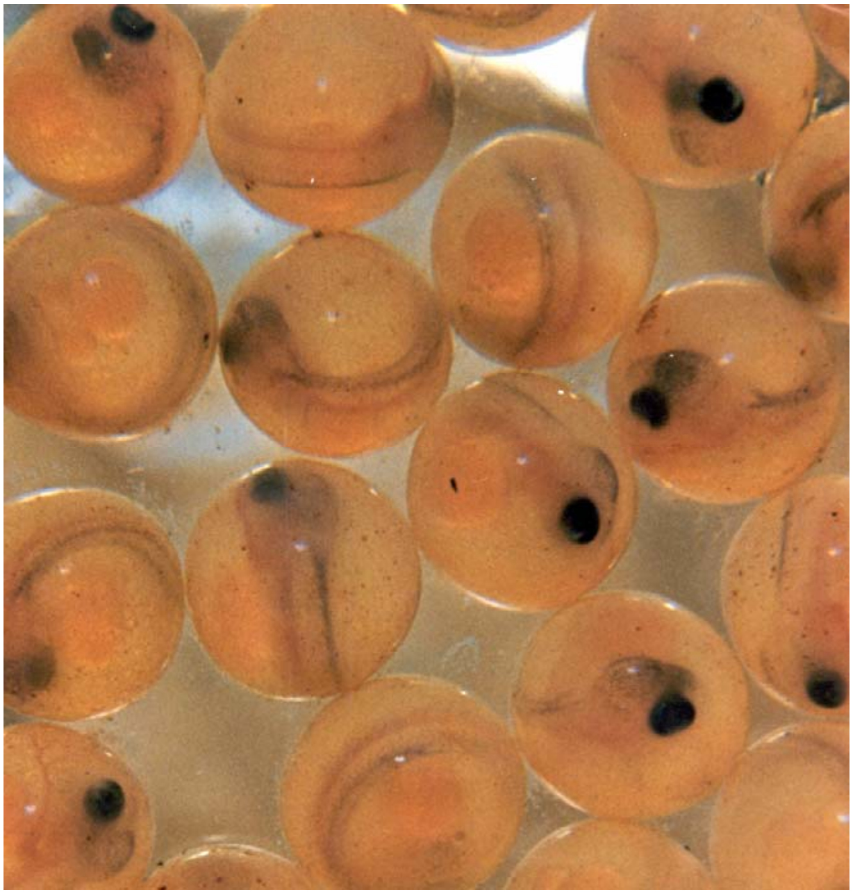
Sustainable Ecosystems Institute

Review of Atlantic Salmon Hatchery Protocols, Production, and Product Assessment



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Review of Atlantic Salmon Hatchery Protocols, Production, and Product Assessment

Science Review Panel

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Dr. Scott McKinley
Dr. Kerry Naish
Dr. David Secor (chair)

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Sustainable Ecosystems Institute is a non-partisan organization of scientists dedicated to using their technical expertise to solve ecological problems. Headquartered in Portland, Oregon, the Institute works nationally and internationally. SEI specializes in independent scientific review. Visit http:// sei.org and http:// sei.org/peerrev.html for more details. Contact SEI at sei@sei.org

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EXECUTIVE SUMMARY

Sustainable Ecosystems Institute (SEI) was contracted by the Maine Atlantic Salmon Commission (MASC) working in cooperation with US Fish and Wildlife Service (USFWS) and NOAA Fisheries Service (NOAA) "to determine whether the current hatchery operations, protocols and practices are being implemented in the most scientifically sound manner with the greatest potential to further recovery of the Atlantic salmon, and that assessment and evaluation is appropriately integrated into the hatchery program."

The Atlantic salmon must survive and reproduce across shallow watershed and ocean ecosystems. This makes the task of integrating science and management particularly difficult and the panel commends the work of the managers and scientists who are faced with this enormous and complex task.

The alarmingly low numbers of Maine Atlantic Salmon make hatcheries a reasonable and obvious choice as a key effort in preventing extinction. But hatcheries are simply one tool for halting extinction and recovering the species. While their importance in preventing extinction is appreciated, their role in recovery has not been fully considered or integrated into a broader plan for the endangered salmon that considers all aspects of recovery.

The overall survival and recovery plan for Atlantic salmon lacks a clear conceptual framework, clear goals, and a strategic approach. This issue needs to be urgently addressed.

Governance structures play a major role in the outcome of natural resources decisions. The panel is impressed by the level of cooperation of the three main agencies who work consistently well together in a complex and difficult management issue. However, their efforts would be made more effective with greater support and better integration of the Technical Advisory Committee (TAC) and the Salmon Recovery Team.

The Green Lake (GLNFH) and Craig Brook (CBNFH) National Fish Hatcheries are well designed salmon hatcheries that incorporate best management practices. Likewise the panel strongly applauds the accomplishments of the river-specific broodstock program and recommends it be continued. However, the panel is also very concerned about the demographics of the populations from which these broodstock are collected. It is far from certain that hatchery augmentation is currently effective in stemming further population declines.

Reasons for low marine survival of hatchery fish, beyond the effects of the natural environment itself, are believed to include stress associated with hatchery rearing conditions, transport and release protocols, and lack of recovery procedures in the wild. The panel encourages further research to better evaluate survivorship of hatchery released fish to determine the relative contribution rates of hatchery fish released at differing stages of their life history, and to consider, evaluate and improve the quality of fish released.

The panel has the following findings and recommendations. The degree of unanimity and concern on specific issues is reflected in the questionnaire section.

FINDINGS/RECOMMENDATIONS

I. Overall Comments, Governance and Adaptive Management

1. The current recovery program lacks a clear conceptual model. This framework, is needed to articulate the basis for understanding the species, system. It is the essential foundation for setting clear goals, making management decisions and evaluating options and outcomes.

2. Increased integration of key elements of the recovery program (i.e., monitoring, assessment, hatchery production schedules, and research) is urgently needed. This integration will require increased allocation of time and resources in support of management and staff. There needs to be structural changes to advisory and TAC committees in order to adequately support the program. Restructuring should emphasize appropriate timelines for decision making, avoidance of conflicts of interest, incorporation of external review and directed research under a competitive request for proposal program.

3. The recovery program is not operating under the rubric of adaptive management. Outside experts should be convened to conduct a workshop on Adaptive Management. Topics covered should include an introduction to the concept, lessons learned from other programs, and an exercise in formulating an Adaptive Management plan. Adaptive management can be implemented at all levels, including a subsection of recovery goals such as an adaptive management approach for the hatchery program (but note this must be integrated into the larger recovery framework for the species).

4. Recovery goals should be the main driver in management decisions: hatchery supplementation should follow, not drive, recovery planning. While hatcheries may be important in preventing extinction, they are only one of the many tools of recovery, and their use should be set by recovery goals. Other factors such as at sea conditions, marine and freshwater survival, as well as reproductive success are key elements in recovery and need to be addressed in the overall program.

5. Hatchery evaluation should not be viewed as research but as a core element of the Recovery Program. Accordingly, it is important to integrate scientific assessment advice into decisions regarding not only hatchery production and release schedules, but even the use of hatchery supplementation to aid in population recovery towards eventual self-sustainability.

II. Hatchery Practices and Assessment

6. Assessments and scientific advice should be formally reported each year to provided informed management decisions, based upon best available science. Periodically these assessments should be reviewed by outside experts.

7. Recent assessments provide evidence that hatcheries contribute more than 80% of returning adults, but this result is heavily weighted by the Penobscot River estimate, which is based upon a smolt stocking program. For DPS rivers, preliminary genetic data suggest that fry releases contribute at least 50% of the returning adults.

8. Assessments indicate that most returning adults are of hatchery origin, but absolute levels of stocking of fry and smolts have been insufficient to retard the further decline of adult returns across DPS rivers.

9. Assessments have not been conducted in a sufficiently rigorous manner to definitively evaluate fry versus other stage (parr, freshwater smolt, estuarine smolt) stocking tactics. Same-river releases of different stage salmon over a several year period should be undertaken to evaluate survivorship and relative contribution rates of hatchery fish released at differing stages of their life history. These studies however should not deter implementation of the panel's recommendation to increase freshwater smolt releases into DPS rivers.

10. One or two rivers within the DPS should be "fully" assessed, where stage specific survivorship can be measured and tracked over longer time spans within the Recovery Program. These rivers should include molecular based pedigrees of all returning fish, in order to track the relative contribution of hatchery fish to self-sustaining populations.

III. Genetic Aspects

11. The river specific integrity of the existing salmon populations should be retained and there is no reason to depart from the river specific nature of the recovery and enhancement strategies without further and extensive research on the fitness implications of crossing river populations.

12. Use of a "vacant" drainage for experimentation with Gulf of Maine DPS salmon to address important research questions that cannot be addressed in the DPS rivers or are deemed too 'high-risk' is considered reasonable. However, it is noted that such out of river stocking potentially diverts important resources away from assessment of recovery in DPS systems and should be considered carefully.

13. Research priorities and performance would be improved with a more directed process of attaching research priorities to assessment of demographic and genetic

objectives (benchmarks) and through a competitive external grants program. Similarly, increased interaction and collaboration with recovery activities north of the border (e.g., Bay of Fundy) could improve research and management knowledge and effectiveness.

14. Due to overlapping monitoring and evaluation capabilities of electrofishing versus screw traps and cost/risk versus benefit of electrofishing, electrofishing should be significantly curtailed.

15. We recommend that changes be made to the program to maximize the effective population size N_e, and that the program should prioritize goals that will lead to natural reproduction in a significant portion of the runs.

16. We recommend that the Penobscot River population be managed using conservation objectives; hatchery populations should be integrated with the wild populations, effective size should be maximized, and inter-basin transfers should be prevented.

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INTRODUCTION

Sustainable Ecosystems Institute (SEI) is a public benefit, non-profit organization, founded in 1992. The goal of the Institute is to provide impartial scientific support for conservation decisions; the Institute is non-partisan, and seeks science-based, cooperative solutions to environmental issues. The organization has previously carried out extensive work on endangered species conservation and management, and has developed the use of peer review in such situations (Brosnan 2000).

SEI was contracted by the Maine Atlantic Salmon Commission (MASC) working in cooperation with US Fish and Wildlife Service (USFWS) and NOAA Fisheries Service (NOAA) "to determine whether the current hatchery operations, protocols and practices are being implemented in the most scientifically sound manner with the greatest potential to further recovery of the Atlantic salmon, and that assessment and evaluation is appropriately integrated into the hatchery program." This followed discussions among the Maine Atlantic Salmon Commission, NOAA Fisheries Service, and U.S. Fish and Wildlife Service management and biological staff. It also followed from a previous review and recommendations of the National Research Council of the National Academies (NRC).

The overall goal of this review is to provide a comprehensive, and critical evaluation of all important information regarding the hatchery program as it relates to recovery of Atlantic salmon. Ultimately, this evaluation will be used by MASC, NOAA and USFWS (signatories) in making management decisions regarding the hatchery program and related issues. These are appropriately the responsibility of the three agencies. SEI's process is designed to provide an impartial scientific evaluation of both the hatchery program and of the use of information in recovery efforts. Our approach is restricted to summarizing, critiquing, analyzing, and synthesizing scientific materials.

The process we adopted was to set up a panel of experts drawn from a range of different academic backgrounds relevant to the review. These experts read the materials that were available or that were developed. Through a site-visit, a public meeting and other discussions, we evaluated the strengths and weaknesses of the various methodologies, practices and opinions.

The public meeting was held in Augusta, Maine on February 21st and 22nd and included a hatchery site visit to Craig Brook National Fish Hatchery on February 20, 2007. The meeting was carefully structured to ensure that the matters of science were discussed, evaluated, and unambiguously presented to meet the objectives of the Maine Atlantic Salmon Commission (MASC), as well as meet the evaluation needs of NOAA Fisheries and USFWS.

Overall project lead was Dr. Steven Courtney, Vice-President of SEI, who has expertise in endangered species research and management, and in the application of peer review processes to natural resource management issues. Ms. Lisa Sztukowski was project manager; she also has extensive experience with endangered species management issues.

Panel members and their particular expertise in the review were:

• Mr. Lee Blankenship	Hatchery management
• Dr. Deborah Brosnan	Governance; adaptive management
• Dr. Ian Fleming	Salmonid biology; evolutionary ecology
• Dr. Scott McKinley	Salmonid biology
• Dr. Kerry Naish	Genetics
• Dr. David Secor (chair)	Hatcheries; fish ecology

CVs of the panelists are appended to this report.

Panelists were selected by SEI to represent a range of necessary and relevant academic disciplines. Each panelist is a recognized leader in their fields of enquiry, and has a record of providing impartial advice. In addition SEI ensured that the panel had no conflict of interests, and understood the importance of providing technical evaluations that could be used by both scientists and decision-makers. SEI also made a point of ensuring that this hatchery review maintained consistency with previous efforts both in Maine and elsewhere. Hence Dr. Blankenship was able to bring to this review his extensive experience reviewing many other hatcheries in the Pacific Northwest and elsewhere. Dr. Fleming previously served with the NAS panel, so that he was able to advise the current panel on issues raised in the previous review, and to evaluate progress since then.

APPROACH AND GOVERNANCE

KEY RECOMMENDATIONS

- Increase support for management and staff to better integrate their program.
- Better integration between the two advisory committees.
- Restructure the TAC committees to provide better support to the programs, avoid conflict of interest, and move to an RFP structure.

SUMMARY

The Atlantic salmon must survive and reproduce in two different environments. This makes management difficult and the panel commends the work of the managers and scientists who are faced with this enormous and complex task.

The disastrously low numbers of Atlantic salmon made hatcheries a reasonable and obvious choice as a key management approach to halt their extinction. Indeed careful implementation of hatcheries may be essential to prevent extinction. But they are one tool in the overall recovery of the species and have not been integrated into a broader approach.

The overall survival and recovery plan for Atlantic salmon lacks a clear conceptual framework, clear goals, and strategic plan. This weakens the effectiveness of the program, and severs the link between hatcheries and species recovery. The committee recommends the development of a conceptual framework that guides senior management and helps the individual programs.

Governance structures play a major role in the outcome of natural resources decisions. The panel’s charge was only with the three main governmental structures (USFWS, NMFS, and MASC). We are impressed by the level of cooperation of the three main agencies. Their efforts would be made easier with greater logistical and financial support.

Currently the program is supported by two committees- the Technical Advisory Committee (TAC) and the Salmon Recovery Team. We recommend better integration between the two. We also recommend restructuring the TAC to make it more effective in providing advice, reviewing proposals, and avoiding conflict of interest. We recommend that the TAC move to an RFP structure.

APPROACH AND GOVERNANCE

The Atlantic salmon is an unusual species in that it must survive and reproduce in two very different and challenging environments. Adult salmon mature in the ocean and return to their natal streams to lay eggs. Newly emerged fry develop in these streams before swimming downriver to the ocean, where they must make a major transition to a marine environment. The fish migrate as far as the western coast of Greenland and after about two years at sea, the surviving adults return to their natal streams to breed, and completing the cycle.

This lifestyle makes salmon vulnerable to natural and human-made changes that occur at sea, in streams and rivers, and adjacent lands. In the past, salmon have been subjected to warming and cooling of the ocean, the damming of rivers which deny them access to spawning habitat, impacts of industrial logging and agricultural activities, acid rain, and overfishing. The NAS also implicated poor hatchery practices in the past as a potentially important negative influence. While several of these threats have now been ameliorated, some still exist. But most importantly the numbers of wild Maine Atlantic salmon remain perilously low. Returns from the sea are not encouraging. The current hatchery program is focused on preventing extinction, although the long-term goal is to recover wild salmon (we acknowledge that the original stocking programs had different goals).

Because numbers of salmon are now so low, it is not surprising that hatcheries have become the main (and in some cases sole) focus for maintaining the species. Although hatchery practices in the past may have contributed to declines, as noted in previous reviews, a hatchery program is now essential to prevent extinction of the species. However its role in recovery has not been fully explored, and its relationship to broader species and ecosystem issues (e.g. at sea or in stream survival), and management approaches has not been fully developed.

The committee feels that it is essential that the hatchery program be understood in the larger conceptual model for the species, its ecosystem, and its recovery. (See suggested preliminary model – Figure 1) Currently the parties have not fully articulated an operating model. This leads to unclear goals. Moreover, without a strong model, a key link between hatcheries and the overall effort to recover the species is weakened. Hatchery managers cannot evaluate where their activities fit in the overall response. This makes it harder to identify opportunities for changes in actions (e.g. stocking) and evaluate the results or consequences. It also makes it harder for scientists and managers to understand each other's priorities, constraints, and opportunities.

CONCEPTUAL MODEL for Maine Atlantic salmon survival and recovery

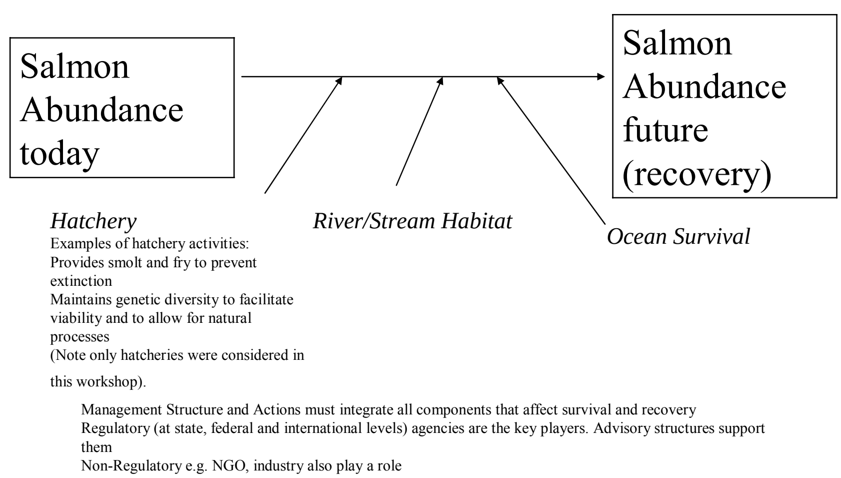

Figure 1: A simple conceptual Model

The prevention of extinction, and recovery of wild Maine salmon populations is determined by three main factors: Hatchery (regarded as a potential aid in preventing extinction); Stream and river conditions (i.e. quantity and quality of habitat) that determine survival and reproduction and "Marine Factors" which determine the survival and condition of salmon prior to their return for spawning.

Based on the above model, hatcheries are one component of the overall goal. Hatchery actions and proposals (including stocking, or adaptive management) are evaluated in the overall context of salmon survival and recovery. This model also helps to articulate what factors can be influenced by hatchery practices, and which are beyond the scope of hatcheries e.g. changes in at sea conditions that influence feeding and survival. (Note: The current conceptual model appears to envision hatcheries as the key determinant of recovery and puts stream and river habitat and at sea factors under the umbrella of hatcheries which can be a source of confusion when wider actions or proposals are being evaluated). The above model is an overarching concept. As noted in the text each of these boxes will have its own series of sub models and processes.

The key decisions are made by regulatory agencies. Senior management (at state and federal level) keep vigil on the bigger picture and makes decisions with regard to the overall model, while hatchery managers and scientists will be most concerned with those actions that fall under hatchery practices. TAC, recovery or other review committees support the managers. Non-regulatory groups e.g. NGO's and industry can provide assistance that fits in with the overall goals and approaches.

There are several other unintended consequences that arise from the lack of a conceptual framework and strategic approach. For instance, proposals can languish indefinitely because there is no clear way to identify their risks or benefits. Staff can become frustrated and valuable ideas lost. A clearly articulated framework would, in our opinion, benefit all the parties who are engaged in salmon survival and recovery. It would take greater advantage of the talents and knowledgebase that is available. (Benefits of a conceptual framework are discussed in greater detail under adaptive management and the reader is directed there for additional information).

The panel recognizes that the managers and scientists who are tasked with saving and recovering the Maine Atlantic salmon face enormous and complex challenges. We commend them for their efforts and commitment. Their work would be made easier and more effective by a more structured and conceptual approach.

Key Recommendation: Develop a conceptual framework that forms the basis for understanding the species, system, and is the foundation for setting clear goals and for management decisions.

GOVERNANCE

Governance structures play huge roles in the success or failure of species recovery and resource management decisions. They are by nature complex and their effectiveness is not frequently analyzed. At their core, governance structures regulate human activities either through laws, policies, or management. There are multiple governance structures that influence the fate of Atlantic salmon ranging from international to local levels. The NRC committee recommended increased coordination across all levels and among all sectors. Our charge concerned only those institutions that govern the scope of the project, -mainly government.

Human activities related to the survival and recovery of Atlantic salmon is under the control of six levels of governmental organizations and programs. They are: local, tribal, state, federal, regional, and international. The scope of our review did not extend to all of these. Primary responsibility for top level governmental management at the federal and state level rests with 3 main agencies- the US Fish and Wildlife Service, the National Marine Fisheries Service and the Maine Atlantic Salmon Commission.

