Summary and Future Plan of BASIS

Dramatic fluctuations in the ocean growth and survival of many Asian and North American salmon populations over the past decade have been attributed to changes in the Bering Sea and other marine ecosystems. The absence of scientific observations for salmon, ecologically related species, and environmental conditions in the North Pacific Ocean has limited our understanding of these changes and how they affect salmon populations and economies around the Pacific Rim. International research efforts to address these issues were developed by the North Pacific Anadromous Fish Commission (NPAFC) as part of its Science Plan. The research plan called BASIS (the Bering-Aleutian Salmon International Survey), began in 2002 as a coordinated program of cooperative research on Pacific salmon in the Bering Sea. The goal of BASIS research was to clarify the mechanisms of biological response by salmon to the conditions caused by climate change in the Bering Sea.

Climate models predict a gradual increase in atmospheric temperature, with the greatest increases occurring in subarctic and arctic regions. The evidence for current warming trends is the pole-ward retreat of seasonal sea ice cover in the Arctic (Fig. 1). Continued warming is predicted to have a profound effect on Bering Sea ecosystems. For instance, a presentation at the BASIS Symposium by Nicholas Bond showed that climate warming will increase water column stability on the eastern Bering Sea shelf, limiting the flux of nutrients into the photic zone and perhaps negatively impacting primary and secondary productivity.

Large-scale climate cycles are affecting regional climate trends. For instance, shifts in the position the Far Eastern Low and Aleutian Low pressure systems determine whether or not the Bering Sea experiences warming or cooling and also affects the velocity of ocean currents. The position of these atmospheric low pressure systems (NE and W, respectively) during 2002 to 2005 brought warmer air to the Bering Sea during winter and was related to decreased storm activity during summer. The position of these low pressure systems shifted again (SW and E, respectively) during 2006, resulting in colder arctic air covering much of the Bering Sea during winter and summer which increased storm activity.

The BASIS research initiated by the NPAFC could not have been more timely. The surveys began during 2002, a time of anomalously warm spring and summer sea temperatures. These warm sea temperatures continued through 2005, switching to anomalously cold during 2006 to 2008 (Fig. 2). Thus many of the papers within these proceedings offer perspective on how salmon and other nekton responded to changing climate states. All papers were peer-reviewed with the objective to provide a broad spectrum of research results from a team of international scientists working on the biological response of Pacific salmon and other nekton to climate change and variability in the Bering Sea and Arctic ecosystems.

The papers in these proceedings are the culmination of oral and poster presentations given at the BASIS Symposium during November 23–25, 2008 in Seattle, Washington. Ed Farley chaired a steering committee consisting of Tominori Azumaya, Richard Beamish, Ki Baik Seong, Vladimir Sviridov, and Shigehiko Urawa. There are four topics within the general theme of the biological responses by salmon to climate and ecosystem dynamics: (1) migration and distribution of salmon; (2) food production and salmon growth; (3) feeding habits and trophic interaction; and (4) production trends and carrying capacity of salmon. During the symposium, NPAFC

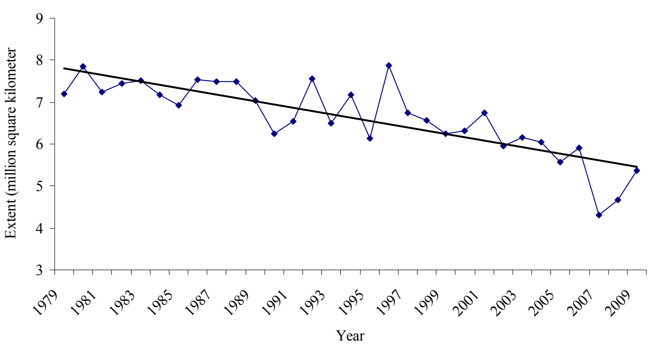

Fig. 1. Average monthly Arctic sea ice extent September 1979 to 2009. (Data courtesy of the National Snow and Ice Data Center).

