

WASHINGTON SEA GRANT PROGRESS REPORT
for the period 2/1/2008 – 1/31/2009

WSG Project Number: **R/F-160**
Project Title: Climate-Change Effects on Steelhead in North Pacific Marine Ecosystems

Principal Investigator(s) and Affiliation:
Katherine Myers University of Washington, School of Aquatic & Fishery Sciences

1. ABSTRACT ELEMENTS

OBJECTIVES

The overarching goal of the proposed research is to increase scientific understanding of the biophysical mechanisms that affect survival of steelhead (*Oncorhynchus mykiss*) in North Pacific marine ecosystems. Specific objectives include: (1) developing a biophysical database on steelhead in North Pacific marine ecosystems, (2) mapping known ocean distributions and migrations routes; (3) reconstructing ocean age and growth histories of steelhead, (4) mapping interannual variation in atmospheric and oceanographic conditions, (5) evaluating interannual variation in marine diets of steelhead; (6) estimating consumption and growth; (7) mapping interannual and spatial variability in ocean growth potential of steelhead; (8) simulating changes in steelhead ocean age and growth under different climate scenarios; and (9) creating a synthesis of scientific knowledge on the effects of climate on steelhead in marine ecosystems.

METHODOLOGY

We propose a comprehensive mechanistic approach including: (1) retrospective analyses of existing time series (1955-present, archived at the University of Washington) steelhead samples and data (catch, effort, biological, oceanographic, tag, scales); (2) shipboard process studies on steelhead diets and marine food webs aboard a Japanese research vessel in 2007-2009; and computer mapping, modeling, and simulations of data and associated environmental effects on steelhead distributions, migration patterns, bioenergetics, and growth. Graduate student research will focus on developing new scientific tools to evaluate effects of climate change on steelhead in North Pacific marine ecosystems.

RATIONALE

Dramatic fluctuations in the abundance of adult steelhead returning to Pacific Northwest rivers in 2000-2006 appear to be linked to climate effects on their ocean survival. We hypothesize that climate induced changes in ocean environmental conditions and food webs in offshore waters of the North Pacific Ocean are affecting ocean growth and survival of Pacific Northwest steelhead. Our proposal addresses National Sea Grant priorities for understanding ocean ecosystems, habitats, and the effects of natural and human-induced climate change, as well as regional priorities for conserving living marine resources and ensuring sustainable fisheries and healthy populations. Millions of federal and state dollars are being spent to protect and restore Pacific Northwest steelhead populations. Our results should provide scientific data and tools needed to

understand the effects of climate change on survival of steelhead in marine ecosystems.

2. ACCOMPLISHMENTS AND OUTCOMES

Decadal-scale (1950-2005) variation in distribution and habitats of North American steelhead in the North Pacific Ocean (NPO: 38-60N, 150E-126W) was evaluated using Geographic Information System (GIS) maps of high seas tag recovery data (n=425 fish) and the International Comprehensive Ocean-Atmosphere Data Set (average sea surface temperatures for summer by decade, 2X2 degree grid). GIS maps showed known ocean distributions of North American steelhead by ocean age group and Distinct Population Segment (DPS). Juvenile (ocean age-.0) steelhead and southern DPSs (Oregon, California) were distributed mainly in the Gulf of Alaska (GOA). Older fish (ocean ages .1-.3) and central (Columbia R.) and northern (Washington and Alaska) DPSs were distributed across the NPO to as far west as the Kurile Islands, Russia (Snake R. DPS). In summer, 90% of tagged steelhead were distributed in surface seawater temperatures of 8-14C. The surface area of cool (2-8C) water in the NPO in summer has been decreasing since the 1970s, and may have shifted summer distribution of older age groups of steelhead northward in the CNP or westward out of the GOA. Analysis of oceanographic survey data from the CNP (1991-present) showed a northward shift (2-3 degrees latitude) in the southern boundary of the Subarctic Current (SAC) in June 1997 that has persisted through June 2008 surveys, effectively reducing cool-water habitat available to steelhead. The SAC area in the CNP likely provides a cool-water refuge for steelhead during warm years (e.g., El Nino) or warm climate regimes in the GOA (e.g., 1977-1998). Temperature data from an archival tag placed on a steelhead in the central GOA and recovered 36 days later in the Copper River, Alaska, indicated diurnal changes in vertical distribution. At night the steelhead remained at the surface (warmest temperatures), and during the day the fish made numerous dives to cooler sub-surface water (to 50-m below surface), presumably to find prey. Analyses of steelhead diets in both the GOA and central North Pacific (CNP) showed that the dominant prey of all age groups were gonatid squid and fish. The percent composition of squid in steelhead diets was inversely related to Russian pink salmon abundance, although the relation was stronger in the CNP, where overlap in distribution of steelhead and Russian pink salmon is higher, than in the GOA. Thus, climate change may affect ocean carrying capacity of steelhead through variation in ocean habitats and density-dependent trophic interactions.

