for a given increase in another objective's indicator. For instance, simulation modelling and other quantitative analyses could estimate how much change

in catch of salmon over a given period would be expected for achieving a given desired increase in the chance of recovery of wild spawners in a particular river.

14. FGFRI scientists must conduct research to enable Finland to comply with the European Union's WFD (Water Framework Directive).

The EU WFD was adopted in 2000 as an operational tool; it sets the objectives for water protection for the future. There are a number of objectives to protect the quality of the water. Ecological protection should apply to all waters; the central requirement of the Directive is that the environment be protected to a high level in its entirety. For this reason, a general requirement for ecological protection and a general minimum chemical standard were introduced to cover all surface waters. There are the two components of "good ecological status" and "good chemical status". A somewhat weaker component, "good ecological potential", will apply to waters heavily modified by human activities.

The salmon research projects of FGFRI are clearly relevant to complying with the EU Water Framework Directive because, for each river basin district, a "river basin management plan" needs to be established and updated every six years. The management plan is a detailed account of how the objectives are to be reached. The plan will include the river basin's characteristics, a review of human impacts on the status of waters in the basin, evaluation of the effects of existing legislation, the remaining "gap" for meeting the objectives, and a set of measures designed to fill the gap. An analysis of human impact is to be conducted to determine how far each body of water is from the objective. At this point, the effect of full implementation of all existing legislation will be considered for the problems of each body of water. If the existing legislation solves the problem, the objectives of the Water Framework Directive will have been met. Otherwise, the Member State must identify why those objectives have not been met and design additional measures to satisfy all the objectives. One additional component of the management plan is that an economic analysis of water use within the river basin must be carried out if the previous steps fail to solve the problem. The requirement for economic analysis is intended to provide a rational basis for discussion of the cost-effectiveness of various management actions, but it is essential that the analysis be open to scrutiny by those who will be affected. Adequate water pricing can act as an incentive for the sustainable use of water resources and can thus help to achieve environmental objectives under the Directive.

Justification: The EU-WFD will likely be an important tool for assessing the future status of all types of waters in Europe. It will probably be a requirement that aquatic organisms in human-manipulated running-water ecosystems be allowed to migrate, survive, and grow. This will be especially true in flow-regulated rivers where the seasonal water balances in many cases are changed (habitats without any water, low summer flows and high winter flows, etc.). Some of our suggestions for researchers at FGFRI on this topic have already been listed above under Recommendation 4 because many restoration efforts will be needed in human-affected freshwater habitats. To solve some of the challenges of restoration and further prevention of problems, FGFRI scientists will need considerable data and understanding of salmon and trout biology in freshwater life stages and their freshwater habitat requirements. As well, technical skills will be needed to help design fishways or bypass systems that will allow migratory fish to swim freely both upstream and downstream. FGFRI scientists should thus be aware of the EU WFD and ensure that their data collection programs, experiments, and analyses on freshwater habitats provide sufficient scientific information for Finland to comply with this Directive.

15. Consider doing more research on sea trout.

The panel also urges the Institute to consider the future well-being of migratory trout in their research. Sea trout are important for both future river fisheries and regional coastal fisheries in the Gulf of Bothnia and Gulf of Finland. High production of wild sea-trout in natural rivers, combined with their short distance of migration (compared to salmon) and relatively large body size, make these northern populations an important focus of interest for all stakeholders.

Recommendations for dealing with potential reductions in budget

Members of the External Review Panel understand that substantial reductions in budgets of the Finnish government, including the FGFRI, are a distinct possibility in the near future. We have therefore been asked for our opinions about the relative priorities of various research activities at FGFRI and our ideas about how budget reductions might be handled.

We offer the following suggestions for dealing with the budget cuts, but we caution readers that these are based on our broad overview of FGFRI activities and a relatively limited understanding of the details, plus we had no information on the financial costs of different research activities. The list below is organized according to the order of sections that appeared in the table of contents of the written background document provided in August to the Panel by FGFRI. The order of those topics therefore does not reflect their relative importance. Furthermore, each broad topic below includes various component activities, some of which the Panel did not see in depth.

