The Ocean Carrying Capacity Research Program (OCC) at the Alaska Fisheries Science Center, Auke Bay Laboratory, Juneau, Alaska

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Dr. Helle was appointed Program Manager for the Ocean Carrying Capacity Program in 1996 at Auke Bay Laboratory. His research history at the Auke Bay Laboratory started as a seasonal employee in 1958-59, studying age and size at maturity of chum salmon in Prince William Sound. He began his full-time career as a fishery research biologist at Auke Bay Laboratory in 1960, studying the success of intertidal spawning pink and chum salmon in Prince William Sound. His research on age and size at maturity continued and expanded in the early 1970s to include chum salmon throughout their range in North America. Dr. Helle directed research on genetic stock identification at Auke Bay Laboratory in the 1980s to mid 1990s and this research was coordinated with other researchers in California, Oregon, Washington, British Columbia and Alaska. This genetic research was expanded to include cooperative genetic stock identification research with groups in Russia and China. He has been active on technical committees within the U.S./Canada Pacific Salmon Treaty and the North Pacific Anadromous Fish Commission. He received his B.S. (1958) and M.S. (1961) degrees in Fishery Management from the University of Idaho, spent a year as an Honorary Research Fellow (1964-65) at Marischal College, University of Aberdeen, Scotland, and completed his Ph.D. (1979) degree in Fisheries Science at Oregon State University.

After the ocean regime change of 1976-77, salmon (*Oncorhynchus spp*.) catches increased greatly in Alaska (*Fig.1*). Salmon catches also increased after the regime change in Japan and Russia. However, salmon on both sides of the Pacific Ocean started to decline in size at maturity about 1980, and continued to decline through 1994. Data from chum salmon *(O. keta*) from 1972-98 at Fish Creek, near Hyder, Alaska, exemplify this decline in size (*Fig. 2*). Chum salmon and other species of salmon matured at older ages during this time. These changes in size and age at maturity associated with large increases in salmon abundance provided evidence for an inverse relationship between body size and abundance of salmon in the Pacific Ocean. Responding to this evidence, the North Pacific Anadromous Fish Commission (NPAFC) called for research on the "critical issue of the impact of change in the productivity of the North Pacific Ocean on Pacific salmon" by studying factors affecting 1) current trends in ocean productivity and their effects on salmonid carrying capacity, and 2) changes in the growth, size at maturity, oceanic distribution, survival, and abundance of Pacific salmon.

The Ocean Carrying Capacity (OCC) Program at Auke Bay Laboratory was formed in 1995 to specifically address the NPAFC concerns. The OCC Program coordinates its research activities with NPAFC, Canadian Department of Fisheries and Oceans (DFO), Alaska Department of Fish and Game (ADF&G), the North Pacific Marine Science Organization (PICES), U.S. Global Ocean Ecosystems Dynamics (U.S. GLOBEC), the Pacific Salmon Commission (PSC), and the Exxon Valdez Oil Spill Trustee Council (EVOS).

The OCC research strategy has three major components: 1) distribution and migration of juvenile, immature, and maturing salmon and associated marine species in coastal and offshore waters, 2) monitoring studies, and 3) retrospective studies.

Distribution and Migrations of Juvenile, Immature, and Maturing Salmon and Associated Marine Species in Coastal Waters

The major objectives of this research component of the OCC Program are 1) to learn the ocean migration patterns and distribution of juvenile, immature, and maturing salmon, 2) to examine variability in these migrations due to species and

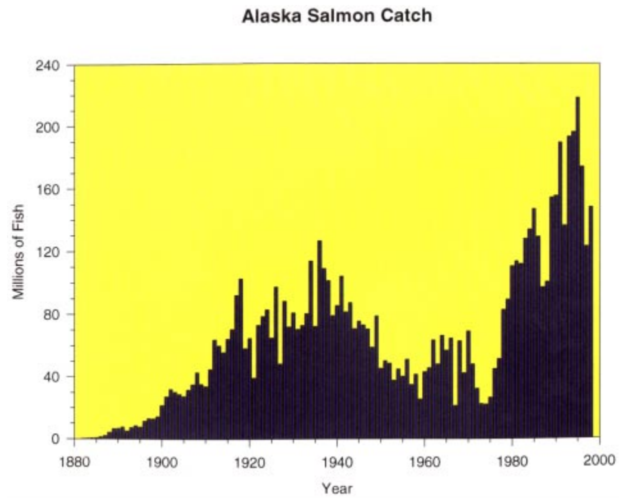

Fig. 1. *Catch of all species of salmon in Alaska from 1880 through 1998 (data from Alaska Department of Fish and Game).*

