

Why Are Pink and Chum Salmon at Such High Abundance Levels in the Gulf of Alaska?

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Historically pink and chum salmon likely have always been the most abundant salmon species in the Gulf of Alaska (GOA). Factors accounting for this include biology requiring less extensive freshwater life history that affords opportunities for producing large numbers of juveniles. Most GOA pink and chum salmon originate from many regions throughout Alaska and British Columbia. Not all, however, originate from North America. Some East Kamchatka pink salmon (Royce et al. 1968) and Japanese chum salmon (Urawa et al. 2009) occur in western parts of the GOA.

Abundance levels of pink and chum salmon in the GOA have fluctuated greatly over the past 110 years. We used long-term Alaska harvest data (1900-2010) as a run-strength proxy to examine changes in periods of abundance. Relatively high levels from around 1910 through 1940 occurred when pink and chum salmon harvests collectively were in excess of 70 million fish. Annual harvest during the following three decades, 1950-1970, fell below 25 million throughout Alaska. However, subsequent to this low abundance period, harvest levels rebounded strongly and have reached record levels of 160 million fish in some years (Fig. 1).

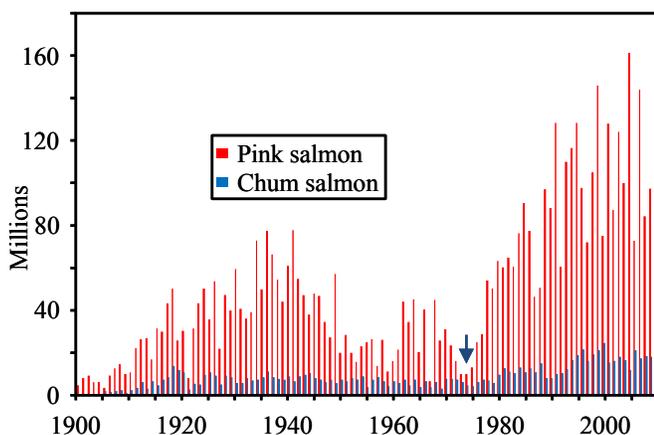


Fig. 1. Commercial harvest of Alaska pink and chum salmon, 1900-2010. Arrow denotes low point in harvest, start of modern hatcheries in Alaska, and 1976-1977 PDO regime shift.

The primary purpose of this report is to explore some of the potential causes of this recent prolonged period of high abundance and to examine some basin-, regional-, and local-scale influences on marine survival.

Two important 1970s events have played significant roles in recent high GOA pink and chum salmon abundances. First was the major 1976-1977 regime shift, characterized by a general sea surface temperature (SST) warming trend reflected in the Pacific Decadal Oscillation (PDO; Mantua et al. 1997). Increased marine survival rates and higher abundance levels of many pink and chum salmon stocks in the GOA followed this basin-scale event. While there have been other minor regime shifts since then, none have yet reversed the current overall trend of high abundance levels in the GOA.

The second major event was developments, beginning in the 1970s in Alaska, allowing private non-profit (PNP) hatcheries, including those operated by regional aquaculture associations, to produce salmon for benefit of common property fisheries (McGee 2004). These programs now support 31 hatcheries that released 1.6 billion juvenile salmon into GOA waters in 2010. Of the total number released, pink and chum salmon releases represent 55% and 39%, respectively (White 2011). Alaska PNP statutes allow operators to harvest some returning hatchery fish in designated areas to help pay for operations, which is similar to procedures in prefectural cooperative hatcheries in Japan (Heard 2011). There is no doubt that hatcheries, in Alaska and elsewhere, have significant impacts on GOA salmon abundance. Eggers (2009) concluded that hatcheries, since the mid-1990s, constitute at least 37% of the total salmon biomass in the North Pacific Ocean.