Our panel commends the level of cooperation and commitment of the representatives of these three governmental agencies. Theirs is a model for cooperation on a critical issue. The strength of this relationship is critical to the continued implementation and improvement of the program and the recovery of endangered salmon. It should be encouraged and supported. Each agency has multiple mandates, and must deal with frequent policy changes. Moreover the recovery of Atlantic salmon is just one of many issues that they face on a daily basis. However it is fair to conclude that the potential extinction of the Atlantic salmon has not always been considered a high priority among policy makers and even members of the public. This is unfortunate, and makes the work of senior and junior management and scientists more difficult. We hope that this will change. Indeed it needs to if the salmon is to be recovered in the wild.

In addition to encouraging the three main agencies to continue to work closely and to better integrate with other efforts (see NRC report) the panel has specific recommendations that we feel will improve governance.

Currently the salmon recovery efforts are supported by two committees- the Technical Advisory Committee (TAC) and the Salmon Recovery Team. For several reasons, mainly to expand the talent base and to prevent mission overlap, these two committees were kept separate. However in practice this distance does not help the program. The system has become cumbersome, and the TAC in particular struggles with several issues.

The Technical Advisory Committee can be a more effective support to the program if structural changes are made. For instance we recommend an overhaul of the mission and make up of this group. We suggest making it into a stronger advisory and review group that is more attuned to the overall priorities and recovery actions. This group should also be charged with reviewing and recommending proposals for implementation and funding in a timely manner, and consistent with the conceptual framework and strategic goals (many to be developed) and time frames consistent with hatchery production schedules. This should be carried out in a formal and standard RFP system. Conflict of interest should be avoided, and the committee should consider adding additional external committee members who have no stake in the outcome (and are not candidates for funding) to provide additional expertise and avoid conflict of interest.

The Recovery Team appears to function mainly to help in outreach to stakeholders, although the primary mission of the Team is stated to be to develop and recommend recovery actions. The Team appears to make valuable contributions, but the committee feels that the work of the Recovery Team and the Technical Advisory Committee are poorly integrated, with inadequate coordination and designation of roles. It appears that the Recovery Team and the Technical Advisory Committee do not cover all the tasks that will be necessary to bring about recovery.

INDEPENDENT AND EXTERNAL REVIEW

Independent, external scientific review is often an important component of large, complex, or controversial programs where there is a significant technical component. There have been some efforts to incorporate this in ongoing efforts. The panel supports the use of independent review and feels that it could be expanded to better assist the recovery effort.

In particular, we suggest that:

1. That the parties consider whether some of the existing committee structure might be usefully supplemented by an independent scientific panel that could provide review and scientific evaluation, either at distance (e.g. by reviewing papers) or in person. Such standing panels have proven useful in other situations.
2. Periodic program reviews which address overall scientific rigor. These might be conducted either on a regular basis (e.g. every 5 years) or at important benchmarks (e.g. following implementation of our recommendations) or at need (e.g. when there is substantive disagreement among the parties).

At the same time, we recognize that peer review takes time, effort and money. It is not useful to expend staff energy on reviews if these are largely *pro forma*. We recommend that as part of the integration of TAC and Recovery Team activities, there should be a clarification of why peer review is being carried out, and whether reviewers should help evaluate the relative value of different scientific endeavors.

ADAPTIVE MANAGEMENT

KEY RECOMMENDATIONS

Adaptive Management should be used in the overall recovery strategy for the recovery of Atlantic salmon. This includes using an Adaptive Management approach for hatchery policies and programs.

However, it is clear that while participants understand that there is value to this approach, most do not understand it and many have differing views on what it is and is not. This is not surprising as the concept, nationwide, is generally poorly understood. Moreover, to date there has been little or no guidance or training for participants in this approach.

We recommend a workshop on Adaptive Management that includes both learning and practical components. Scientific, management, and stakeholders should be represented. Three key sections should be included:

- Introduction to Adaptive Management
- Adaptive Management in Action- Examples from existing programs on what works and what does not work
- Participants develop an adaptive management approach and elements of a plan. At the workshop, this could be carried out for a submodel e.g. for the hatchery program

SUMMARY

Adaptive Management allows managers to act in the face of acknowledged uncertainty. It is used to effect change, to learn about the system, and to make course corrections as needed. It is a formal process that has several key elements. These include clear conceptual models; stated objectives; implementation tests/actions; evaluation against performance measures; and decisions or course correction based on results. When used poorly however it is little more than ad hoc changes.

In the framework of Adaptive Management, the Salmon Hatchery Program constitutes a submodel. That is, it is a component of the overall recovery and management plan. It is designed to stand-alone and therefore has its own objectives and actions. Yet it is remains part of the larger conceptual model that forms the basis for recovery of the species, and must contribute to those goals.

The Salmon Recovery Program, including the Hatchery Program would clearly benefit from an Adaptive Management approach. Indeed this has been highlighted in other reviews (notably NRC). However little guidance has been provided to this program on what an Adaptive Management approach entails. Thus there is confusion over the elements and implementation of Adaptive Management which has made it difficult to move forward.

In this review we have provided an overview of some of the key elements of an Adaptive Management approach. This is to highlight the essential components and to reference similar programs where it has been used effectively. However, full treatment of Adaptive Management is outside the scope of this review, and moreover it is not something that can or should be carried out by a small panel of scientists. Adaptive management is a scientific, management, and stakeholder process. Thus we strongly recommend a workshop. This workshop should include three key components:

1. Introduction to Adaptive Management
2. Adaptive Management in Action- Lessons learned from other programs
3. Participants develop an adaptive management plan

OVERVIEW

Adaptive management is a tool that allows managers to act in the face of acknowledged uncertainty. Monitoring and management actions are constructed to reduce uncertainty over time while permitting change in response to surprising outcomes. Interventions are designed to test assumptions and hypotheses. Thus management is a mechanism to effect change (e.g. recover a species) and also a way to learn about the species or system being managed. Sound conceptual models, adequate planning, implementation, monitoring with a process to evaluate results, and a process for making course corrections are hallmarks of an Adaptive Management Program (see Table 1). In the absence of these key steps adaptive management can quickly become a series of ad hoc changes in management actions that do little to improve decisions or the recovery of species.

Table 1. Basic Components of Adaptive Management Approach
1. Formal conceptual models
2. Stated goals
3. Clearly articulated objectives (includes hypotheses statements)
4. Design and implementation of tests and actions which take account of current information and resources available.
5. Monitoring that is tied to performance measures. Performance measures follow from objectives.
6. Evaluation of results in light of objectives and performance measures
7. Incorporate lessons learned, make appropriate changes to models/objectives etc. if needed and decide on continuation or modification of management actions
  -Depending on results repeat actions from the appropriate step in the process

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Adaptive Management has been proven effective when well implemented. It is clearly an approach that can benefit this program. Indeed it has been recommended by several previous reviewers (notably NRC report). However, to date there has been little information or guidance provided on how to implement such an approach and consequently there is confusion surrounding the concept, and differing views on what it is and isn't.

In the sections below we have provided information on Adaptive Management. This is included as an introduction to the concept only, and to reference similar programs where it is being implemented. It is also used to illustrate how the Hatchery Program fits under an Adaptive Management framework. The Hatchery Program is in effect a submodel that has specific objectives, actions, and evaluation methods that stand alone but should feed directly into the larger conceptual model and management for salmon recovery. Also in this section we specifically highlight the importance of conceptual models as we feel it is important that these models be more clearly considered and stated in the overall salmon recovery approach (see previous section on Governance)

Adaptive Management is a scientific, management, and stakeholder process that should be developed by representative from all these sectors.

Our key recommendation is for a workshop on Adaptive Management that includes an introduction to the concept, lessons learned from other programs, and the formulation of an Adaptive Management plan. This plan can be created for a subsection of the recovery goals for example, an adaptive management plan for the hatchery program.

An Adaptive Management plan for the hatchery program would include:

- Relationship between the hatchery program and the overall conceptual model
- Clear articulation of goals and assumptions of the program
- Action plan
- Monitoring plan
- Evaluation Plan
- Decision plan including feedback mechanism to the larger conceptual model and goals.

ADAPTIVE MANAGEMENT: BACKGROUND AND KEY FEATURES

There is a widespread recognition in the policy literature that effective management in the face of complexity and uncertainty is best approached as series of incremental decisions, each informed by treating previous decisions as experiments and monitoring outcomes (see, for example, Quinn 1992, Mintzberg et al. 1998 for applications to business strategies). This approach is used widely in arenas outside of natural resources. For instance, business policy theorists emphasize that well-run organizations typically devote 5-10% of the cost of the project to collecting data on performance indicators and using the information to evaluate outcomes of past decisions. Unfortunately, public environmental and natural resource agencies tend to under-invest in the information needed to formulate effective and responsive public policy (President’s Council of Advisors on Science and Technology 1998).

Experience in the management of endangered species as well as initiatives to restore large ecosystem functioning has led to a series of guidelines in how to design programs to inform effective management (see Busch and Tessler 1992, Atkinson et al. 2004 for recent reviews). Adaptive Management, a tool for addressing complexity and environmental uncertainty, is now common in several ESA and large environmental programs. However definitions and approaches vary considerably (Holling 1973, 1978, Lee and Lawrence 1986, Bormann et al. 1993, Halbert 1993, McLain and Lee 1996, Salasky et al. 2002). Yet at their core, they all share the goal of combining research and management by integrating program design, management practices, and monitoring and using these to test assumptions methodically (Ringold et al. 1996, 1999). In this way, managers gain an understanding of how to adapt their management approach while concurrently answering questions about whether their approach is effective, and why it may or may not work (Salasky et al. 2002, Smit 2003).

Adaptive Management is not a risk-free or cost-free endeavor. Indeed it is often difficult to implement both conceptually and programmatically. For instance, regional management models capable of predicting quantitative outcomes of management alternatives are complex. They are also hard to construct and validate in large heterogeneous landscapes such as large rivers, estuaries, oceanic and forest ecoregions. Effective predictive modeling can be hampered by the hugely variable time scales between the days-to-weeks of operations models and the years to decades involved in assessing the recovery of long-lived species (Walters et al. 2000, Geist 2000). In some cases, a more focused approach e.g. a submodel (see below under Conceptual Models) to Adaptive Management can be effective e.g. where a particular class of policies or actions is being investigated for their potential in contributing to recovery of a species. The hatchery program for salmon is one such example. However, all the key components of adaptive management must be used.

Conceptual Models: The need for conceptual models has been discussed in the section above. This section is included here to explain their role as a tool in Adaptive Management. Formal conceptual models vary in form, but are typically box-and-arrow diagrams illustrating a web of causality relating habitat condition, external stressors, management actions, and the dynamics of a number of response variables (e.g., water quality, ocean changes) of management concern. Both boxes (environmental states) and arrows (causal processes) often contain embedded submodels. Formulating conceptual models that are relatively simple, yet that captures key processes and promote consensus among stakeholders, remains an art.

Explicit conceptual models serve a number of useful purposes. First and foremost, they force managers to explicitly state the assumptions and priorities underlying management actions. The diverse agencies and stakeholders invested in any species management or recovery process represent a diverse collection of conceptual models. Thus this initial stage is essential to formulating a joint approach to monitoring that is acceptable to the major participants (Lee 1993, 1999). It is also a first step toward insuring that all of the key variables needed for analysis are in fact being assessed. Conceptual models also provide a powerful approach for clarifying management information needs. In several programs they have been useful in specifying what parts of operations in a spatially and biologically complex environment are subject to management actions, what predicted outcomes of those actions are, and what indicators should be chosen for monitoring to assess the particular effects of those actions- factors that are important for hatchery practices in light of salmon recovery.

Explicit conceptual models can help clarify for scientists and field monitoring programs what specific information managers are seeking for particular decisions -- not only on operations or legal or reporting mandates, but also on responses to sudden changes in the system or changes in the policy environment.

Conceptual Models are tied to monitoring programs. Recently the designers of monitoring programs in most adaptive management efforts have built evaluation frameworks around a series of explicit conceptual models. Notable examples include most of the largest and most mature regional restoration efforts in the U.S., most of which have been driven by a need to recover endangered species. These include the Northwest Forest Plan (FEMAT 1993, Noon et al. 1999, Mulder et al. 1999, Thom 2001), the Everglades (Ogden and Davis 1999), the Sierra Nevada Framework (Manley et al. 2000), the Columbia River (Geist et al. 2000), the Sacramento River Delta/San Francisco Bay (Atkinson et al. 2004), and the Colorado River (Walters et al. 2000). Successful conceptual models describe the dominant ecosystem processes, stressors, control points, existing and desired endpoints (outcomes to be controlled), and usually legal and institutional mandates and constraints on decision-makers' actions (see Olson et al. 1994, Busch and Trexler 2002, Atkinson et al. 2004, for reviews).

Evaluation and decision making are among the final steps in Adaptive Management. We note that decision making has been previously covered in the NRC report and as this section is designed primarily to provide an introduction to the concepts of Adaptive Management we refer to reader to that section of the NRC report.

RIVER SPECIFIC STOCKING/ OUT OF RIVER RELEASES

FINDINGS/RECOMMENDATIONS

1. Care is needed to ensure that hatcheries do not drive recovery plans, but recovery goals should dictate the use of the hatcheries as one of the tools for recovery. As pointed out by NRC (2004), the hatcheries should be seen as only one option in an integrated strategy that includes rehabilitation of habitat, fishery management, and other strategies. There was some concern expressed by the SEI committee that hatcheries were being viewed as the principle recovery tool rather than as part of an integrated strategy. In the absence of addressing of other components of a strategy, hatchery supplementation is likely to be ineffective. Hatcheries should be seen as a tool to temporarily bridge the current period of low adult returns with the goal of attaining self-sustaining wild spawning populations (see NRC 2004, National Marine Fisheries Service and U.S. Fish and Wildlife Service 2005).

2. There is a need to determine the degree to which hatchery supplementation is aiding population recovery towards eventual self-sustainability. This was identified originally by NRC (2004), however, the SEI committee saw limited progress towards addressing the issue. Assessment of whether the stocked salmon provide a net long-term benefit to the natural populations remains inadequate. "The success of hatchery programs that aim to rebuild depleted populations lies in their ability to allow fish to bypass the high mortality of early life in the wild and then survive, breed and produce offspring that will contribute to natural reproduction in the wild. In that sense, 'contribute' means that the stocked fish should not take away from the production of the wild population but rather add to it" (NRC 2004). The potential demographic benefits of hatchery supplementation need to be examined in light of concerns about domestication, interactions with

wild fish and impeding adaptation (i.e. through natural selection) to contemporary conditions in the wild.

3. Greater attention needs to be given to evaluating hatchery supplementation in an adaptive-management context to determine the risks and benefits of various practices. It is reasonable to try different approaches, while maintaining the integrity of the individual stocks, that might or might not work, providing that the approach is designed in a way that one can learn from it. That is, the actions should be designed as experiments where results can be assessed and thus allow for modifications of future actions.

4. The river specific integrity of the existing populations should be retained. There are no indications that the populations are suffering from inbreeding depression and would benefit from mixing / hybridization at this time. Such hybridization and release to the wild could disrupt co-adaptive gene complexes and have irrevocable consequences. Thus, the committee saw no reasons to depart from the river specific nature of the recovery and enhancement strategies at this time. However, contained, laboratory research / monitoring might be put in place to evaluate inbreeding depression, and when benefits may out-weigh the dangers of interpopulation hybridization. There is likely some form of threshold where the negative consequences of inbreeding outweigh those due to outbreeding (interpopulation hybridization), which is as yet poorly understood (reviewed in Edmands 2007). Similarly, what degree of outbreeding (i.e. introgression), if any, that would be appropriate and what source of genetic material should be used (e.g., neighboring or more distant, but ecologically similar population; reviewed in Tallmon et al. 2004))?

5. While the committee felt strongly that river specific stocking should continue where Atlantic salmon populations persist, the possibility of using a "vacant" drainage for experimentation with GoMDPS salmon was considered reasonable. Such experimentation could involve research that could not otherwise be conducted in drainages were GoMDPS salmon persist without threatening their integrity. The committee did note one caveat to such research. Resources are limited across hatchery, assessment, and research groups. We see very large resources expended on systems of reintroduction in Connecticut and Merrimack rivers. From the standpoint of requiring careful assessment of hatchery contribution rates, the panel urges caution in using vacant habitats as experimental systems that diverts resources away from DPS rivers. In particular, diversion of assessment and hatchery resources to these systems could come at high trade-offs against assessment/research needs in DPS rivers.

BACKGROUND

Based on petitions to list Atlantic salmon throughout its historic range in the contiguous United States under the Endangered Species Act, a Biological Review Team (BRT) was established by the US Fish and Wildlife Service (USFWS) and National Oceanic and Atmospheric Administrations' National Marine Fisheries Service (NMFS) in 1995. The charge of this review team was to evaluate the status of Atlantic salmon. In their 1995 report they identified seven rivers (Dennys, East Machias, Machias, Pleasant, Narraguagus, Ducktrap and Sheepscot Rivers) as being in danger of extinction. Conservation plans were then enacted. A subsequent status review by the BRT in 1999 proposed a rule to list the Gulf of Maine Distinct Population Segment as endangered. This distinct population segment was defined as all naturally reproducing wild populations of Atlantic salmon, having historical river-specific characteristics found north of and including tributaries of the lower Kennebec River to, but not including the mouth of the St. Croix River and Penobscot River above the site of the former Bangor Dam. It was decided that the Dennys, East Machias, Machias, Pleasant, Narraguagus, Sheepscot, Ducktrap and Cove Brook rivers met the criteria. In 2000, the final rule was issued confirming the endangered species listing as proposed, and was amended to incorporate the river-specific hatchery populations of Atlantic salmon having historical river-specific characteristics (see Fay et al. 2006 for a history of the listing).

The ensuing controversy that accompanied the listing led the US Congress to request the National Research Council (NRC) to examine the science relevant to understanding and reversing the declines in Maine's salmon populations. The first charge to the NRC's Committee on Atlantic salmon in Maine was to report on genetic distinctiveness of the salmon populations in Maine (National Research Council 2002). That is the degree to which populations in Maine differ from adjacent populations in Canada and the degree to which populations in different Maine rivers and tributaries differ from each other. It was recognized that such information is important in the choice of recovery options that are most likely to be effective. The Committee concluded that despite extensive additions of nonnative hatchery and aquaculture genotypes to Maine's rivers, the evidence was "surprisingly strong" that the wild salmon in Maine are genetically distinct, based on a variety of protein and DNA markers, from Canadian salmon. They also concluded that there was considerable genetic divergence among populations in the eight Maine rivers where wild salmon are found. The question of whether the genetic differences among the Maine populations reflected natural selective processes within the watershed or recent genetic drift caused by small population sizes could not be answered. However, the Committee did note that the pattern of genetic variation seen among Maine populations was similar to patterns seen elsewhere in salmon and their relatives where no stocking has occurred.

CURRENT EVIDENCE OF DISTINCTIVENESS

Research published since the NRC (2002) report continues to support the genetic distinctiveness of the Gulf of Maine Atlantic salmon populations from Canadian populations (Spidle et al. 2003, Cordes et al. 2005, Verspoor et al. 2005). Moreover, it provides evidence of statistically significant genetic variation among all populations in Maine (Spidle et al. 2003, Cordes et al. 2005). This was further confirmed by the recent results presented at the SEI Review Meeting in Augusta, Maine, by Meredith Bartron

(USFWS, 21 February 2007) using a neighbor joining tree based on Chord distances and from broodstock samples during 2000-2004. While the extent of genetic differentiation among Maine populations appears to be less than that observed among Canadian populations, this may have been due to greater levels of within population diversity and/or the broader geographic scale of Canadian populations surveyed. There has also been evidence indicative of quantitative trait differentiation among the Maine salmon populations (Obedzinski and Letcher 2004, see also Sheehan et al. 2005, Wilke 2006), suggestive of local adaptation. The findings of Lage and Kornfield (2006), however, suggest that some of the Maine populations may have incurred a genetic bottleneck and loss of variation for "neutral" genetic markers.

At this time, there appear to be no indications of inbreeding depression (e.g. Fay et al. 2006), though detailed investigation is lacking. Estimates of effective population sizes (N_e) for the different broodstocks at Craig Brook National Fish Hatchery (CBNFH) are small (Barton et al. 2006, see Broodstock Management and Genetics section below regarding concerns about the measure of N_e). There are also indications, at least for the Dennys River population, of a significant reduction in N_e from 1963 to 2001 (Lage and Kornfield 2006). However, while the N_e of Maine populations may be low compared to historic levels, most (except the Pleasant) appear not to be out of the norm for small Atlantic salmon populations in the wild elsewhere within the species' native distribution (i.e. with annual census sizes below 200).

The hatcheries of Craig Brook and Green Lake have become one of the principal recovery tools by which to implement the river-specific recovery program (e.g., National Marine Fisheries Service and U.S. Fish and Wildlife Service. 2005, Barton et al. 2006). A detailed and well thought out broodstock management plan does exist and is being implemented.

HATCHERY OPERATIONS AND RELEASE STRATEGIES

The Green Lake (GLNFH) and Craig Brook (CBNFH) National Fish Hatcheries appear to be well designed salmon hatcheries that incorporate best management practices. In particular the water intake and discharge components at CBNFH were noteworthy, as were the physical facilities and isolation and rearing protocols for river-specific hatchery management. The lack of disease outbreaks and survival rates within both hatcheries reflect good husbandry practices.

