Size Decreases in Adult Chum Salmon

Long-term studies of age and growth of chum salmon (*Oncoryhynchus keta*) conducted by members of the Auke Bay Laboratory (ABL) over the past 20 years show significant declines, particularly during the last decade, in the size of returning adult chum salmon. Long-term observations of size-at-maturity of salmon can be considered indicators of the ocean environment, reflecting the physical and biological characteristics of the sea experienced by the species over time. In addition, density-dependent factors such as competition for food by the same species or competing species can also be thought to influence size-at-maturity.

ABL scientists initiated age and growth studies on chum salmon in 1972-73 with the objective of observing over time the influence of the marine environment on size-at-maturity of two distinct chum salmon populations. The studies were designed to focus on two populations that were separated geographically and that had very different spawning times in order to eliminate potential sources of unquantifiable variability in size and age due to stock differences of sampling catches of mixed-stock fisheries. One population was from Fish Creek, Alaska, a tributary of the Salmon River which enters the ocean at the head of Portland Canal near Hyder, Alaska. Chum salmon from this stream are wild and are known for their large size (Fig. 1), some weighing as much as 38 lb. The second population was from the Quilcence National Fish Hatchery (U.S. Fish and Wildlife Service) located on Hood Canal near Quilcene, Washington (Fig. 2), where chum salmon have been artificially propagated for more than 80 years. Length, weight, and scale samples were taken from spawned carcasses at Fish Creek (1972-92) and from fish sacrificed for gametes at Quilcene National Fish Hatchery (1973-92) each year at approximately the peak of the spawning migration—mid-August at Fish Creek and mid-December at Quilcene National Fish Hatchery. Except for 1 year at Quilcene Hatchery, all fish were measured by one person (the senior author) to assure continuity in data. Likewise, the same person aged all the scales.

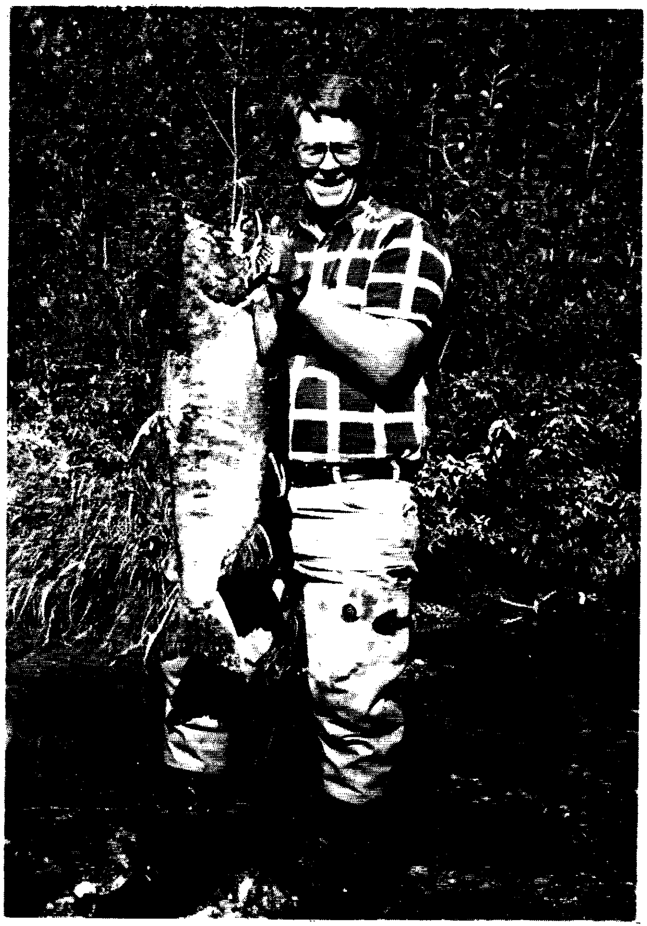

Figure 1. The senior author with a large male chum salmon from Fish Creek, Alaska, where chum salmon are known for their large size, some weighing as much as 38 pounds.