3. IMPACTS

Sea Grant research supports ecosystem-based management of declining runs of US West Coast steelhead. Steelhead are ranked as one of the top five sport fish in North America, and are also an important commercial species for US West Coast tribal fisheries. Steelhead are listed as either threatened or endangered under the United States Endangered Species Act (ESA) in 11 of 15 Distinct Population Segments in the western United States south of Canada. The most recent listing was Puget Sound, Washington, steelhead (May 11, 2007). Dwindling steelhead runs have led to curtailment of recreational and tribal fisheries, and the loss of jobs in these fisheries and related industries. This is an important large-scale marine ecosystem problem because steelhead populations are declining throughout their endemic range in Asia and North America. **Impact:** Although millions of federal and state dollars are being spent to protect and restore US West Coast steelhead populations and their freshwater habitats, fishery managers frequently attribute recent large and unpredictable interannual and decadal-scale fluctuations in steelhead runs to changes in ocean (not freshwater) environmental conditions. As a result, the

response of steelhead to management and restoration actions in freshwater habitats cannot be correctly interpreted without understanding how ocean-climate processes regulate steelhead abundance. Our research will provide the marine community with a scientific foundation for informed policy and management decisions, especially when open ocean conditions for steelhead are unfavorable. During this reporting period, ongoing research led to new collaborations among the University of Washington, Washington Department of Fish and Wildlife, and the Pacific States Marine Fisheries Commission to propose development and application of innovative genetic stock identification and tagging tools to determine climate impacts on Washington steelhead populations in the North Pacific Ocean.

4. PERFORMANCE MEASURES

Measure 1: Economic and societal benefits derived from the discovery and application of new sustainable coastal, ocean, and Great Lakes products from the sea.

Actual (reporting period covered by this report):

No actual discovery and application of new products from the sea during this reporting period.

Anticipated (12-month period following this reporting period):

No anticipated discovery and application of new products from the sea during the 12-month period following this reporting period.

Measure 2: Cumulative number of coastal, marine, and Great Lakes issue-based forecast capabilities developed and used for management.

Actual (reporting period covered by this report):

No actual issue-based forecast capabilities developed and used for management during this reporting period.

Anticipated (12-month period following this reporting period):

No anticipated issue-based forecast capabilities developed and used for management during the 12-month period following this reporting period.

Measure 3: Percentage/number of tools, technologies, and information services that are used by managers (NOAA and/or its partners and customers) to improve ecosystem-based management.

Actual (reporting period covered by this report):

No actual tools, technologies, and information services provided during this reporting period.

Anticipated (12-month period following this reporting period):

9 tools and services:

(1) Steelhead database and associated metadata, 1955-2009 (on CD or DVD/pdf of metadata on website)

(2) GIS atlas of ocean distribution, abundance, and habitats of steelhead (on CD or DVD/pdf on website; manuscript for publication)

- (3) Scale pattern database of steelhead seasonal and annual growth measurements (on CD or DVD; manuscript for publication)
- (4) Evaluation of interannual variation in steelhead diets (manuscript for publication)
- (5) Bioenergetics models and estimates of growth potential for steelhead in the North Pacific Ocean (manuscript for publication)
- (6) Synthesis of scientific knowledge on effects of climate on steelhead in marine ecosystems (manuscript for publication)

5. PUBLICATIONS

Please refer to instructions for hardcopy reprint requirements and citation formats.

