the consumption of squid, small fishes, and euphausiids varies with region (Davis et al. 2009, Qin & Kaeriyama 2016). Collectively, this evidence suggests that pink salmon may directly and indirectly affect Chinook salmon growth and survival by consuming the same prey and by altering the food web that supports small fishes, squid, and zooplankton consumed by Chinook salmon.

Chinook salmon harvests, abundances, and average body sizes in northern regions where freshwater habitat is mostly intact have been declining for several decades (Bigler et al. 1996, Lewis et al. 2015, Ohlberger et al. 2018, Welch et al. 2021), and several studies have suggested Chinook survival and growth may be inversely related to pink salmon abundance at sea (e.g. Cunningham et al. 2018, Oke et al. 2020). We examined the time series of annual Chinook salmon commercial harvests in Alaska and BC from 1952 to 2021. Commercial harvests reflect fishing effort, based on abundance predictions and fishery regulations (PSC 2022), and can provide a first-order approximation of abundance, although they can also be confounded by changes in fishery regulations and effort over time. Consistent with the hypothesis that pink salmon affect Chinook salmon, we found that harvest trends during the 70 yr period were opposite those of pink salmon abundance trends (Fig. 10a).

Body size of adult Chinook salmon in Alaska also declined with increasing abundance of pink salmon since 1952. Average weight of commercially caught Chinook salmon was relatively stable over time when abundance of pink salmon was low during 1952 to 1975 (Fig. 10b). Immediately after the 1977 ocean regime shift, body size of Chinook salmon reached its maximum (9.3 kg) and then declined steadily over time as pink salmon abundance increased (Fig. 10b). Chinook salmon body size reached the long-term minimum during 2015–2021 (avg. 5.7 kg) when pink salmon abundance was peaking (564 million yr^{-1}) and when marine heat waves became more frequent (Ross et al. 2021). We note, however, that these trends in size and commercial harvest can be confounded with other long-term trends in oceanographic and freshwater processes, and so should be interpreted with caution. Also, the Japanese salmon fishery on the high seas removed, on average, 334 000 Chinook salmon per year from 1955 to 1980, then harvests declined steadily until its termination in 1991 (NPAFC 2022a). Most of the Chinook salmon had originated from western and central Alaska (Rogers et al. 1984; Text S1), suggesting that Chinook salmon harvests in Alaska would have been even higher during the period when pink salmon abundance was low. Other factors contributing to long-term declines in catch and size of North American Chinook salmon have been hypothesized, including size-selective predation by resident killer whales (Ohlberger et al. 2018, 2019; Text S1).

Lewis et al. (2015) demonstrated a consistent decline in Alaskan Chinook salmon length-at-age and age-at-maturation over a 30 yr period while noting the potential influence of competition for prey with other salmon species. Our analyses of these data

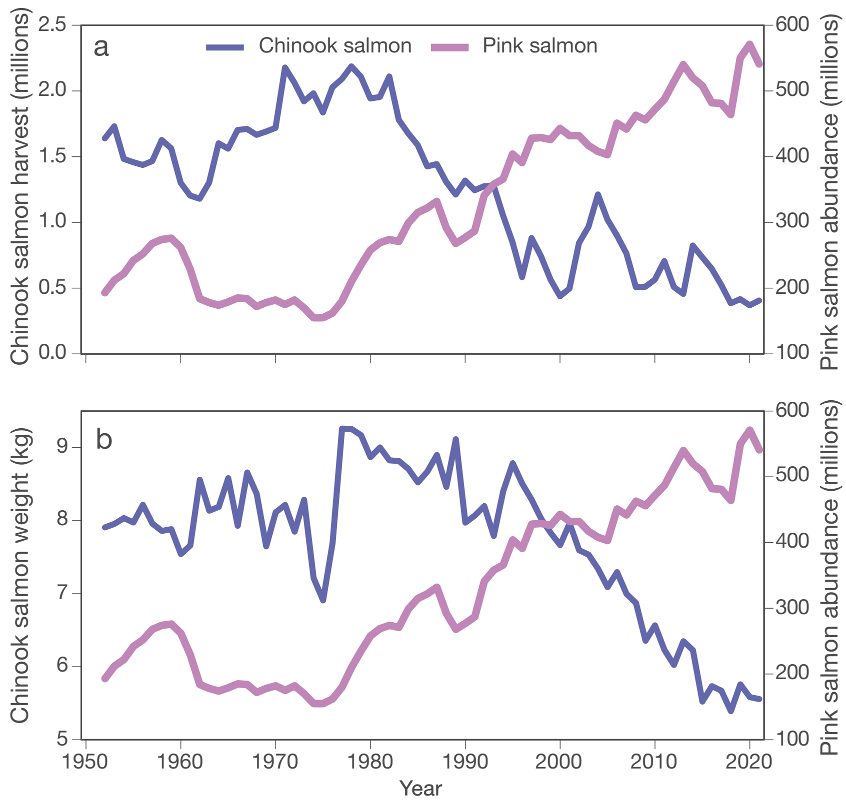

Fig. 10. Time series of (a) Chinook salmon commercial harvests in Alaska and British Columbia, and (b) average weight of Chinook salmon in Alaskan harvests in relation to average pink salmon abundance returning from the North Pacific Ocean 1 to 4 yr prior to the Chinook salmon harvest during 1952–2021 (e.g. harvest in year 2000 was related to average pink salmon abundance during 1996–1999, corresponding to the period of species overlap and potential direct and indirect effects of pink salmon). Data sources: Ruggerone et al. (2010, 2021), Ruggerone & Irvine (2018), NPAFC (2022a)