Changes in Size

Trend lines calculated for age-3, age-4, and age-5 chum salmon at Fish Creek clearly show that the mean lengths of both males and females have been decreasing over time (Fig. 3). In 1976 for example, the mean size of age-3, -4, and -5 males at Fish Creek measured 594, 651, 690 mm, respectively, compared to

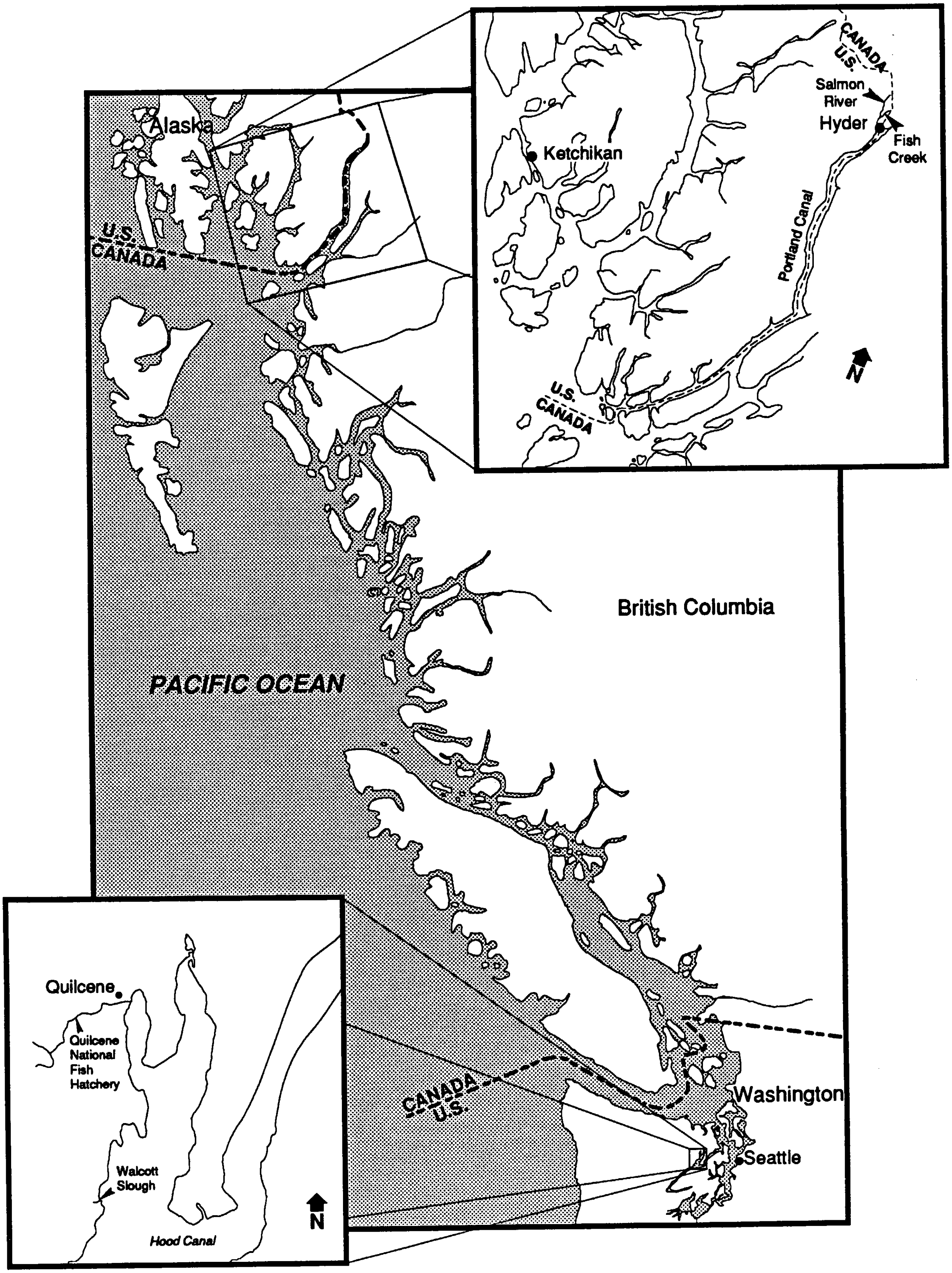

Figure 2. Location of Fish Creek near Hyder, Alaska, and Quilcene National Fish Hatchery near Quilcene, Washington.