16. Expand the application of Bayesian methods of analysis.

Scientists at FGFRI have successfully applied Bayesian statistical methods while developing models of abundance of Atlantic salmon. This work was done by collaborating with graduate students and professors at the University of Helsinki. This complex statistical method of salmon stock assessment was formally accepted recently by the EU. It was the first such EU acceptance of this advanced method of conducting fish stock assessments, which attests to the quality of work done by the FGFRI and university scientists. The success of this collaborative project between FGFRI and the University of Helsinki suggests that good-quality applied research can come out of such associations and more should be encouraged. As well, costs to FGFRI could be reduced by relying more heavily on university researchers for analyses and for their ability to obtain funding that might not otherwise be available to FGFRI scientists. This could also be true for the future application of the Bayesian approach to developing forecasting models for the M74 syndrome, as we recommended above.

17. Extend the research on fish stocking, but seek funding from non-government sources.

Costs of FGFRI research on strategies for salmon hatchery rearing and release for "compensation stocking" (about 2 million smolts per year) should be paid for by the hydroelectric companies whose facilities are the reason for such stocking. This recommendation also applies to research at the Kainuu facility aimed at improving survival rates of such stocked juveniles. There are many examples of such legally mandated, as well as voluntary, financial support in Sweden and the United States. The Swedish initiative to compensate for damaged waterways is a relatively good example. There, the hydro-power industry is legally responsible for compensating for the reduced natural fish production caused by damming rivers and regulating flows. Because of decisions taken in the Swedish environmental courts, where there are flow-regulated waters with lost salmon production, the water power companies have to

follow rules that support wishes from the people of Sweden, e.g., salmon fishermen in different areas. The Bonneville Power Administration situation described above under recommendation 8 provides another good example.

Other research on fish stocking is also being done by FGFRI. The marine survival of hatchery-reared smolts released into Finnish rivers in the Baltic has decreased in recent years, much more than the decrease in wild-smolt survival rate. It is well known that marine survival of salmon smolts depends on a number of factors such as "smolt quality" (size, physiological status, etc.), factors in the marine environment, predation, competition, availability of suitable prey, and ecological changes made by man. The survival of hatchery-reared salmon may be affected by additional factors such as smolt-production methods, timing of release, smolt size at release, and stress during transport and release. With the development of salmon farming, much new information on production of juveniles has been developed. In spite of this, marine survival of hatchery-reared smolts has decreased. This leads to a question. "Is this a result of applying smolt production methods that were developed to maximize perceived economic benefits for fish farming (measured by the number of smolts released) and not to maximize survival rate of those fish released into the wild?" The possible causes for this decline should continue to be investigated.

18. Continue stream-habitat research, but rely more heavily on universities on this topic.

The Panel learned that there are relatively few habitat restoration activities currently under way, although proposals exist for future projects such as fish ladders on formerly productive rivers where access is now blocked by dams. Given this context and the imminent budget cuts, perhaps research on stream habitats is a lower priority for being funded by the Institute than other topics. Such research could possibly be shifted to a university. No matter where such research is conducted, if large numbers of restoration projects are approved and proceed, having such background scientific knowledge on habitat preferences of salmon and hydro-dynamics will be an asset to developing reliable restoration plans. A lot of restoration projects and related stream habitat research programs are presently being undertaken in Nordic streams, especially in Sweden and Norway. Cooperative programs directed towards stream habitats and salmon issues could be set up between nations interested in these environmental topics and money could be applied from other financial sources, i.e., EU-structural funds or EU-interregional funds. It is also important to realize that many of these more general ecological questions related to stream habitats could be directed to rivers where considerable research is already being conducted, for example, national "index" rivers such as the Tornionjoki.

19. Continue research on the M74 syndrome and expand research on environmental toxins.

Research on the M74 syndrome in Atlantic salmon and effects of environmental toxicants are being conducted at many government marine laboratories and universities in other countries (e.g., Norway, Sweden, United Kingdom). Increased collaboration with such researchers might result in a cost-efficiency for the Institute while still pursuing the application of Bayesian methods to the M74 problem that was recommended above. The M74 syndrome is considered as the worst problem related to the future of salmon stocks because we do not know the underlying mechanism for this disorder and we cannot currently predict future outbreaks. Financial support from all Baltic countries should help to solve these questions.