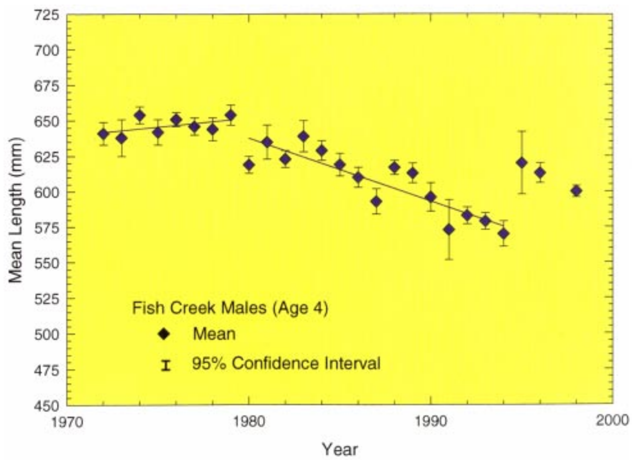

Fig. 2. *Mean length and 95% confidence interval for age-4 male chum salmon spawners at Fish Creek, 1972-98. Length measurement is mid-eye to end of hypural plate. Escapement in 1997 was insufficient to obtain samples.*

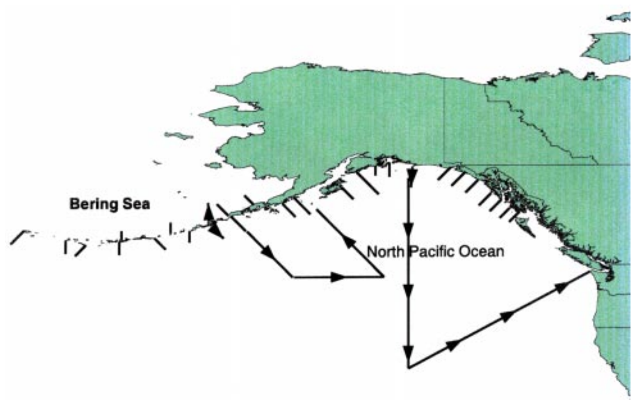

Fig. 3. *Habitat types fished on coastal transects from the chartered F/V Great Pacific in 1996-98.*

stock differences, 3) to identify the major food items of salmon at sea, and 4) to examine how growth and survival of salmon at sea relates to ocean environmental conditions.

Salmon are captured at sea mostly from a chartered fishing vessel built for trawling. Other government vessels of opportunity are also used, e.g. the NOAA research vessels *(R/V) Miller Freeman* and *John N. Cobb*, and the Canadian *R/V Ricker.* A large trawl towed near the surface has proved effective for sampling, especially juvenile and immature salmon. The trawl is towed through four habitat types from near shore to beyond the edge of the continental shelf-nearshore, shelf, slope, and oceanic (*Fig. 3*). Most transects are fished perpendicular to shore and start near shore and extend beyond the continental shelf (*Fig. 4*). Some purely oceanic transects have been fished to locate salmon on the high seas. Transects have been made from offshore of central California to beyond Attu Island in the Aleutian Islands (*Fig. 4*).

Samples of chum, pink (*O. gorbuscha*), and sockeye (*O. nerka*) salmon are retained for genetic stock identification and otolith studies. Samples of all species of salmon and most marine species are sampled for scales, length, weight, condition, and stomach content. Adipose-clipped salmon (primarily coho [*O. kisutch*] and chinook [*O. tshawytscha*] salmon) are retained for coded-wire-tag (CWT) analysis. Conductivity-temperature-depth (CTD) measurements are taken between most tows. In addition, certain transects are identified as oceanographic transects, and plankton are sampled along with CTD measurements from near shore to beyond the continental shelf.

The "heat marks" recorded on the otoliths of chum and pink salmon by changing incubation temperatures in hatcheries in Alaska and British Columbia have turned out to be a good source of growth and stock identification information. We have captured hatchery fish with these marks in surprising numbers offshore (*Fig. 5*). We have also captured much smaller numbers of heat-marked otoliths from sockeye salmon from enhancement facilities in southeastern and southcentral Alaska.

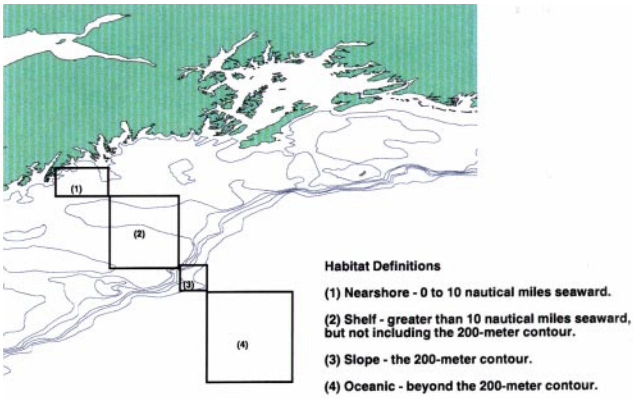

Fig. 4. *Transects fished from the chartered F/V Great Pacific in 1996-98. Transects with arrows were fished in April and May 1998. Transects along the coast without arrows were fished in July and August 1996 and 1998.*