511, 573, 602 mm in 1991. The mean lengths of age-3 and age-4 males and females at Quilcene National Fish Hatchery also show a clear trend of decreasing size (Fig. 4). In 1976, the mean size of age-3 and age-4 males at Quilcene National Fish Hatchery measured 570 and 631 mm compared with 476 and 546 mm in 1991. Age-5 chums were not abundant until recent years at Quilcene National Fish Hatchery.

The most abundant age group through the years at both Fish Creek and Quilcene usually has been age 4 for both males and females. The mean length of male and female age-4 fish plotted with the 95% confidence interval for each mean is shown for Fish Creek in Figure 5, and for Quilcene National Fish Hatchery in Figure 6. The calculated trend lines show again that the mean size is decreasing, especially in recent years. At Fish Creek, it is especially apparent that fish in the 1970s were larger than fish in the mid-1980s through 1992. The confidence intervals of the means show the significance of the decrease in mean size.

Weights for age-4 male chum salmon from Fish Creek were measured from spawned-out carcasses and weights for Quilcene age-4 males were measured from fresh-killed mature fish, so they are not directly comparable. Nevertheless, the carcass weight difference between age-4 male chum salmon spawners at Fish Creek in 1976 and 1991 was about 2 kg. Similarly, the weight difference between age-4 male chum salmon spawners at Quilcene in 1976 and 1991 was also about 2 kg.

Fish Creek is about 1,100 km north of Quilcene National Fish Hatchery. Chum salmon at Fish Creek are wild. Quilcene Hatchery chum are artificially propagated, and until recent years, the fry were released, and adults were recovered at Walcott Slough near Brinnon. The similar trends in declining size-at-maturity shown by the two distant stocks suggest that the declines are the result of a common cause in the marine environment and are not the result of fish culture practices or stock differences due to geographic distance.

Recent reports from the Japan Fisheries Agency and Hokkaido Salmon Hatchery that describe declining size-at-maturity of Asian stocks of chum salmon provide evidence that some factor or factors in the marine environment are causing similar size changes in both Asian and North American stocks of chum salmon. Decreases in size may be due to population density-dependent factors in the ocean. Very large releases of chum salmon (and other species of salmon) have been made in the last two decades from artificial propagation facilities in Japan, Russia, and North America. Japan alone has released more than 1.5 billion chum salmon juveniles from hatcheries each year since