Physical space for expansion and phosphorous discharge are limiting factors at both hatcheries. The use of a reduced phosphorus diet such as Skretting's BioDay 1000LP should be investigated to improve water quality discharge. Hatcheries in Quebec, Michigan and the Pacific Northwest have experienced positive results with low phosphorous feed.

Since instituting the river-specific broodstock program in 1991 at CBNFH, the goal of conserving the genetic integrity of seven genetically distinct stocks has been accomplished; due to evidence that genetic and phenotypic differences exist between these stocks, the committee strongly applauds this accomplishment and recommends that it be continued. However, the panel is also very concerned about the demographics of these populations. This concern was also expressed in the National Research Council Report (2004).

The gene-banking program of the six DPS stocks has maintained a captive broodstock program that uses captured parr from fry releases. This novel approach effectively reduces the domestication risk associated with a captive broodstock program. Current fry to adult survival in the wild however has too low of a survival rate to re-establish self-sustaining population. Thus, unless marine survival rates were to greatly increase, the current program as being implemented would probably never lead to recovery. Except for the natural rearing period from fry to parr, the hatchery environment is driving the long-term adaptation and fitness of each population. The panel strongly believes it is vital that the natural environment drive the long-term adaptation which in turn will increase the fitness and overall survival. To increase demographics and allow the natural environment to control long-term adaptation the panel recommends actions that will increase the number of natural spawners for the current river-specific gene banking program.

Several of the reports and presentations given to the committee referred to "excess" fry or parr and expressed concerns about competition between wild and hatchery juveniles or redd imposition from hatchery adults. The co-managers have done a good job in emphasizing habitat productivities and carrying capacity in the recovery program. However, even with inherent uncertainties in estimating habitat productivity, current release levels are unlikely to be constrained by carrying capacity. For instance, even if the number of hatchery fry or parr were released at the levels approaching carrying capacity, the actual number of survivors within a few days would be halved. Survival is density dependent and lower densities of fry or parr typically relate to higher survival. However, higher survival from fewer individuals does not necessarily mean it results in a higher number of smolts or adults which is the primary objective. Although scant, the information provided to the panel showed the expected juvenile to adult survival was higher respectively from smolts, parr and fry releases. A greater emphasis needs to be placed on releasing smolts and parr from the limited number of available fry to increase adult returns. Due to the rearing limitations at CBNFH and GLNFS the co-managers will need to explore other rearing options. These should include rearing of smolts by private industry or other agency facilities as well as NGO cooperative programs for short-term acclimation sites for smolt releases or longer-term fry or parr-to smolt rearing or acclimation ponds.

Maximizing the potential of pre and post spawn adults that are in excess of those needed for the core captive broodstock program is also recommended. Pre-spawned adults should be released in an area and time where their chance of successful spawning is high. Post-spawned adults should be re-conditioned if possible prior to release. Releases should occur in areas where there is at least a chance for survival and their carcasses can contribute to the freshwater ecosystem if survival isn't realized.

The objective of the recommendations above, as stated before, is to increase the number of returning adults for natural spawning with the idea that each succeeding generation will produce juveniles with a greater adaptation, fitness, and survival than hatchery juveniles. These release strategies should be monitored and evaluated to determine their effectiveness in meeting objectives. Additional benign tagging or marking methods beyond genetic marking and elastomer will be needed. Adipose fin marking, coded wire tags, and combinations of the different identification methods are commonly used in salmonid evaluations. The use of fins other than the adipose fin should be carefully considered. Even the ventral fin has been shown to cause considerable mortality, especially with fry and parr releases.

QUALITY OF FISH

Suggestions for monitoring and potentially enhancing the migratory activity and performance of hatchery reared salmon smolts.

OBSERVATIONS (O) / RECOMMENDATIONS (R)

O – Overall percent return from smolt production has not been adequately quantified, with the exception of the Penobscot.

O –Despite some solid assessment of smolt to adult survival for the Narraguagus population, estimates of mortality are not known for the migratory phases (freshwater, estuarine, and marine) across the DPS rivers. Ability to assess potential variations in rearing conditions, handling and transportation protocols, and release mechanisms in rivers does not appear to be in place.

O – Hatcheries are geared to maximise production of smolts. Assessing the quality of the smolt released: stress level, salt water tolerance, and degree of readiness relative to release time does not appear to be a component of the hatchery operational plan.

O – Incorporation of procedures to assist in the conditioning of smolts to the natural environment prior to release have not been investigated.

R – Mortality estimates should be determined for freshwater, estuarine and marine migratory phases and tracked over time in one or two of the DPS rivers (i.e. number of smolts exiting relative to time of release, percent of adult returns). At a minimum one river, designated as an experimental river, should be adequately outfitted (traps, listening receivers) and continuously monitored to assess the success of alternating rearing conditions, capture and handling techniques, and release mechanisms on smolt success.

R – Some of the effort presently focused on production should be re-directed to permit an adequate investigation and evaluation into alternate rearing conditions, handling and transfer protocols, and release methods on smolt survival. Assessments should include the degree of damage to the fins, including bacterial analyses, nutritional condition, immunity, and the prevalence of pathogens.

R – Incorporation of stress-reducing methods, especially recovery protocols after transport, should be investigated and implemented as appropriate, as potential mitigative strategies to improve migratory behaviour and performance.

INTRODUCTION

Hatchery smolt production accounts for >85% of adult returns in the Penobscot despite evidence that smolt marine survival is less than one percent. Percent contribution of smolt releases, relative to other life stages stocked, to adult returns has not been quantified in all DSP rivers. Nevertheless, stocking of hatchery reared smolts likely represents a high percentage of all adult returns.

A low marine survival of hatchery reared smolts is not unique to the hatcheries of the USFWS Maine Program. Typically, marine survival of hatchery reared smolts has been found to be approximately half of estimates for wild Atlantic salmon smolts (Jonsson et al. 1991). Reasons for low survival are believed to be, in part, related to stress associated with hatchery rearing conditions, transport and release protocols, and lack of recovery procedures in the wild. Considerable effort is now being expended among the Nordic countries to mitigate stress and therefore improve smolt quality and performance following release.

Stress responses, from handling and transport procedures, have been well documented (Iwama et al. 1997, Barton 2000). Furthermore, stress has been shown to suppress the immunological capacity in fish (Schreck et al. 1993), affect seawater tolerance (Iversen et al. 1998), migratory activity (Specker and Schreck 1980) and as a result, influences migratory activity and performance.

A variety of methods, anaesthetics and other sedatives (Burka et al. 1997), have been employed to alleviate stress through the reduction in metabolism and the related reduction in oxygen consumption and decrease in the generation of metabolic waste products. Benefits include a reduction in excitability and swimming activity, which in turn reduces fin injuries during transport (Ross and Ross 1999). Other procedures employed to mitigate stress include the addition of mineral salt formulations to reduce the ionic strength of transport water. The benefit of salt is related to its ability to inhibit the decrease in plasma chloride, sodium concentration and minimize chronic cortisol increases (Mazik and Simco 1994, Soivio and Nikinmaa 1981, and McDonald and Milligan 1997).

This report suggests procedures and protocols that could be used to assist in the estimation of smolt survival and to alleviate stress associated with the transport and release of hatchery reared smolts. The underlying questions addressed include:

- How can post-release survival be measured?
- Could smolt survival be improved by increasing the quality and performance of hatchery reared smolts?

Q1. HOW CAN POST-RELEASE SURVIVAL BE MEASURED?

The monitoring of migratory behaviour and survival rates can effectively be carried out as a result of recent advances in acoustic telemetry (Voegeli 1998, Thorstad 2004, Moore, 1994 and Johnstone et al. 1995). The tags now available are of a size that can be implanted in out-migrating smolts as small as 12cm, but powerful enough to be heard and recorded using underwater receivers. “Listening lines” of acoustic receivers have been put in place up the BC coast to detect any acoustically tagged animals migrating overhead (Welch et al. 2003). Studies have used these lines to observe differences between wild and hatchery survival and behaviour in the fresh and marine environments by calculating percentages of tags detected at each consecutive listening line (Welch et al. 2004) (Figure 2). Similar approaches have been employed to estimate natural and fishing mortality rates by modeling fish counts at consecutive time steps. Listening lines serve as “virtual gates” and take a snapshot in time and uses last known locations of fish to estimate survival.

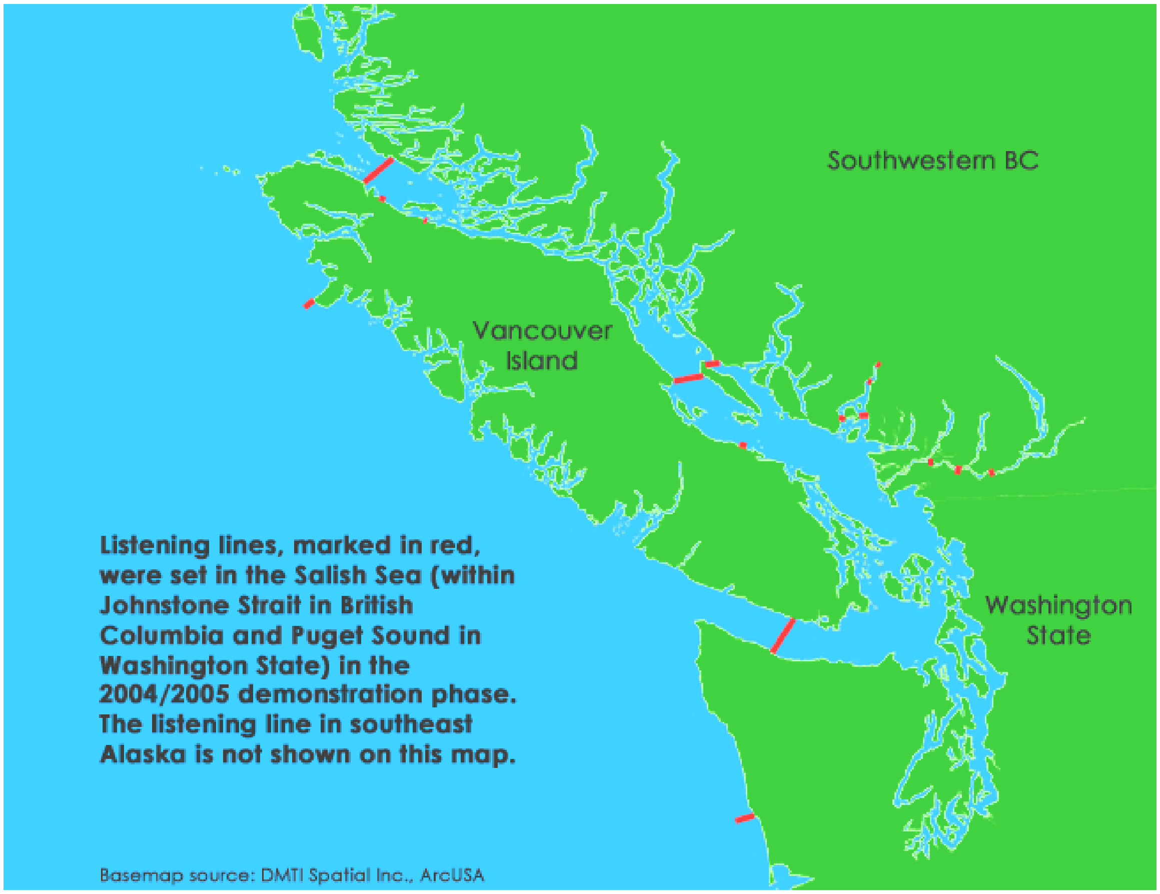


Figure 2: POST listening lines

Two key components of a telemetry system are the accuracy of the receivers in detecting and decoding tagged individuals and the assessment of handling and tagging procedures on the test subjects. It is critical that the reception area of the receivers be accurately measured in the field using transmitters of equal power and code frequency. Furthermore, these tags should be drawn through the system at speeds similar to the speed of the water and swimming ability of the tagged smolts (Peake et al. 1997) and detection frequency noted. Typically, receivers in the freshwater environment are established at "choke points" in the river to ensure complete coverage of downstream migrating smolts. In estuarine and marine environments, detection efficiency must also be determined throughout the water column using the reference transmitter at various distances and towing speeds from the receiver. Ideally, the receiving system should have a pre-determined detection rate approaching 100%. In this way, it will be known if a fish has emigrated from one section of the study area to another and therefore permit an estimate of survival at various points during their out migration.

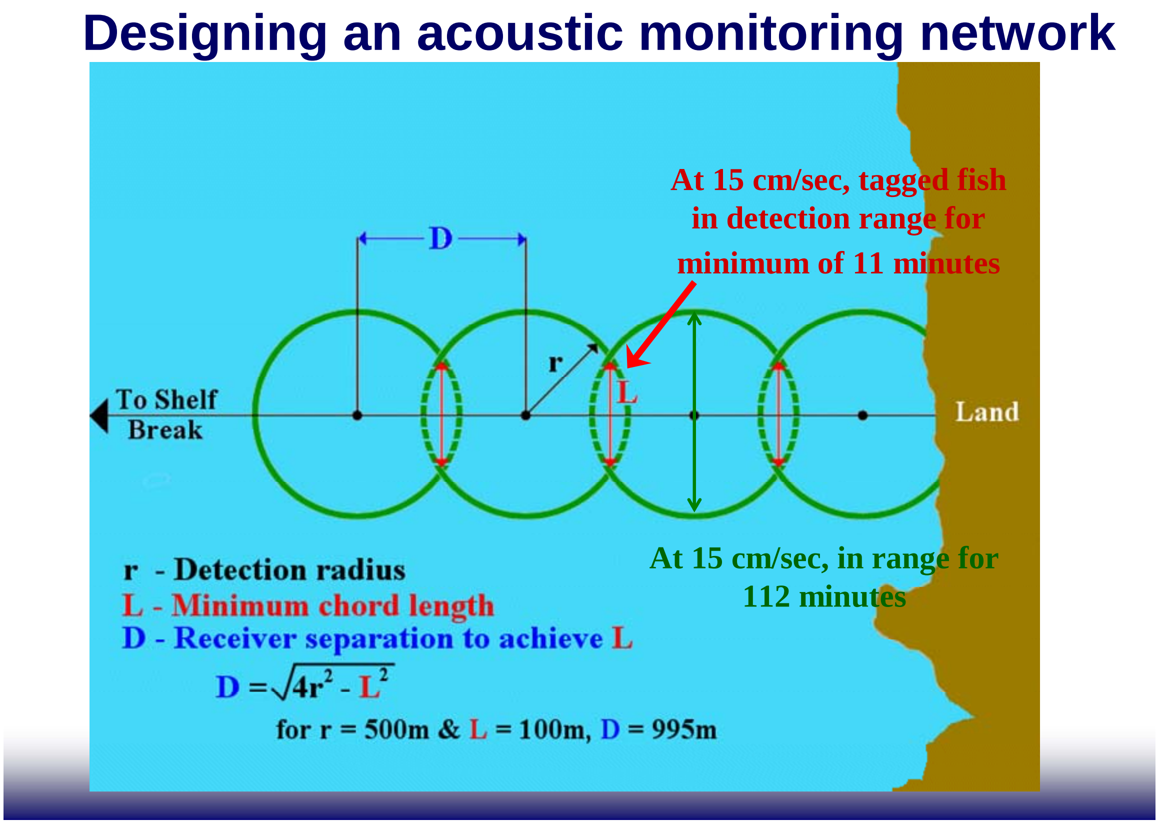
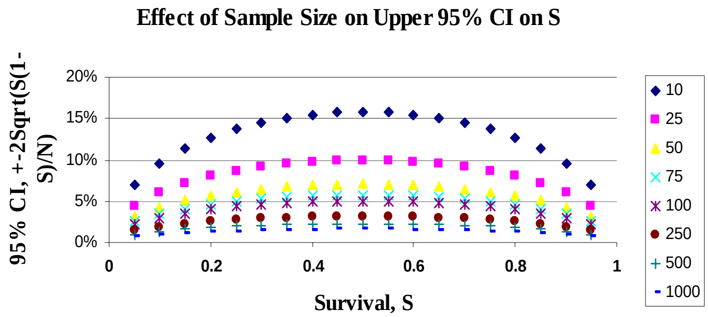


Figure 3: Positioning of underwater receivers to maximize efficiency

Determining the number of individuals to be tagged has always dominated discussions on the application of telemetry. Typically, as the number of fish tagged and monitored is increased, one can expect the 95% Confidence Intervals of survival estimates to be minimized (Figure 3). Our experience in estimating the number of smolts leaving tributaries of the Fraser River in BC suggest a sample of 100 tagged individuals is adequate. The cost/benefit of additional tagging does not appear to justify the additional cost of transmitters. It must be emphasised that the confidence intervals presented are based upon the number of smolts surviving capture, handling and tagging protocols and a near 100% receiver detection efficiency. Assessing handling and tagging effects of individuals to be released for the purpose of estimating where out migration survival is compromised (i.e. freshwater, estuarine, marine) is critical to the establishment of mitigative strategies.



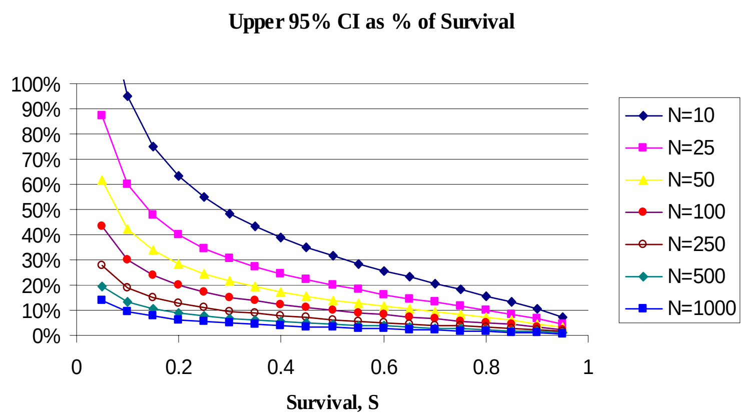


Figure 4: Effect of sample size (number of fish tagged and released) on the width of the 95% confidence interval on the proportion surviving at some later point in the migration path (for simplicity, the normal approximation is used to the underlying binomial calculation). (Top) The absolute value of the upper CI as a function of the survival, S, and the number of tags released, N. (Bottom) The upper 95% CI on the survival proportion, expressed as a percentage of the measured survival, S. Note that for survival proportions of 20% or more, typical of the marine survival out of the Strait of Georgia, tag releases of N=100 smolts will allow very tight confidence intervals on both the proportion surviving to leave freshwater. From POST data collected over the past three years, typically, SFW≈0.2-0.8 and SMarine≈0.2 out of the Strait of Georgia ecosystem. This means that confidence intervals on the proportion surviving to leave freshwater will range from SFW=20%±4% to SFW=80%±4%. Confidence intervals on the marine survival to exit from the Strait of Georgia will range from SMarine=20%±8% to 20%±5%, depending upon whether the number of smolts leaving freshwater is high (SFW=80%) or low.

In addition to understanding hardware efficiency, assessing tagging effects is equally important. A number of studies are published outlining anaesthetic and surgical protocols for Atlantic smolts, including procedures to monitor post surgical effects (i.e. challenge tests, see Peake et al. 1997). Typically, gastric or external attachment procedures are not recommended for Atlantic salmon smolts as these procedures have been shown to compromise swimming ability and therefore survival. Assessing post surgical/implantation procedures on salmon smolts is best evaluated using a swimming challenge test. Typically, the swimming performance of tagged, untagged and sham tagged (similar surgical procedure but the transmitter is removed) is compared and assessed. Regardless of the challenge test applied to assess handling and surgical procedures, tagging effects on the behaviour and performance of smolts must be determined and accounted for in field survival estimates prior to the launch of any study to evaluate smolt out river migration performance.

An example of freshwater mortality rates found for some of the salmon stocks tagged on the Pacific coast and monitored in 2004 and 2005 are shown in Figure 4. Interesting to note is that differences in survival can be seen to vary from year to year for fish species from similar tributaries. Results highlight the need to ensure receiver efficiency is adequate and tagging effects are assessed year to year.

Q2 - COULD SMOLT SURVIVAL BE IMPROVED BY INCREASING THE QUALITY AND PERFORMANCE OF HATCHERY REARED INDIVIDUALS?

The post – release survival of hatchery fish tends to be lower than that of wild fish. Behavioural deficiencies due to artificial rearing environments are thought to be the primary cause of these failures. Conservation aquaculture principles aim to return fish stocks to their original genetic, physiological and behavioural characteristics (Flagg and Nash 1999, Brown 2002). Conservation hatcheries have clear goals with measurable outcomes, programs are carried out using all available technologies, and outcomes are consistently evaluated and monitored. Few re-introduced captive-bred animals successfully establish wild populations (Gipps 1991, Clark et al. 1994, Olney et al. 1994). Behavioural deficiencies due to artificial rearing environments are thought to be the primary cause of these failures. Examples of hatcheries that are using conservation aquaculture methods to 'naturalise' the behaviour of their smolts include the Nez-Pearce Hatchery, the Dungeness Hatchery, and the Lower Elwha Tribal Hatchery in Washington State. These hatcheries have created enriched rearing environments, including matrices for egg and alevin development, in-stream structures such as old Christmas trees and floats, and camouflaged nets suspended above the surface for cover. Water temperature and quality and light regime is maintained to resemble local conditions, flow rates in holding tanks are higher to promote exercise, and food is introduced below the surface of the water using belt feeders. Hatchery fish raised in these semi-natural conditions had body colouring that more closely resembled that of wild fish, and had 50% higher survival rates than traditionally-reared smolts to a weir 2.2km downstream (Maynard et al. 1997). Fish reared in natural environments also demonstrate better physical condition and less disease (Banks 1994, Mundie et al. 1990). At the very least, light/temperature conditions should mimic natural conditions (Fig. 5).

