

*North  
Pacific  
Anadromous  
Fish  
Commission*



# **BULLETIN NUMBER 6**

## *Pacific Salmon and Steelhead Production in a Changing Climate: Past, Present, and Future*

Edited by: Shigehiko Urawa, Marc Trudel, Richard J. Beamish, Edward V. Farley, Jr.,  
Jeffrey R. Guyon, James R. Irvine, Toshihiko Saito, Alexander V. Zavolokin,  
Olga S. Temnykh, and Nancy D. Davis

Consulting Editor: Natalie Moir

Technical Editors: Nancy D. Davis, Harold Belongilot, and Yuko Uchida

Published by:

North Pacific Anadromous Fish Commission  
Suite 502, 889 West Pender Street  
Vancouver, BC V6C 3B2  
Canada

Tel: 604-775-5550  
Fax: 604-775-5577  
E-mail: [secretariat@npafc.org](mailto:secretariat@npafc.org)  
Website: <http://www.npafc.org>

© 2016 North Pacific Anadromous Fish Commission



## Preface

This Bulletin is a compilation of 37 papers presented at an International Symposium on Pacific Salmon and Steelhead Production in a Changing Climate: Past, Present, and Future held in Kobe, Japan, May 17–19, 2015, under the auspices of the North Pacific Anadromous Fish Commission. In addition, this Bulletin includes one paper submitted after the symposium that reviews the NPAFC 2011–2015 Science Plan. The NPAFC Science Plan was developed with the goal to explain and improve forecasting of the annual variation in Pacific salmon production under a changing climate and provided the impetus for convening the 2015 Symposium. All articles in this Bulletin have been peer-reviewed, and the list of reviewers is provided at the end of this volume.

The Symposium was hosted by the NPAFC and was co-sponsored by the Fisheries Research Agency (Japan), Gordon and Betty Moore Foundation, Hokkaido Salmon Propagation Association, Hokkaido Stationary Net Fisheries Association, North Pacific Research Board, Pacific Salmon Foundation, Pacific Seafood Processors Association, and North Pacific Marine Science Organization (PICES). Members of the Symposium Organizing Committee included Shigehiko Urawa (Chairperson), James Irvine, Ju Kyoung Kim, Alexander Zavolokin, Edward Farley, and Nancy Davis.

Understanding how climate change and variability impacts the marine ecology of Pacific salmon and steelhead is important to their future sustainability. Over the past several decades there have been significant variations in marine production of Asian and North American salmonid populations linked to climate change. Better information on the

migration and survival mechanisms of salmonids during critical periods of their marine life history, specifically their initial period of marine life and possibly the winter period, is needed to better explain annual variation of salmon production. There is a strong need for improved information on the ecological mechanisms regulating production of anadromous populations and for estimating climate impacts on salmon in the North Pacific. Anadromous populations may function as an ecological indicator of marine ecosystems; and long-term monitoring of salmon populations and environments can yield the information required for retrospective studies that are fundamental to gauging long-term changes in salmon ocean habitats. Stock identification, marking, and tagging methods yield critical information on where salmonids go in their ocean habitats and contribute significantly to models incorporating ecosystem and environmental conditions by which to explore possible salmonid production scenarios. Accurate forecasting of returning salmon abundances offers opportunities to improve fisheries management and hatchery techniques by anticipating future variations in salmon production.

In 2017 the NPAFC will observe its 25<sup>th</sup> Anniversary. It is hoped that the research presented in this volume will act as a springboard toward future improved scientific understanding of factors influencing salmon survival and production in the North Pacific Ocean.