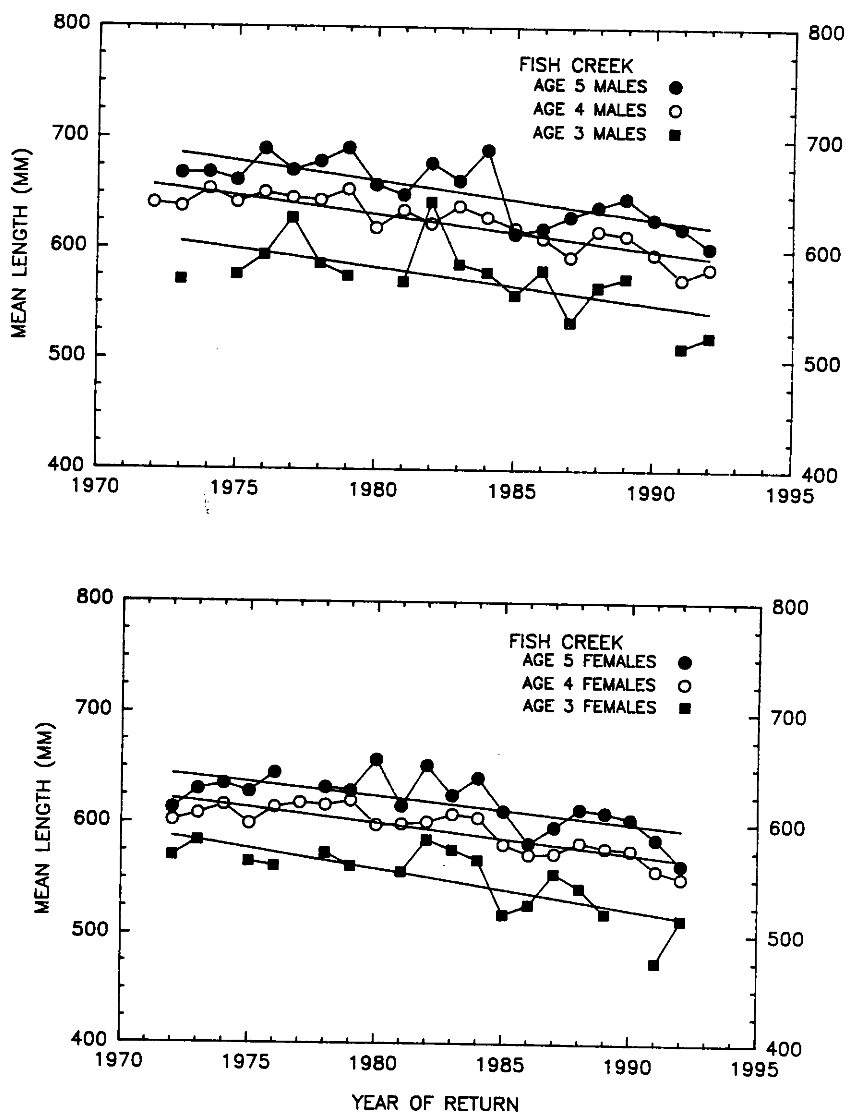

Figure 3. Mean length of age-3, -4, and -5 male and female chum salmon spawners at Fish Creek, 1972-92.