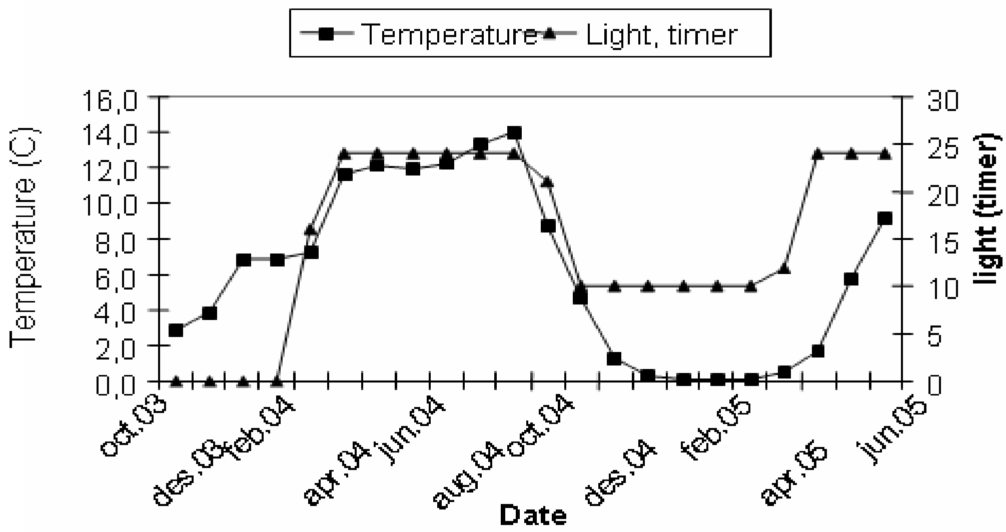
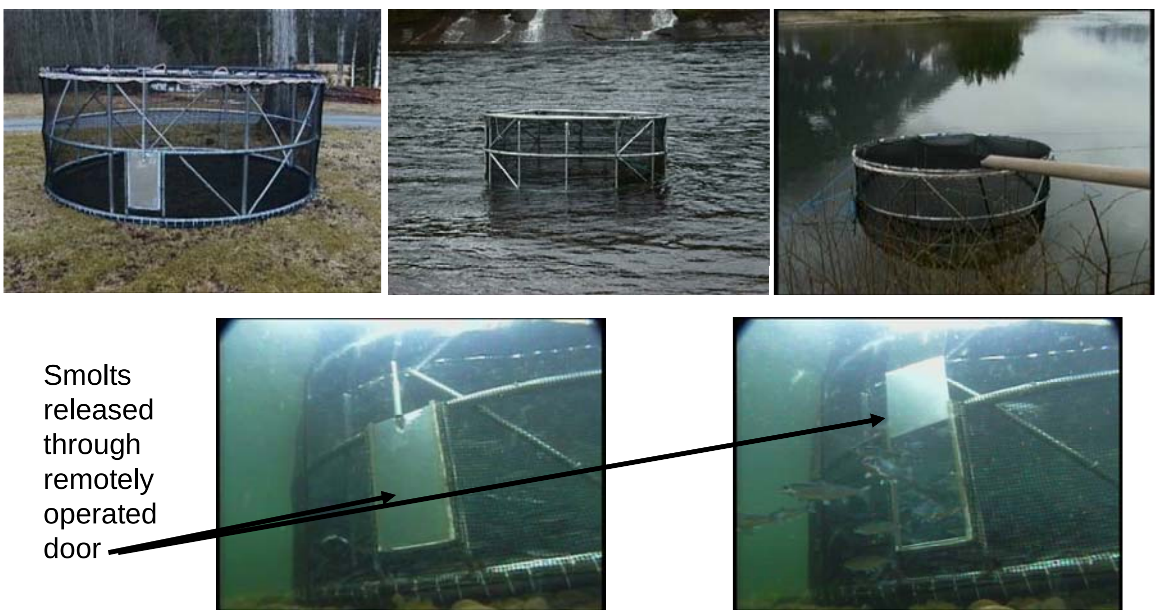


Fig. 5: Temperature/light regime for the production of smolts prior to release.

In addition to raising hatchery fish in a natural setting for improved colouring and physical health, conditioning the smolts in various ways can improve their swimming, foraging and predator-avoidance abilities. The swimming abilities and growth rates of Atlantic salmon and brook trout improved significantly with only six weeks of swim training (Leon 1986, Besner and Smith 1983). Logically, post-release survival also improved in smolts that were exercised (Burrows 1969, Cresswell and Williams 1981). These studies measured survival by adult returns and smolts recovered in the estuary. Predator avoidance training using direct exposure, caged predator, and electric model approaches were found to increase the instream survival of test subjects up to 26% over un-conditioned fish (Thompson 1966, Maynard et al. 1997). Supplementing the diet of hatchery chinook with live feed increased the smolts' foraging ability two-fold (Maynard et al. 1996) and naturally-fed tiger muskellunge had higher post-release survival than those fed only pellets (Johnson 1978). Releases of hatchery brook trout and Atlantic salmon that had been hand-fed pellets were more surface-oriented and more likely to approach moving objects than were wild fish (Sosiak 1978, Mason et al. 1967). Decreasing rearing densities has also been found to improve smolt growth, condition, gill ATPase levels, and survival significantly (Banks 1992, Refstie 1977). High densities increase agonistic behaviour in smolts, which could increase the likelihood that smolts will suffer higher predation rates post-release (Moore 1994). Volitional releases should be used to ensure that smolts are migrating out only when they physically ready. This type of release also maintains out-migration diversity and allows smolts to travel at night when the risk of predation is lower. Predictions of ocean carrying capacity during the release year should be considered so that an appropriate number of smolts are released.

One method used to permit smolts to recovery following transport and has demonstrated higher and faster downstream migrations is placing smolts in pens placed in the river (Fig. 6). The procedure resulted in a 20-30% difference in marine entry for smolts and may result in improved survival rates (Finstad et al. 2003). Schreck et al (1989) also noted an increase in the survival of Coho salmon transported as juveniles and allowed a few months of recovery. Capture and transport of smolts appear to require recovery times ranging from 24 hour (Robertson et al. 1987) to over 48 hours (Iversen et al. 1998). Maintaining hatchery smolts in a pen with a remote release mechanism would appear to offer the best means for recovery following handling and transport.

Fig. 6. An example of a holding cage for smolts in freshwater prior to release



Smolts to be released must be monitored for their “degree of readiness”. Studies have shown that delayed migration and /or impaired sea water tolerance can compromise the return of spawning adults (Staurnes et al. 1993). Plasma chloride levels can be used to track the readiness of individuals to migrate downstream (Fig. 7). Samples should be collected a few weeks prior to projected release date to validate the readiness of smolts to migrate. Plasma chloride levels provide an early warning of the readiness of smolts to migrate, regardless of the size of the hatchery smolt. Actual exit from the river may be one or two weeks after plasma chloride signals the readiness of the smolts to migrate (Fig. 8).

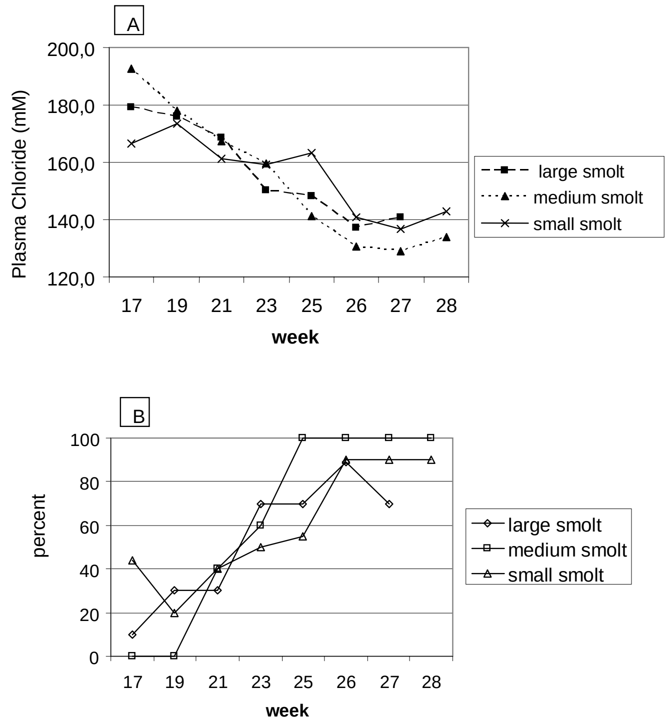
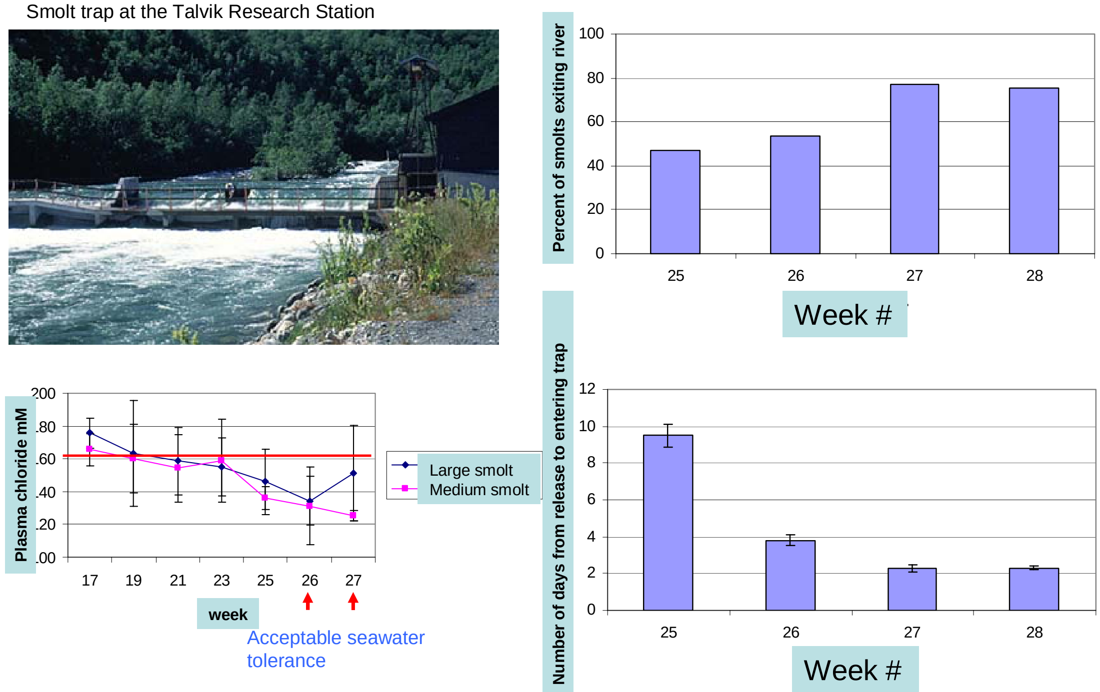


Fig. 7. A - Plasma chloride levels in smolts by week number. B – Percent of different sized individuals smoltified by week number

Fig. 8. Timing of Smolt descent to trap as related to time of release and plasma chloride level



Capture, handling and tank confinement all induce a stress response in smolts and unless mitigated can affect activities associated with survival including food acquisition , predator avoidance, aggression, learning, and habitat selection (Pickering et al. 1982, Mesa 1994, Olla et al. 1995, Schreck et al. 1997). All of the above can potentially decrease survival in the wild. While all of the above initiate an immediate stress response in fish, it can take up to weeks for fish to return to their pre-stress levels (Schreck et al. 1997).

Several methods have been employed to mitigate stress associated with capture and transportation of smolts. First, the energy stores of fish are depleted quicker in freshwater transport than in salt water, particularly on long hauls. Mitigative strategies have included adding a mild sedative to freshwater (Burka et al. 1997), addition of NaCl to the transport water (Mazik and Simco 1994) and a pre-anaesthetic (metomidate – Kreiberg 1991) to reduce stress during transport of smolts. The best perhaps appears to be the use of brackish water plus metomidate as the transport medium. This method alone led to significantly increase in the migratory ability of smolts (Finstad et al. 2003). This study also suggested that accumulation of stressors can intensify physiological responses and manifest itself in an increased predator avoidance time (Sigismondi and Weber 1988). While sub-lethal responses to stress alone are not harmful, the accumulation of these stressors within a period of time that are not adequately compensated for during a recovery period can impact the fish and ultimately percent adult return.

HEALTH INDEX MEASUREMENTS

Smolts should be assessed using a compilation of assays that address the interaction between nutrition, physiology, and immunity to provide a comprehensive snap-shot of the potential for disease or reduced fitness of the stock. Migrating salmon are faced with many challenges during their outward migration - lack of prey (starvation), predators, elevated water temperatures (stress), poor water quality (sediments, toxicants), and pathogens (disease). Maintaining energy stores is vital for migrating salmon, which means dietary lipid contents must be adequate. Dietary lipid is also essential to support vital immunophysiological functions such as smoltification, disease resistance and growth. Dietary lipid is determined by the prey nutritive value, which in turn is determined by the selection of prey available to the migrating salmon.

Plasma and muscle fatty acid profiles can provide an estimate of the energy available for migration. Sampling fish tissues for fatty acid profiles to determine the impact of diet on fish health could provide a measure of the overall well being and condition of smolts. For example, the fatty acid composition of polar and neutral fractions of tissue samples will provide information on the structure and function of cell membranes, which play a critical role in the immune response through such processes as phagocytosis, antigen presentation, and liberation of immunomodulatory eicosanoids (eg. prostaglandins, leukotrienes). The fatty acid profile of tissues will also provide information on the susceptibility of membranes to oxidative stress. High levels of the highly unsaturated fatty acids (HUFAs) are particularly susceptible to oxidation. The level of oxidation can be further compounded because migrating smolts are particularly susceptible to oxidative stress due to the endocrine changes associated with smoltification. Conditions of stress and starvation are also commonly experienced by migrating smolts, and have been shown to increase oxidative lipid damage in laboratory conditions. Therefore, due to the negative impact of lipid oxidation on fish health, determining the oxidation level of fish tissues can provide some insight into smolts dietary intake. Another role of dietary lipid in the health of migrating salmon is the energy it supplies for the actual swimming behaviour. Research has shown that lipid levels decrease during migration due to the effects of increased energy requirements, smoltification, decreased feeding, and increased water temperatures. Levels of plasma non-esterified (free) fatty acids are indicative of the energy available for migration, and can be determined from sampled fish.

A health index could also involve a necropsy-based evaluation of fish health that can be performed in the field. This method provides a crude estimate of fish health, as well as morphometric data such as condition factor, weight and length. Blood and tissue samples collected in the field can be collected and used for later analyses. These analyses could include measures for the prevalence of pathogens such as Renibacterium salmoninarum, which cause bacterial kidney disease (BKD). BKD is a disease known to be endemic in eastern Canada and USA populations and is a major source of pre-spawning mortality. Other pathogens, in consultation with Federal and State Health Units and the aquaculture industry, could easily be screened using PCR.

Immunophysiological factors should also be measured and included in the fish health index and could include haematological parameters (haemoglobin, hematocrit, differential leucocyte numbers), immune factors (phagocytic activity, lysozyme activity, Ig levels), smoltification status (Na+,K+-ATPase activity), growth (plasma insulin-like growth factor) and other physiological parameters (plasma glucose, protein).

Analyses of this comprehensive list of parameters could potentially provide evidence as to which factors are better able to predict or explain fish survival. It is well known that stressed fish are more susceptible to disease than unstressed individuals. The goal for the creation of a fish health index is to identify those factors that are best correlated with survival, and incorporate those factors into a risk model, a model that will integrate migratory behaviour and survival with pathogen prevalence and condition. Assessment of fish disease prevalence does not appear to have been previously conducted during the out migration of smolts in any of the DSP rivers. While the incidence of disease in the hatcheries was not evident, incorporation of molecular techniques to determine the prevalence of pathogens, long before they are exhibited, could provide an estimate of risk for a disease playing a role in smolt performance following release. Integrating pathogen prevalence and condition with survival would provide hatchery managers with estimates of out migration success in real time and in season. Response time of fishery managers to stocking "issues" could potentially be greatly enhanced.

SUMMARY

Survival rates of released smolts need to be accurately estimated. Telemetry appears to be the best available method to monitor migratory behaviour and survival. Maine Atlantic Salmon Commission and NOAA staff is knowledgeable and to some extent, equipped to carry out a study. The two critical factors that require special attention are the positioning and estimation of detection rates of receivers. The goal should be to ensure 100% coverage, as well as ensure that handling and attachment effects are accounted for in estimating migratory activity and performance.

Emphasis needs to be placed on the quality of smolt produced to improve survival and performance in the wild. Some of the present effort to produce smolts should be re-directed to assessing rearing conditions, stress responses to handling and transfer of smolts, development of recovery procedures and the creation of a health index. The underlying assumption is that improved smolt quality and the minimization of stress should result in improved migratory activity and performance.

ASSESSMENT

FINDINGS/RECOMMENDATIONS

1. Recent assessments provide evidence that hatchery contribution rates (i.e., hatchery/total adult returns) exceed 80%, but this result is heavily weighted by the

Penobscot River estimate, which is based upon a smolt stocking program. For DPS rivers, preliminary genetic data suggests hatchery contribution rates of at least 50% from fry releases, assuming that marine survival of stocked fry and wild Atlantic salmon is similar.

2. Assessments indicate that most returning adults are of hatchery origin, but absolute levels of stocking of fry and smolts have been insufficient to retard the further decline of adult returns across DPS rivers.

3. Assessments have not been conducted in a sufficiently rigorous manner to definitively evaluate fry versus other stage (parr, freshwater smolt, estuarine smolt) stocking tactics. Same-river releases of different stage salmon over a several year period should be undertaken to evaluate survivorship and relative contribution rates of hatchery fish released at differing stages of their life history.

4. One or two rivers within the DPS should be "fully" assessed, where stage specific survivorship can be measured and tracked over longer time spans within the Recovery Program.

5. Hatchery evaluation should not be viewed as research but as a core element of the Recovery Program. Accordingly, it is important to integrate scientific assessment advice into decisions regarding hatchery production and release schedules.

6. Assessments and scientific advice should be formally reported out each year to provided informed management decisions based upon best available science. Periodically these assessments should receive review by outside experts.

7. Out of river stocking potentially diverts important resources away from assessment of recovery in DPS systems and should be considered carefully.

8. Research priorities and performance would be improved with a more directed process of attaching research priorities to assessment of demographic and genetic objectives (benchmarks) and through a competitive external grants program.

INTRODUCTION

The SEI review panel was asked to consider several issues that fall under the umbrella of assessment of hatchery released fish survival and contribution rates to returning adults and the next generation. From questions articulated by the signatories, we identified the following questions that have relevance to assessment needs:

1. What is the current contribution of hatchery offspring to recovery?
2. Has there been adequate assessment of whether returning stocked salmon contribute to the next generation?

3. Can we improve hatchery release tactics of fry, parr, or smolts to improve survival and adult returns?
4. Are decisions being made on the basis of best available science?

The first three issues emphasize the recovery program's overall goal, performance benchmarks and means to improve tactics to attain these. The last issue engenders issues of governance (see Governance section), but in this section we highlight opportunities and tradeoffs in making use of best available science under the constraint of limited resources.

WHAT IS THE CURRENT CONTRIBUTION OF HATCHERY OFFSPRING TO RECOVERY?

Adult returns across DPS rivers are chiefly assessed by redd counts. In the Penobscot and Narraguagus rivers, fishway traps at dams permit absolute counts of returning adults. Redd counts have been compared to trap counts and show that redd counts, while moderately imprecise are unbiased in their depiction of spawner returns. In general the expected relationship of two redds per spawning female occurred.

In those systems, where fry stocking occurs (all DPS rivers except Cove Brook and Ducktrap Rivers), there are no direct estimates of hatchery contribution to spawners. In presented summary statistics, hatchery-released fry are combined with naturally produced fry and termed "naturally-reared fry," which can create confusion in evaluating hatchery contribution rates. Initial analysis of genetic markers, based upon hatchery adult genotypes, indicated that at least 50% of the in-river parr are produced from fry stocking. This estimate is probably biased low because not all hatchery brood stock have been genetically identified (see Genetics section). Thus, the majority of emigrating smolts are comprised of either hatchery-produced parr or released smolts. Under the assumption that marine survival is similar between hatchery and wild origin smolts, then the majority of returns are of hatchery origin.