A. Journal articles:

Myers KW, Davis ND, Walker RV, Fukuwaka M, Atcheson M, Mantua N (In preparation) High seas distribution, migration, and abundance of steelhead, *Oncorhynchus mykiss*.

Atcheson M, Myers KW, Davis ND, Walker RV, Beauchamp D, Mantua N (In preparation) Interannual variation in marine diets of steelhead, *Oncorhynchus mykiss*.

Atcheson M, Davis ND, Walker RV, Myers KW, Fukuwaka M. (In preparation) Trends in ocean age and growth of steelhead, 1991-2009.

Atcheson M, Beauchamp D, Davis ND. (In preparation) Bioenergetics and growth potential of steelhead in the North Pacific Ocean.

Myers KW, Mantua N, Atcheson M, Davis ND, Walker RV, Fukuwaka M. (In preparation) Climate-change effects on steelhead in North Pacific Marine Ecosystems.

B. Theses and dissertations:

No theses and dissertations during this reporting period.

C. Book chapters:

No book chapters during this reporting period.

D. Book or Monograph:

No books or monographs during this reporting period.

E. Paper in Proceedings

No paper in proceeding during this reporting period.

F. Proceedings or Symposia:

Davis ND, Myers KW, Walker RV, Atcheson M, Fukuwaka M (2008) Ocean distribution and habitat of North American steelhead trout. Summary of the Eleventh Pacific Coast Steelhead Management Meeting, Boise, March 4-6 2008. Pacific States Marine Fisheries Commission and US Fish and Wildlife Service, p 32

G. Technical reports:

Celewycz AG, Berger JD, Cusick J, Davis ND, Fukuwaka M (2008) High seas salmonid coded-wire tag recovery data, 2008. North Pacific Anadromous Fish Commission Document 1111, 25 pp

Davis ND, Atcheson M, Marvin D, Fukuwaka M (2008) Interception of a PIT-tagged Columbia River Basin steelhead in the central North Pacific Ocean. North Pacific Anadromous Fish Commission Document 1106, 7 pp

Fukuwaka M, Davis N, Atcheson M, Yamamoto Y, Toge K (2008) International salmon research aboard the R/V *Wakatake maru* in the central North Pacific Ocean and Bering Sea during the summer of 2008. North Pacific Anadromous Fish Commission Document 1115, 19 pp

H. Advisory publications (e.g. handbooks, manuals, guides):

No advisory publications during this reporting period.

I. Magazine articles:

No magazine articles during this reporting period.

J. Media Placements:

No media placements during this reporting period.

K. Other publications (e.g., videos, DVDs, software, websites):

No other publications during this reporting period.

6. PRESENTATIONS - inc. Conference (Poster or Oral), Seminar & Public

Atcheson M. Climate change and growth in steelhead trout, *Oncorhynchus mykiss*. Presentation of MS Thesis proposal to Committee, School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA, February 2008

Davis ND, Myers KW, Walker RV, Atcheson M, and Fukuwaka M (2008) Ocean distribution and habitat of North American steelhead trout. Presentation to the Eleventh Pacific Coast Steelhead Management Meeting, Boise, ID, March 4-6

Mantua N (2008) Climate change impacts on PNW steelhead. Invited oral presentation at the Steelhead Summit Alliance, SeaTac Marriot, SeaTac, WA, May 31

Atcheson M (2008) Steelhead trout and climate variability in the North Pacific: a bottom-up analysis. Poster presentation at the 10th Annual Salmon Ocean Ecology Meeting, Coast Bastion Hotel, Nanaimo, BC, Canada April 28-29

Atcheson M (2008) Interannual variation in marine diets of steelhead trout, *Oncorhynchus mykiss*. Oral presentation at UW School of Aquatic and Fishery Sciences Graduate Student Symposium, School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA November 20

7. PATENTS AND COPYRIGHTS

No patents and copyrights during this reporting period.

