Salmon Aquaculture Dialogue
Meeting Summary
December 11-13, 2007
Santiago, Chile

Background and Overview

The Salmon Aquaculture Dialogue met in Santiago, Chile on December 11-13, 2007 to discuss new reports about two of the key impacts of salmon aquaculture production – chemical inputs and nutrient loading/carrying capacity – and the socioeconomic costs and benefits of salmon aquaculture.

Input from the meeting – attended by more than 80 producers, government officials, nongovernmental organizations and other salmon industry stakeholders – will be used to create measurable, performance-based environmental and social standards that minimize or eliminate the key impacts of salmon farming. Seven key impacts of salmon aquaculture globally were identified by Dialogue participants in past meetings. In addition to chemical inputs and nutrient loading/carrying capacity, the other key impacts identified are feed, disease/parasites, social impacts, escapes and benthic impacts/siting. Reports regarding escapes and benthic impacts will be reviewed at the two-day Dialogue meeting in Barcelona that will begin on January 31, 2008. The first report was published in 2005 and relates to salmon feed and the environment.

To learn more about each impact, the Steering Committee for the WWF-initiated Dialogue created technical working groups that drafted a series of "State of Information Reports." Each working group was agreed upon by the multi-stakeholder steering committee and was comprised of scientists with expertise in the sub-topics of the reports and the geographic regions. Each report assesses existing research related to an impact, identifies gaps or areas of disagreement in the research and suggests a process for addressing the gaps. Two of these reports were presented and discussed at the December 2007 meeting. Dr. Barry Costa-Pierce, of the University of Rhode Island and lead author of the report on nutrient loading and carrying capacity, presented the report which was co-authored by Dr. Alejandro Buschmann, Universidad de los Lagos; Dr. Stephen Cross, University of Victoria, Canada; Dr. Jose Luis Iriarte, Universidad Austral de Chile; Dr. Yngvar Olsen, University of Science and Technology, Norway; and Dr. Gregor Reid, University of New Brunswick, Canada. Dr. Buschmann was able to attend and contribute to the presentation and discussion at the Dialogue meeting.

Dr. Les Burridge of St. Andrews Biological Station presented the report on chemical inputs, of which he was the lead author. The additional members of the technical working group on environmental impacts associated with chemical inputs are Dr. Felipe Cabello, New York Medical College; Dr. Jaime Pizarro, Universidad de Santiago de Chile; and Dr. Judith Weis, Rutgers University.

To view the full reports, and their executive summaries in Spanish, go to http://wwf.worldwildlife.org/site/PageNavigator/SalmonSOIForm. For general information on the Salmon Aquaculture Dialogue and to access documents from each Dialogue meeting (e.g., PowerPoint presentations and meeting summaries), go to http://www.worldwildlife.org/cci/dialogues/salmon.cfm.

DAY ONE: December 11, 2007

The meeting opened with a welcome and introductory remarks by Katherine Bostick of WWF and the introduction of the Steering Committee of the Salmon Aquaculture Dialogue. Steering Committee members Giuliana Furci, of Fundacion Terram, and Rodrigo Infante, of SalmonChile, then presented the background of the Salmon Dialogue and the technical working groups. Their presentation is available, in Spanish, at http://www.worldwildlife.org/cci/pubs/Salmon_Dialogue_Intro_final.pdf

Dr. Barry Costa-Pierce then presented an overview of the report on nutrient impacts from farmed salmon on pelagic ecosystems and the implications for carrying capacity. He expressed that better integration of the three aspects of measurement, management, and modeling is needed in many salmon producing areas. Dr. Costa-Pierce identified that environmental nutrient loadings and the effects, or impacts, of the nutrient releases are related to five primary factors:

- Standing stock: seasons, densities, sizes of fish
- Production: seasons, densities of fish
- Conversions: Physiology, feeds
- Quality/Quantities of feed: seasons, densities, and
- Temperature/3 D Hydrodynamics

Over the course of the morning, Dr. Costa-Pierce presented and the meeting participants discussed the first two chapters of the report, which focused on nutrient releases from salmon aquaculture, and the impacts of these releases on pelagic ecosystems. The discussion related to nutrient releases focused on feeds, their digestibilities, feed conversion ratios, and the implications of feed composition and management on nutrient outflow from farms.

