Alaska Salmon Enhancement: A Successful Program for Hatchery and Wild Stocks

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Abstract

Alaska salmon have been the focus of major commercial harvesting since the latter part of the 1800s. Cyclic fluctuations of salmon abundance in various regions of the state, sometimes synchronous statewide, cause periods of high or low run strength associated with variable harvest levels. Poor harvest from weak wild stocks can result in socio-economic disruptions throughout the state. Modern salmon hatcheries in Alaska were developed in response to record low wild-stock runs in the 1960s and 1970s and now provide important complements to fisheries dependent on these resources. Initially conceived as state-run systems, most Alaskan hatcheries are now run by private sector corporations, primarily regional aquaculture associations comprised of fishermen and other stakeholders. Alaska now has 33 production hatcheries in a balanced program designed to enhance fisheries while maintaining healthy wild stocks. Some hatcheries release over 100 million juvenile salmon annually. Statewide totals are 1.2 to 1.4 billion annually over the last decade. Following a major turnaround from record low runs two decades earlier, commercial harvest of Alaska salmon in the 1990s have been at or near record high levels, although wild stocks in some areas, especially western Alaska, are at depressed levels. During the past decade hatcheries have produced 27-63 million adults annually, accounting for 14-37% of common-property statewide commercial harvest. This successful hatchery program, however, involves some controversy and some scientists have challenged its effectiveness. As Alaskan salmon enhancement has matured 13 hatcheries have been closed for various reasons. This salmon enhancement program has focused on protecting wild stock fitness and other unique stock characteristics through strict regulation by geneticists, pathologists, and managers for siting and capacity of hatcheries. The use of hatchery brood stocks has been restricted and controlled by policy and regulation. New mass-marking technologies have enabled harvest managers to better protect wild stocks in mixed-stock fisheries. A cornerstone of Alaska's successful salmon program has been the application of escapement-based, adaptive management for wild stocks and judicious use of technologies appropriate for enhancement. Salmon enhancement in Alaska is designed to supplement common property fisheries, not to supplement wild spawning populations or to rebuild depressed wild stocks with hatchery-origin fish. In spite of generally healthy wild stocks with important contributions from hatcheries, the economics of Alaska's commercial salmon industry, based on common property capture fisheries, is clouded by competition from continuing increases in worldwide production of farmed salmon. As global production annually, approaches 2 million tons farmed production now surpasses all capture fisheries for salmon.

Salmon runs in Alaska may be characterized by cyclic periods of high and low abundance that may last for decades. These cycles are varied and generally not well understood. The dramatic shift in numbers of returning fish, once thought to be primarily caused by harvest levels, spawning escapements, and various survival factors in freshwater habitats, are now known to be affected by cyclic, climatic and environmental fluctuations during the marine life history of salmon (Francis and Hare, 1994; Mantua *et al.*,1997).

Alaska commercial salmon fisheries have a colorful history spanning a 120-year period (Byerly *et al.*, 1999). After reaching record high harvest levels of over 100 million salmon caught annually during the 1940's, a long decline began to reduce annual catch levels to 50 million by the 1960s. This was shortly after Alaska had attained statehood and some felt a long period of pre-statehood federal mismanagement, highlighted by the widespread use of fish traps, was responsible for the decline. Runs began to recover briefly under management by the new State of Alaska only to take a new downturn that resulted in only 22 million salmon caught commercially in 1973 (Fig. 1).