8. NEW BUSINESSES OR JOBS CREATED

No new businesses or jobs created during this reporting period

9. LIST ALL STUDENTS SUPPORTED BY OR AFFILIATED WITH THIS PROJECT

Student Name: Margaret (“Megan”) Atcheson

Department: School of Aquatic and Fishery Sciences

Major/Degree field: Fishery Sciences

Major Professor: Nathan J. Mantua

Student Type: MS

Dissertation/Thesis title: “Climate change and growth in steelhead trout, *Oncorhynchus mykiss*”

Date of graduation (anticipated): June 2010

Total support or affiliation period: September 2007-January 31, 2010

Type of support: RA, research and tuition costs

Current employment if applicable: Graduate Research Assistant, School of Aquatic & Fishery Sciences, University of Washington, Seattle

10. INTERACTIONS

During this reporting period, we had significant interactions (information exchanges) on high seas steelhead research and management issues with the Washington Department of Fisheries (H. Bartlett, S. Young), the Washington State Representative to the North Pacific Anadromous Fish Commission (G. Smith), the Pacific States Marine Fisheries Commission (D. Marvin), and the North Pacific Anadromous Fish Commission. The Fisheries Research Agency of Japan made a substantial contribution by providing ship time for our field research (cost sharing of approximately \$58,000 per year in ship time aboard the *Wakatake maru*).

11. OUTREACH AND INFORMATION/TECHNOLOGY TRANSFER

Outreach activities included provision of technical reports on Sea-Grant funded high seas (*Wakatake maru*, tagging) research to the North Pacific Anadromous Fish Commission at their research planning and coordinating and annual meetings in 2008, and presentations at the Pacific Coast Steelhead Management Meeting in Boise, Idaho, the Northeast Pacific Coastal Ecosystem Workshop and Forecasting Forum in Nanaimo, B.C., the Wild Steelhead Coalition, Steelhead Summit Alliance in SeaTac, Washington, and the North Pacific Anadromous Fish Commission annual meeting in Seattle, Washington. A copy of our WSG proposal for this project was provided in response to a request from ESA Adolfson:Biological Resources, Seattle, Washington (L. Thoreson), an environmental consulting firm compiling information on research relevant to marine research on steelhead. Project graduate student, M. Atcheson, was an invited (by

Government of Japan) participant in the June-July 2008 research cruise of the *Wakatake maru*, and was also an invited participant in the second PICES (North Pacific Marine Science Organization) Summer School on “Ecosystem-based management and ecosystem approach” held August 23-26, 2008 at the Graduate School of Fisheries sciences, Hokkaido University, Hakodate, Japan (major funding for the school was provided by Japanese programs). Fifty students and early career scientists from China, Japan, Korea, Russia, and the U.S.A. attended.

12. FUTURE ACTIVITIES

In the last year of our project (year 3 of 3), we will complete all objectives and manuscripts reporting our results for peer-review journal publication. Ongoing lab work involves estimating growth of steelhead, parameterization of a steelhead-bioenergetic models, evaluation of NEMURO (North Pacific Ecosystem Model for Understanding Regional Oceanography) output as a measure of productivity of ocean habitats of steelhead, mapping interannual and spatial variability in ocean growth potential of steelhead, and simulating changes in steelhead ocean age and growth under different climate scenarios,

We do not anticipate any changes to our project during the next year. Outreach activities will include presenting information on our research findings to fishery agency administrators, managers, and biologists, and to the public at several meetings, including but not limited to the 11th Annual Salmon Ocean Ecology Meeting in Juneau, Alaska, the American Fisheries Society Washington – British Columbia Chapter 2009 Annual General Meeting in Shelton, Washington, and the North Pacific Anadromous Fish Commission Annual Meeting in Niigata, Japan.