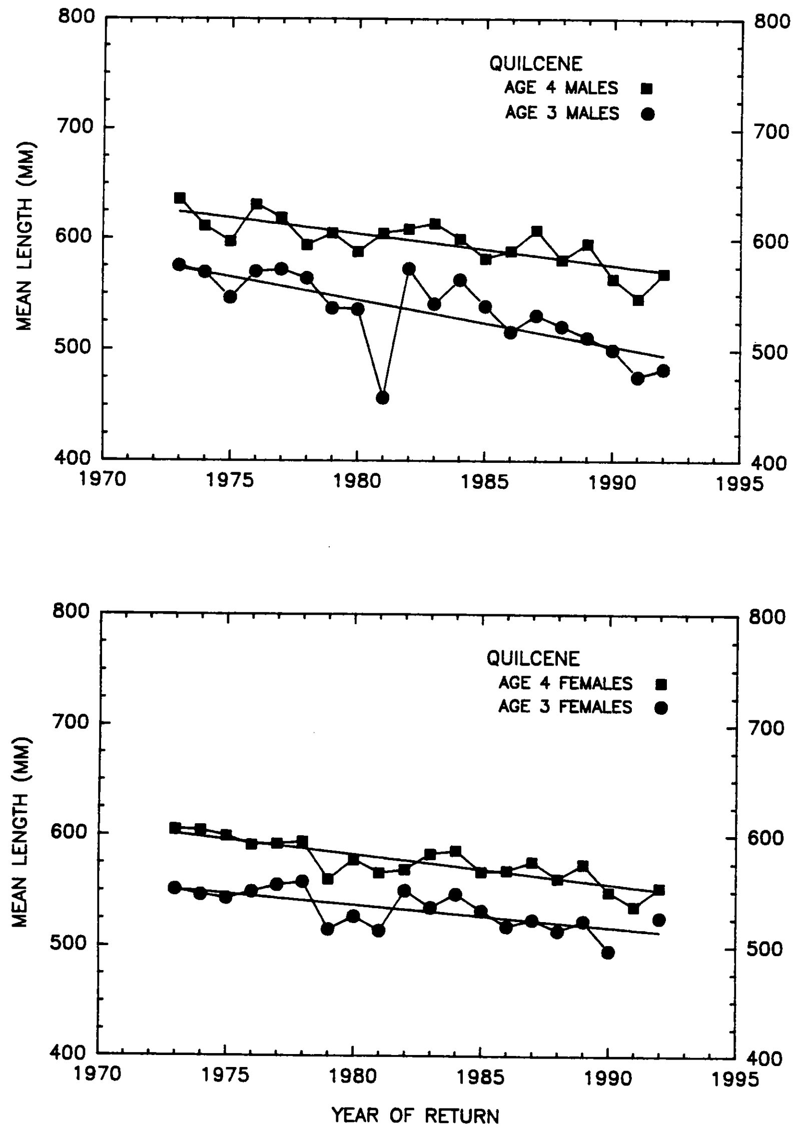

Figure 4. Mean length of age-3 and -4 male and female chum salmon spawners at Quilcene National Fish Hatchery, 1973-92.

1976. Presently a total of about 5 billion juvenile Pacific salmon are released each year from hatcheries in Asia and North America. The decline in size-at-maturity of chum salmon from Fish Creek and Quilcene National Fish Hatchery does coincide with the dramatic increase in catch which is predominantly of Japanese hatchery origin (Fig 7).

There is convincing evidence for density-dependent factors being responsible for decreases in size and increases in age-at-maturity of chum salmon and other species of Pacific salmon; however, changes in climate and oceanographic conditions also should be considered. Climate and oceanographic changes in the North Pacific Ocean since the early 1970s are well documented, especially the anomalously cold winters of 1971-75, followed by the coastal warming of the northeast Pacific Ocean during 1976-83. Many populations of salmon, especially in Alaska, experienced low survival rates during these very cold winters. However, the coastal warming conditions were highly favorable for survival of salmon at sea, particulary in Alaska, and enormous numbers of salmon were harvested in the 1980s in the North Pacific Ocean. Catches of sockeye salmon in Bristol Bay, Alaska, and of pink salmon in southern Southeast Alaska exceeded the previous record catches of the 1930s when Alaska salmon were in the early stages of commercial exploitation. Mean catches of pink and sockeye salmon in southern Southeast Alaska for the 1980s equaled record catches of these species for the 1930s and exceeded mean catches for these species during the 1920s and 1940s. The mean catch of chum salmon in southern Southeast Alaska in the 1980s also was greater than the mean catches of the 1960s and 1970s, although not greater than the mean catches for the decades from 1920 to 1950. (The reason for the lower recovery of chum salmon catches may be that this species is caught incidentally in fisheries for the more abundant pink and sockeye salmon. Management for optimal escapements is more attainable in pink and sockeye salmon fisheries.)

The range of North American and Asian chum salmon in the ocean overlaps considerably. Competition for food resources by chum salmon is mainly intraspecific because chum salmon utilize food items such as ctenophores, medusae, and salps, which are consumed rarely by other species of salmon. Both environmental conditions and density-