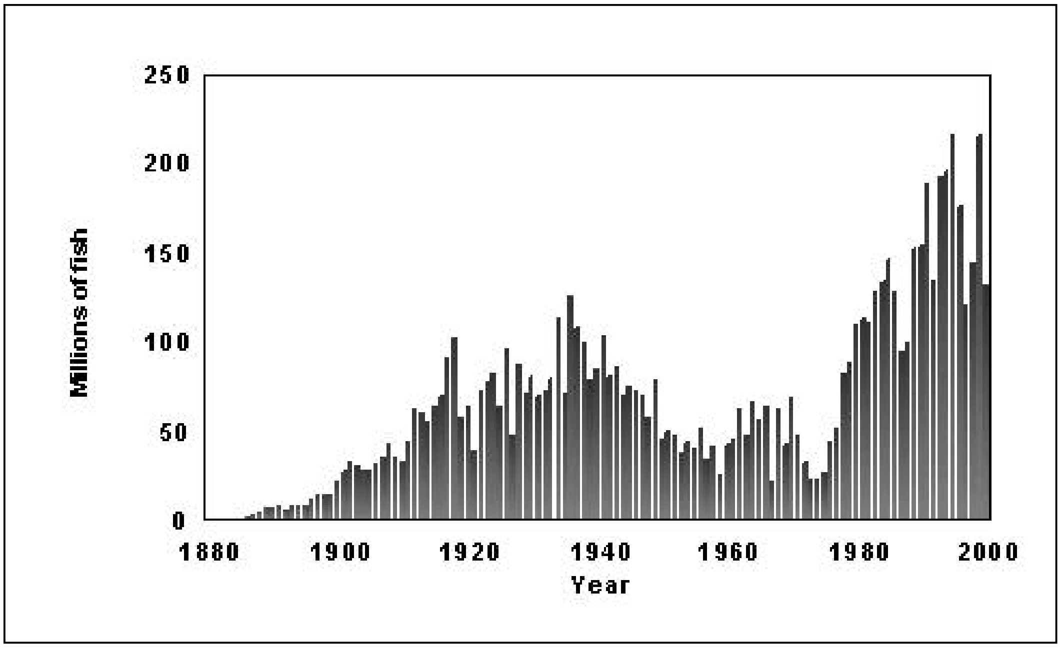

Figure 1. Commercial salmon catches in Alaska, 1880s-2000.

In response to these low returns, the Alaska State Legislature in 1971 created a new division within the Alaska Department of Fish and Game (ADF&G) to develop a coordinated salmon enhancement program. This was soon followed by legislation authorizing the concept of private non-profit hatcheries and the formation of regional aquaculture associations. Primary responsibilities and goals of this new legislation were to: [AS 16.05.092] (1) develop a comprehensive, coordinated state plan for the orderly rehabilitation, enhancement, and development of the state's fisheries; (2) encourage investment by private enterprise in technological development and economic utilization of fisheries resources; and (3) encourage, sponsor, and conduct research on the basic problems limiting sound development of hatcheries.

Over the next several years, as the new focus on salmon enhancement was implemented, a dramatic turnaround occurred in overall abundance and run strength of Alaska's wild stocks. This improvement in wild stocks, strongly influenced by better ocean conditions due to climatic regime shifts (Hare and Mantua, 2000), was concomitant with favorable performance levels of most new hatcheries as they came on line. By the 1990s commercial salmon harvests were at or near record levels in many regions of the state. On a statewide basis commercial harvests since 1980 have exceeded 100 million salmon every year except in 1987. Record harvests of 217 million and 216 million salmon occurred in 1995 and 1999, respectively (Fig. 1). As wild stocks produced impressive catches during the 1990s, hatcheries also produced 27-63 million adults annually, accounting for 14-37% of statewide common-property harvest (McNair, 1999, 2001).

In this document I review elements of current Alaska salmon hatchery programs with a focus on the development of policies guiding their operation and performance. I also discuss the general status of wild stocks, fisheries, economics, and controversies in different regions of the state.

Policies and Procedures

Development of a modern hatchery program in Alaska was based on a different set of circumstances than that of other hatchery programs. First, while fisheries on wild stocks were at historic low levels in the 1970s, spawning populations were still relatively healthy. Second, spawning and rearing habitats essentially were still in pristine conditions with no dams on major anadromous rivers or lakes and with minimal habitat loss from urbanization or industrial developments. Third, there was a growing awareness of concerns over performance and effectiveness of hatcheries and the potential adverse interactions between cultured and wild salmon stocks in hatchery programs in other areas.

These conditions provided a framework for implementing more conservative approaches to avoid past mistakes in other hatchery programs. Paramount among guidelines in developing policies for Alaska's program was a strong bias favoring wild stocks in situations with potential for adverse hatchery-wild stock interaction. Because natural spawning populations of salmon throughout the state were relatively healthy (although at low levels) with an unspoiled habitat base, the emerging hatchery system at the outset was designed not to supplement or rebuild wild stocks, but to supplement and enhance fisheries. This is a different policy foundation compared with other Pacific Rim salmon hatcheries that were developed as mitigation for losses of salmon production due to dams, overfishing, industrial and urban development, or other forms of habitat deterioration.

Scientists and professionals from ADF&G and other agencies developed special policies for genetics, fish health, pathology, limnology and fish culture procedures for the new hatcheries. Some of these policies were codified into state law. The genetics policy prohibited both interstate transports of live salmonids (including gametes) into Alaska and interregional transport of salmonids within the state (Davis *et al.*, 1985; Davis and Burkett, 1989). Engineering requirements and especially the siting of hatcheries were also carefully considered. Most Alaska hatcheries are located at or near tidewater and are often built on non-anadromous water sources below barrier waterfalls so that freshwater interactions between wild and hatchery salmon are eliminated. Hatcheries in Alaska also made ready use of new fish culture practices and technologies, such as high-density substrate incubation systems, marine net-pens for short-term rearing of pink and chum salmon fry, floating raceways, and barriered lake systems for natural rearing of anadromous juveniles (Heard, 1998).