We examined long-term commercial harvest patterns and effects of hatcheries beginning in 1979 on pink and chum salmon harvests in three regions in Alaska: Southeast (SEAK), Prince William Sound (PWS), and Kodiak (KOD). The SEAK pink salmon showed a distinctive high-low-high cyclic harvest pattern with minimal influence from hatcheries (Fig. 2a); PWS pink salmon had a moderate level of pre-hatchery fluctuations followed by dramatic increases in harvest due to hatcheries since the mid-1990s (Fig. 2b); and KOD pink salmon had a pattern intermediate of the other

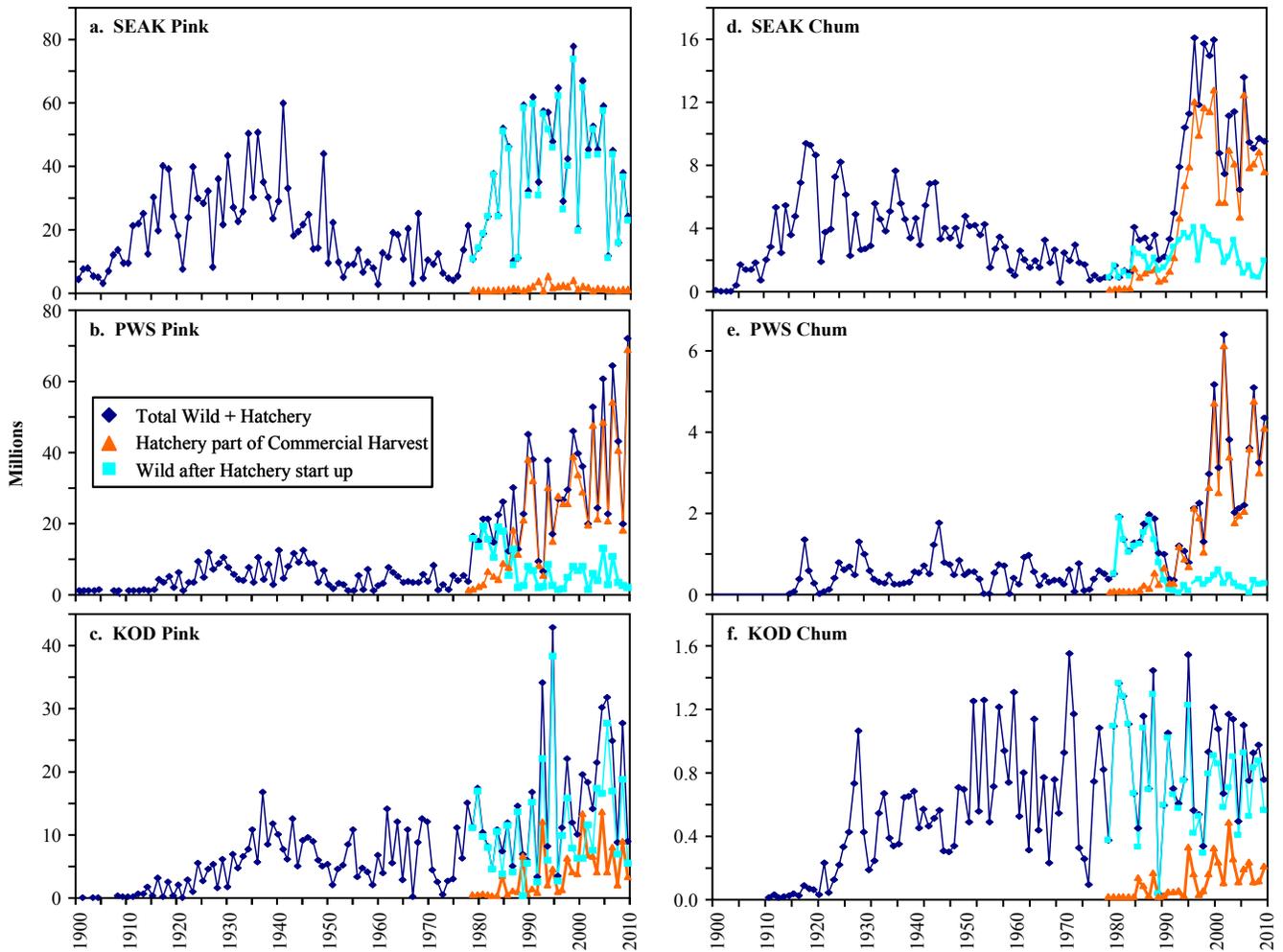


Fig. 2. Commercial pink (a-c) and chum (d-f) salmon harvest in Southeast Alaska (SEAK), Prince William Sound (PWS), and Kodiak (KOD), Alaska, 1900-2010, including hatchery contributions beginning in 1979. Note: Scale of Y-axes vary.

two regions (Fig. 2c). The SEAK chum salmon had long pre-hatchery declining harvest trends followed by a strong rebound due to hatchery production after 1990 (Fig. 2d); PWS chum salmon had moderate pre-hatchery fluctuations, then significant increases following the start of hatchery production (Fig. 2e); and KOD chum salmon had wide pre-hatchery fluctuations, then moderate hatchery increases in recent years (Fig. 2f).

