Exxon Valdez Oil Spill
Restoration Project Final Report

Development of Culture Technology to Support Restoration of Herring in Prince William Sound: Use of *in vitro* Studies to Validate and Optimize Restoration Actions

Project 090821
Final Report

Tim Linley, Ph.D.

MariCal, Inc.
400 Commercial Street
Portland, Maine 04101

and

Howard Ferren

Alaska SeaLife Center
301 Railway Avenue
Seward, Alaska 99664

September 2009

Exxon Valdez Oil Spill
Restoration Project Final Report

Development of Culture Technology to Support Restoration of Herring in Prince William Sound: Use of *in vitro* Studies to Validate and Optimize Restoration Actions

Project 090821
Final Report

Tim Linley

MariCal, Inc.
400 Commercial Street
Portland, Maine 04101

and

Howard Ferren

Alaska SeaLife Center
301 Railway Avenue
Seward, Alaska 99664

September 2009

Development of Culture Technology to Support Restoration of Herring in Prince William Sound: Use of *in vitro* Studies to Validate and Optimize Restoration Actions

Project 090821
Final Report

Study History: In 2007 the *Exxon Valdez* Oil Spill Trustee Council awarded project 070821 as the first phase of the multi-year project "Development of Culture Technology to Support Restoration of Herring in Prince William Sound: Use of *in vitro* studies to validate and optimize restoration actions." The project's first year focused on herring culture techniques. Project 080821, funded in 2008 as the second year investigation, subsequently addressed herring stress, disease and yolk proteins. The project's final year, awarded as project 090821provided for a translation into English of the Japanese technical manual on herring culture *(Herring Fry Culture Techniques, 2001)* and a synthesis report of supplementation alternatives. In addition, the investigators were supported to collaborate with other scientists to formulate strategies for herring restoration.

Abstract: This project supplemented work accomplished with FY2008 funding that supported travel and collaboration with Japanese herring scientists, and investigation of factors affecting egg quality in herring. The project supported the translation and synthesis of the Japanese technical manual on herring culture, and permitted collaboration with other *EVOS* TC principal investigators on herring restoration strategies and stock supplementation objectives and actions for inclusion within the Integrated Herring Restoration Plan (IHRP). Work products include the herring culture technical manual translation, synthesis of this document into a report that provides a template for evaluating culture methods for use in PWS supplementation, and integration of the proposed methods with supporting science and herring management investigations and actions. The work was accomplished in Seward and Anchorage, Alaska, and Portland, Maine.

Key Words: Pacific herring (*Clupea pallasi*), herring fry production techniques, herring culture in Japan, herring eggs, herring larva, stock supplementation, Hokkaido fisheries, herring genetic diversity, Akkeshi Station, *Artemia*, rotifers, otolith marking, stock enhancement, disease, viral hemorrhagic septicemia virus, Icthyophonus.

Project Data: *Description of data* – Translated technical manual on Japanese herring culture techniques. *Format* – MS Word, .pdf and .jpg formats. *Custodian* – All herring data are available upon request via the Alaska SeaLife Center website: www.alaskasealife.org. The custodian of these data is Howard Ferren, Alaska SeaLife Center, 301 Railway Avenue, P.O. Box 1329, Seward, AK 99664, howard_ferren@alaskasealife.org. *Limitations* – None.

Citation:

Linley, T., and H. Ferren. 2009. Development of culture technology to support restoration of herring in Prince William Sound: Use of *in vitro* studies to validate and optimize restoration actions, *Exxon Valdez* Oil Spill Restoration Project Final Report (Restoration Project 090821), MariCal, Inc., Portland, Maine and Alaska SeaLife Center, Seward, Alaska.

TABLE OF CONTENTS

Executive Summary 1

Introduction 2

Objectives 3

Methods 3

Results 4

Discussion 4

Conclusion 4

Acknowledgement 6

Literature Cited 6

EXECUTIVE SUMMARY

The project focused on several important steps to illuminate herring culture techniques and applications of herring culture to restoration actions. Through the beneficial relationships developed between the PI and Japanese collaborators we were able to obtain the Japanese technical manual on herring culture *(Herring Fry Culture Techniques, 2001)* which documents 20 years of herring culture experience in Japan. Funding supported a contract to translate the manual into English so it could be made available to scientists and managers engaged in discussing PWS herring restoration. We were also funded to provide a synthesis report summarizing Japanese herring culture and best practices with regard to PWS herring restoration. These work products are submitted in their entirety as appendices.

INTRODUCTION

The decline and persistent low abundance of Pacific herring in Prince William Sound since the early 1990's has prompted interest in evaluating methods of stock supplementation as a potential mechanism to assist in recovery of the population. Studies indicate that the *Exxon Valdez* oil spill likely impacted recruitment early on, but other stressors such as pathogens (e.g. VHSV, ICTH) and shifting predator-prey abundance also appear to have contributed to the decline and may now be limiting recovery. This suggests intervention in the form of artificial propagation may be needed to restore PWS herring to levels that can effectively support the marine food web and provide for sustainable fisheries.