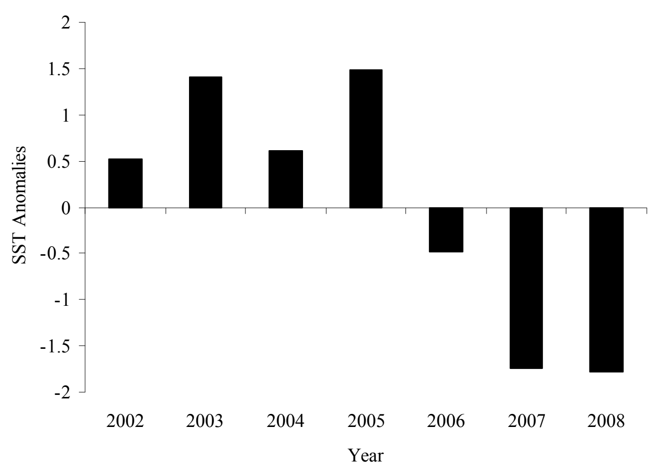

Fig. 2. Anomalies of sea surface temperatures (bars, SSTs,°C) during May 2002 to 2008 in the southeastern Bering Sea (data obtained from http://www.beringclimate.noaa.gov). Mean May SSTs are averaged over the area 54°18'N to 60°0'N, 161°12'W to 172°30'W using data from the National Centers for Environmental Protection and the National Center for Atmospheric Research (NCEP/NCAR) reanalysis project (Kalnay et al. 1996). The anomalies are the deviations from the mean May SST value (2.33°C) for the 1970–2000 period normalized by the standard deviation (0.76°C).

commemorated the efforts from research and contract vessels: *Kaiyo maru* and *Wakatake maru* (Japan), *TINRO* (Russia), and *Sea Storm* and *Northwest Explorer* (USA) for their expertise and support in conducting BASIS research surveys.

The success of the symposium was due to the steadfast dedication of the NPAFC Secretariat: Vladimir Fedorenko, Shigehiko Urawa, Wakako Morris, and Denise McGrann-Pavlovic. In addition, the papers within this Bulletin were published one year after the Symposium because of the timely management by Shigehiko Urawa and the symposium editorial group members. Approximately 60 reviewers contributed to peer reviews of original manuscripts, and Natalie Moir worked closely with authors for the final editions.

Migration and Distribution of Salmon

There are 14 papers utilizing a combination of stock identification techniques including genetics, hatchery otolith thermal marks, scale pattern analysis, temperature-depth archival tags, and otolith microchemistry used to describe the distribution, vertical migration, and potential migratory pathways/overwintering grounds for juvenile, immature, and maturing salmon. New information on the distribution of juvenile chum salmon in the Arctic during fall presented by Chris Kondzela indicated a large percentage of juvenile chum salmon captured in Bering Strait were from the Anadyr-Kanchalan river system of northeastern Russia, whereas the majority of juvenile chum salmon captured in the Chukchi Sea region were from northwestern Alaska. Jim Irvine used otolith microchemistry to examine whether or not juvenile chum salmon from the Mackenzie River (Arctic) over-winter in the Beaufort Sea region and determined that they could not rule out this possibility. Shunpei Sato found that Asian chum salmon stocks dominated the catch in the central Bering Sea during summer months, whereas Alexander Bugaev found that Japanese and North American stocks were primarily distributed in the northern sections of the Russian EEZ and Russian stocks were primarily distributed in the southern region of the Russian EEZ during summer and fall. Terry Beacham found that immature chum salmon captured in the Gulf of Alaska during winter were primarily from North America in the northern region and from Asia in the southern region. Tomonori Azumaya developed a new model linking chum salmon bioenergetics to their high-frequency vertical migrations, as determined from archival tags data to describe why these vertical migrations optimize their feeding opportunities while minimizing their energetic requirements. Shigehiko Urawa clarified the stock-specific ocean distributions of Asian and North American chum salmon by using genetic and otolith marks, and he modeled the seasonal migration patterns of Japanese chum salmon between the Bering Sea and North Pacific Ocean, which mainly responded to changing seawater temperatures.

Papers from Toru Nagasawa and Pat Martin offer new information on the influence of sea surface temperatures on immature and maturing sockeye salmon distributions and CPUE trends in the Bering Sea. New information on stock structure of immature sockeye salmon in the Russian EEZ indicated the presence of Bristol Bay and Asian stocks of sockeye salmon in the northwestern Bering Sea during summer and fall. Papers on Chinook salmon distribution by James Murphy and Alexander Bugaev suggested that juvenile western Alaska Chinook salmon maintain distinct stock-specific distributions during their first year in the ocean, but are intermixed with Russian Chinook salmon in the northwestern Bering Sea the following years at sea. In addition, Robert Walker describes how information from an archival temperature depth tag placed on an immature Chinook salmon was used to infer that this fish over-wintered in the Bering Sea before migrating back to the Yukon River the following summer.