Key points related to soluble nutrient releases included:

- Nutrients digested (absorbed through the intestinal wall) are excreted because they are catabolized (converted) or, the amount digested exceeds metabolic requirements
- Soluble nutrients dissolve in water; their initial dilution and transport are a function of hydrodynamics; persistence is determined by uptake by the marine planktonic ecosystem
- Protein is metabolized and discharged as ammonium NH4+ through the gills and to a lesser extent as urea in urine.
- Phosphorus is discharged at PO4+
- Lipids are metabolized to carbon dioxide and water

Other key topics of discussion related to the first chapter on nutrient releases included:

- Measurement techniques for nutrient impacts from salmon culture, and that measuring nitrogen levels in the water column cannot measure nitrogen which has been taken up by plants or bacteria. These include Seaweed scientists who can look at tissue concentrations. Macrophyte monitoring unit in critical areas around a farming system could tell us more. Systems that can integrate impact over time rather than point measurements.
- How improved understanding of nutrient releases and hydrodynamics and water flows can help producers implementing integrated multi-tropic aquaculture to maximize their

production and environmental benefits. Representatives from the salmon industry in Canada provided the example of hydrodynamics being used in Eastern Canada in their bay management programs. Representatives from the scientific community in Chile called attention to a series of oceanographic cruises which have collected data in Southern Chile which could be used to help understand these systems.

- The idea that improved feed management, technology and siting has led to significant reductions in visible nutrient impacts and cases of on-farm eutrophication. However, this is countered by the dramatic growth of the industry and limited understanding of impacts associated with the cumulative increase in nutrients that are more widely dispersed into the marine environment. Additionally, regions of the world reporting higher FCRs have also reported having water quality problems.

Discussion the second chapter, pelagic impacts, focused on the following themes:

- The effectiveness of modeling as a tool to predict nutrient impacts.
- The frequently rapid flow of nutrients away from farm sites and the challenges with understanding or measuring the far-field impacts.
- The varying capacity and speed with which different organisms are able to take up different forms of nutrient releases and the delay in the increase in biomass.
- The assimilative and carrying capacity implications of the cumulative effects of releases from salmon farms and from other activities in a region (e.g. agriculture, municipal wastes).
- The implications of differences between Norwegian fjords which typically have unilateral flows, and the Chilean coast, where there is significant upwelling.
- The apparent contradiction between siting farms in less dynamic areas, where nutrients will have greater, but more measurable and therefore manageable impact, and siting farms in more dynamic areas where impacts are dispersed, and therefore potentially decreased, and is it extremely difficult to measure biomass accumulation effects. This has implications for how one develops a standard related to nutrient impacts.

In the afternoon, Dr. Costa-Pierce presented and the group discussed more specifically nutrient impacts in Chile, and the issue of harmful algal blooms (HABs) globally. Key points from this discussion included:

- Globally, the frequency and intensity of HABs seems to have increased. It is caused by many different issues.
- The lack of many studies of algal blooms that are related to aquaculture. Most of the research is in oceanography. It documents how HABS are formed, what we know about their oceanography and how they are transported. Most of the work has been done in labs (3-5 studies) but only one field study has actually been done. This is true in Chile but also globally an issue. Soluble waste from salmon aquaculture is more of a theoretical cause/effect relationship which is based on lab research only. A question that has yet to be answered is whether salmon aquaculture could be a catalyst for dormant cyst development or blooming.
- Within Chile, some participants expressed concern that the oceanographic studies that exist are not focused on the areas with salmon aquaculture production to the degree needed to understand these impacts and interactions. Hydrodynamic and tidal work is of particular importance. This relates not only to the issue of HABs, but also to other nutrient impacts. The information exists for the macrozone in which salmon is being produced in Chile,

though it may not be enough. There is, more critically, a need to integrate findings by different groups, including the industry and academics. There is also a need for oceanographic data in the 11th region.