Smolt stocking has recently occurred in the Penobscot, Dennys, and Pleasant rivers. In the Penobscot, smolt releases account for >85% of adult returns. This occurred despite evidence of very low marine survival (<1%).

Overall, hatchery contribution rates (i.e., hatchery/total adult returns) are estimated to exceed 80% in the recent period. However, this estimate is heavily weighted by the Penobscot, which is heavily stocked with smolts, which allows precise assessment. The rate of hatchery contribution in absolute numbers of returning adults has not yet been sufficient to stem the recent downward trend in adult returns and the goal of a zero-net loss in adult returns through hatchery releases has not yet been achieved.

HAS THERE BEEN ADEQUATE ASSESSMENT OF WHETHER RETURNING STOCKED SALMON CONTRIBUTE TO THE NEXT GENERATION?

Quantitative assessment should be a center piece of the recovery program. The panel heard from very able population assessment scientists working on central questions, which address improved strategies for hatchery-based recovery of Atlantic salmon. In particularly, the panel liked the strategy of linking tactics of stage-specific releases to expectations for habitat carrying capacity, the so-called Conservation Spawning Escapement Approach (Elson 1975).

Assessments are currently limited by the precision of adult return numbers and the classification of those adults to natural or hatchery origin. Redd count precision and accuracy should continue to be assessed in those systems where fishway traps occur (i.e. the Narraguagus). Wet years can bias redd counts and a longer term effort could potentially isolate whether weather and other external factors are important and permit them to be statistically discounted. Improved genetic classification methods to identify hatchery progeny released as fry are well underway, and the panel expects that these markers will permit reliable estimates of hatchery contribution rates in the near future.

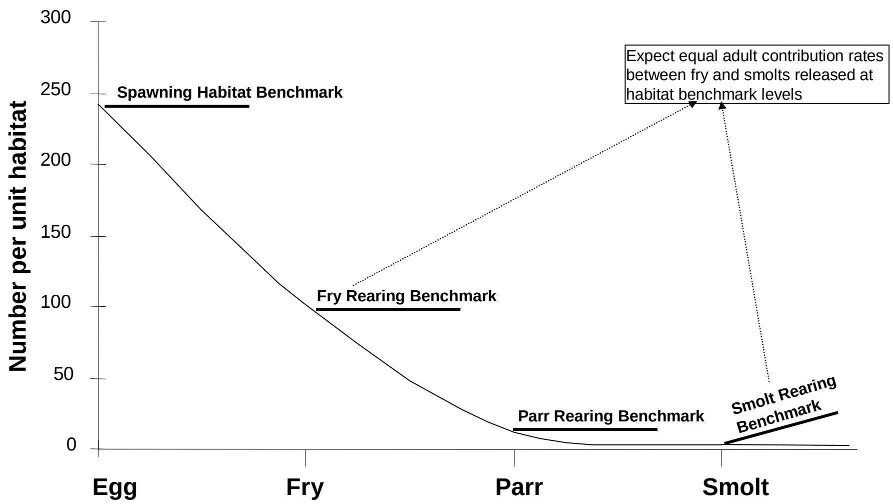
The use of screw-traps and adult weirs was viewed by the committee to be a good method for evaluating smolt emigration, different release strategies, carrying capacity and overall survival. The committee also noted the extensive electrofishing of juveniles that was currently being conducted and questioned whether the resources required for this activity (other than parr for broodstock) along with the risk of injury to the fish warranted the information gained. The Biological Review Team indicated in their "Status Review for Anadromous Atlantic Salmon" that they were not concerned with the risk associated with electrofishing because the initial observed mortality was low and in the larger demographic context the mortality to the entire population was much smaller. The report also states that the Narraguagus is extensively electrofished. The committee was also informed there is an adult trap on the Narraguagus and downstream screw traps for smolts.

The committee feels the biological risk and amount of human resources needed for electrofishing outweigh the benefits of additional information that could be gained from electrofishing that wouldn't be gained from the other trapping methods that provide a more comprehensive amount of information. The committee is also concerned that the effects and mortality of electrofishing are being underestimated by the co-managers. Snyder (2003) states "although not often externally obvious or fatal, spinal injuries and associated hemorrages sometimes have been documented in over 50% of fish examined internally." Other physiological and behavioral changes include impairment of cardiac function, growth effects, and sluggish swimming (Mitton and McDonald 1994, Ainslie 1998, Schreer et al. 2004). A casual observation the committee made, albeit a small sample, was with the tank of electrofished juveniles at Craig Brook hatchery. These juveniles had been captured the previous fall as parr and are now yearlings. There were a couple of fish that noticeably had broken backs and at least one that was "S" shaped. This severity of broken vertebrae didn't cause an immediate mortality and will probably survive to maturity in the hatchery in the absence of predators and abundance of food but not in the wild. While most fish with less severely broken vertebra and physiological damage will heal and survive the trauma of electrofishing there may be a component of predation that is not being realized. Mesa and Schreck (1989) reported distinct behavioral changes requiring 3-4 hours for 50% of the fish to return to normal behavior. These changes included remaining relatively inactive, not feeding, and being easily approachable by divers. For the reasons above the committee recommends electrofishing activities be significantly curtailed.

At least one river should be designated a full assessment river, in which survival and growth of natural and hatchery-origin fry, parr, and smolts can be assessed to verify and modify, hatchery-based recovery tactics. It was quite apparent to the panel that state and federal scientists had already *de facto* designated the Narraguagus an assessment river. This designation should be formalized in the recovery plan, and priority placed on sustained assessment of all principal life stages in the Narraguagus. Given important differences within DPS rivers, efforts should be made to designate at least one other assessment river for comparison purposes (i.e., to support generalities in survivorship patterns or lack thereof).

CAN WE IMPROVE HATCHERY RELEASE TACTICS OF FRY, PARR, OR SMOLTS TO IMPROVE SURVIVAL AND ADULT RETURNS?

The NRC report placed highest priority for evaluating fry v. parr v. smolt stocking and verify survivorship expectations. Recent tests of fry versus smolt stocking depend upon cross-system comparisons, which are flawed due to large differences between comparison systems. A definitive test should occur by simultaneous releases of fry, parr and smolt into the same river (a full assessment river) over a several year period. This has not yet occurred.



The expected survivorship curve from CSE benchmarks provides a useful framework for evaluating release tactics. Here the expectation of fry versus smolt carrying capacity and survival can be tested simultaneously with tests of fry versus smolt hatchery contribution rates. For instance, with releases of CSE levels of fry in year t+1 and smolts in year t+3, we should expect equivalent returns for adult returns of year-class t. These experiments need not compromise recovery aims (i.e. sufficiently high release numbers can be maintained), but only require simultaneous releases of fry and smolts within the same river. Comparison of ratio methods offer a sensitive statistical method for comparing releases across different stages (including parr releases) (e.g., Hoenig et al. 1990), although such tests will depend upon the ability to classify adults to either hatchery smolt or fry origins. Similarly, differing tactics related to smolt releases (conditioned v. non-conditioned individuals) can be tested most efficiently through same river releases (see Marine survival section).

ARE DECISIONS BEING MADE ON THE BASIS OF BEST AVAILABLE SCIENCE?

1. Assessment and Review

Best available science (Sullivan et al. 2006) entails,

1. Clear Objective(s)
2. Conceptual Model
3. Experimental Design
4. Statistical Rigor
5. Clear Documentation
6. Peer Review

Issues pertaining to objectives and conceptual models are discussed elsewhere (Governance Section). It is also critical that management decisions are made based upon scientific assessments of recovery program goals and that the assessments periodically receive independent peer review. Assessment results across DPS and "full assessment" river(s) should be formally documented and scientific advice reported out each year on benchmark indicators for all ME Rivers. Periodic independent review of assessment will insure that the assessment is best available science and highly relevant to policy makers.

2. Allocation of hatchery produced fish

Hatchery release schedules and assessment needs clearly need to be better integrated. Because hatcheries are designed to allocate production across multiple rivers and are limited in their production capabilities due to the availability of parr, the capacity to rear parr, and are under effluent controls (potentially curtailing smolt production), their schedules of production must be carefully planned over a multi-year timeframe. However, hatchery production schedules should be driven by recovery goals, which include assessment and research. We recommend that decisions move towards a schedule of core release allocations across DPS river systems where allocations do not change for 3-6 year time line. Decisions on allocations must involve an assessment scientist(s), and a strategy for evaluating hatchery contribution rates through fry, parr and smolt releases. Allocation for this evaluation should not be viewed as research, but a central element in the recovery program and related hatchery allocation schedule. A small research allocation for other purposes should also be built into the allocation schedule.

Hatchery allocations across systems should be viewed as targets; excess production should be expected and should be released into assigned rivers. Within limits (e.g. ±25%), these should not affect assessment goals as long as release numbers are accurately known.

3. Out of River Stocking

Please see River Specific Stocking/ Out of River Releases section.

4. Research

The current approach for evaluating research priorities and dispersing limited research dollars is not sufficiently efficient given strong research priorities involved in assessment of recovery aims. Research should be identified by lead assessment and genetic scientists in the recovery program and funds made available through a competitive request for proposals. Periodic review of research priorities by either independent scientists or the current larger body of scientists conducting Atlantic salmon studies would be valuable. The panel emphasizes that even small resources available through this proposal program (e.g., $500,000) can go a long way if proffered every year under a targeted external research program.

GENETIC ASPECTS OF BROODSTOCK MANAGEMENT

KEY RECOMMENDATIONS

- *We recommend that changes be made to the program to maximize the effective population size N_e, and that the program should prioritize goals that will lead to natural reproduction in a significant portion of the runs.*
- We recommend that the Penobscot River population be managed using conservation objectives; hatchery populations should be integrated with the wild populations, effective size should be maximized, and interbasin transfers should be prevented.

OVERALL GOALS, AND CONTEXT OF RECOMMENDATIONS

The Maine Atlantic salmon hatchery program is conservation oriented, and management is focused on two main issues relevant to maintaining evolutionary potential; loss of genetic diversity and inbreeding, and domestication selection. A third issue may arise – outbreeding depression – and is relevant to "river specific stocking". We concentrate on the first two issues in this section.

From the outset, it is important to state that the Broodstock Management Plan is well designed, and effective monitoring approaches based on pedigrees and molecular data have been implemented recently. The review below is intended to assist in enhancing those existing strategies.

The program places a large emphasis on reducing domestication selection by;

1. outplanting fry and collecting parr for broodstock, possibly incorporating wild spawned individuals. Individuals are exposed for 1-2 years to natural selection in parr collection programs (DPS rivers; Dennys, East Machias, Machias, Narraguagus, Pleasant, Sheepscot)
2. release of a *portion* of fry production and in corporation of parr into pedigree-based captive programs (DPS Rivers; Dennys and Pleasant Rivers)
3. adult collection following release of fry, parr and smolt from capture facilities in the Penobscot

Effective size N_e is largely controlled by mating unrelated individuals as far as possible; mate choice in the hatchery is based on dissimilarity between alleles.

It is possible that domestication selection is being prioritized over loss of genetic diversity and inbreeding, although managing this trade-off is not simple. Theory has shown that the selection differential s is related to the effective population size N_e as follows; $s > 1/2N_e$. In other words, genetic drift can be expected to be the dominant process affecting genetic change in small populations (unless selection is strong). However, the larger a population be comes, the more likely it will respond to selection, and captive breeding programs with large population sizes be come more vulnerable to domestication[i]. Given both risks, *we recommend that changes be made to the program to maximize N_e, and that the program should prioritize goals that will lead to natural reproduction in a significant portion of the runs in as few generations as possible.*

Thus, we make specific recommendations for maximizing N_e within the framework of the Broodstock Management Plan. We also identify those practices that may be managed to minimize selection. We then comment on the potential role of natural reproduction in reducing genetic risks and end with a discussion of potential research directions.

COMMENTS ON THE BROODSTOCK MANAGEMENT PLAN

To assist clarity, the following section is divided into those issues which should receive immediate priority, and those that are of concern and should be investigated further. Comments are based on the section headings within the Broodstock Management Plan.

PRIORITY ISSUES

Section 3.1.1 Juvenile broodstock collection

Currently, goals for broodstock collection are based on fry stocking requirements within a given river, and not on N_e.

Recommendation: Set a realistic target of N_e, and adjust collection practices so that this target can be met along with the demographic targets. As an example, the Hatchery Scientific Review Group on the West Coast recommends an N_e of 1000 for Pacific salmon (Mobrand et al. 2005).

It is important to recognize in a salmon species with overlapping generations, the correct term to use is N_b, where $N_b \sim N_e/L$, and L is the generation length[ii] (Waples 1990, Waples 2004). Simplistically, this means that for a species with average generation length of 4 years, an N_b of 250 will give an N_e of 1000. It is therefore very important to determine the age structure of the broodstock using scale reading or pedigree analyses.

The value of N_e is affected by the following; sex ratios, variance in family sizes, fluctuating population sizes, overlapping generations and inbreeding. Each can be manipulated in order to reach the target, and in many cases, have already been implemented. Sex ratios are largely 1:1, broodstock collection facilitates overlapping generations, and inbreeding is reduced during spawning. Setting a target N_e will minimize fluctuation in population sizes (which reduces N_e) and equalizing family sizes will double the N_e/N_c ratio (section 3.4.4).

Section 3.2 Penobscot collection

We recommend that the maintenance of genetic diversity be prioritized within the Penobscot run, and identify issues accordingly.

Currently, goals for broodstock collection are based on fry and smolt production, and not on N_e.

Recommendation: Set a realistic target of N_e, and adjust collection practices so that this target can be met along with demographic targets.

Unequal sex ratios in the broodstock lower the N_e. We recognize that the numbers of returning males is often limited.

Recommendation: Setting of targets for N_e (3.1.1) will assist in equalizing the sex ratio.

Domestic populations may be come differentiated from returning adults.

Recommendation: Develop criteria for integrating naturally produced broodstock into the captive populations.

Section 3.3.1 – Genetic evaluation of DPS broodstock

The rationale for target for family recapture reflects the difficulty of balancing a trade-off between avoiding domestication selection and maximizing N_e. The target of 75% does not have a clear basis for its justification and might impose a level of artificial selection between families; the relationship between the target and natural selection is currently unknown. Loss of 25% of the families will increase variance in family size and reduce N_e.

Recommendation: If current practices are continued, we recommend the use pedigree based approaches to research the rate of inbreeding in the populations and examine impact of inbreeding on the populations. However, we suggest that N_e be prioritized at this stage of the program.

Section 3.4.4. Effective population size

The equation used for determining effective size assumes random family sizes. An equation based only on the sex ratio significantly overestimates the true N_e (Waples 2004).

Recommendation: The following equations, which take into account family sizes and sex ratios, would be more appropriate.

$$N_e = \frac{4N_{ef}N_{em}}{N_{ef} + N_{em}}$$

where $N_{ef} = \dfrac{N_f k_f - 1}{k_f - 1 + \frac{Vk_f}{k_f}}$ and $N_{em} = \dfrac{N_m k_m - 1}{k_m - 1 + \frac{Vk_m}{k_m}}$

where N_{ef} is the effective number of females, N_{em} is the effective number of males, N_f is the number of females, k_f is the mean number of progeny produced by females, Vk_f is the variance in the number of progeny produced by females, N_m is the number of males, k_m is the mean number of progeny produced by males, and Vk_m is the variance in the number of progeny produced by males (Hedrick 2000). Note that the terms Vk_f and Vk_m include the *lifetime* number of progeny produced by individuals. Note also that the data should be converted to N_b.

The equation reveals a key practise that can be changed to improve N_e/N_c ratios in the broodstock in particular (where N_c is census size). *We recommend that family sizes in the broodstock and the fry/smolt release be equalized*; under these conditions, N_e would be twice the size of N_c. (it is important to emphasize this condition will only be meet if the family contribution is equalized in the broodstock; equalizing at fry and smolt stages will only partly attain this goal).*This equation emphasizes a strong need for the development of pedigrees for all of the captive broodstock used to perpetuate the DPS populations*.

We note again the factors driving N_c in the populations and the effect on N_e, and emphasize again the importance of setting targets for N_e. We also note the concern about work load for staff, but changes recommended here may not substantially increase the number of broodstock required annually.

<u>Section 3.5.1 Pedigree broodstock</u>

We strongly support the use of pedigree broodstock in all lines, because such data provides the following;

- An ability to monitor the rate of inbreeding
- An ability to monitor the contribution of naturally spawned individuals
- An accurate estimation of the N_e of the captive and wild populations
- An ability to control the variance in family size
- Development of an accurate understanding of the contribution of different age classes to the broodstock
- Development of an accurate measure of generation length
- Examine contribution of program “surplus” juveniles and adults following release to the wild (Section 3.6 and especially, steps taken in Table 10)

Many of these advantages have been identified in the Management Plan.

Section 4.5 Smolt stocking, GLNFH

We noted that smolts are high-graded for size before release. Such a practise represents inadvertent selection for size and possibly, life history strategy.

Recommendation: Release the entire range of smolt sizes (supported in section 4.8 of the Management Plan).

ISSUES REQUIRING FURTHER INVESTIGATION

Section 3.1.1 Juvenile broodstock collection

There may be an unequal contribution of related individuals to the broodstock. Juvenile salmon are known to aggregate in related groups, and collection may be biased towards relatives. We recognize that current collection is aimed at minimizing this effect, and fry release may result in mixing, but advocate specific monitoring of this effect.

Recommendation: Evaluate existing molecular data in order to determine kin structure within the broodstock, and implement broodstock selection protocols that reduce these levels. We understand that full pedigrees may not yet be available, and suggest the use of programs such as *Colony*[iii] in the interim period.

Levels of wild fish contribution are currently unknown, and should be quantified in order to gain an understanding of the role of an integrated program. "Integration" is most effective when migration from the wild to the hatchery environment exceeds the reverse (Ford 2002, Mobrand et al. 2005). We recognize that wild spawning population is small in the DPS rivers, but believe that collecting this data at this stage is relevant to the long-term management of the populations and is an important monitoring tool.

Recommendation: Molecular-based protocols for measuring relatedness and assignment of hatchery and wild fish have been established recently; emphasis should be placed on expanding power of methods and in supporting this vital area of research.

Section 3.1.2 Adult broodstock management

One important life history stage, mature parr, are unlikely to be incorporated into broodstock management, and may lead to selection against this life history form.

Recommendation: Explore methods for incorporating mature parr into broodstock in proportion to their frequency in the wild population (may need to rely on historical data for this information).

Section 3.2 Penobscot collection

There is some potential for selection during broodstock collection

Recommendation: Research whether target number of grilse in the broodstock is representative of the return rate within the run as a whole, research whether spawn timing is related to return timing.

Section 3.3.2 Genetic evaluation of Penobscot broodstock

Recommendation: We suggest that fin clips be obtained from all returning adults; the river has considerable potential to contribute to research on fry versus smolt contribution to returning adults (see research section).

Section 3.4.1 Spawning strategy

Several practices have been implemented in order to maximize N_e during spawning. However, the population analyses demonstrated high bootstrap values between collection years, which may indicate genetic drift. There are a number of explanations for this phenomenon; for example, the possible exclusion of certain life histories such as precocious parr, or late maturing (3SW) individuals, may reduce gene flow between collection years.

Recommendation: Examine the age structure of the captive population be examined in order to rule out this possibility.

See comment on Penobscot sex ratios section 3.2.

Recommendation: Develop a clear framework for evaluating impact of female bias in Penobscot.

Section 3.4.2 Spawning optimization

Limitations to broodstock handling require that five males and five females are mated in batches. These individuals are checked for degree of relatedness (allele sharing), and outcrossed to maintain diversity. This is an advanced approach, and we commend the practise. However, this scheme may become more limiting if the population becomes more inbred. In addition, allele sharing is also an indirect measure of inbreeding. Thus, we commend the plan to examine existing data to determine whether more related individuals are being inadvertently mated with each other (3.4.3). If so, we recommend developing contingency plans for mating schemes, such as the use of an incomplete factorial design.

Section 4.5 Smolt stocking, GLNFH

We noted that fish from different spawn dates are pooled together in rearing tanks, and may establish size hierarchies based on age. It is possible that such a practise leads to selection for the earlier spawned individuals following release.

Recommendation: The impacts of this approach on early survivorship should be examined. Alternatively, the smolts should be maintained separately and released according to spawn date.

Section 4.7 Adult stocking

Some concern about excess contribution of hatchery fish to the wild population is expressed. Given current low returns in the wild, it should be recognized that the hatchery fish have strong potential to contribute to the overall genetic diversity, especially if they are managed as recommended and increase the overall effective size. We support the guidelines for adult stocking outlined in this section.

Section 4.9 Summary of Approaches
We recommend that the consequences of each of the release strategies to the wild be monitored, and the N_e of the wild populations be evaluated.

THE ROLE OF NATURAL REPRODUCTION

The committee has, at several points throughout this document, stressed that the hatchery program be regarded as a core element toward recovery. The existing program is functioning well as a "seed bank", but has not yet moved towards restoration and recovery. The importance of natural reproduction must be emphasized in light of concerns about the maintenance of genetic diversity.

