hypothesize that increased food supply was more than offset by increased sockeye abundance, which resulted in greater competition and smaller body size in recent years.

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Influences of the 1997-1998 El Niño and 1999 La Niña on juvenile chinook salmon in the Gulf of the Farallones

R. Bruce MacFarlane, Steven Ralston, Chantell Royer, and Elizabeth C. Norton
NOAA Fisheries, Southwest Fisheries Science Center, Santa Cruz Laboratory, 110 Shaffer Road, Santa Cruz, CA 95060, U.S.A. E-mail: Bruce.MacFarlane@noaa.gov

El Niño, the warm phase of El Niño/Southern Oscillation (ENSO) events, has been shown to produce dramatic effects on marine communities. Alterations in physical oceanographic properties of the marine environment can be observed as far north as Alaska. Less is known of the influences of La Niña, the cool phase of ENSO events that follows an El Niño. During the 1982-83 El Niño, anomalous plankton distributions, altered fish community structure, and reduced fish catch occurred in coastal waters of southern California (Simpson, 1992). Along the central California coast, the 1992-93 El Niño corresponded to delayed phytoplankton blooms, changes in the abundance and distribution of invertebrates, improved recruitment of southern fish species, but recruitment failure in the northerly rockfish species (Lenarz *et al*. 1995). More recently, the largest decline in macrozooplankton abundance off central and southern California in the 50-year series of CalCOFI cruises was recorded during the 1997-98 El Niño (Lynn *et al*. 1998).

In addition to ecosystem impacts, changes in physiology and behavior of fishes, including salmon, have been noted during ENSO events. Poor growth and low condition, ascribed to low fat content, were found in adult rockfish off central California during 1992-93 (Lenarz *et al.* 1995). And in a study of widow (*Sebastes entomelas*) and yellowtail rockfish (*S. flavidus*) in coastal waters of central and northern California, Woodbury (1999) reported reduced otolith growth, a conservative measure of somatic growth history, during the 1982-83 El Niño. Reduced condition and growth of sockeye salmon (*Oncorhynchus nerka*) in the Gulf of Alaska during the 1997-98 El Niño event were related to feeding on zooplankton, prey of lower caloric content than squid, their primary food in 1998 following the El Niño (Kaeriyama *et al.* 2000). In a review of El Niño effects on fisheries, Mysak (1986) detailed other impacts to sockeye, including changes in migration patterns and the timing of returns to streams. Lower survival in juvenile coho salmon (*O. kisutch*) following ocean entry, great mortality in adult coho, and reduced size in both coho and chinook salmon (*O. tshawytscha*) were described off Oregon during the 1982-83 El Niño (Pearcy and Schoener 1987).

We report here the results of a study of juvenile chinook salmon in the Gulf of the Farallones, an embayment on the central California coast. The Gulf of the Farallones, a broad expanse of continental shelf extending from Pt. Reyes to Pillar Pt. out to the Farallon Islands, receives freshwater outflow through the Golden Gate from the Sacramento and San Joaquin Rivers and their tributaries in California's Central Valley. It is also the point of ocean entry for an estimated 50-60 million chinook salmon smolts spawned from four runs (fall, late fall, winter, spring) in streams and hatcheries in the Central Valley. The purpose of the information presented here is to document juvenile salmon development, and how it was influenced by the environment in the Gulf of the Farallones during the 1997-98 El Niño and 1999 La Niña.

Juvenile salmon were captured by surface trawl at locations in the Gulf of the Farallones in June to October of 1998 and 1999. El Niño was evident in the Gulf of the Farallones in August 1997 and persisted to August 1998 (Fig. 3). By late 1998, La Niña was apparent and continued into spring 2000. Plankton samples were taken by Tucker Trawl at 5 m and 15-25 m below the surface to estimate secondary productivity and zooplankton composition.