- Participants questioned whether there could exist a critical threshold of nutrient levels that has to be met before HABs become a problem, which could be met if the salmon aquaculture industry continues to grown, especially in dense areas of production. Theoretically, dinoflagelletes are consistently a part of the phytoplankton community, and some dinoflagelletes will become toxic in the presence of excess nutrients. In stagnant water, this type of threshold could exist, but when you introduce hydrodynamics that possibility is less clear.
- Whether there is evidence in the algal field that species exist where they did not exist before and whether with the expansion of the salmon aquaculture industry, this is something that we should be concerned about. While the movement of fish clearly is associated with invasives, this is most visible in larger organisms. It is suspected that smaller organisms are also being moved. This is an issue that is of potential concern not just for dinoflageletes, but also for diseases and parasites.

Presentations and discussion then shifted to focus on nutrient impacts related to salmon smolt production in freshwater ecosystems in Chile. Dr. Barry Costa-Pierce presented the relavant chapter of the report. View his presentation, in English, at http://www.worldwildlife.org/cci/pubs/BCP%20Chile%20Nutrient%20Presentation%20December%202007.pdf . Jorge Leon then discussed the findings of a report commissioned by WWF Chile related to salmon smolt production in lakes in Southern Chile. View his presentation, in Spanish, at http://www.worldwildlife.org/cci/pubs/Leon_Lakes_Chile_SalmonDialogue.pdf
Key points from the presentations and discussion included:

- Turnover time, depth, exchange rate if connected to rivers, and size are all important factors which determine the impact of nutrient releases from salmon production or other sources or nutrients. With freshwater environments depth and volume the key factors. Shallow depth and small size mean a higher potential for eutrophication.
- Phosphorous inputs into the freshwater lakes will typically have a greater impact than nitrogen inputs. In some other countries which permit freshwater aquaculture, they have legal limits on the maximum phosphorous levels in feed.
- Some participants expressed concern with assuming that there is a significant impact on the lakes from salmon farming based on these two reports. Others expressed concern that the precautionary principle was not being used and that an indication of significant impact should be enough to incite action to change practices and to conduct key research studies.
- Point source sampling has some shortcomings. However, the point source samples of standing levels of nutrients that were found in the Chilean lakes are globally high and bordering on very high if you compare them to samples from other temperate lakes around the world.

Dr. Costa-Pierce initiated the closing session for the day with his conclusion and recommendations. Participants discussed these conclusions and recommendations and the best way to use this information to move forward within the Salmon Dialogue to develop standards. Key points from this discussion included:

- The three most important factors determining the impact of salmon farming on water column nutrients, water quality, and pelagic ecosystems are the:
  - loading rate of inorganic nutrients, especially nitrogen for marine systems and phosphorus for freshwater ones; the hydrodynamics; and the water depths of cage sites,
  - morphometry and topography (degree of "openness") of bays and the nearshore coastal areas,
  - stocking density of fish (local scale) and the density of fish farms (regional scale).
- The need to better connect the small community of marine ecosystem modelers, especially the subset who do modeling related to salmon culture or other aquaculture.
- There is a need to study the denser production areas, as much published research related to nutrient releases are from lower density production areas. The Reloncavi estuary in Chile would be a potential location for this research. There is an opportunity to develop a center of excellence on this theme here in Chile through collaboration.
- The authors of the report agreed that aquaculture will continue to expand, but not necessarily to the extent predicted by some groups due to constraints on the ground. They encourage the shift away from monoculture towards integrated systems as a way to address some of these constraints.
- Generally, it should be recognized that this is a new industry and a new field of science. The first salmon farms and the first scientific aquaculture publications came about in our lifetimes. Tremendous advances have been made, and we need to accelerate that motion even further through collaboration.
- Siting of farms is a key issue which can help to minimize impacts. However, there is not consensus about whether siting is sufficiently well-planned, regulated, or monitored.
- Although there is a need for research, and research can't be rushed or shortcut, we can use current knowledge to develop social, economic, and environmental indicators to measure change. And by measuring change we can influence change.