Hatchery programs cannot mimic processes in the wild, and genetic change is inevitable (Waples 1999, Waples and Drake 2005). The degree of change is related to a number of factors, including the number of generations that a population is held captive. Ideally, a program should attempt to re-introduce individuals to the wild as soon as it is demographically secure in captivity ("demographically secure" includes measures of N_e). Reintroductions resulting in individuals that spend their entire life cycle in the wild have the potential to minimize domestication selection; natural selection will have the opportunity to act on these individuals. Naturally produced individuals can, in turn, be used to contribute to hatchery broodstock (Ford 2002, Mobrand et al. 2005) and thus reduce the average number of generations maintained in a captive environment. A program that results in salmon that spend their life cycle in the wild will be more successful at reducing domestication selection than one that releases fry and collects parr for broodstock. *The committee strongly recommends the development of strategies and benchmarks that will support this goal.*

OPPORTUNITIES FOR RESEARCH

Clearly, some experiments aimed at measuring the effectiveness of recovery strategies will have greater risks to the genetic diversity of the Maine populations than others. The committee advocates developing a risk averse program that prioritizes researching solutions that lead to population recovery. The relative importance and possible locations for such research should be identified *a priori*. In light of this view, we recommend developing research questions that can be carried out within the existing structure of the program in the first instance (the research of Wilke and Kinnison is a good example).

We make some suggestions below;

- The key question of whether a fry, smolt or adult release program is the most effective at recovering a naturally reproducing population remains largely unanswered. However, the molecular program has developed pedigree based approaches that can address this issue. All three life stages are released in the Penobscot, which also has a wild run. This system can be used to compare the survivorship and mating success of fish released under all strategies with wild individuals. The Narraguagus is monitored by NOAA, and offers another system for such an experiment.

- There is concern that the loss of genetic diversity in the Dennys may have led to inbreeding and inbreeding depression. Molecular based pedigrees implemented within this system can be used to compare the fitness of inbred versus outbred individuals, and determine whether the implementation of pedigree-based mating protocols can be used to minimize kinship within the captive population.
- Experimental outcrossing between Dennys and other populations can be conducted within the hatchery rearing facilities in the first instance. It is recognized that there may be genotype by environment interaction that may vary from the wild environment. However, there are two genetic mechanisms underlying outbreeding depression, and hybrid vigour in the first generation of outcrossing is not necessarily indicative of recovery (McClelland and Naish 2007). Thus, the genetic mechanisms underlying fitness recovery or loss must be determined by conducting research over two or more generations (which is not trivial!). The power of such an experiment is determined by the number of families and individuals within families; wild returns are typically low, experimental hybrid populations pose a risk to DPS populations and individuals are more readily tracked in a captive environment.

QUESTIONNAIRE

The Atlantic salmon questionnaire addresses many of the important issues considered by the review panel. The individual panelists' responses will show the degree of unanimity or uncertainty on different topics. They will also show which data are considered most reliable, and why panelists have reached their individual conclusions.

Each 'X' represents one response; 'x' was used when the panelist selected more than one response (i.e. their opinion lies between the two given response categories). Initials are used to identify comments from individual panelists.

Q1. Compared to other endangered species you have worked with, how would you characterize the knowledge base for understanding the ecology and potential recovery of Atlantic salmon?

Major information gaps (X with qualifications) XX
Minor information gaps X
Well understood X

Additional comments
DB: This workshop was primarily limited to hatchery issues and so much of the information centered around this issue. For hatcheries, there was considerable information and knowledge on hatchery practices. But there are major information gaps in how that work related to the overall biology and recovery of the species.
LB: Hatchery and wild survival rate information for different life stages was sparse along with freshwater vs estuarine vs marine survival rates and associated primary causes of mortality.
DS: There is a tremendous knowledge base for Atlantic salmon as opposed to other endangered fishes. Still, this does not mean to imply that there do not remain critical research issues pertinent to their recovery that curtails management strategies and tactics.
IF: There is a tremendous amount of knowledge about the freshwater life stages of Atlantic salmon, particularly that of juveniles (less known about the reproductive stages).

However, knowledge of the marine life stages is comparatively weak, in large part due to the scale and intractability of the marine environment used by Atlantic salmon. Marine survival is a critical issue in the recovery of salmon in Maine.

In terms of the effective use of captive breeding and rearing to restore populations, I believe that critical unknowns remain. How to balance the use of captive breeding and rearing against the associated declines in fitness experienced by salmon held under such conditions? While information can be garnered reasonably effectively on the survival benefits of captive rearing, little understanding exists on how effective these fish can be in a fitness context. That is, what is their contribution not only in terms of survival, but also in terms reproductive success and thus contribution to the next generation? What

extent of captive supplementation is appropriate, and when should it be ramped back and ultimately discontinued? Captive supplementation will impair local adaptation and evolutionary responses to current conditions.
SM: None of the rivers have been adequately assessed in terms of % survival of out migrating smolts, quality of smolts produced and any evidence of an adaptive mgt. plan.
KN: I'm afraid I cannot comment on the ecology of the species, because this area is outside my field.

Many of the issues faced in the field of conservation genetics of Atlantic salmon have not been resolved in other species. For example, the relationship between inbreeding, population size and fitness losses due to inbreeding depression is not known, and is likely to be species specific. Similarly, the relationship between genetic divergence between populations and loss of fitness due to outbreeding depression is also unknown. Addressing these questions will be important for the recovery of Atlantic salmon in particular, but experiments will take several generations of research.

The theory for measuring effective population size is better developed for Pacific salmon, but I believe that minor adjustments to that theory will be applicable for Atlantic salmon.

The information underlying the DPS review is not as extensive for Atlantic salmon as it is for Pacific salmon, primarily because Atlantic salmon in Maine is at the periphery of its range, and efforts have not been fully integrated with those in Canada to date. Information on the distribution of life history strategies prior to the decline of Maine Atlantic salmon is not extensive (important for the "evolutionary significance" criterion in the Endangered Species Act). I would like to point out that these are simply observations, not criticisms.

An understanding of the best approaches towards recovering populations is underdeveloped compared to Pacific salmon, a result of the fact that the hatchery program started when the populations were in decline, and criteria for improving habitat do not appear to have been clearly defined to date. Much of the efforts are targeted at releasing fry; research should be actively targeted at determining the best release stage for recovery of naturally spawning populations. Finally, I believe that research should be aimed at determining the best strategy for recovering spawning and rearing habitat.

Q2. In your opinion, the overall quality of the scientific information available during the review (in your subject areas, and for the documents you personally read) was:

High quality, majority of conclusions strongly supported
Generally high, many conclusions strongly supported XX
Mixed quality, some conclusions based on limited evidence XX
Very mixed, some conclusions based on sparse evidence X
Generally low, many conclusions based on weak evidence (X—Adap mgmt)

Additional comments
DB: I felt that the quality of scientific information available during the review for "hatchery biology" was high. However for issues relating to the science of adaptive management, etc. it was generally low primarily because this topic is new and hasn't been explored.
LB: Examples include fry versus parr versus smolt survival, carrying capacity issues, lack of concern with regard to effects of electofishing, and being overly concerned with release of hatchery fish near wild fish redds.
DS: Mixed quality here means that there was some very high quality material – such as that related to instream smolt tagging and genetics, but other information pertinent to monitoring and assessment would have benefited with increased synthesis and review.
IF: I was already fairly well versed on much of the older material. However, for one not so familiar with the material, it would certainly be daunting to deal with given the relatively short nature of this review.
SM: Assessing the quality of smolts, or any other product (fry, egg) not addressed, simply dismissed as irrelevant.
KN: The quality of the studies was very high; however, it is clear that additional information was needed. This additional information can only be obtained through long term studies, and researchers are laying the groundwork for this research.

Just one comment; I found it difficult to develop a full understanding on past molecular genetic studies that were not conducted by Dr Bartron's lab. I would strongly encourage researchers from other labs to work with Dr Bartron to facilitate the integration of all data sets, and encourage all to use a standardized set of loci.

Q3. For some areas under consideration, the panel had access to peer-reviewed papers and reports. In other areas, the panel relied on information that had not yet been peer-reviewed. In your opinion, the degree of discussion and scrutiny by the panel assured that when such information was used, it was used appropriately.

Strongly agree XXXX
Agree with qualification XX
Disagree

Additional comments
DB: This questions and scrutiny by panel members often exceeded that of peer reviewers in publications.
LB: I felt the panel sufficiently probed for answers and received clarity where there were questions.
DS: There was insufficient occasion for full vetting of source material for the review. Limited material provided was in fact peer-reviewed, but substantial synthesis of past research was made available through NMFS and NRC documents. Thus, I built on these previous review activities, judging them to be sufficiently rigorous.
SM: The mixed quality of the material made it difficult to assess its relevance.

Q4. In your opinion, the SEI review process comprehensively addressed the information available on relevant issues regarding the role of hatcheries in recovery.

Strongly agree XXX
Agree with qualification XXX
Disagree

Additional comments
LB: Given the timeframe allowed I thought the process covered the most important issues like governance but felt there was inadequate time to really drill down on issues like hatchery/wild interactions, broodstock management or freshwater habitat parameters effecting survival.
DS: The schedule of the panel was too tight to address all information relevant to the role of hatcheries in recovery. Still, sufficient material was evaluated for me to feel confident that major issues relevant to recovery were considered in the SEI review process.
IF: Given the time frame and the single meeting it was not possible to "comprehensively" address all available information on the role of hatcheries in recovery. This is a complicate and controversial issue. While we touched on some key areas, there are other areas we did not have the opportunity to explore fully – see response to Q1

Q5. The following conclusions are made in the consensus report. Please indicate your degree of agreement with them

	Strongly agree	Agree with qualification	Disagree
The current recovery program lacks a clear conceptual framework	XXXXX(SM: A single, concise, and clear strategic document required)	X (KN: Many elements have been clearly outlined and implemented)	
Increased integration of key elements of the recovery program is essential to the recovery of Atlantic salmon.	XXXXXX (SM: Difficult to judge without an overall strategic document)		
Implement adaptive management	XXXXX	X	
Hatchery supplementation should follow, not drive, recovery planning	XXXXXX		
Stocking of fry and smolts have been insufficient to retard the further decline of adult returns across DPS rivers.	X-smoltsXX	XX (SM: Since assessment does not appear to have been accurately completed, difficult to make any comment; KN: There are certain "outside" factors that may be preventing recovery, and stocking of fry and smolts is insufficient on its own)	
Same-river releases of different stage salmon over a several year period should be undertaken	XXX	X (IF: but the scale of this I question. Concern about: (1) the degree to which evolutionary responses to contemporary conditions will be	X (SM: First implement an assessment strategy for the different life stages. Second, it does not appear that the literature

		impaired and (2) domestication selection impairing wild fitness)	suggests that a several life stage release strategy has ever been successful.)
One or two rivers within the DPS should be “fully” assessed	XXXXXX(SM: Urgently required)		
Hatchery evaluation should not be viewed as research but as a core element of the Recovery Program	XXXX	X DB:Not sure I understand this- Hatcheries are key to prevent extinction, but have not been evaluated for their role in recovery. Strongly suggest that this role be evaluated X IF: but … “hatchery evaluation should not be viewed only as research” – research should be an important component of the whole.	
Assessments and scientific advice should be formally reported	XXXXXX (sm: Formally reported and independently sought)		
The river specific integrity of the existing salmon populations should be retained	XXXX	X (KN: Yes, given current status of knowledge)	
Use of a "vacant" drainage for experimentation with Gulf of Maine DPS salmon is considered reasonable	XX	Xx	x
Research priorities and performance would be improved with a more directed process	XXXXXX		
Electrofishing should	XX	XXX (IF: Yes, but	

be significantly curtailed.		only after thorough study to assess degree of impact. Smolt wheels and traps also impose mortality. Trade-offs need to be carefully assessed – mortality vs information gained towards recovery; KN: Unable to comment conclusively on this aspect, but research appears to support this step)	
The program should prioritize goals that will lead to natural reproduction in a significant portion of the runs	XXX	XX (SM: Would be great but my gut tells me it is likely too late!; KN: Equal attention should also be paid on retaining the genetic diversity within the populations)	

Q.6. In your opinion, the current governance structure ensures that Atlantic salmon hatchery management is well integrated with recovery goals and objectives.

Strongly agree
Agree with qualification
Disagree XXXXX

Additional comments
DB: Hatcheries are focused/integrated towards preventing extinction but not well into recovery goals and objectives.
LB: Fixing the current governance structure to promote a better decision making process needs to be the first priority.
DS: I think this issue is well presented in the review and central to future development of best science in support of recovery.

IF: It seems hatchery management is driving recovery goals and objectives, rather than the vice versa.
KN: I am unable to comment strongly on this aspect. I feel that the management of the hatchery program is fairly well integrated with recovery goals – it appears that researching alternative strategies for recovery is less well integrated. It is not clear whether the current governance structure explains this observation, or whether the agencies have had the opportunity to fully explore alternative approaches.

Q.7. In your opinion, the research program, as supported by the TAC, ensures that high priority items are addressed.

Strongly agree
Agree with qualification
Disagree XXXXX (X with qualification)

Additional comments
LB: The current TAC program does not seem to serve much useful purpose. Likely a result of the governance issue.
DS: The program can no longer afford to conduct ad hoc research as is now occurring.
IF: There is a need for a clear set of research priorities and independent, peer review of these priorities, as well as research proposals.
KN: I would like to suggest that the TAC meet to prioritize research areas, and then send out their recommendations for peer review. The priority list can then be used as a framework for researchers to submit proposals. Individual proposals should also be sent out for peer review, and the TAC should then act as a grant panel.

Q.8. In your opinion, adaptive management is currently being well implemented in the hatchery program as it relates to recovery objectives.

Strongly agree
Agree with qualification
Disagree XXXXX

Additional comments
DB: Currently there is no adaptive management.
LB: An adaptive management approach was not embedded or at least implemented into the overall management or recovery planning.
KN: Unable to comment – my knowledge of the principles and application of adaptive management is not extensive!

Q.9. The Green Lake (GLNFH) and Craig Brook (CBNFH) National Fish Hatcheries appear to be well designed salmon hatcheries that incorporate best management practices.

Strongly agree XXX
Agree with qualification XXX
Disagree

Additional comments
DB: The hatcheries were impressive. If their work was better integrated into the recovery goals the overall program would be extremely strong.
LB: Impressive and functional. Low mortality and generally good fish health at all life stages.
IF: Could benefit from more attention to release strategies.
SM: Too much focus on production, quality of product should also be addressed
KN: The hatchery facility design greatly surpasses the majority of hatcheries that I have seen. However, there is some concern about lack of duplication. The hatcheries are also focused on fry rearing, and water quality issues constrain a significant move to smolt rearing. Given reduced resources, it is not clear how these constraints can be feasibly addressed.

Q. 10 The Broodstock Management Plan is, in general, well designed.

Strongly agree XX
Agree with qualification XXX
Disagree

Additional comments
LB: I thought the overall broodstock management plan was very good with one exception being the effective broodstock population size. I felt the effective size could be increased with the fish on hand with more mixing between brood years.
KN: My extensive comments on the Broodstock Management Plan are found in the main document

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Waples, R. S., and Drake, J. (2005). Risk/Benefit considerations for marine stock enhancement: a Pacific salmon perspective. *In* "Stock enhancement and sea ranching" (K. M. Leber, S. Kitada, H. L. Blankenship and T. Svasand, eds.), pp. 260-306. Blackwell, Oxford.

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APPENDIX

QUESTIONS POSED TO THE PANEL

The below questions were provided to the review panel to guide their evaluation. We have addressed most of the suggested questions; the appended table shows where in the report our responses are to be found.

(1) <u>Facilities and Products</u>

a) Are the physical facilities adequate for the existing program? What limitations do they pose to the current program or to modifications to that program?
b) Are the existing containment protocols adequate? How could they be improved?
c) Identify and evaluate different rearing options within a facility – how independent are rearing bays (equipment, waters source, electricity, etc.)? Is that independent enough? Identify alternative approaches to be considered, if any. Characterize the demographic and disease risks of isolation rearing options (stocks spread across facilities, stocks isolated in a single rearing bay in one facility, stocks spread across multiple bays in one facility).
d) Identify ways other private and public partners can supplement the Federal hatchery program to further recovery.

Numbers produced

e) Are the production goals appropriate and are they being met? Identify alternative goals, if appropriate.
f) Could the survival and overall quality be enhanced by reducing the quantity of fish stocked?
g) Should products be artificially manipulated during early life history in order to meet production goals (1-year versus 2-year smolts)?

Genetics

h) Are the short- and long-term genetic goals appropriate and are they being met? Includes review of broodstock management plan. Identify alternative goals, if appropriate.
i) Should the hatchery population, e.g., broodstock, be integrated or segregated from the natural population? Identify strategies to accomplish suggested approach.
j) Is there a more effective method, other than stocking, to preserve the genetic integrity of the Gulf of Maine DPS until such time that improvements in environmental conditions permit populations to expand and recover?
k) Identify and evaluate different strategies – maintain river specific strains versus managing as a DPS.
l) Characterize the risks and benefits of collecting broodstock at a variety of life histories.
m) Identify strategies for increasing genetic diversity within a population, including how to respond to outside influences such as unintentional introductions from freshwater hatcheries and/or marine sea cages.

Quality (disease status, size, physiologic condition)

n) Are the quality goals appropriate and are they being met?

- Includes review of protocols for fish care and incident reporting
- Includes review of fish health protocols
- Review protocols for timing of spawning, temperature, light, rearing conditions
  (artificial versus natural river conditions)
- Identify alternative goals, if appropriate.

(2) Stocking and Evaluation

a) What is the contribution of the hatchery program to the recovery effort?
b) Is the current monitoring and evaluation adequate? Are there better ways to evaluate the hatchery products? Are "best management practices" for successful hatchery-assisted recovery programs being used?
c) Identify and assess the risks and benefits of alternative stocking strategies for their ability to further recovery [what life stage, when stocked, how stocked, where stocked (including consideration of vacant habitat)].

(3) Adaptive Management

a) Do the hatchery, management and assessment programs function as an integrated adaptive management program?
b) Identify ways in which the hatchery program could be used adaptively as a scientific tool for addressing critical uncertainties.

Issue	Pages
1a	15
1b	15
1c	15-17
1d	
1e	Throughout
1f	
1g	23
1h	36-40
1i	36-40
1j	
1k	12-14
1l	36-40
1m	36-40
1n	17-29
2a	31
2b	19-23, 32
2c	19-23, 33
3a	7-10
3b	7-10, 34, 42

PANEL RESUMES

H. Lee Blankenship

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Olympia, WA 98516
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EDUCATION

- B.S. Degree, University of Washington, School of Fisheries, Seattle, Washington, 1965-69
- Continuing Education/Other Training:
  - Fish Genetics and Management Implications, University of Washington
  - Statistical Methods and Data Analysis, University of Idaho
  - Salmon Management Seminar, University of British Columbia
  - Technical Communications
  - Mid-Management Development Core
  - Preventing Conflict Through Effective Management
  - Conflict Resolution

PROFESSIONAL EXPERIENCE

Senior Research Scientist — 2002-Present
Northwest Marine Technology — Olympia, Washington

- Work with customers to insure they are successful with tagging and stock identification applications. Provide biological advice and assist engineers and physicists with development of automated fish vaccination and sorting machines.

Senior Research Scientist — 1972-2002 (Retired)
Washington Department of Fisheries/Fish and Wildlife — Olympia, Washington

- Responsible for supervision, management, and budgeting of Stock Identification Program (Genetic, Scale Analysis, Coded-Wire Tagging and Recovery Units). This includes annually tagging and marking of 18 million salmonids and processing of 50,000 tagged adults/year. Lead scientist for implementation of mass marking 50 million hatchery salmonids, development of selective fisheries, electronic detection of coded wire tags, and automated mass marking machine. Lead WDFW scientist for Congressional Hatchery Reform Initiative. This involved an annual budget in excess of 5 million and 22 staff.

Consultant

- Consultant work on stock identification, hatchery management and fisheries enhancement in Hawaii, South Carolina, Florida, Mississippi, New Hampshire, New Mexico, Tennessee, Australia, and New Zealand.

References upon request.

MEMBERSHIP ON FISHERY RESOURCE COMMITTEES AND PROFESSIONAL GROUPS

WDFW Coordinator

- Pacific States Marine Fisheries Commission Subcommittee on Mass Marking

Chair or Co-Chair

- Washington State Hatchery Scientific Review Group
- Pacific Salmon Commission Selective Fishery Evaluation Committee
- World Aquaculture Society/Committee on Marine Stock Enhancement

Member

- Senator Slade Gorton's Science Advisory Team
- Pacific Salmon Commission Research and Statistics Work Group
- American Fisheries Society
- World Aquaculture Society

GRANT MANAGEMENT EXPERIENCE

Extensive experience and successful applicant in all phases of grant/contract management including Commerce and Interior Anadromous Fish Act, Pacific Salmon Treaty, Dingall Johnson/Wallop-Breaux, Bonneville Power Administration, Sea-Grant, Saltonstall-Kennedy, and numerous inter-
agency agreements and personal service contracts.