Relative growth for juveniles caught in 1998 and 1999 was estimated by microstructural analysis of otoliths. Growth rates and size-at-age of juvenile chinook salmon can be estimated by measuring daily otolith increment widths (Bradford and Geen 1987). We calculated mean otolith increment widths as an index for somatic growth between increments 160 and 260, representing the first 100 days after leaving the estuary. Juvenile salmon exited San Francisco Estuary at 160±1 days old in 1998 and at 168±3 days old in 1999. Growth rate indices for salmon caught in 1998, during the El Niño period, were significantly greater than for fish collected in 1999 ($P<0.0001$). Mean growth rates of otolith increments were 3.37±0.03 μm in fish sampled in 1998 and 3.02±0.03 μm in 1999 (Fig. 4).

Whole body concentrations of triacylglycerols (TAG), the primary metabolically-available form of stored energy in salmonids and other fishes, differed between the two years. Upon entering the Gulf of the Farallones, juvenile salmon had greater levels of TAG in 1999 than in 1998, 30.5±3.1 mg/g and 11.5±1.8 mg/g wet weight, respectively. However, lipid stores of salmon in the gulf were depleted to a greater extent in 1999. Juveniles collected from the gulf in 1999 had TAG levels of 4.4±1.4 mg/g, whereas those from 1998 were 7.9±1.0 mg/g. These data support previous research that found depleted TAG

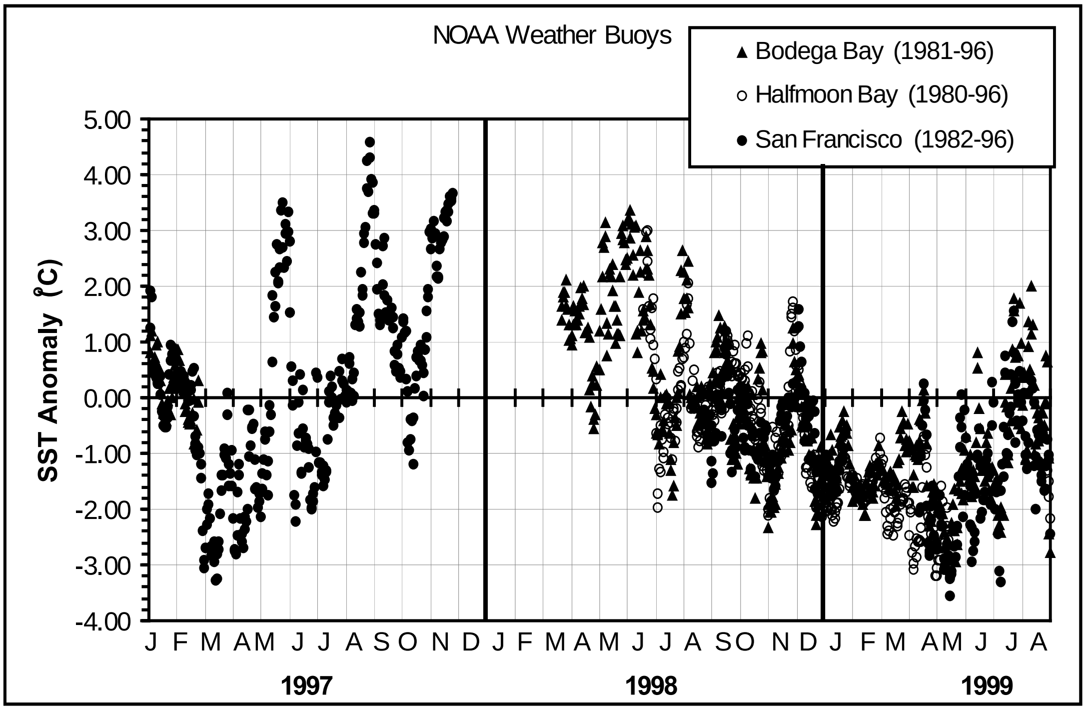

Fig. 3 Sea surface temperature anomalies from buoys at Bodega Bay, San Francisco, and Half Moon Bay. Anomalies were calculated from longer-term averages shown in parentheses in the legend. All three buoys were out of operation from December 1997 to mid-March 1998 when El Niño conditions were most evident.