DAY TWO: December 12, 2007

The second day of the meeting began with a welcome and brief introduction by Steering Committee member Petter Arnesen of Marine Harvest. Petter reiterated the focus of the Salmon Dialogue on developing social and environmental standards, and introduced Dr. Les Burridge, the lead author of the report of the technical working group on chemical inputs.

Dr. Burridge presented an overview of the reports on chemical inputs to salmon aquaculture. View the presentation, in English, at
http://www.worldwildlife.org/cci/pubs/Burridge_Chemicals_SalmonDialogue_2007.pdf
Key points from this presentation included:

- The reports considers the use, trends, and potential impacts of the primary intentional chemical inputs to salmon aquaculture, which can be categorized as antibiotics, anti-sea louse drugs/pesticides, antifoulants, disinfectants, and anaesthetics.
- With the exception of anaesthetics, all of these compounds are designed to kill something, meaning that they are all toxic, and their effects will depend on the dose delivered. Important factors include the amount of the chemical present, the species, and the exposure time.

- Regardless of the chemical, water solubility, affinity for sediments or tissue, and persistence are three key characteristics which dictate where a chemical may go and how long it will stay there. The physical and chemical characteristics of the receiving body or water are also critical in determining where a chemical will go and its bioavailability.
- Areas where chemicals carry the most risk include the impact of bio-deposits, the impact on benthic communities of the accumulation of metals, and the impact on non-target organisms of the use of therapeutants.
- Despite the regulation of chemicals used in salmon aquaculture in all producing regions, accessing information about their use is extremely difficult in some areas.
- A key research gap identified by the research team is that cumulative effects of chemicals and of interactions between chemicals and between chemicals and the marine environment are largely unknown. Studies must be designed and carried out to address this need both in the near site and far-field environment.
- A key conclusion of this report is that the public availability of verifiable data on chemical use in salmon aquaculture is variable. This variability makes it difficult to compare data, prepare general recommendations and to comment on risks associated with chemical usage. The need for an improved level of transparency and availability of information on chemical use is highlighted by the researchers. The report also showed that the rate of application of certain chemicals is higher in some jurisdictions than others.
- The research team recommended that regulatory agencies in all jurisdictions require yearly reporting of the quantities of antibiotics, antifoulants, parasiticides, disinfectants and anaesthetics used by salmon farms. If reporting is already required, that these data be made available to the public. The model used by the Scottish Environmental Protection Agency is a good example.

Dr. Burridge then presented and the group discussed the information related specifically to antibiotic use and the potential environmental and human health impacts of this use. Key points and conclusions from this discussion included:

- The key concern with antibiotics lies with ability of bacteria to develop resistance to antibiotics and to rapidly pass this trait on, even to human pathogens. This has implications for fish health, environmental health, and human health. (The discussion on human health implications of antibiotic used focused on the local effects of use, and not on potential residues in an end product or the salmon consumer. This latter issue is beyond the scope of the work of this team.) Concern is greatest for classes of antibiotics that are used for human health as well as in aquaculture.
- Not all chemicals are equal. A toxicity “budget” could be created for each farm. Some categories are more toxic than others and, therefore, have greater risks associated with them.
- Additives and compounds that are undisclosed ingredients in medicines were not included in this study. How can we get to those compounds? A lot of that information is proprietary and difficult to obtain. It is hard to tell how important impacts associated with those compounds might be without more information.
- The comparatively high use of antibiotics in Chile is related to a difference in the disease problems faced in Chile compared to other producing regions.

- Data for antibiotic and other chemical use in Chile and eastern Canada were the most difficult for the team to obtain, and in some cases they were unable to access them. Several representatives from industry and government participating at the meeting offered to provide Dr. Burridge with some of the data he was unable to locate. Within Chile, SERNAPESCA is currently validating data from past years and plans to make it available within a few months. The system for reporting use of chemicals was described, and it appears that the data made available in Scotland and some other jurisdictions is collected, but the steps to make it publicly available need to be taken.