We examined variations in hatchery survival patterns of pink and chum salmon released at different locations. For pink salmon, coefficients of pair-wise correlations dropped off quickly with increased distance between release sites. Most correlations between sites located within 105 km were ~0.5-0.6, while those located > 150 km were < 0.25. Highly correlated sites were all within PWS, but even within this region there was a wide range in co-variation among sites. There was little correlation between PWS, KOD, and SEAK release sites and low but negative correlation between SEAK and KOD release sites (Fig. 3).

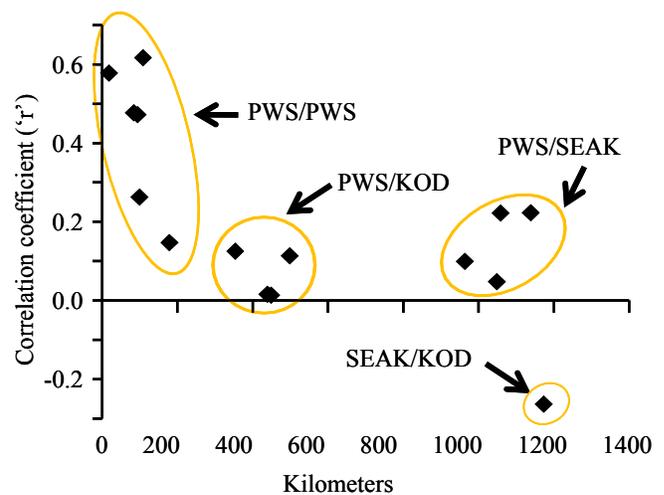


Fig. 3. Correlation coefficients relating survival of Alaska hatchery pink salmon releases from different locations and distances between release sites. PWS=Prince William Sound, KOD=Kodiak, and SEAK=Southeast Alaska.

For chum salmon, there was considerable variability in pair-wise correlations between release sites located relatively close in the same region: within 120 km, correlations ranged from 0.2-0.9 (Fig. 4). There was also a clear decreasing correlation with distance. The percentage of pair-wise correlation coefficients with $r > 0.5$ was 67% for release sites within 120 km, 31% for sites located 120-500 km apart, and only 3% for sites located > 500 km apart.

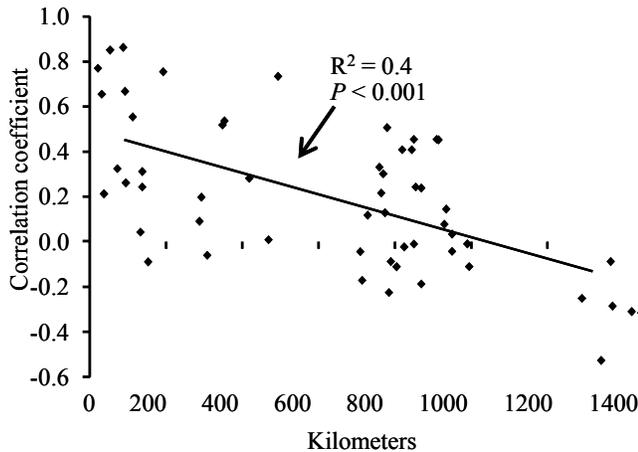


Fig. 4. Correlation coefficients relating survival of Alaska hatchery summer chum salmon releases and distances between release sites.

Differences in chum salmon survival trends by release site, even within 100 km, can be large. The PNP programs near Juneau release chum salmon reared from a common brood using similar rearing and release strategies at four release sites: Limestone, Gastineau, Amalga, and Boat Harbor. Survival rates from three sites (shown in blue) have correlation coefficients from 0.7-0.8, and the Limestone site (shown in red) has coefficients of only 0.2-0.3 with the other sites (Fig. 5). Marine survival rates at the Limestone site are also significantly less and average one-half to one-third the rate of the other sites, even though it is located within 40-100 km of the others.