Stock supplementation projects are typically designed to protect young fish through their most vulnerable life stages (egg and larval stages) when the greatest mortality occurs. To be successful, such projects must support favorable conditions for nurturing the production of healthy juvenile fish in large numbers that can be released back into the environment. Thus, detailed knowledge of optimal husbandry conditions, favorable nursery conditions for rearing and release of juvenile fish, as well as the effects of restoration on life stage development are critical building blocks in the formation of successful herring restoration methods. Although extensive research has been conducted on herring life history and ecology, little is known about the husbandry requirements for herring outside of Japan.

The contemporary program for artificial propagation of herring in Japan dates to the early 1980's when the Japan Aquaculture Association was petitioned to develop aquaculture techniques for local herring stocks on the island of Hokkaido. Initial efforts focused on stocks in the Furen and Akkeshi Lakes region in eastern Hokkaido and were subsequently expanded to western Hokkaido and northern Honshu. Local fishermen had a major role in the development of the program through regional fisheries cooperatives and the the Nemuro Jurisdiction Herring Seed Production Management Commission.

The history of and techniques for culturing herring were described in detail by Yamamoto (2001) in a technical report titled Herring Fry Production Techniques, published by the Japan Aquaculture Association Corp. The document provides basic information on herring culture technique development that occurred at the Japan Aquaculture Association, Akkeshi Station and considerable information regarding the ecology and physiology both for culture of the parent stock and fry production techniques. This document was translated into English (M. Mottet, Alaska-Southeast Bio-Research, 2009) as an objective of this project.

Translation of the Japanese technical manual and subsequent synthesis document summarizing the Japanese experience as well as our own herring culture investigations provides stakeholders and others interested in stock supplementation an overview of the potential for use of these techniques in PWS. Although not complicated, the techniques developed and employed in Japan span much of the

herring life cycle and give stakeholders a range of options that can be considered to accommodate specific environmental and ecological conditions within PWS.

OBJECTIVES

1. Translate into English the Japanese herring culture technical manual (Yamamoto, Y. 2001. Techniques for juvenile production of herring. Technical Report of Stock Enhancement. Vol. 7. 100 p. Japan Sea Farming Association).

2. Synthesize the translated report into an assessment document to evaluate supplementation alternatives based on actual data from the Japanese herring experience.

3. Formulate goals, objectives and strategies in collaboration with other EVOS funded scientists in response to the FY2010 RFP and Integrated Herring Restoration Plan.

METHODS

1. *Translate the Japanese herring culture technical manual.* We contracted for professional translation of the document. The Japanese herring culture technical manual is 100 pages in length, covering over 20 years of research, development and stock supplementation of herring in Japan.

2. *Synthesize the translated report into an assessment document to evaluate supplementation alternatives based on actual data from the Japanese herring experience.* Limited information has been presented regarding the viability of stock supplementation methods for herring and their potential utility in PWS. Hay (2007) provides an overview of the Japanese experience, but details regarding specific culture methods are needed to guide supplementation actions and funding. We have condensed the translated document into a best practices procedure manual for use in developing and implementing stock supplementation projects.

3. *Formulate goals, strategies and objectives in response to the FY2009 RFP and Integrated Herring Restoration Plan in collaboration with other EVOS funded scientists to integrate scientific investigations with supplementation actions.* The Integrated Herring Restoration Plan (IHRP) will require alignment and integration of herring supplementation actions with prioritized scientific investigations, technology, permit requirements and resource management. We collaborated with scientists in various planning sessions. Specific options and actions for herring culture were included in the *Draft Integrated Herring Restoration Plan.* http://www.evostc.state.ak.us/Universal/Documents/Publications/IHRP%20-%20Draft%2012-31-08.pdf

RESULTS

A contractor was identified to translate the Japanese herring culture technical report. The contract was issued in the fall/winter of 2008, and translation completed by the spring of 2009. This report is attached as Appendix A.

A herring culture synthesis document been completed. The Japanese report is the primary source document for the synthesis report.

Mr. Ferren and Dr. Linley met with other herring PIs in Anchorage during the herring PI meeting arranged by the *EVOS* TC staff in November 2008. Comments were contributed regarding supplementation goals, objectives and strategies. The 2010 *EVOS* TC RFP was reviewed and inquires were submitted to various herring PIs and other scientists regarding use of the Alaska SeaLife Center as a herring culture / rearing facility for mass marking experimentation. There was no interest expressed to pursue mass marking investigations at ASLC.

DISCUSSION

The contents of the Japanese culture technical report have been summarized by Dr. Linley in our Herring Culture Synthesis Report, attached as Appendix B.

CONCLUSION

Large scale herring fry production for stock enhancement has occurred in Japan since 1982. The development and refinement of the techniques for herring culture has enabled communities and organizations throughout Hokkaido and northern Honshu to establish programs that have helped stabilize and restore local herring populations at levels that support sustainable fisheries. Similar methods may be suitable for use in rebuilding herring in PWS, provided that critical biological and ecological characteristics of the population can be defined so as to maximize growth, survival and recruitment of released fish to the spawning stock. The critical components include: (1) the degree to which adult herring exhibit homing or site fidelity to the area of origin, (2) whether large numbers of cultured fish can be effectively mass marked (and recovered) to determine their contribution to the spawning population, (3) the susceptibility of cultured fish to marine pathogens, and (4) production costs for large scale enhancement.