Regional Aquaculture Associations

Perhaps the most distinctive feature of modern Alaska hatcheries is that most are managed and operated by private sector associations of fishermen, both commercial and recreational, conservationists, and local civic interests. Developed under state Private Non-Profit (PNP) statutes, these resource stakeholders and associations are allowed to: (1) build and operate hatcheries; (2) assist ADF&G in developing and maintaining regional salmon plans; (3) authorize tax assessments on common property commercially caught salmon (usually 2-3%) to support hatcheries; and (4) provide for the sale of a portion of returning hatchery fish to help cover operational cost and repay state loans (McKean, 1991). This framework has allowed the Alaska salmon hatchery program to evolve into an innovative blend of public and private sector participation.

In the 1970s and early 1980s new hatcheries were operated both by ADF&G and private operators with somewhat duplicate roles (Orth, 1978). During that twenty-year period, however, as the system matured, operations for most public hatcheries were transferred to regional associations. Under these arrangements associations have become responsible for the annual cost of operating the hatcheries while the ADF&G has maintained special programs for genetics, fish health, and limnology for oversight assistance (Koenings, 1993; McNair and Holland, 1994). This close coordination between private sector stakeholders, enhancement, and public resource stewardship, similar in many ways to the prefectural fishermen cooperative system in Japan (Nasaka, 1988), has provided important economic and societal benefits in salmon resource management (Pinkerton, 1994).

The primary purpose of Alaska hatcheries, as required by law, is to benefit common property fisheries. Not all PNP hatcheries, however, are required to be part of regional associations. Statutes allow for individuals or small corporations to build and operate hatcheries at specified sites with production levels that are carefully reviewed and approved through detailed regional planning processes. A paramount issue during planning for all hatchery development has been to establish an enhancement program, based on the available science that protected to the greatest extent possible the abundant and viable wild salmon stocks across the state.

Regional Hatcheries

Currently there are eight regional aquaculture associations in Alaska. Five of these have either built hatcheries or are operating facilities initially built as public hatcheries (Mc Nair and Holland, 1993; Mc Nair, 1999). Three aquaculture associations in southwest and western Alaska do not presently operate hatcheries.

Southeast

Two associations in the southeast region, the Southern Southeast Regional Aquaculture Association (SSRAA), headquartered in Ketchikan, and the Northern Southeast Regional Aquaculture Association (NSRAA), headquartered in Sitka, operate six major production hatcheries in the region. In addition, several federal experimental hatcheries, the Bureau of Indian Affairs (BIA) hatchery on the Annette Island Indian Reservation and ten non-association private hatcheries, produce salmon in this region. Douglas Island Pink and Chum, Inc. (DIPAC) operate the largest non-association hatchery in Juneau. Southeast Alaska hatcheries released over 500 million juvenile salmon in 2000, including the salmon species (in descending order of magnitude) chum (*Oncorhynchus keta*), pink (*O. gorbuscha*), coho (*O. kistutch*), sockeye (*O. nerka*), and chinook (*O. tshawytscha),* McNair, 2001).

Prince William Sound
The Prince William Sound Aquaculture Corporation (PWSAC) headquartered in Cordova operates five production hatcheries in the region. The Valdez Fishery Development Association also operates one large non-association hatchery in Valdez. Prince William Sound (PWS) hatcheries released over 700 million juveniles in 2000, including (in descending order of magnitude) pink, chum, sockeye, and coho salmon (McNair, 2001). Hatchery production of sockeye salmon by PWSAC occurs at Main Bay Hatchery within PWS and at Gulkana in the upper reaches of the Copper River System that enters the Gulf of Alaska at the eastern edge of the PWS region. The Gulkana project, one of many unique applications of hatchery technology in Alaska, involves a remote egg incubation system that allows fry to emerge naturally into unutilized sockeye salmon lake nurseries (Roberson and Holder, 1987). Gulkana is also one of the few hatchery operations in Alaska not located at or near tidewater.

Cook Inlet
The Cook Inlet Aquaculture Association (CIAA), headquartered in Soldotna, operates two hatcheries in the Cook Inlet region. The ADF&G operate two hatcheries there and a non-association company operates one. Cook Inlet hatcheries released 85 million juveniles in 2000, including (in descending order of magnitude) pink, sockeye, chinook and coho salmon (McNair, 2001).