PROFESSIONAL RECOGNITION AND AWARDS

- Washington Department of Fisheries Director's Commendation Award
- Washington Department of Fisheries Director's Award of Merit
- Washington Department of Fish and Wildlife's Innovator Award
- Associate Editor of North American Journal of Fisheries Management
- Sportsman of the Year
- Mote Marine Laboratory (Florida) Adjunct Scientist
- Oceanic Institute (Hawaii) Visiting Scientist
- Scientific Review Panel, Florida Department of Natural Resources
- Bodega Bay Marine Laboratory (California) Visiting Scientist

SELECTED PEER REVIEW PUBLICATIONS (30+ PEER REVIEWED PUBLICATIONS)

Blankenship, H.L. 1990. Coded-wire tag loss in chinook and coho salmon. Amer. Fish. Soc. Symp. 7: 237-243.

Buckley, R.M. and H.L. Blankenship. 1990. Internal extrinsic identification systems: an overview of implanted wire tags, otolith marks, and parasites. Amer. Fish. Soc. Symp. 7: 173-182.

Blankenship, H.L., and P.R. Hanratty. 1990. Effects on survival of trapping and coded-wire tagging coho salmon smolts. Amer. Fish. Soc. Symp. 7: 259-261.

Haw, F., P.K. Bergman, R.D. Gralick, R.M. Buckley, and H.L. Blankenship. 1990. Visible implanted fish tag. Amer. Fish. Soc. Symp. 7: 311-315.

Bergman, P.K., F. Haw, H.L. Blankenship, and R.M. Buckley. 1992. Perspective on design, use, and misuse of fish tags. Fisheries. 17(4): 20-25.

Blankenship, H.L. and J. Tipping. 1993. Evaluation of visible implant and sequential coded-wire tags in sea-run cutthroat trout, N. Am. J. Fish. Manage. 13: 391-394.

Blankenship, H.L. and K.M. Leer. 1995. A responsible approach to marine stock enhancement. Amer. Fish. Soc. Symp. 15: 165-175.

Godin, D.M., W.H. Carr, G. Hagino, F. Sequra, J.N. Sweeney, and L. Blankenship. 1996. Evaluation of a fluorescent elastomer internal tag in juvenile and adult shrimp. *Penaeus Vannamei*. Aquaculture 139: 243-248.

Leber, K.M., H.L. Blankenship, S.M. Arce, and N.P. Brennan. 1996. Influence of release season on size-dependant survival of cultured striped mullet, *Mugil Cephalus*, in a Hawaiian estuary. Fishery Bulletin. 95: 267-279.

Thompson, D.A. and H.L. Blankenship. 1997. Regeneration of adipose fins given complete and incomplete clips. N. Amer. J. Fish. Mgmt. 17: 467-469.

Sharpe, C.S., D.A. Thompson, H.L. Blankenship and C.B. Shreck. 1998. Effects of routine handling and tagging procedures on physiological stress responses in juvenile chinook salmon. N. Amer. J. Fish. Mgmt. 60: 81-87.

Vander Haegen, G.E., H.L. Blankenship, A. Hoffman and D.A. Thompson,. 2005. The effects of adipose fin clipping and coded wire tagging on the survival and growth of spring chinook salmon. N. Amer. J. Fish. Mgmt. 25: 1161-1170.

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Personal Statement:

As a Ph.D. marine scientist, my goal is to advance science so that it becomes a relevant and vibrant presence in all our lives. Science plays a unique and powerful role in helping us to understand our world and make better choices for ourselves and the planet. It is urgently needed today.

In pursuit of this mission I founded a successful non-profit organization (Sustainable Ecosystems Institute SEI) aimed at making science a major influence in environmental decisions. I've nurtured the organization to attract top scientists to participate in its vision and efforts. Over 300 scientists are formally affiliated with SEI which is now a recognized "go to" group by national and international governments as well as other sectors seeking science-based solutions. SEI has won the respect and recognition of scientists and all sides of the environmental debate. Additionally, I've participated as a board member and in an advisory capacity in several organizations. I helped to set up new national science organizations, and led board development and strategic planning efforts to advance existing one. I am keenly aware of the challenges that organizations face in making a difference, and responding to new opportunities while sustaining a core constituency.

As a scientist, I carry out research (field and lab) and work at the interface of government, private and NGO sectors, and in educational facilities, and communities. I've led teams of scientists on national and international efforts. I've helped to set up and design marine reserves and monitoring programs in the Caribbean and USA. I've pioneered new approaches and new roles for scientists, including taking teams into disaster areas where science itself can play a new and humanitarian role. By helping government develop scientific approaches for major issues (e.g. Everglades Restoration) I'm aware of the challenges in translating science to government as well as all stakeholders, and I've successfully navigated them. My current research centers around Marine Protected Areas in changing climates and the impact of natural disasters on ecosystems and communities.

We live in a unique time where science has opportunities to capture the imagination of the public and change lives in ways we never before imagined. This is both exciting and challenging for science and for scientists. I have been fortunate to help create and participate in many of these new opportunities and I relish the prospect of doing more and in new ways.

EDUCATION

B.S.	University College Galway Ireland 1978 Honors in Zoology and Botany
M.S.	Shellfish Research Laboratory, Ireland UCG 1981 Fisheries Science
Ph.D.	Oregon State University 1994 Marine Ecology "Environmental Factors and Plant-Animal Interactions on Rocky Shores" (Drs Jane Lubchenco, and Bruce Menge major professors)

CAREER

1994 to Present	President and Founder, Sustainable Ecosystems Institute (SEI) *s a scientific organization that uses science to bring all sectors together to solve ecological problems. Headquartered in Oregon with a full-time staff, and a Conservation Science Panel of 300 top scientists, SEI provides independent scientific advice and assistance to all sectors nationally and internationally. At SEI I developed the SEI process which is now an established method for assessing uncertainty, risk and building scientific basis for decisions.*
2003 to 2004	Visiting Scholar Stanford University
2003 to 2007	Visiting Faculty, Envirovet Program (UC Davis and U Wisconsin)
2002 to 2007	Visiting Professor, Marine Science and Law, Northwestern School of Law
1995 to 2002	Visiting Scientist – University of Washington, Friday Harbor Laboratory, Friday Harbor, Washington
1998 to 2005	Adjunct Professor Portland State University, Portland, Oregon
1992 to 1994	Assistant Professor – Lewis and Clark College, Portland, Oregon
1986 to 1992	Instructor – University of Oregon Department of Biology, Eugene, Oregon
1982 to 1985	Principal Scientist leading 12 teams charged with developing new indices of marine degradation for use in environmental laws NOAA/Brookhaven National Lab. New York

SCIENTIFIC AND COMMUNITY SERVICE AND BOARD MEMBERSHIP (1995-PRESENT)

2005 to Present	Founder of the Tsunami Reef Action Fund which provides ecological and economic support to communities devastated by the SE Asia tsunami to remove debris from reefs, restore their reefs, and rebuild their communities. (note that this Fund is currently evolving into an ocean fund for broader assistance, and will focus on underwater life and people)
2004 to Present	Member of NEON National Earth Observatory Network Consortium Design Committee (NEON is a US Congress and National Science Foundation program to establish an earth observatory network throughout North America). Our role was to develop and set up the new NEON Inc Non-profit organization.
2007 (Present)	Chair Missouri River Science Advisory Panel
2005 (Present)	Board member Center for Coastal Monitoring Oregon Health and Sciences University
2004 to 2005	Chair, Blue Ribbon Panel to develop and review code of scientific ethics for US Department of Interior, Washington D.C.
2003 to Present	Washington State University, Science Advisory Board
2000 to Present	All Species Foundation – Science Board Member
1999 to Present	Board Member SeaDoc Marine Ecosystem Health Program – An independent grant-awarding foundation for marine issues on the West Coast administered through UC Davis.
1998 to 2005	Oregon State University – College of Forestry – Appointed to the Board by the Oregon State Board of Higher Education
1998 to 2000	Washington State Task Force on Invasive Aquatic Species
1999 to 2000	Co-Chair (with Dr. H. Ronald Pulliam,)The Santa Barbara Group – An interdisciplinary group of scientists, private sector and government and environmental groups working on science in Endangered Species issues
1998 to 2000	Co-Chair (with Gail Achterman, attorney) The Science and Policy Forum – The forum brings national leaders in science and policy together quarterly. The forum attracted national attention and was written up in the journal *Science* in the summer of 1999

SCIENTIFIC REVIEWER FOR PEER REVIEWED SCIENTIFIC JOURNALS

Journals: Conservation Biology; Ecology. Marine and Coastal Research
Publishers: Reviewer for Island Press

AWARDS AND GRANTS

Grants
Grants totaling over $4 million (List available on request) from National Science Foundation, National and International Government, and Foundations

Awards

University of Washington Friday Harbor Marine Laboratory – The Whiteley Center – Whiteley Senior Fellowship “Scholar in Residence” – Awarded for Book Preparation –

Museum of Natural History – Lerner Gray Award for Marine Scientific Research
Sigma Xi – Award for Marine Research

OTHER AWARDS

Red Cross Good Samaritan Award – Awarded for heroism and helping other victims during a major plane crash – 2001

KEYNOTE ADDRESSES AND INVITED TALKS – 1998 TO PRESENT

June 1 and 3, 2007. Launching Address for Ocean Week at N. Carolina Aquarium and at Roanoke Aquarium.

Ecosystem Services in the Marine Environment Wildlife Health Center UC Davis, 2007.

“A Bridge too Far” Opportunities and Challenges for science and law- The Need for a new discipline. Opening Talk, Science, Law, and the Environment NW School of Law April 2007

Invited Public Lecture Series Restoring *Coral Reefs and Communities after the SE Asia tsunami- The work of Tsunami Reef Action Fund with scientists, and the community*
Presentation to Seattle Aquarium -
Newport Aquarium October 2005

Seattle Aquarium November 2005,
Newport Aquarium December 2005,
Scripps Institution of Oceanography, La Jolla CA January 2006
Aquarium of the Pacific, Los Angeles CA February 2006
Tampa bayside Aquarium March 2006
John Shedd Aquarium Chicago March 2006
New England Aquarium, June 2006

The 2006 Earth Day Speaker, New York Aquarium, New York. April 15 2006

New York Reef Keepers Association, June 2006

Coral reef ecosystems, ecology and restoration. Washington State University, November 2005.

Scientific Ethics for scientist who work in Conservation science, policy and the law NW School of Law October 2005

Ecosystem Management UC Davis 2005

Scientists and Divers NW Divers Association 2005

Independent Science Review in Natural Resources Policy Keynote Address Missouri River Conference 2004.

Science in the Endangered Species Act" 30th Anniversary of the Endangered Species Act, NW School of Law 2003

Where Science and Policy Meet Stanford University 2003

Leaving an Environmental Legacy Keynote PKAL Conference for Professors of Undergraduate Environmental Science 2003

Scientists in Natural Resources - Lessons from the Trenches – Washington State University Lecture Series on Scientific Ethics – 2002

The Role of Science and Scientists in Resources Management – Willamette University Forest Futures Conference – 2002

Navigating Science and Policy – Oregon Health and Science University Lecture Series – 2002

Science and Conservation in Colorado's Valleys – Telluride Science Forum – February 2001

Science and Monitoring of Coral Reefs – Opening Address – Bali – October 2000

Coral Reefs: Volcanoes, Science, and Conservation Planning – University of Washington – July 2000

Marine Research Needs in the Pacific Northwest – UC Davis – Orcas Symposium – March 2000

Challenges for Science in Science and Policy – Oregon Graduate Institute Lecture Series – 2000

Effects of Volcanoes on Coral Reef Ecology – University of Washington – August 2000

Universities, Museums and Biodiversity for the 21st Century – Invited Keynote Speaker – Stanford University – May 1999

Peer Review and Scientific Involvement in Habitat Conservation Plans and the Endangered Species Act – National Center for Ecological Synthesis and Analysis – Santa Barbara, California – 1999

Scientists are from Mars, Policymakers are from Venus – Bridging Gaps between Science and Policy – Society for Conservation Biology Annual Meeting – Maryland – 1999

Science in Advocacy – Invited Speaker – IFAW Annual Convention – 1999

Science and Conservation in Developing Countries – US Forest Service – March 1999

National Science Foundation Graduate Women in Science Symposium for National

Women Graduate Students – Invited Speaker – 1998

Interagency Task Force on Ecosystem Management – Invited Speaker/Participant – 1998

Volcanoes, MPAs and Caribbean Coral Reefs – New England Biolabs Lecture Series – 1998

Effects of Climate Change on the Outcome of Species Interaction– University of Nevada

US Senate and Congressional Testimony

United States Congress Transportation Committee: Use of Peer Review in Environmental Decisions 2004

United States Senate Sub-committe on Environment and Public Works 2001 Peer Review in the Endangered Species Act

Congressional Advising on Natural Disaster Response after Hurricane Katrina and Rita and SE Asia Tsunami

United Nations

Advising UN Special Envoy on natural disaster, science, and the environment (ongoing)

Some Examples of Project Leadership (1999 to Present)

SE Asia humanitarian Science in the aftermath of the Tsunami 2005- ongoing (Founded and lead TRAF which provides scientific expertise and funding to affected communities. Coordinated scientists across several disciplines, and countries to work internationally.)

Currently chairing Science Review and Assessment panels for Missouri River Science (11 States); Atlantic Salmon; and Everglades Restoration.

Developed and Implemented a Marine Science and Law Curriculum . This is a course designed for environmental lawyers and law students to teach them the science that underpins our environmental laws and policies, and how to integrate science and law for ocean issues. Taught (with Professor C. Wold faculty and attorney) at Scripps Institution of Oceanography and U. Washington.

Ecosynthesis A forum for marine conservation science and environmental law (D Brosnan and Daniel Rohlf. (Upcoming 2006 symposium and book)

Led Several Program Review Teams including :
Review of Marine Programs for David and Lucille Packard Foundation and the Gordon and Betty Moore Foundation 2004 and
Review of Marine Programs: Marine Protected Areas Program and Marine Conservation Science, for David and Lucille Packard Foundation 2003-4

South Florida Ecosystem Restoration (Everglades) 2002 and 2004, Scientific panel, workshops and reports

Developed and Advanced the Marine Protected Area Science for Marine Ecosystem Health Program 2003-5

Coral Reef Monitoring to meet the needs of science and managers. ICRI Coral Reef Symposium Bali Indonesia 2000. Co-convened with Dr. Brian Tissot WSU

Scientific Assessment and Conservation Recommendations Telluride Colorado (Led a team of 32 scientists in field work, write up, and public symposium)

Scientific Involvement in the Endangered Species Act. NCEAS Santa Barbara 1999 with H. Ron Pulliam and S. P. Courtney

Bridging the gap between science, policy and management. Special Symposium for Society of Conservation Biology Annual Conference Maryland 1999.

<u>Books and Contributed Chapters</u>

Books

" Natural Disaster: Impacts on science, ecosysystems and communities (working title only)" Book in preparation

"Biology Study Guide" – Publisher – Random House

"The Science of Life Study Guide" – Publisher – Random House

Contributed Chapters

Conservation Biology- Science and Policy: The Pursuit of Knowledge meets the Use of Knowledge" Chapter 17 in *Principles of Conservation Biology* Groom M, G. Meffe and R Carroll Editors 2006, Sinaur (2 editions)

Marine Protected Areas: The Channel Islands Marine Reserves. Airame S, and D. Brosnan *in Principles of Conservation Biology, Chapter 14 Marine Protected Areas.* Groom M, G. Meffe and R Carroll Editors 2006, Sinaur

Should the Southern Resident Orca (killer whale) Population be listed as endangered? A science or policy decision? D. Brosnan in *Principles of Conservation Biology* Groom M, G. Meffe and R Carroll Editors 2006, Sinaur

Ecology of Tropical Rock Shores: Plant-Animal Interactions in Tropical and Temperature Latitudes. In *Plant-Animal Interactions in the Marine Benthos* S.J. Hawkins and D.J. John – Editors – Oxford University Press – Contributed Chapter:

Functional Dynamics of Phytophagous Insects – Oxford Press - S.P. Courtney, M. Holbert, T. Singleton, T. Kobbot, D. M. Brosnan – Contributed Chapter: Host Specificity Metapopulations and Conservation *D. Magnaquinaria*

"Genes and Genomes" – R. Hartwell and Leroy Hood – Random House – Contributed Chapter: Mitosis and Meiosis

<u>Scientific Articles and Reports – 1994 to Present</u>

Brosnan, 2007 Scientific uncertainty, risk and its incorporation into law and policy. *Journal of Environmental Law* (in press)

Brosnan 2005 The Effects of the SE Asia Tsunami on coral reef ecosystems of SE Asia, and recommendations for the future*. TRAF/SEI Report*

Brosnan 2005 Lessons Learned from the SE Asia Tsunami for science and aid. *Report for US Congress Asia committee*

Brosnan 2005, Planning for and recovering from Tsunami's, West coast marine issues *Report for US Congress Science Committee*

D. M. Brosnan 2004 Balancing the needs of multiple species in Everglades Restoration I Scientific Recommendations. Scientific Panel Report to US Fish and Wildlife Service

D. M. Brosnan 2004 *Balancing the needs of multiple endangered species in Everglades Restoration II Addressing Managers and Policy makers Questions.* Scientific Panel report to US Fish and Wildlife Service

D. M. Brosnan, B. Tissot 2001 – Central Concepts and Questions in Coral Reef Monitoring. ICRI *International Coral Reef Society Proceedings*

D. M. Brosnan 2000 Can Peer Review Help Solve Natural Resources Conflicts? *The Journal of the National Academy of Sciences* —

D. M. Brosnan 2000 *Scientific Review in Habitat Conservation Plans* NCEAS Meeting on Science in Endangered Species Act , NCEAS Santa Barbara California 2000

D. M. Brosnan, et al. 2000 Scientific Assessment and Conservation Planning for the Telluride Valley Floor Report to Telluride Committee (250 pp).

D. M. Brosnan, C. Becker. 1997. *El Nino Southern Oscillations (ENSCO) and their Impact on Marine Populations* to California Department of Fish and Game. 55 Pages. Also available on CDFW website.

Booth, D.J. and D. M. Brosnan 1995 The Role of Recruitment in Structuring Rocky Intertidal and Coral Reef Fish Communities *Advances in Ecological Research*

D. M. Brosnan 1994. Ecosystem Management: An Ecological Perspective for Environmental Lawyers. *Baltimore Journal of Environmental Law 4 (2) 135-153*

- Selected for reprinting in *Anthology of Environmental Law* Series – 1995

D. M. Brosnan 1995. Bridging Gaps among Ecology, Law and Policy. *Wildlife Society Bulletin Journal of the Society of Wildlife Biology*

D. M. Brosnan 1995 Integrating Science and Policy: The Oregon Territorial Sea Plan as a Case Study. *Recent Advances in Marine Science and Technology 1995 Annual publication*

D. M. Brosnan and L. L. Crumrine, 1994 The Effects of Human Trampling on Rocky Shores — 1994 *Journal of Experimental Marine Biology and Ecology*

D. M. Brosnan, C. Becker, T. L. Grubba, 1998 *Scientific Monitoring of Coral Reefs in St. Barthelemy, French West Indies*. Report to French Government.

D. M. Brosnan, T. L. Grubba, A. Cooper, D. Cassell, C. Becker – 1997 Emergency Jetty Montserrat Report *UK Government Report*

D. M. Brosnan, T. L. Grubba 1996 Marine Reserve and Coral Reef Monitoring, St. Barthelemy, French West Indies Report to French Government

D. M. Brosnan, T. L. Grubba, D. K. Backman, K. Boylan and L. T. Moore. 1996 The Coral Reefs of Montserrat West Indies: Diversity, Conservation and Ecotourism. Report

S. P. Courtney, T. L. Grubba, W. Beattie, D. M. Brosnan 1996 *Sea Bird Surveys in Puget Sound Washington* Report for NW Indian Fisheries Commission Volumes 1 and 2 –

D. M. Brosnan, J. Elliott, I. Quon 1995 Effects of Human Impacts on Rocky Shores in Southern California: Experimental Study. *California Sea Grant Biennial Report*

D. M. Brosnan, M. Deithier, A. Warren. 1995. *Lime State Park: Marine Survey and Recommendations for Education, Interpretation, Monitoring and Management.* Report to Washington State Parks and Recreation Commission

Bureau of Land Management Report Volumes 1 and 2 – A Scientific Monitoring Program and Species Introduction Plan for Wheelchair Accessible Tidepools at Quarry Cove – D. M. Brosnan, S. B. Yamada – 1994

Report to Bureau of land Management – Human Impact of Four Shores on the Oregon Coast: Impact and Management Recommendations – D. M. Brosnan, L. L. Crumrine – 1994

Ecology in Action – Guidelines for Monitoring and Detecting Human Impact – D. M. Brosnan, T. L. Grubba, I. Quon – 1994

Ecology – Effects of Climate on Outcome of Species Interaction – D. M. Brosnan, B. A. Menge

Report to Bureau of Land Management – Human Impact and a Management Plan for Yaquina Head Marine Gardens – D. M. Brosnan, L. L. Crumrine

Popular Articles and Op Ed.