Dr. Burridge then presented the second chapter of the report, which focused on antiparasitics, or parasiticides. He described the modes of action and application of the compounds, trends in use, and the concerns associated with their use. Key points from the presentation and associated discussion included:

- The key environmental concerns related to antiparatisics are the effects on non-target organisms, persistence, and resistance and associated overuse.
- The key concerns for fish farmers related to antiparasitics are resistence, under-fortified feed, and costs.
- It appears as though there are no new therapeutants in the regulatory system. In the absence of new treatment options and in support of sustainable salmon aquaculture, studies need to be conducted to identify best management practices that reduce the need to treat fish against infestations of sea lice.
- Risk assessment of anti-parasitics are often based on single-species, single chemical, lab-based studies. Field studies need to be conducted to determine the biological effects on non target organisms of therapeutants under operational conditions.
- The research team noted that some of the necessary data to fill gaps in knowledge may exist. Where field studies have been conducted as part of the registration process, the data should be more readily available to the public. It appears that all jurisdictions currently require some monitoring of sediment geochemistry, and these sediments samples should be utilized for further (organics) analyses. One study is underway in British Columbia related to the fate of SLICE in the environment.
- The possibility that lower grade pharmaceuticals are being used in some regions, or that concentrations are not marked properly, leading to improper dosage by those applying the product. This could lead us to believe there is a problem with resistance where there might not be a problem.

After lunch, Dr. Burridge presented and the group discussed issues related to heavy metals, disinfectants, and anesthetics. Key point from this discussion included:

- Copper-based antifoulants are universally used in the net salmon aquaculture industry. Since the 1970s, levels of copper in marine organisms have steadily increased, indicating increasing copper in the aquatic environment. This is more than an aquaculture issue.
- Disinfectants are a suite of chemical compounds including Iodine compounds, chlorine compounds (bleach) and Virkon. In relation to environmental impacts, the greatest concern is that they are largely unstudied, and could have impacts related to their solvents and surfactants.
- Anaesthetics are generally considered to have a low risk in terms of species and environment, and only a few products are used. Only Norway and Scotland report their usage.

- There are very little available data regarding the presence of disinfectants and particularly of formulation products in the marine environment. Similarly little data are available for use, and fate of anaesthetics. Studies need to be conducted to document the patterns of use, the temporal and spatial scales over which these compounds may be found.

The group then discussed final conclusions, recommendations, and the way forward within the Salmon Dialogue for this issue.

- In order to effectively study the effects of any of the chemical inputs to salmon aquaculture on the environment, there is a need to have areas free of farming activity to act as a control in studies. This was viewed by some to be an issue of concern in terms of there not being enough areas from of farming in regions which produce a lot of salmon.
- Absence of evidence is not evidence of absence—there is a lot of information on toxicity, but not on in-field effects in the marine environment. We understand the hazard, but not enough about the risk.
- The way forward is through standard development. We can set that benchmark and move forward. Although this seems like a long, slow process, changing an industry is a long process and if we can develop and begin to meet standards by the end of next year, 5 years is not too long to change an industry.

The day concluded with a presentation of a Life Cycle Assessment (LCA) of Wild and Farmed Salmon by Dr. Astrid Scholz, Ecotrust, and Dr. Ulf Sonesson, Swedish Institute for Food and Biotechnology. LCA is a systematic tool to evaluate the environmental performance of a product or service at a global level throughout its "life-cycle." View the presentation, in English, at http://www.worldwildlife.org/cci/pubs/Scholz_LCA_Chile_December_200_%20LCA.pdf

DAY THREE: December 13, 2007

On the final day of the Dialogue meeting, discussion shifted to focus on social impacts including socio-economic costs and benefits to salmon production around the globe, and labor issues. Because a number of new participants joined the meeting for this day, steering committee members Giuliana Furci and Rodrigo Infante once again presented the history and goals of the Salmon Dialogue. View their presentation, in Spanish, at http://www.worldwildlife.org/cci/pubs/Salmon_Dialogue_Intro_final.pdf. The Salmon Dialogue will be forming a technical working group on social issues in salmon aquaculture in the coming months, and information from the session will be used to help guide the work of that team.