Kodiak
The Kodiak Regional Aquaculture Association (KRAA), headquartered in Kodiak, operates the only two hatcheries in this region. In 2000 KRAA released 168 million juveniles, including (in descending order of magnitude) pink, chum, sockeye, and coho salmon (McNair, 2001).

Hatchery Closures

Contrary to the belief that most salmon hatcheries, once built, continue to operate indefinitely, regardless of whether they achieve objectives and reach performance goals (Hilborn, 1992; 1999), a total of 13 hatcheries, 28% of those built since the inception of the Alaska program, have been closed (Fig. 2).

Closures have occurred in all regions due to a variety of factors including: disease or genetic concerns for protecting wild stocks; avoiding major disease consequences in hatcheries; other biological concerns in the hatchery; management concerns over mixed stock fisheries; and cost efficiencies or other economic issues.

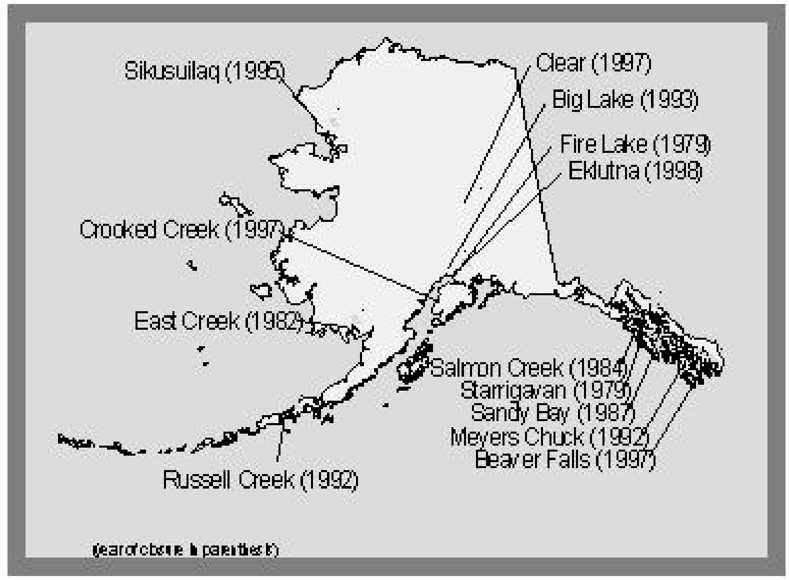

Figure 2. Location and names of thirteen Alaska hatcheries that have been closed since the beginning of the current salmon enhancement program.

Statewide Commercial Harvest

A look at the relative contributions of each species of wild and hatchery salmon to Alaska commercial catches provides a better understanding of how enhancement operations complement common property harvest in statewide fisheries. There are many hatcheries that do not contribute to fisheries. Many hatcheries emphasize some species over others. The focus on one species over another is based on both historical precedence of salmon fisheries within regions and on comprehensive regional planning.

Pink Salmon

Pink salmon are the most abundant species of pacific salmon in Alaska, accounting for 40-70% of the total commercial harvest each year. Between 1970 and 2000 pink salmon comprised 57% of the average annual commercial harvest. Pink salmon are mostly harvested by purse seines in Southeast, South-central (including PWS) and Kodiak Island regions of the state. Over the past six-year period (1995-2000) commercial catches of wild pink salmon have ranged from 25 to over 100 million fish, while catches of hatchery-reared fish ranged from 23-47 million (Fig. 3). In 2000 wild and hatchery pink salmon contributions to the fishery were about equal. Hatchery production of pink salmon is greatest in the PWS Region where 60-80% of the commercial harvest in recent years consisted of hatchery-reared fish, an issue of some controversy.

Chum Salmon

Chum salmon are harvested commercially by purse seines, drift and set gillnets, and, in large Western Alaska rivers, by fishwheels. Between 1970 and 2000 chum salmon have accounted for 10% of Alaska's total salmon harvest. Between 1995 and 2000 the average annual chum salmon harvest across Alaska totaled 20 million fish, with the commercial catch in 2000 above this average at a record 24 million (ADF&G, 2001).