In the wake of Hurricane Katrina and Rita Oregonian 2006

Coral Reefs and the SE Asia Tsunami FINS Asia Dec 2005

The Vulnerable Ocean CLF Conservation Matters – Article Reprinted for NOAA, Year of the Ocean and Selected for Reprint on ENN and CNN – 1998-1999

Making Better Land Use Decisions – Daily Planet OpEd – 2001

Caribbean Coral Reefs: Fragile, Beautiful, and in Trouble – Transcripts – 1999

Misuse of Science – LA Times and San Jose Mercury News – 1999

A Mussel Wears a Seaweed Scarf – Natural History – 1995

Public Outreach

Guest on Oprah Winfrey Show

48 hours

Outdoor Living Network Ecological effects of Natural and Man-made Disasters

Public Television - Featured on Oregon Field Guide – Coral Reef and volcanoes Research

BBC - Featured on National Geographic – Volcanic Research

National Public Radio – Sea Web Interviews on Marine Research with Peter Benchley

Talk of the City with Kitty Felber Los Angeles Public Radio

National Public Radio, Time Magazine, E-magazine, National and International Newsprint, etc. – Various Interviews

Briefing Senators, Senate Staff. at Federal Level

IS Senate: Senators – Senator Diane Feinstein (D-CA) Senator Michael Crappo (R-ID), Senator,– Congressman Earl Blummenaur (D- OR): David Wu (D OR).
Senate Staffers: Environment and Public Works Committee, Senator Ron Wyden (D-OR) (Chief of Staff) and Senator Gordon Smith (Chief of Staff)

Students

Timothy Grubba – M.S. – Effects of Human Trampling on Succession in Intertidal Communities
Zasha Bassett – M.S. – Impacts of the Invasive Green Crab on the NW Marine Ecosystem
Lana Crumrine – B.S. – Human Impacts of Intertidal Communities
John Elliott – B.S. – Effects of Humans on Southern Californian Shores
Ingri Quon – B.S. – Human Impacts on Southern Californian Shores
Tina Davis – B.S. – Effects of Harvesting on Marine Community Dynamics
Dwayne King – B.S. – Role of Seaweeds in Protection from Environmental and Biological Stress

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Education
Bachelors: Queen's University (1983)
Masters: Simon Fraser University (1986)
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Overview of Research Interests and Activities
Ian Fleming's research integrates perspectives from ecology and evolution with fishery and conservation biology, and his areas of expertise include fish behavioural and evolutionary ecology, reproduction, life history and population biology. He has worked extensively on the management and conservation of wild fish populations, particularly salmon, and the ecological interactions with marine finfish aquaculture. He has also served in a number of capacities related to fisheries research and policy, including review panels for Fisheries and Oceans Canada (DFO) on the Status of Atlantic salmon (2006) and for National Research Council (US) on the Status of Atlantic Salmon in Maine (2002-4), DFO Aquaculture Collaborative Research and Development Program Regional Committee (2006), Co-chair of the Scientific Advisory Board of the Cooperative Institute for Marine Resources Studies at Oregon State University (2001-4), the Northwest Power Planning Council's Artificial Propagation Assessment Committee (2002-3) and the Steering Committee of the Norwegian Institute for Nature Research's program on Effects of Ecosystem Changes on Biodiversity (1999-2000). Ian has previously held academic/research positions at the Hatfield Marine Science Center of Oregon State University (2001-04) and the Norwegian Institute for Nature Research (1991-2001), and continues to hold adjunct status at both institutes, as well as at the University of Siena.

Publications (peer reviewed; since 2000)

Koseki, Y and Fleming, I.A. Spatial synchrony and temporal variation in the frequency dynamics of alternative life-history phenotypes in male coho salmon, *Oncorhynchus kisutch*. Canadian Journal of Fisheries and Aquatic Sciences, *in press*.

Henning, J.A., Gresswell, R.E. and Fleming, I.A. Use of enhanced seasonal wetlands by fishes in a temperate river-floodplain. Journal of Fish Biology, *in press*.

Brodeur, R.D., Fleming, I.A., Bennett, J.M. and Campbell, M.A. Summer distribution and feeding of spiny dogfish (*Squalus acanthias*) off the Washington and Oregon coasts. Special Symposium of the American Fisheries Society, *in press*.

Einum, S. and Fleming, I.A. 2007. Of chickens and eggs: diverging egg size of iteroparous and semelparous organisms. Evolution, 61: 232-238.

Sundt- Hansen, L., Sundström, L.F., Einum, S., Hindar, K., Fleming, I.A. and Devlin, R.H. Genetically enhanced growth causes increased mortality in hypoxic environments. Biology Letters 3: 163-168.

Garcia de Leaniz, C., Fleming, I.A., Einum, S., Verspoor, E., Jordan, W.C., Consuegra, S., Aubin-Horth, N., Lajus, D., Letcher, B.H., Youngson, A.F., Webb, J., Vøllestad, L.A., Villanueva, B., Ferguson, A. and Quinn, T.P. 2007. A critical review of inherited adaptive variation in Atlantic salmon. Biological Reviews 82: 173-211.

Hallerman, E.M., MacLean, E. and Fleming, I.A. 2007. Effects of growth hormone transgenes on the behavior and welfare of aquacultured fishes: a review identifying research needs. Applied Animal Behaviour Science, 104: 265-294.

Ferguson, A., Fleming, I.A., Hindar, K., Skaala, Ø., McGinnity, P., Cross, T. and Prodöhl, P. 2007 Farm escapes, pp. 367-409. *In*: E. Verspoor, L. Stradmeyer and J. Nielsen (eds.) The Atlantic salmon: Genetics, Conservation and Management. Blackwell, Oxford. (ISBN-13:978-1-4051-1582-7)

Garcia de Leaniz, C., Fleming, I.A., Einum, S., Verspoor, E., Jordan, W.C., Consuegra, S., Aubin-Horth, N., Lajus, D., Villanueva, B., Ferguson, A., Youngson, A.F. and Quinn, T.P. 2007. Local adaptation, pp. 200-240. *In*: E. Verspoor, L. Stradmeyer and J. Nielsen (eds.) The Atlantic salmon: Genetics, Conservation and Management. Blackwell, Oxford. (ISBN-13:978-1-4051-1582-7)

Jordan, W.C., Fleming, I.A. and Garant, D. 2007. Mating system and social structure, pp 172-199. *In*: E. Verspoor, L. Stradmeyer and J. Nielsen (eds.) The Atlantic salmon: Genetics, Conservation and Management. Blackwell, Oxford. (ISBN-13:978-1-4051-1582-7)

Koseki, Y. and Fleming, I.A. 2006. Spatio-temporal dynamics of alternative male phenotypes in coho salmon populations in response to ocean environment. Journal of Animal Ecology 57: 445-455.

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Viken, Å., Fleming, I.A. and Rosenqvist, G. 2006. Premating avoidance of inbreeding absent in female guppies (*Poecilia reticulata*). Ethology 112: 716-723.

Henning, J.A., Gresswell, R.E. and Fleming, I.A. 2006. Floodplain emergent wetlands as a rearing habitat for juvenile salmonids. North American Journal of Fisheries Management 26: 367-376.

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Fleming, I.A. and Reynolds, J.D. 2004. Salmonid breeding systems, pp. 264-294. *In* A.P. Hendry and S.C. Stearns (eds) Evolution Illuminated, Salmon and Their Relatives. Oxford University Press, Oxford, USA. (ISBN 0-19-514385-X)

Weir, L.K., Hutchings, J.A., Fleming, I.A. and Einum, S. 2004. Dominance relationships and behavioural correlates of individual spawning success in farmed and wild male Atlantic salmon, *Salmo salar*. Journal of Animal Ecology 73:1069-1079.

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Fleming, I.A. (ed.) 2001. Proceedings of the Workshop on the Release of Salmonid Fishes in Norway. Nordic Journal of Freshwater Research 75(1): 1-152. (ISSN 1100-4096)

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Education

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Research Interests

Biotelemetry, environmental physiology, fish monitoring techniques, fish handling and anaesthetics, animal performance, fish activity/health, biotelemetry data analysis

Dr. McKinley's research interests include monitoring the health and welfare of cultured finfish, the role of aquaculture sites to sea lice infestation levels in wild stocks, environmental risk of cultured/wild interactions, determining the migratory behaviour of several fish species using telemetry, evaluating the effectiveness and efficiency of fish ways using physiological telemetry and determination of critical habitat using wireless communication devices. These studies have been conducted throughout North and South America as well as Scandinavia and Europe.

Publications

Cote, D., L.M.N. Ollerhead, D.A. Scruton, and R.S. McKinley. 2003. Microhabitat use by juvenile Atlantic cod in a coastal area of Newfoundland as determined by 2-D telemetry. Mar. Ecol. Prog. Ser. 265: 227-234.

Wagner, G.N., & McKinley, R.S. 2004 Anaemia and salmonid swimming performance: the potential effects of sub-lethal sea lice infection. Journal of Fish Biology (2004) 64, 1-12.

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(*Salmo salar*) smolts. P. xx-xx, In: E. Thorstad, I.A. Fleming, and T. Naesje (eds.), Proceedings of the Fourth Conference on Fish telemetry in Europe , Hydrobiologia Special Issue XX: xx pp. *(in press).*

Cottril, A., J. Denis-Dutil, K. Reid, K. McGraft and R.S. McKinley. Seasonal variation in non-esterified fatty acids in the American eel. J. Fish Biol.

Cote , D., S. Moulton, D.A. Scruton and R.S. McKinley. Microhabitat Use of Juvenile Atlantic Cod in a Coastal Area of Bonavista Bay , Newfoundland . Trans. Amer. Fish Soc

Brodeur, J.C., B. Finstad, D.G. Dixon and R.S. McKinley. Sublethal concentrations of aluminium in acidic water reduce cardiac output of adult Atlantic salmon mainly through reduced stroke volume. Aquat. Toxicol.

Cotrill, A., G. Van Der Kraak and R.S. McKinley. Evaluation of morphometric characteristics in distinguishing yellow and silver American eels. Env. Bio. Fish

Scruton D.A., K.D. Clarke, N.L.M. Ollerhead, D. Perry, R.S. McKinley, K. Alfredsen, and A. Harby. 2002. Use of telemetry in the development of biological criteria for, and in the validation of, habitat hydraulic modelling. P. xx-xx, In: E. Thorstad, I.A. Fleming, and T. Naesje (eds.), Proceedings of the Fourth Conference on Fish telemetry in Europe , Hydrobiologia XX: xx pp. *(in press).*

Scruton, D.A., R.S. McKinley, N. Kouwen, W. Eddy, and R.K. Booth. 2002. Use of telemetry and hydraulic modelling to evaluate and improve fish guidance efficiency (FGE) at a louver and bypass system for downstream migrating Atlantic salmon (*Salmo salar*) smolts and kelts. P. xx-xx, In: E. Thorstad, I.A. Fleming, and T. Naesje (eds.), Proceedings of the Fourth Conference on Fish telemetry in Europe , Hydrobiologia XX: xx pp. *(in press)*

Singer, T.D., K.M. Clements, J.W. Semple, P.M. Schulte, J.S. Bystriansky, B. Finstad, I.A. Fleming, and R.S. McKinley. (2002) Seawater tolerance and gene expression in two strains of Atlantic salmon smolts. Can. J. Fish. Aquat. Sci. 59: 125-135.

Singer, T.D., B. Finstad, S.D. McCormick, S.B. Wiseman, P.M. Schulte, and R.S. McKinley. (2002) Interactive effects of cortisol treatment and ambient seawater challenge on gill Na+,K+-ATPase and CFTR expression in two strains of Atlantic salmon smolts. Aquaculture. *(in press)*

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Bridger, C., R. Booth, R.S. McKinley, D. Scruton and R. Lindstrom. 2001. Monitoring fish behaviour with a remote, combined acoustic/radio biotelemetry system. J. Appl. Ichthyol. 17(3): 126-129.

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Cooke S.J.; McKinley R.S., Philipp D.P. 2001. Physical activity and behaviour of a centrarchid fish, Micropterus salmoides (Lacapede), during spawning. Ecology of Freshwater Fish 10(4): 227-237.

Cote , D., L.M.N. Ollerhead, R.S. Gregory, D.A. Scruton, and R.S. McKinley. 2001. Environmental and substrate effects on activity levels of juvenile Atlantic cod (*Gadus morhua*) in Buckley's Cove, Newfoundland . P. xx-xx, In: E. Thorstad, I.A. Fleming, and T. Naesje (eds.), Proceedings of the Fourth Conference on Fish telemetry in Europe , Hydrobiologia Special Issue XX: xx pp. *(in press)*.

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Ytrestoyl, T., B. Finstad and R.S. McKinley. 2001. Swimming performance and blood chemistry in Atlantic salmon spawners exposed to acid river water with elevated aluminum concentrations. J. Fish Biol. 58(4) 1025-1038.

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Aquaculture Geneticist, Overseas Development Administration, Swansea, UK

Teaching at University of Washington:
Conservation Genetics; Introductory Biology and Undergraduate research coordinator

Relevant Publications (out of 23):
Naish, K. A., Taylor, J., Levin, P., Quinn, T. P., Winton, J. R., Huppert, D., and Hilborn, R. (2007). An evaluation of the effects of conservation and fishery enhancement hatcheries on wild populations of salmon. *Advances in Marine Biology* **In press**.

McClelland, E. K., and Naish, K. A. (2007). Comparisons of F_{ST} and Q_{ST} of growth related traits in two populations of coho salmon. *Transactions of the American Fisheries Society*. **In press**

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Eldridge, W. H., and Naish, K. A. (2007). Long term effects of translocation and release numbers on fine scale population structure among coho salmon (*Onchorhynchus kisutch*). *Molecular Ecology, in press* **doi: 10.1111/j.1365-294X.2007.03271.x**.

Hauser, L., Seamons, T. R., Dauer, M., Naish, K. A., and Quinn, T. P. (2006). An empirical verification of population assignment methods by marking and parentage data: hatchery and wild steelhead (*Oncorhynchus mykiss*) in Forks Creek, Washington, USA. *Molecular Ecology* **15**, 3157-3173.

McClelland, E. K., Myers, J. M., Hard, J. J., Park, L. K., and Naish, K. A. (2005). Two generations of outbreeding in coho salmon (*Oncorhynchus kisutch*): effects on size and growth. *Canadian Journal of Fisheries and Aquatic Sciences* **62**, 2538-2547.

Phillips, R. B., Morasch, M. R., Park, L. K., Naish, K. A., and Devlin, R. H. (2005). Identification of the sex chromosome pair in coho salmon (*Oncorhynchus kisutch*): lack of conservation of the sex linkage group with chinook salmon (*Oncorhynchus tshawytscha*). *Cytogenetic and Genome Research* **111**, 166-170.

Relevant Funded Research 2003-present (out of 12 grants)

Naish, KA, Phillips RB, 2007-2010 Locating the genomic regions underlying adaptive divergence in Chinook salmon life history traits. Washington Sea Grant

Naish, KA. 2007-2011 Quantifying domestication selection on life history in hatchery coho salmon. NOAA, National Marine Fisheries Service, “Biological Opinion”.

Quinn TP, Hauser L, Naish KA. Sept06 – Sep10. Evaluation of the reproductive success of wild and hatchery steelhead in natural and hatchery environments. Bonneville Power Administration

Naish, KA Oct2004-Sep05. Genetic basis of maternal contribution to offspring evolution in chinook salmon. NOAA, National Marine Fisheries Service

Naish KA, Hard JJ. 2001-2006. A test of the relationship between inbreeding and inbreeding depression in chinook salmon, *Onchorynchus tshawytscha*. Bonneville Power Administration

Naish KA Jun03 – Jun 05. An evaluation of the long-term effects of anthropogenic disturbances on coho salmon in Puget Sound: A genetic analysis of population structure using archival and contemporary samples. JISAO

Naish KA, Phillips R, Sewell M. Jan04 – Dec07. Genome mapping of growth and growth related traits in coho salmon: Implications for conservation. Washington Sea Grant

Quinn TP, Hauser L, Naish KA. Sept03 – Sep06. Evaluation of the reproductive success of wild and hatchery steelhead in natural and hatchery environments. Bonneville Power Administration

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1985	M.S., University of South Carolina, Biology
1990	Ph.D., University of South Carolina, Biology

Professional Background:

2005-present	Professor, Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science
2000-2005	Associate Professor, Chesapeake Biological Laboratory
1994-2000	Assistant Professor, Chesapeake Biological Laboratory

Research Interests

Population ecology of coastal and estuarine fishes, migration and life cycles, habitat and pollution ecology, physiological ecology and bioenergetics, fisheries science and management

Publications selected from >80

Secor, D.H. 2007. The year-class phenomenon and the storage effect in marine fishes. J. Sea Res. 57: 91-103.

Secor, D.H. and P.M. Piccoli. 2007. Determination of frequency of anadromous migrations by Chesapeake Bay striped bass based upon otolith microchemical analysis. Fisheries Bulletin 105: 62-73.

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Secor, D.H. and H. Austin. 2006. Element 8: Externalities, p. 269-306, In Fisheries Ecosystem Planning for Chesapeake Bay. American Fisheries Society, Bathesda.

Sullivan, P.J., et. al. 2006. Defining and implementing - Best available science for fisheries and environmental science, policy, and management. Fisheries 31(9): 460-465.

Arslan, Z. and Secor, D.H. 2005. Analysis of trace transition elements and heavy metals in fish otoliths as tracers of habitat use by American eels in the Hudson River estuary. Estuaries. 28: 382-393.

Kraus, R.T. and Secor, D.H. 2005. A test of the nursery-role hypothesis. Marine Ecology Progress Series. 291: 301-305.

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Niklitschek, E.J. and Secor, D.H. 2005. Modeling spatial and temporal variation of suitable nursery habitats for Atlantic sturgeon in the Chesapeake Bay. Estuarine, Coastal, and Shelf Science 64: 135-148.

Kraus, R.T. and Secor, D.H. 2004. The dynamics of white perch (*Morone americana* Gmelin) population contingents in the Patuxent River Estuary, Maryland USA. Marine Ecology Progress Series. 279: 247-259.

Professional Service

Chesapeake Bay Fisheries Steering Committee, 2006-; Member, Chesapeake Bay Program Scientific, Technical, Advisory Committee, 2005-; Chair, ASMFC American Eel Stock Assessment Review Panel, 2005-; Chair, ASMFC Atlantic Sturgeon Technical Committee, 2005-; Chair, Bluefin Tuna Working Group of U.S. ICCAT 2003- (Advisory Committee to U.S. Delegation, Int'l Comm. Conservation of Atlantic Tunas (ICCAT), 2003-2006); Chair, Review of Chesapeake Bay Program Analytical Tools; Scientific, Technical, Advisory Committee, Chesapeake Bay Program, 2005-2006; Essential Fish Habitat Working Group, NOAA NE Center, 2005; U.S. Representative to ICES Eel Working Group, 1999- ; Sustainable Ecosystems Institute Pallid Sturgeon Review Team, 2004-present; NMFS Shortnose Sturgeon Endangered Species Act Review Panel, 2003; Representative to ICES Stock Identification Work Group, 2004-; US Fish&Wildlife Beluga Sturgeon ESA Proposal Review Panel 2002-2003; American Fisheries Society/Estuarine Research Federation Best Science Committee, 2002 –2006; EPA Chesapeake Bay Dissolved Oxygen Criteria Team, 2000-2003; NOAA Chesapeake Bay Fisheries Ecosystem Management Advisory Panel, 2000-2003; Co-Chair Fisheries Area of Specialization, University of Maryland, College Park, 1999-; Faculty Senator, Univ. Maryland Center for Environmental Science, 2000-2004.

Professional Recognition

Phi Beta Kappa, Macalester College, 1983; Japanese Foundation Award 1985; Japanese Ministry of Education Research Fellowship, 1986-1987; Best Paper Award, ICES Anadromous and Catadromous Committee, 1992; Foreign Specialist Research Award, National Inst. of Fisheries Science, Japan, 1996; Excellence in Fisheries Education Award, Tidewater Chapter, American Fisheries Society, 2004. Plenary Speaker, Inter'l Flatfish Symposium, Maizuru, Japan 2005; Keynote Speaker, Man and the Ocean-Sustainable Utilization and Conservation of Marine Resources, University of United Nations/University Tokyo Conference; Plenary Speaker, Challenges for Diadromous Fishes in a Global Environment, Halifax 2007.

FOOTNOTES

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[i] Theoretically, there are a number of ways recommended to deal with this issue; "fragment" captive populations so that selection is less effective within each component and instigate frequent migration between fragments (Woodworth et al. 2003); reduce selection differential between hatchery and wild environments; initiate an integrated program in which a larger component of the broodstock comprises individuals that have been subject to natural selection throughout their life history (Mobrand et al. 2005). All of these approaches are largely untested empirically, especially in salmon, but can serve as guidelines for future goals.

[ii] Generation length is defined as the average age of parents that produced the current generation, although see comment on the effect of repeat spawning in Waples 2004; a non-trivial contribution by precocious parr will result in N_e close to the harmonic (and not arithmetic) mean N_e of the population over time.

[iii] http://www.zoo.cam.ac.uk/ioz/software.htm#COLONY