Food Production and Salmon Growth

There are six papers examining salmon size and growth as a proxy to ocean productivity. There is a long history of researchers using size at age to determine when or if density-dependent growth occurs for salmon in the ocean inferring an ocean carrying capacity. The Japanese scientists have one of the best time series on salmon length, where salmon were collected using variable mesh research gillnets during open ocean surveys in the North Pacific. Masa-aki Fukuwaka determined that bias-corrected mean fork lengths for chum salmon captured using research gillnets were smaller than uncorrected means, but concluded that the temporal trends in salmon size were not different. Ellen Martinson used scales collected from adult sockeye salmon returning to the Karluk River from 1922 to 2000 to suggest that fish length indices from salmon scales can be useful predictors of climate variability - shifts and ecosystem status. Alexander Zavolokin determined that Russian chum salmon tend to be distributed in regions where high concentrations of forage are found but can experience density-dependent growth patterns during their second, third, and fourth years at sea indicating that ocean conditions can affect ocean carrying capacity for these salmon. Alex Andrews showed how shifts between warm and cold ocean temperatures among years can alter juvenile pink salmon diets, size, and whole body energy content. Jamal Moss found that juvenile pink and chum salmon captured in the Chukchi Sea fed on high energy prey and had higher growth rates than those captured further south.

Feeding Habits and Trophic Interaction

Many fisheries resource managers are turning from single species management to an ecosystem approach to management in order to provide a comprehensive framework for living marine resource decision making. A necessary component of an ecosystem approach to management is the study of fish food habits and trophic interaction. There are six papers in these proceedings examining this topic. Svetlana Naydenko showed that in the western Bering Sea juvenile walleye pollock consumed a large portion of the forage resource during 2002 and 2003 and Pacific salmon, squids, Atka mackerel, herring, and capelin were the dominate consumers of the available forage during 2004 to 2006. She concluded that salmon production is not limited by zooplankton abundance. Kristen Cieciel examined the relationship between jellyfish and juvenile and immature salmon distributions and found that in some years there could be a potential for competition for food resources. Nancy Davis with Thaddaeus Buser have several papers on salmon diets. One paper reveals that salmon diets shifted between warm and cold years and that there is a difference in salmon stomach contents amongst regions of the Bering Sea. The others indicate that immature Chinook salmon feed on fish offal during winter months in the Bering Sea, where the offal is identified as walleye Pollock body parts discarded from high seas factory trawlers. Rusty Sweeting examined diets of juvenile hatchery and wild coho salmon collected in the Strait of Georgia and found no differences in appetite or diet of these fish during the summer growing months.

Production Trends and Carrying Capacity of Salmon

There are seven papers addressing this topic. Vyacheslav Shuntov suggests that climate warming will not impact carrying capacity for salmon in the western Bering Sea and that current models indicate that the carrying capacity for salmon in the Bering Sea is much higher than present abundance levels. Greg Ruggerone presents a different view on carrying capacity, suggesting that the large increase in the abundance of hatchery salmon impact wild salmon stocks by limiting growth via density-dependent processes in the ocean, increasing their mortality rates. Ed Farley found that pelagic productivity on the eastern Bering Sea was highest during years with warm SSTs, as abundance levels of juvenile salmon and age-0 pollock are much higher than during years with cool SSTs. A model assessing links between ecosystems presented by Nate Mantua suggests that for any level of ocean productivity, the ocean will only support a certain biomass of fish. Masahide Kaeriyama shows prediction models for the impact of global warming on the ecosystems of the North Pacific Ocean and concludes that (1) global warming will decrease salmon carrying capacity by reducing their preferred ocean habitat; (2) an increase in density-dependent effects on growth of salmon, thus potentially reducing their marine survival; (3) Hokkaido chum salmon will no longer migrate to the Sea of Okhotsk, an important rearing region for juvenile chum salmon. In addition, Yukimasa Ishida examined archeological remains of chum salmon from sites along the Japan coast and determined that global warming will reduce salmon production in Japan if sea surface temperatures rise such as they had in the past.

Future BASIS Research

There was a lively discussion at the end of the symposium regarding future research for BASIS and a resounding commitment to continue this vital research by Parties within NPAFC. Since the meeting, Parties within NPAFC agreed to continue BASIS into Phase II (2009–2013). The Phase II plan (NPAFC 2009) will focus on the following research questions:

1) How will climate change and climate cycles affect anadromous stocks, ecologically related species, and the Bering Sea ecosystems?
2) What are the key climatic factors affecting cyclical changes in Bering Sea food production and pelagic fish communities?
3) How will climate change and climate cycles impact the available salmon habitat in the Bering Sea?
4) How will climate change and climate cycles affect Pacific salmon carrying capacity within the Bering Sea?

There was a general sense of satisfaction knowing that BASIS research captured the response of the Bering Sea pelagic ecosystem to cyclic patterns in climate. There was no question that the North Pacific Anadromous Fish Commission BASIS research strengthened our knowledge of the effects of climate variation on pelagic ecosystems of the Bering Sea. This research also fostered unprecedented cooperation among NPAFC Parties and is a model for future collaborative research efforts in the North Pacific Ocean.

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Edward V. Farley, Jr.
Chairperson
BASIS Working Group