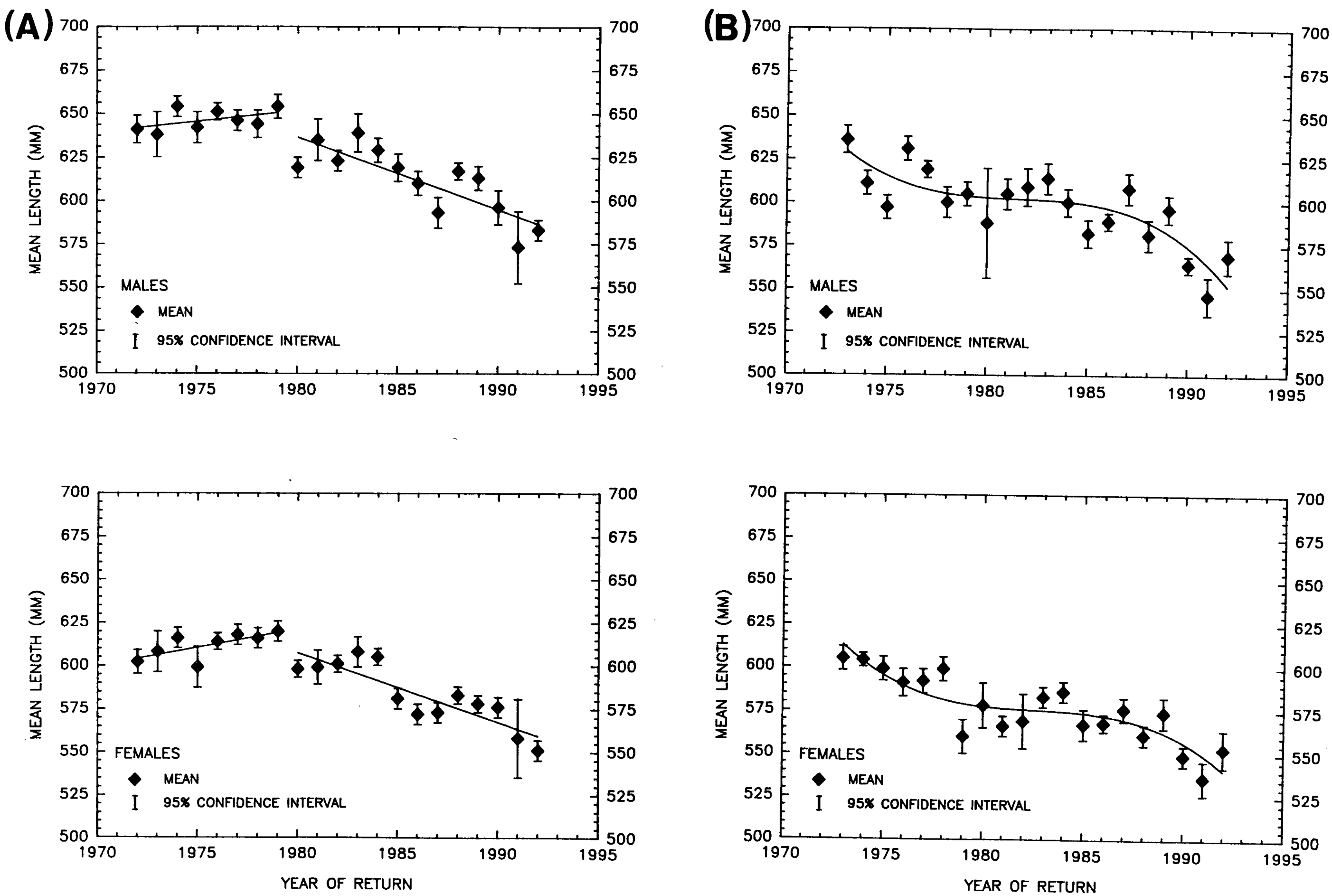

Figure 5. Mean length and 95% confidence interval of age-4 male and female chum salmon spawners at Fish Creek 1972-92 (A) and at Quilcene National Fish Hatchery, 1973-92 (B).