The NPAFC Secretariat  
December 2016



## Table of Contents

<b>Preface</b> .....	<i>i</i>
<b>Table of Contents</b> .....	<i>v–viii</i>
<b>1. Migration and Survival Mechanisms of Salmonids during Critical Periods in Their Marine Life History</b>	
Size-selective mortality of Chinook salmon in relation to body energy after the first summer in nearshore marine habitats K.G. Howard, J.M. Murphy, L.I. Wilson, J.H. Moss, and E.V. Farley, Jr. ....	1–11
Thiamine and lipid utilization in fasting Chinook salmon D.C. Honeyfield, A.K. Peters, and M.L. Jones .....	13–19
An exploratory assessment of thiamine status in western Alaska Chinook salmon ( <i>Oncorhynchus tshawytscha</i> ) D.C. Honeyfield, J.M. Murphy, K.G. Howard, W.W. Strasburger, and A.C. Matz .....	21–31
The influence of environmental variation on the Columbia River estuarine fish community: implications for predation on juvenile salmonids L.A. Weitkamp, T.P. Good, D.E. Lyons, and D.D. Roby .....	33–44
Initial estimates from an integrated study examining the residence period and migration timing of juvenile sockeye salmon from the Fraser River through coastal waters of British Columbia C.M. Neville, S.C. Johnson, T.D. Beacham, T. Whitehouse, J. Tadey, and M. Trudel .....	45–60
Early marine migration of juvenile chum salmon along the Pacific coast of eastern Hokkaido K. Kasugai, H. Saneyoshi, T. Aoyama, Y. Shinriki, A. Iijima, and Y. Miyakoshi .....	61–72
Adapting Hokkaido hatchery strategies to regional ocean conditions can improve chum salmon survival and reduce variability M. Nagata, Y. Miyakoshi, M. Fujiwara, K. Kasugai, D. Ando, M. Torao, H. Saneyoshi, and J.R. Irvine .....	73–85
Effects of release timing on the recovery of late-run chum salmon in the Okhotsk Sea coast of Hokkaido, Japan M. Nagata, D. Ando, M. Fujiwara, and Y. Miyakoshi.....	87–95
Observations of steelhead in the California Current lead to a marine-based hypothesis for the "half-pounder" life history, with climate change implications for anadromy S.A. Hayes, A.J. Ammann, J.A. Harding, J.L. Hassrick, L. deWitt, and C.A. Morgan.....	97–105

A water-recycling system for hatchery rearing of chum salmon fry  
 T. Shimizu, T. Morita, and Y. Yamamoto..... 107–111

Pacific salmon and steelhead: life in a changing winter ocean  
 K.W. Myers, J.R. Irvine, E.A. Logerwell, S. Urawa, S.V. Naydenko,  
 A.V. Zavolokin, and N.D. Davis..... 113–138

Is winter the critical period in the marine life history of Pacific salmon?  
 S.V. Naydenko, O.S. Temnykh, and A.L. Figurkin ..... 139–152

Stock-specific abundance of chum salmon in the central Gulf of Alaska during winter  
 S. Urawa, T.D. Beacham, S. Sato, T. Kaga, B.A. Agler, R. Josephson, and M. Fukuwaka ..... 153–160

Allometric relationships between body size and energy density of juvenile Chinook  
 (*Oncorhynchus tshawytscha*) and chum (*O. keta*) salmon across a latitudinal gradient  
 J.H. Moss, J.M. Murphy, E.A. Fergusson, and R.A. Heintz ..... 161–168

Chinook salmon first-year production indicators from ocean monitoring in Southeast Alaska  
 J.A. Orsi, E.A. Fergusson, A.C. Wertheimer, and E.V. Farley, Jr..... 169–179

**2. Climate Change Impacts on Salmonid Production and Their Marine Ecosystems**

Temporal and spatial variation in growth condition of Pacific salmon  
 H. Ueno, M. Kaeriyama, M. Otani, M. Oe, Y. Qin, M.N. Aita, S. Yoon, and M.J. Kishi ..... 181–187

Correlations between winter sea surface temperatures in the North Pacific Ocean and  
 continental-scale commercial catches of Pacific salmon, 1983–2013  
 A.V. Bugaev, O.B. Tepnin, and K.W. Myers ..... 189–205

Variation in zooplankton and micro-nekton biomass in response to seawater temperature changes  
 in the central Bering Sea during summer  
 T. Sato, S. Sato, S. Urawa, and T. Nagasawa ..... 207–217

Distribution, diet, and bycatch of chum salmon in the eastern Bering Sea  
 J.M. Murphy, E.V. Farley, Jr., J.N. Ianelli, and D.L. Stram..... 219–234

Potential role of the magnetic field on homing in chum salmon (*Oncorhynchus keta*) tracked  
 from the open sea to coastal Japan  
 T. Azumaya, S. Sato, S. Urawa, and T. Nagasawa ..... 235–241

**3. Retrospective Analysis of Key Salmonid Populations as Indicators of Marine Ecosystem Conditions**

Future climate-related changes in fish species composition including chum salmon  
 (*Oncorhynchus keta*) in northern Japanese waters, inferred from archaeological evidence  
 Y. Ishida, A. Yamada, and K. Nagasawa..... 243–258