Two steering committee members, Kjell Maroni of the Norwegian Seafood Federation, and Jay Ritchlin of the Coastal Alliance for Aquaculture Reform presented some of the social issues and socioeconomic costs and benefits of salmon farming in Norway and Canada, with a focus on British Columbia. View Maroni's presentation, in English, at http://www.worldwildlife.org/cci/pubs/Maroni_Social_Norway_December2007.pdf and view Ritchlin's presentation, in English, at http://www.worldwildlife.org/cci/pubs/Ritchlin_Social_BC_December2007.pdf Key points from these presentation and discussion included:

- The salmon farming industry provides jobs to coastal citizens in both Norway and Canada. These jobs extend beyond on-farm positions. For example, in Norway, employment has been created for fishermen who catch wrasse that are then used for sea lice control on some salmon farms.
- Integrated coastal zone planning and dialogue with other coastal zone users (e.g. fishermen, tourism interests) can help to avoid conflicts as various groups are competing for space. Greater conflict can arise if one coastal zone user decreases, or is perceived as decreasing, the value of another of the coastal zone activities.
- Within British Columbia, there are regions where First Nations have rights and hold title. This adds a unique dynamic to the development of the salmon farming industry in the region. There are First Nations who support salmon farming within their holdings, and other First Nations who opposed salmon farming due to concerns about impacts to the environment and on fish and shellfish populations in the region. In the November 2007 Salmon Dialogue meeting in Vancouver, two perspectives on salmon aquaculture were given by First Nations. These are available on the website.

This discussion was followed by three presentations and discussion related to social issues in Chile.

View the presentation, in Spanish, by Roberto Alvarez of the Banco Central of Chile at http://www.worldwildlife.org/cci/pubs/Banco_Central_Los%20Lagos-Dec-13.pdf

View the presentation, in Spanish, by Franciso Pinto of Fundacion Terram at http://www.worldwildlife.org/cci/pubs/Pinto_Social_Labor_Chile_December2007.pdf

View the presentation, in Spanish, by Rodrigo Infante of SalmonChile at http://www.worldwildlife.org/cci/pubs/Infante_Social_Chile_December2007.pdf

Key points and from these presentations and the discussion included:
- The link between environmental issues and social issues was recognized. It was questioned whether it is possible to decrease social impacts by improving environmental performance, or vice-versa.
- In Southern Chile, and in any region around the world where there is a strong reliance on the salmon farming industry for employment, workers face a great risk when there are collapses in the industry. For example, a number of workers have recently lost their jobs or are concerned with their job security due to the spread of ISA in Chile. Crashes in the industry have happened in Norway in the past. This is an issue that should be addressed.
- Key statistics related to employment, education, poverty levels, and markets for Chile are tracked within Chile and information related to the salmon producing regions are available all three of the presentations.
- Even though Norway and Chile produce approximately the same volume of salmon, 10 times more workers are employed in Chile than in Norway. Participants discussed that this difference can be explained by the type of product produced in Chile versus Norway, with an increased focus on adding value. More work is done in Chile to remove bones. It is very hard to withdraw bones with machines. This explains why many people are needed. In Norway, 85 percent of the product is made by machines. Industry representatives stated that if the

labor costs in Chile and Norway were the same, they would have to increase salmon prices or automate.

- Concern was expressed in terms of discrepancies in policies or performance of companies operating in more than one country. It was questioned why a producing company may have progressive social policies in one country but not in another.

The meeting closed with a thank you to all participants for their willing participation over course of the three day meeting. Participants were encouraged to contact Steering Committee members with any additional thoughts or suggestions. As a terms of reference for the social technical working group is developed, it will be distributed to Salmon Dialogue participants for feedback.