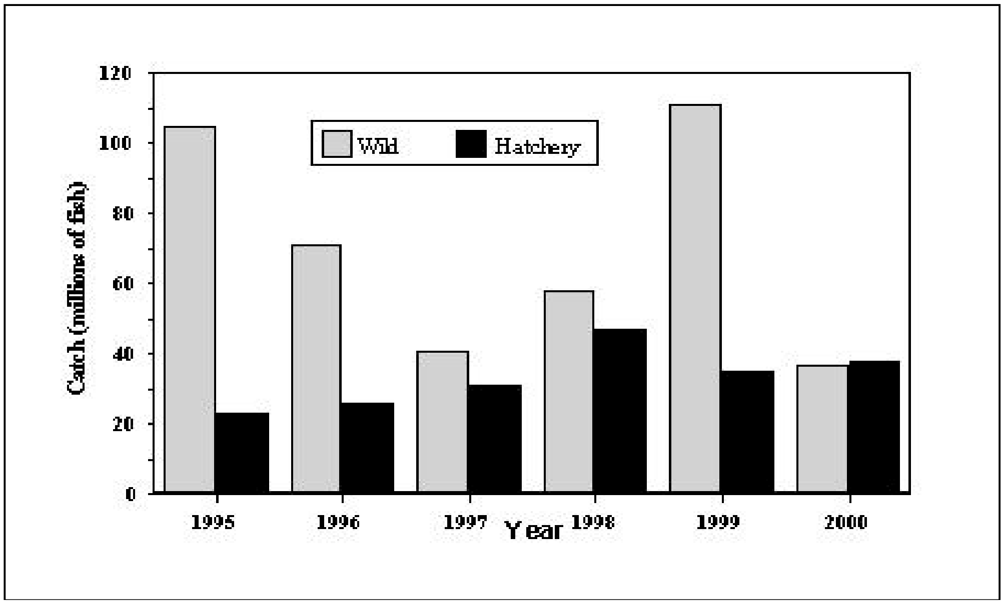

Figure 3. Statewide contributions of wild and hatchery pink salmon in Alaska commercial fisheries 1995-2000.

In contrast to pink salmon, statewide hatchery production of chum salmon in Alaska exceeds wild stock contributions in commercial catches. Chum salmon hatcheries during the past six years have produced from 9-18 million fish, while wild stocks have contributed 4-9 million fish annually to the commercial harvest (Fig. 4). Currently 60-70% of the commercial harvest of chum salmon in the state occurs in the Southeast Region where hatcheries produced an even greater portion (80%) of the catch in 2000 (McNair, 2001).

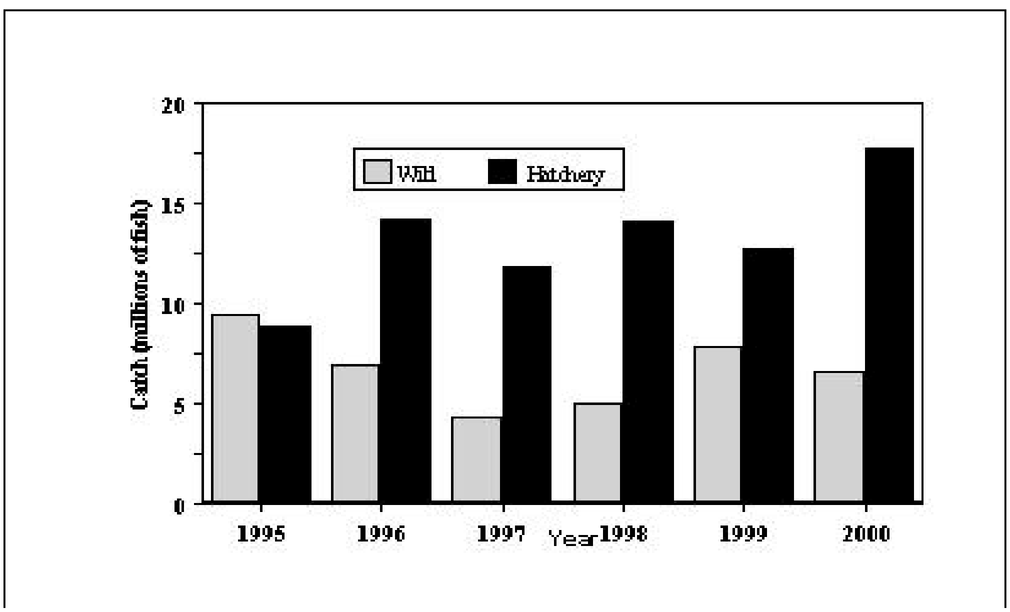

Figure 4. Statewide contributions of wild and hatchery chum salmon in Alaska commercial fisheries between 1995-2000.

Coho Salmon

Coho salmon in Alaska are caught commercially by purse seines in the Southeast and South-central regions, by hand and power troll gear in the Southeast region, and by drift or set gillnets in all regions. During the period 1995-2000 commercial catches of coho salmon statewide ranged from 3-6 million fish, 20-25% of those being of hatchery origin (Fig. 5). Commercial harvest in 2000 totaled 4.2 million fish, somewhat less than recent average harvest levels, but well above the record low catches in the 1970s (ADF&G, 2001).