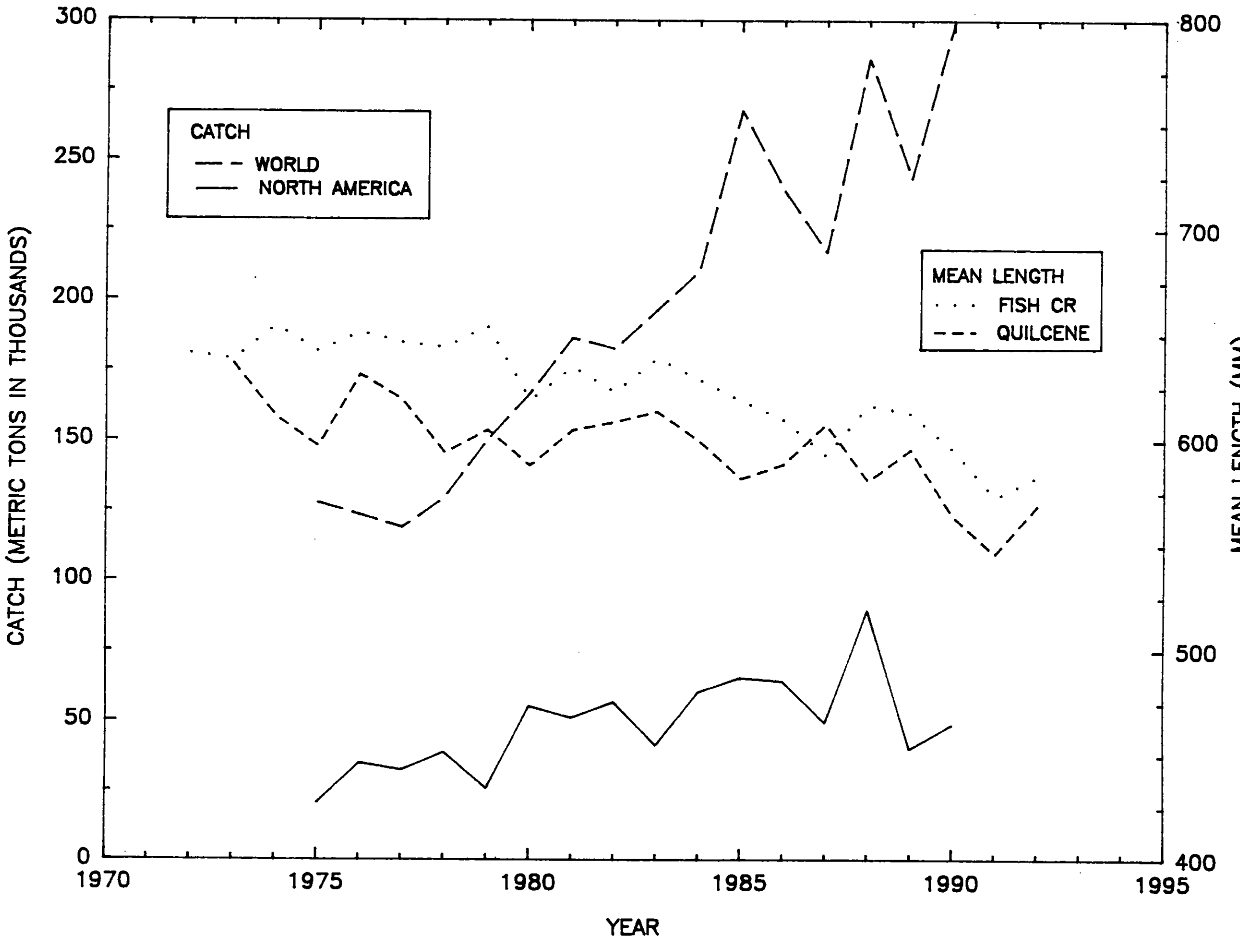

Figure 7. Weight of world (North American and Asian combined) and North American catch of chum salmon, and mean length of age-4 chum salmon spawners from Fish Creek and Quilcene National Fish Hatchery.

dependent factors could affect chum salmon stocks from North America and Asia in a similar manner when they are present in the same areas.

The preliminary results of the ABL's age and growth studies, along with studies on Asian chum salmon, suggest that the recent world population levels of chum salmon may have approached the upper limits of the ocean's present carrying capacity for that species. There are strong arguments for either environmental change, density-dependence, or both being responsible for the decline in size-at-maturity of chum salmon. Regardless, the trend for smaller size-at-maturity of chum salmon on both sides of the Pacific Ocean could be a harbinger of a major change in the abundance of chum salmon. It has been reported for a wild stock of chum salmon in Prince William Sound, Alaska, that survival to maturity is strongly related to mean size- (length) at-maturity of parents. If this relationship applies in general to most chum salmon stocks and the mean size-at-maturity does not start to significantly increase in the next few years, survival rates of chum salmon should start to decline.

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