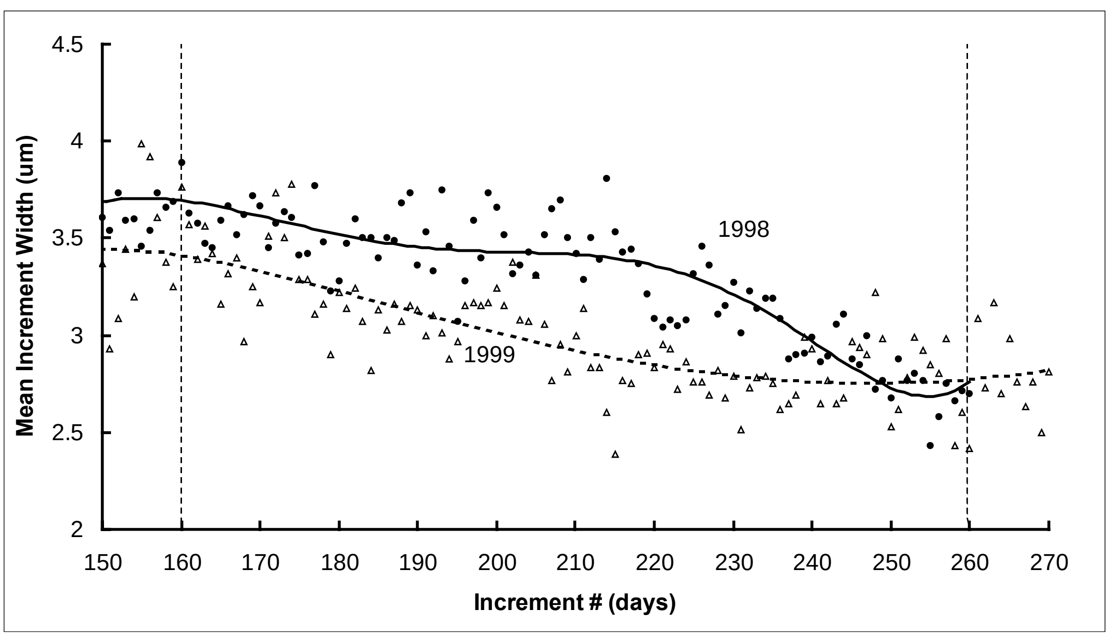

Fig. 4 Mean otolith increment widths for juvenile chinook salmon from the Gulf of the Farallones in 1998 (solid circles) and 1999 (open triangles). Lines represent least squares fit of daily mean increment widths; solid line - 1998, dashed line - 1999. Vertical dashed lines at 160 and 260 increments represent estimated first 100 days in the ocean after leaving the San Francisco Estuary.

concentrations in juvenile salmon after exiting the estuary (MacFarlane and Norton, 2002).

Juvenile salmon in the Gulf of the Farallones not only grew faster and maintained a greater TAG concentration during the 1998 El Niño period, their condition (Fulton's K-factor) was better as well. In 1998, mean K increased to 1.42±0.01 for gulf salmon from 1.03±0.01 at ocean entry, compared with a change from 1.04±0.01 at ocean entry to 1.32±0.01 in the gulf during 1999.

Although there were differences in growth, energy status, and condition between the two years, feeding data did not resolve the disparity. This is not unexpected because stomach contents reflect only recent feeding, whereas growth and lipid accumulation integrate metabolic processes over longer time scales. Stomach fullness was estimated to be 45.5% in juveniles sampled in 1998 and 56.7% in 1999. In both years, fish were the primary food item, comprising greater than 50% of the stomach contents volume. Decapod early life stages were of secondary importance, especially for salmon later in the season in August to October.

The marine environment in the Gulf of the Farallones differed between the two years. From May through August, mean sea surface temperatures were about 1.0°C warmer in 1998 and about 1.3°C cooler in 1999 than long-term averages (Fig. 3). The 1997-98 El Niño was characterized by heavy precipitation in California and this was evident in freshwater outflow from the Central Valley. Freshwater outflow into the gulf averaged 2,940 cubic meters per sec (m^3/s) from January to June 1998, whereas outflow in 1999 was much reduced during the dryer La Niña to 1,330 m^3/s.