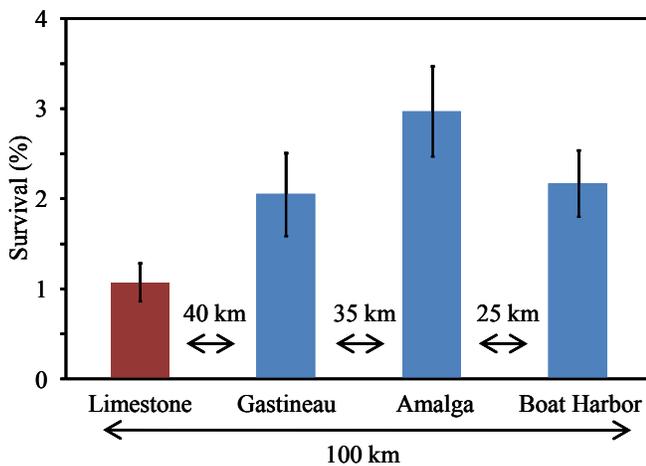


Fig. 5. Average survival rates (%) of summer chum salmon released at four private non-profit (PNP) hatchery sites located within 100 km of each other.

These findings illustrate how local effects can have large-scale impacts on trends and magnitude of survival are consistent with other studies on temporal variations in salmon survival (Pyper et al. 2001; Mueter et al. 2005; Farley 2010). However, temporal variations in marine survival rates and high or low correlation coefficients among different local or regional areas do not negate larger basin-scale climatic influences on overall production levels of pink and chum salmon in the GOA. Prevailing basin-scale conditions likely determine relative environmental factors that favor a higher or lower range or level of potential survival for juvenile salmon from different regions. Regarding long-standing continued influence of the 1976-1977 regime shift on salmon production in GOA, Minobe (1997) suggested major basin-scale climatic oscillations over the North Pacific Ocean could last 50 years or longer.

Recent 1999-2004 studies on PWS hatchery pink salmon by Armstrong et al. (2005, 2008), Cross et al. (2008, 2009), and Bond (2011) found high and low survival between brood lines associated with juvenile diets. They found high survival with pteropod-dominated diets and higher gut fullness and low survival with copepod-dominated diets and lower gut fullness. Even-odd year cycles from 2002 to 2007 illustrate an almost perfect parallel synchronous marine survival and adult return pattern between brood lines (Fig. 6). Within this time period, there were three even-numbered years of 3% survival and 30 million fish returning to PWS, versus three odd-numbered years of 8-9% survival and 50 million fish returning. Release timing, release numbers, and sizes of hatchery releases were similar in all six years. Could this biennial pattern be caused by something as simple as pteropods versus copepods in diets, and if so, what drives the biennial variability in pteropod abundance?

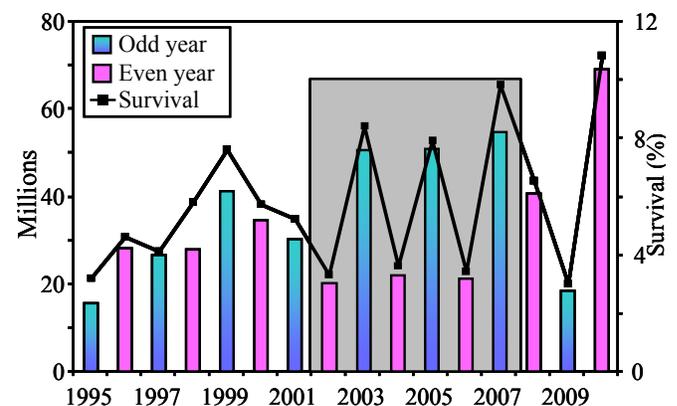


Fig. 6. Prince William Sound (PWS) pink salmon hatchery survival rates, 1995-2010, and a six-year period of low-high synchrony between even- and odd-year brood lines presumably due to diets.

In summary, we conclude a favorable ocean environment following the 1976-1977 regime shift and SST warming trend has contributed to increased productivity of both wild stocks and large-scale hatchery releases of pink and chum salmon in the GOA. Improved management of wild stocks, cessation

of high-seas interceptions through INPFC and NPAFC efforts, and improved fish-culture technologies have also helped produce historically high harvest levels throughout GOA regions.

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