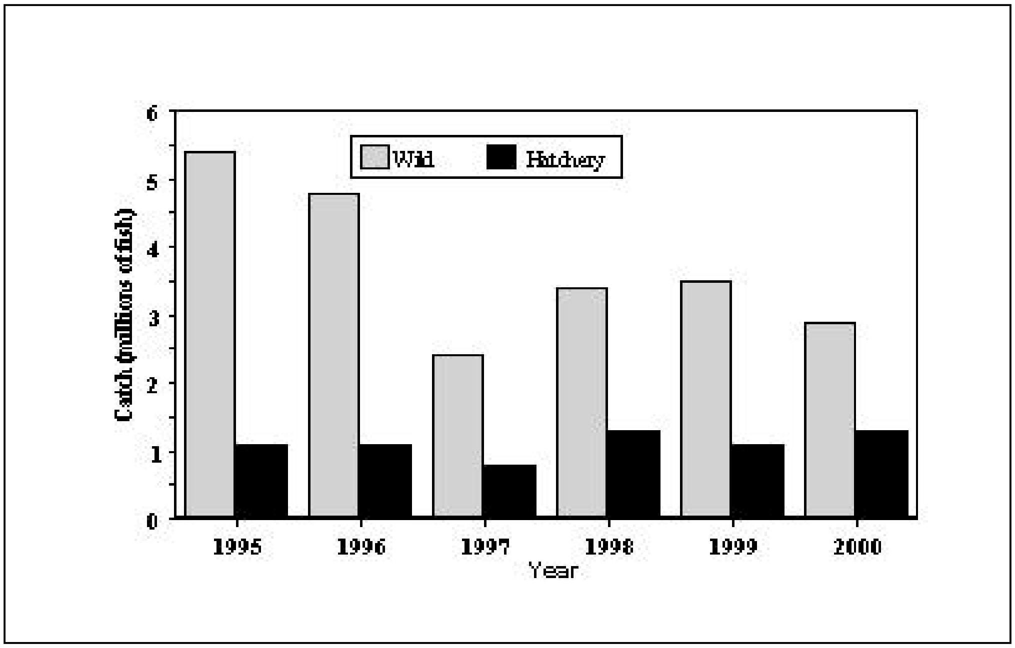

Figure 5. Statewide contributions of wild and hatchery coho salmon in Alaska commercial fisheries between 1995-2000.

About 60 percent of the statewide harvest of coho salmon come from the Southeast region. This relatively high commercial harvest was due to generally favorable ocean survival conditions and good returns in the Southeast region where 3.0 million or more coho salmon from hatchery and wild stock production were caught in three out of the last five years. Hatcheries in Southeast produce around 30% of the annual commercial catch.

Sockeye Salmon

Sockeye salmon, harvested commercially by purse seine in Southeast, Kodiak and Chignik fisheries and by drift gillnet or set gillnet throughout the state, are the second most abundant species caught in Alaska fisheries and account for about 28% of the total salmon harvest in recent years. The largest fisheries for sockeye salmon occur in Bristol Bay, Cook Inlet, Alaska Peninsula-Aleutian Islands, and Kodiak regions while other regions, also have fisheries for this species.