Changes in the trophic structure of an epipelagic community in the western Bering Sea and western North Pacific Ocean with an emphasis on Pacific salmon (*Oncorhynchus* spp.)  
A.V. Zavolokin, V.I. Radchenko, and S.V. Naydenko.....259–278

Recent decline of pink salmon (*Oncorhynchus gorbuscha*) abundance in Japan  
T. Saito, Y. Hirabayashi, K. Suzuki, K. Watanabe, and H. Saito .....279–296

Population dynamics of pink salmon in the Sakhalin-Kuril region, Russia  
A.M. Kaev and J.R. Irvine.....297–305

Changing growth and maturity in western Alaskan Chinook salmon, *Oncorhynchus tshawytscha*, brood years 1975–2005  
M.V. McPhee, J.M. Leon, L.I. Wilson, J.E. Siegel, and B.A. Agler .....307–327

Effects of climate and competition for offshore prey on growth, survival, and reproductive potential of coho salmon in Southeast Alaska  
L.D. Shaul and H.J. Geiger .....329–347

Pink and sockeye salmon interactions at sea and their influence on forecast error of Bristol Bay sockeye salmon  
G.T. Ruggerone, B.A. Agler, B.M. Connors, E.V. Farley, Jr., J.R. Irvine,  
L.I. Wilson, and E.M. Yasumiishi .....349–361

Stock-recruit analyses of Fraser River sockeye salmon  
S.A. Akenhead, J.R. Irvine, K.D. Hyatt, S.C. Johnson, and S.C.H. Grant.....363–390

Habitat manipulations confound the interpretation of sockeye salmon recruitment patterns at Chilko Lake, British Columbia  
S.A. Akenhead, J.R. Irvine, K.D. Hyatt, S.C. Johnson,  
C.G.J. Michielsens, and S.C.H. Grant .....391–414

#### 4. Application of Stock Identification and Models for Salmonid Population Management

Genetic identification of juvenile pink salmon improves accuracy of forecasts of spawning runs in the Okhotsk Sea basin  
N.Yu. Shpigalskaya, A.I. Kositsina, U.O. Muravskaya, and O.N. Saravansky .....415–420

Microsatellite identification of sockeye salmon rearing in the Bering Sea during 2009, and 2011–2014  
T.D. Beacham, J.R. Candy, S. Sato, and S. Urawa.....421–432

Occurrence of white-fleshed coho salmon in northern Southeast Alaska  
W.R. Heard.....433–437

Genetic analysis identifies consistent proportions of seasonal life history types in Yukon River juvenile and adult chum salmon  
C.M. Kondzela, J.A. Whittle, C.T. Marvin, J.M. Murphy, K.G. Howard, B.M. Borba,  
E.V. Farley, Jr., W.D. Templin, and J.R. Guyon .....439–450

Genetic variation in chum salmon in the Sanriku Region, Japan, inferred from mitochondrial DNA analysis  
H. Tsukagoshi, S. Terui, G. Ogawa, S. Sato, and S. Abe ..... 451–454

**5. Forecasting Salmonid Production and Linked Ecosystems in a Changing Climate**

Applying the Krogh Principle to find shortcuts to understanding Pacific salmon production  
R.J. Beamish and C.M. Neville..... 455–468

Feeding habits and trophic levels of Pacific salmon (*Oncorhynchus* spp.) in the North Pacific Ocean  
Y. Qin and M. Kaeriyama ..... 469–481

Forecasting pink salmon production in Southeast Alaska using ecosystem indicators in times of climate change  
J.A. Orsi, E.A. Fergusson, A.C. Wertheimer, E.V. Farley, Jr., and P.R. Mundy ..... 483–499

**6. Review of the NPAFC 2011–2015 Science Plan**

Forecasting Pacific salmon production in a changing climate: a review of the 2011–2015 NPAFC Science Plan  
S. Urawa, J.R. Irvine, J.K. Kim, E.C. Volk, A.V. Zavolokin, T. Azumaya, T.D. Beacham, A.V. Bugaev, E.V. Farley, Jr., J.R. Guyon, S.G. Kim, M.J. Kishi, N.V. Klovach, M.V. Koval, D.H. Lee, S.V. Naydenko, D.S. Oxman, T. Saito, S. Sato, M.W. Saunders, O.S. Temnykh, A.M. Tompkins, M. Trudel, V.V. Volobuev, K.I. Warheit, and N.D. Davis ..... 501–534

**List of Reviewers**..... 535