The Gulf of the Farallones is buffered from large-scale oceanic influences because it is in the upwelling shadow of Pt. Reyes to the north, bounded by the Farallon Islands and associated marine banks on the west, and subjected to the effects of freshwater outflow from San Francisco Bay. Although El Niño typically produces enhanced poleward flow of the California Current, near-surface current data from an Acoustic Doppler Current Profiler in May and June 1998 did not reveal such a pattern. Currents in the gulf were forced by tidal circulation and persistent northwesterly winds, which also produced positive upwelling index anomalies throughout the summer and fall of 1998 (April - November mean monthly anomaly for 39°N 125°W: +44.5±25.6). As expected, strong northwesterly winds during the summer and fall of the 1999 La Niña event resulted in intense upwelling with a mean April to November monthly index anomaly of 104.6±35.1.

Biological productivity is highly variable in the Gulf of the Farallones region and modulated to varying degrees by upwelling, advection, wind-driven and tidal circulation, and freshwater outflow. Primary productivity, estimated by chlorophyll *a* concentrations in May and June, was similar between the two years, but the distribution of phytoplankton differed. In 1998, phytoplankton were distributed within the gulf on the continental shelf whereas during the 1999 La Niña they were primarily off the shelf, seaward of the gulf. Greater nutrient-rich freshwater influx coupled with higher temperatures in 1998 may have accounted for greater primary productivity within the gulf during the El Niño event. Greater phytoplankton biomass within the Gulf of the Farallones in 1998 was accompanied by greater secondary production. Mean zooplankton biomass in the near-surface waters was 0.30±0.12 ml/m^3 in May and September 1998. In contrast, zooplankton mean settled volume was 0.13±0.03 ml/m^3 in August and October 1999.

In summary, during the 1997-98 El Niño, juvenile salmon in the Gulf of the Farallones grew at a greater rate, maintained higher TAG reserves, and were in better condition than those during the 1999 La Niña. This profile may be attributed to somewhat higher biological productivity in the gulf in 1998, due to increased nutrient input from freshwater inflow, and the protection afforded by Pt. Reyes and the Farallon Islands, which buffered the embayment from the full impacts of oceanic processes. But, for all measures of salmon development the differences were not great. The data do support the contention, however, that the 1997-98 El Niño was not detrimental to juvenile chinook salmon development in this region during the early stage of the ocean phase of their life cycle.

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Variability of the pink salmon sizes in relation with abundance of Okhotsk Sea stocks

Olga S. Temnykh[1] and Sergey L. Marchenko[2]

[1] Pacific Research Fisheries Center (TINRO-center), 4, Shevchenko Alley, Vladivostok, Russia, 690600. E-mail: tinro@tinro.ru

[2] MoTINRO, Magadan, Russia. E-mail: tinro@online.magadam.su

Beginning in the mid-1970s there was an increase in abundance of all Pacific salmon species. It was shown that global climatic factors may have caused changes in salmon abundance in the North Pacific (Beamish and Bouillon 1993, Klyashtorin and Sidorenkov 1996, Radchenko and Rassadnikov 1997, Shuntov *et al*. 1997). The rise in abundance of Asian and American stocks of salmon was accompanied by a decrease in the average size of fish, by an increase in age at maturity (due to the growth rate reduction during marine period of their life cycle), and by a reduction of the fecundity of females (Ishida *et al*. 1993, Welch and Morris 1994; Bigler *at.al*. 1996). Nevertheless, there are some exceptions to the general trend of Pacific salmon productivity in relation to stock abundance. For example, a decrease in abundance was observed for the Japan/East Sea pink salmon stocks (especially for the Primorye stock) while the average size of the Primorye pink salmon decreased during the 1970-1980s (Temnykh 1998). At the same time, abundant pink salmon from Sakhalin maintained a large size (Nagasawa 1998).