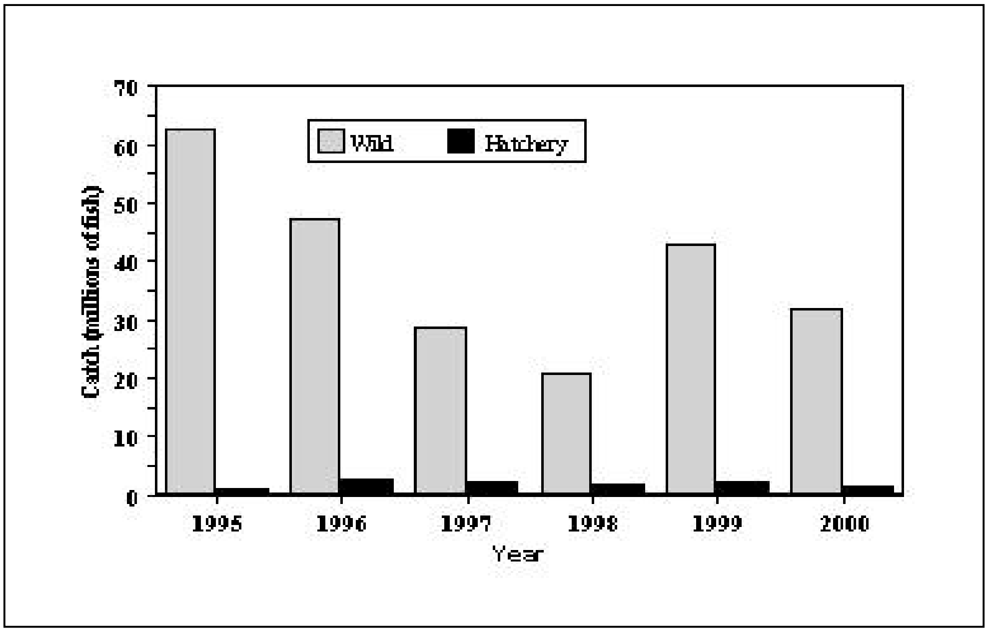

Figure 6. Statewide contributions of wild and hatchery sockeye salmon in Alaska commercial fisheries between 1995-2000.

Statewide one to two million sockeye salmon from hatcheries are caught by commercial fisheries, whereas wild stocks have produced from 23 to 62 million fish annually over the past six-year period (Fig. 6). Sockeye salmon provide greater dollar value to Alaska commercial fishermen than all other salmon species combined, usually yielding from 60-70% of the ex-vessel value of the annual commercial harvest. The Bristol Bay sockeye salmon fishery in Southwest Alaska is the most valuable capture fishery for salmon in the world, yielding $300-400 million (ex-vessel) per year in the 1980s and early 1990s. In more recent years, however, world salmon prices have declined significantly and ex-vessel values of Bristol Bay sockeye salmon averaged only $88 million during the three-year period between 1998-2000 (ADF&G, 2001).

Chinook Salmon

The annual commercial harvest of chinook salmon in Alaska has averaged between 400 and 700 thousand fish in recent years with hatcheries producing from 75,000-100,000 of the total (Fig. 7). Chinook salmon, like coho salmon, are commercially harvested by purse seines in the Southeast and Southcentral regions, by drift or set gillnets in all regions, and by hand and power troll gear in the Southeast region. In addition, fishwheels harvest chinook salmon in Western Alaska rivers for commercial sales and subsistence uses.

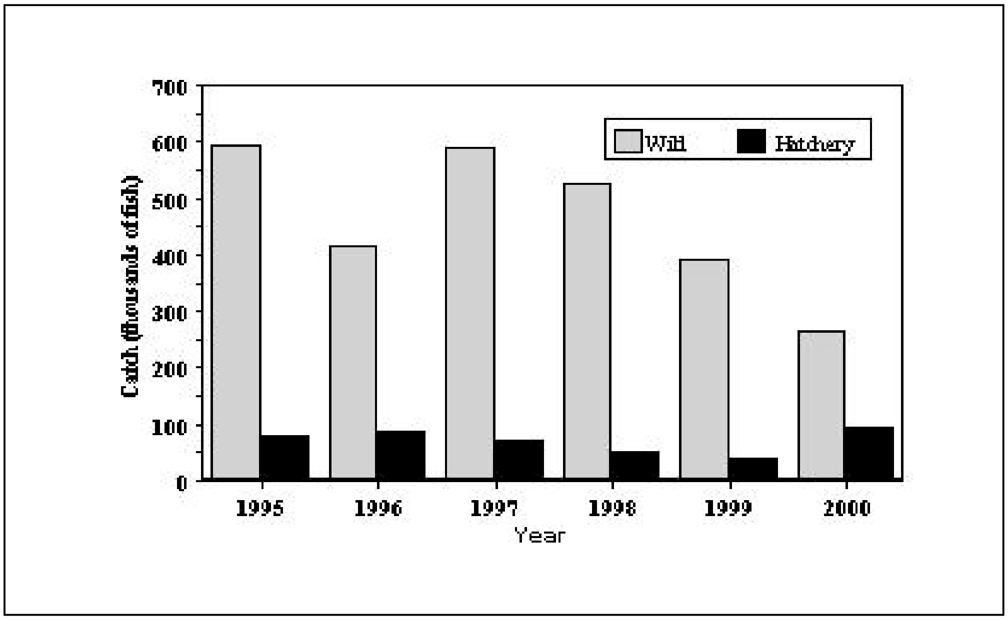

Figure 7. Statewide contributions of wild and hatcherty Chinook salmon in Alaska commercial fisheries between 1995-2000.