Environmental toxins, such as dioxin, flame retardants, and PCBs, are becoming recognized worldwide as problems for health of humans as well as other biological organisms.

We recommend that the FGFRI increase its research and monitoring efforts on such toxins because, among other things, they may have a negative effect on future salmon fisheries through national or international trade restrictions on allowable concentrations of these compounds in salmon products sold to consumers.

20. Continue genetic research, but rely more heavily on universities on this topic.

Research in molecular biology is highly valuable for fisheries management through its ability to identify stocks and sub-stocks. However, because of the rapid development in markers, software for genetic analyses, equipment for reading samples, etc., it can be questioned who should be responsible for costs responsible for this type of research. Many of these basic studies can be done at universities where such expertise is well developed. However, if the emphasis for this research area is shifted to universities, it is important that the Institute support and collaborate with university researchers so that proper questions can be asked from a fisheries management standpoint.

21. Maintain as a high priority the research on technical regulations for salmon fisheries management.

Research on this topic includes how the estimated status of salmon populations affects scientific advice provided to salmon fisheries managers who must choose among options for regulations (times and areas open for fishing, allowable fishing gear, etc.). This research topic is a key link between research at the Institute, decision makers in Finland, and scientists at ICES. Research on technical regulations in salmon fisheries management must therefore remain a top priority for work based at the Institute. Of course, collaborations with researchers at the University of Helsinki and other institutions are still encouraged.

22. Explore new salmon fishing technologies in collaborations largely funded by fishermen.

The Panel learned about the Institute's research on designing more selective fishing gear that would reduce injuries to salmon so that wild salmon could be released while fishermen retain hatchery-origin fish. This work was conducted in collaboration with commercial trap-net fishermen at no cost to the Institute, aside from the time of Institute scientists involved. The Panel recommends that such costs of designing improved fishing methods continue to be borne by the fishing industry rather than the Finnish government because the industry is the one that benefits most. Note that this type of research also provides salmon harvesters with a "window" into research at the Institute, which will help the Institute achieve the goal of increasing the public appreciation of the applied and useful nature of its research.

23. Encourage interdisciplinary research with other partners.

Similarly, research on how social and economic objectives can be met also directly links research at the Institute to the needs of the public and decision makers (who must make difficult tradeoffs among interest groups). However, to reduce costs to the Institute, collaborations on these topics with partners at universities should continue to be encouraged and even expanded.

24. Continue applying expertise in international settings.

It is very important that Institute scientists continue to maintain their strong presence in international working groups. In fact, some of these activities are legally mandated, such as reporting to ICES, the EU Fisheries Directorate, and Regional Advisory Councils. However, in

the recent past, due to their strong, leading-edge research programs, scientists from FGFRI have led teams such as Baltic Salmon and Trout Assessment Working Group (WGBAST). Perhaps leadership should be given to scientists from other countries to permit more time for FGFRI scientists to work on other topics.

Conclusion

The Evaluation Panel was impressed by the high quality of research and monitoring conducted by salmon researchers at FGFRI. It was also clear that most of this salmon work at FGFRI is either directly relevant to solving salmon management problems or is a necessary foundation on which high-quality scientific advice is built. The FGFRI is also providing such excellent advice on a wide range of salmon problems on an ongoing basis.

Nevertheless, the Panel makes 24 recommendations to further improve salmon research and monitoring at FGFRI. Among other things, these recommendations emphasize the need to continue long-term research programs on critical questions and important salmon populations, to apply new methods of analysis with which the Institute already has some experience, and to help decision makers by quantifying where possible the trade-offs among user-groups of waterways and salmon that are implied by different management options. Another set of recommendations recognizes the difficult financial environment that the Finnish government faces in the future and makes suggestions for ways to maintain funding from other sources for FGFRI research programs, which provide excellent scientific advice for decision makers and the public. In particular, plausible options appear are to increase collaborations and shared funding of research with universities, hydro-electric power companies, and salmon user groups. Such partnerships will help ensure that the salmon populations of Finland continue to produce substantial benefits to people in all regions of Finland.

(FinalPanelReportOnFGFRI-20December2007)