In Japan, studies on herring propagation have focused on populations that repeatedly spawn at the same location. These populations have comparatively restricted ranges and at maturation return to coastal areas to spawn. Since they repeatedly return to spawn in limited spawning areas, it is comparatively easy to determine the abundance of the resource and to obtain results from released fish. The herring stock(s) in PWS exhibit similar characteristics. Their natural range (PWS, near shore Gulf of Alaska)

is somewhat restricted. Although inter-annual spawner abundance in specific areas in PWS can vary widely, spawner activity in specific areas (e.g. Port Gravina, Sheep Bay, St. Matthews) has been consistent in recent years. Mark – recapture studies at Furen Lake, Akkeshi and Miyako have clearly demonstrated that cultured herring originating from local stocks to the bays from which they were released, suggesting the potential for similar results with PWS herring. Identifying suitable areas with limited spawning abundance but consistent inter-annual spawning activity would be a key step in testing the hypothesis that cultured PWS herring return to their area (bay) of release.

Mass marking of cultured herring in Japan has been based on either immersion or oral administration of two fluorescing compound to label otoliths: alizarin complexone (ALC) and tetracycline hydrochloride (TC). Both have been shown to be effective, although there is ~ 10 fold difference in cost between the two compounds ($0.018 per fish for ALC, $0.0013 per fish for TC. Regardless of the method, mass marking techniques for herring have been developed and used routinely in Japanese herring stock enhancement programs to assess the contribution of cultured fish to the spawning populations. Alternative methods (e.g. thermal otolith marking, otolith marking using trace elements / isotopes) may prove to be technically or economically more effective, but the important point is that identification of cultured fish in the spawning stock is not a major impediment to supplementation.

In contrast to observations on both natural origin and cultured herring in Japan, pathogens have a marked effect on the health of herring in PWS. VHS has been reported in some marine fish species in Japan, but not in herring. If large scale production methods similar to those used in Japan are adopted for use in PWS, then techniques to mitigate the risks associated with VHSV and Ichthyophonus must be developed. Although techniques are available for early (hatchery) life stage production (e.g. depuration of hatchery water supply and discharge), this is not the case for the later stages of production associated with cage culture. Additionally, the transport of juvenile herring from shore-based facilities to seawater net pens is inherently stressful, which will exacerbate the risk to pathogen exposure. Development of pathogen specific vaccines or methods to boost innate immune response may be needed. Similarly, adjusting the timing, location and duration of cage culture may further aid in reducing disease risk.

The Japanese herring supplementation program is based on an approach that is technically intensive and hence has significant upfront capital costs as well as high operating costs. Yamamoto provides estimates for both total capital and operating costs related to the production of juvenile herring. In 2001 the estimate to produce ~ 1 million herring for release (at 70-80 mm length) was approximately 19 yen per fish (in $US today ~ $0.19 per fish). This reduces to ~ $0.08 per fish for 3 million herring due to the economy of scale. Assuming a similar approach with similar costs for PWS, a pilot project to evaluate the contribution of e.g. 1 million juvenile herring release would cost at a minimum of ~ $200,000 annually. This figure is almost an order of magnitude less than the lower estimated provided by Hay (2007) for a pilot

scale release of 1 million fish in PWS, although Hay's estimate also includes substantial funds for strategic planning, research, discretionary needs etc. Factoring in different assumptions for major expenditures such as facility costs (i.e. all up front or amortized) and labor, the actual cost for such a project is likely to fall somewhere between these estimates.

The Japanese herring program provides an excellent model for stakeholders to consider with regard to rebuilding the herring resource in PWS. Much of the methodology for successful juvenile production has been developed and refined over a period of 25 years. The stock enhancement / supplementation programs that have been built on this technology have clearly contributed fish to the spawning populations throughout Hokkaido and northern Honshu. Whether these programs will be ultimately self-sustaining (i.e. do the contributions to the spawning stock result in additional recruitment in the future, or are these simply put-and-take fisheries) remains to be seen. Nevertheless, the technical framework certainly exists for a pilot scale project to evaluate the utility of stock supplementation for PWS.

ACKNOWLEDGEMENT

We would like to thank the *Exxon Valdez* Oil Spill Trustee Council for funding this investigation. Additionally, we would like to thank Dr. Takahiro Matsubaru (Japan Fisheries Agency, Hokkaido National Fisheries Research Institute - HNFRI) for his guidance, perseverance and generous contribution of the Japanese herring culture technical report.

LITERATURE CITED

Hay D. (2007). Herring enhancement in Prince William Sound: feasibility, methodology, biological and ecological implications. Report to the *Exxon Valdez* Trustee Council. March 30, 2007. 77 pages.