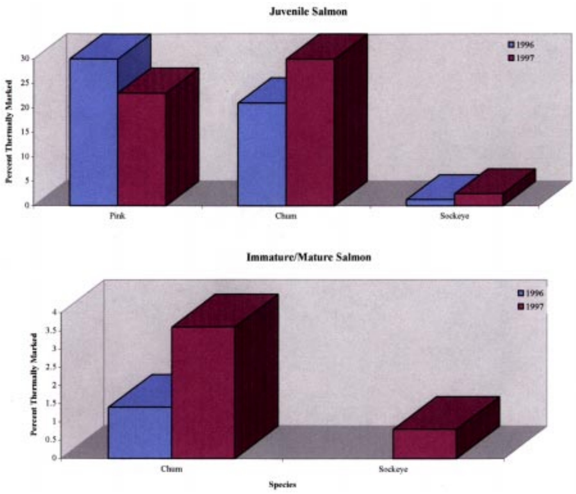

Fig. 5. Percent of otolith-marked juvenile, immature, and mature pink, chum, and sockeye salmon captured during cruises from the chartered F/V Great Pacific in 1996 and 1997.

Distribution and Migration of Immature and Maturing Salmon in Offshore Waters

Cooperative salmon research on the high seas with Japan is contracted by OCC through the University of Washington's Fisheries Research Institute (FRI). This research is also coordinated through the NPAFC. Research is focused on OCC objectives and is accomplished from Japanese research vessels. Activities include sampling salmon for size, age, maturity, condition, and diet. Some salmon are also tagged and released with Petersen disk tags or archival tags to monitor migrations and habitats. Recoveries of archival-tagged salmon in 1998 have shown remarkable variations in daily water temperature experience.

FRI scientists have also developed baseline databases on scale patterns of chum, chinook, and sockeye salmon and use this information to estimate stock origins of salmon captured in the high seas.

Monitoring Studies

Long-term monitoring activities provide data for evaluating the influence of marine climate on the dynamics of salmon and marine fish populations. Abundance and age and size at maturity of salmon are essential information for monitoring studies. Chum salmon populations are of special interest because most of their growth occurs in the ocean and they mature at various ages. OCC monitors the age and size at maturity and abundance of chum salmon in Olsen Creek, on the eastern shore of Prince William Sound; Chilkat and Klehini Rivers, in northern southeastern Alaska; Fish Creek, at the head of Portland Canal in southern southeastern Alaska; and Quilcene National Fish Hatchery, in Hood Canal west of Seattle, Washington.

The OCC has also resumed the operation of the weir at Sashin Creek, in Little Port Walter, on the southern end of Baranof Island. This weir was first operated in the early 1930s and abandoned in the mid 1980s. Pink salmon is the dominate natural species of salmon at Sashin Creek and because of their strict adherence to a two-year life cycle, they provide yearly information on brood abundance.

Retrospective Studies

Understanding the influence of marine climate change on the abundance, age, and size of Pacific salmon in the past is crucial to understanding the present status of salmon populations as well as to our attempts to predict these parameters in the future. The OCC Program is concentrating retrospective research in three areas: 1) examining salmon growth from historical collections of scales, 2) time-series analyses of catch, escapement, and growth of salmon, and 3) reconstruction of salmon abundance from paleoenvironmental analysis of sediment cores from sockeye salmon lakes and anoxic isolated marine bays. Some of these scale studies are contracted, and the sediment core research is contracted with the University of Alaska Fairbanks.

Reconstructing long-term growth patterns from scales is in process for sockeye, chum, and pink salmon. Marine and freshwater scale growth patterns are being reconstructed for sockeye salmon from the early 1900s to the present from Karluk Lake on Kodiak Island and in Bristol Bay from the Kvichak River. Estimating marine growth patterns from chum salmon scales is in process from the early 1970s to the present for populations from the Yukon River, Fish Creek, Chilkat and Klehini Rivers, Olsen Creek (Prince William Sound, Alaska), and Quilcene National Fish Hatchery. Estimating growth from pink salmon scales from the mid-1970s to the present is in process for Auke Creek (near Juneau, Alaska).

Time-series analyses of catch, escapement, and growth data are in process for sockeye salmon populations in Bristol Bay and for other major sockeye salmon stocks in Alaska and British Columbia.

Conclusion

Understanding carrying capacity for salmonids in the Pacific Ocean and the Bering Sea is an enormous task. We have no pretensions about being able to accomplish this goal quickly. However, since the mid-1970s, huge changes in abundance, size, and growth of Pacific salmon have occurred. When I started my career in fisheries science in the late 1950s and early 1960s, I never dreamed we would experience salmon catches again like those that occurred in the early part of this century, but in Alaska in the mid-1980s through the mid-1990s, we greatly exceeded those catches. And it appears that we are again in the midst of changes: catches in Alaska have declined from the peak in 1995, and the mean size of chum salmon has increased since 1995. Biologically, these past 20 years have been increasingly exciting times to study the dynamics of Pacific salmon populations. We have a unique opportunity to attempt to understand these changes in relation to the changing ocean conditions. Hopefully, we are expending enough research effort to obtain the answers we need to anticipate biological responses to future ocean climate changes.