Generally, chinook salmon are the first species each year to begin spawning migrations into Alaska rivers. Only in a few Bristol Bay and Western Alaska rivers are fisheries permitted to directly target these early returning runs. In fisheries targeting on other salmon, however, chinook salmon are often taken incidentally. Sockeye salmon migrations into many larger river systems begin during the later portion of chinook salmon runs into the same rivers. In these cases, for example in certain Cook Inlet, Southeast rivers, and in the Copper River near Cordova, fisheries that target on sockeye salmon may catch significant numbers of chinook salmon. Some of these fisheries may have quotas limiting the chinook salmon catch. The region-wide chinook salmon harvest in the Southeast, where significant numbers of non-Alaska origin fish are also caught, is normally regulated by an abundance-based management system under provisions of the Pacific Salmon Treaty. Because of Treaty related limits on commercial and recreational catches much of the hatchery focus on chinook salmon in Alaska is in the Southeast region (Heard *et al.*, 1995).

Recreational Fisheries

While all species of salmon are important in Alaska sport fishing circles, coho, sockeye, and chinook salmon are the most popular target species in recreational fisheries throughout the state. Coho salmon were the most popular sport caught salmon in 1999, representing 44% of the 1.4 million salmon caught by recreational fishermen, followed by sockeye salmon (26%), chinook salmon (13%), pink salmon (12%), non-anadromous landlocked salmon (2%) and chum salmon (2%, Howe *et al.*, 2001). Roughly one third of the total Alaska sport catch of coho salmon in 1999 originated from hatcheries (McNair, 2000). Alaska hatcheries are providing important recreational fishing opportunities in many of the urban areas of the state, including Anchorage, Juneau, Ketchikan, Petersburg, Sitka, and Valdez.

Discussion

During the six-year period between 1995-2000 the additional contribution from Alaska's statewide hatchery production to commercial harvests over wild stocks was greatest for chum salmon followed by pink, coho, chinook and sockeye (Fig. 8). Over the past two decades wild stocks have made dramatic recoveries from their record lows, and together with implementation of the current hatchery program, commercial harvests have reached record highs. Hatcheries are now making significant contributions to commercial and recreational fisheries in several regions of the state, most notably in the Southeast and PWS regions.

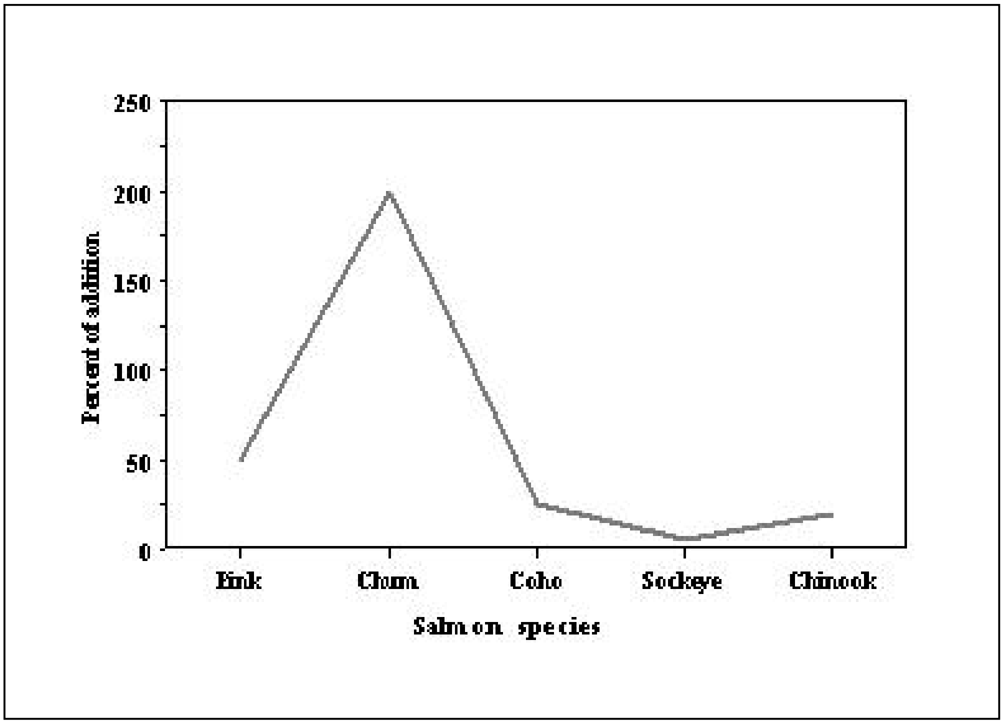

Figure 8. Additional statewide hatchery contributions of salmon by species over wild stock harvest in Alaska commercial fisheries between 1995-2000.

While depressed fisheries dependent on wild stocks were the impetus for the current hatchery program, a novel system of public and private non-profit hatcheries has evolved to augment, not replace, wild salmon in common property fisheries. One goal of this program is to smooth out sharp downside fluctuations in long-term abundance cycles that are strongly correlated with climatic-driven changes in the marine environment (Beamish and Bouillion, 1993; Francis and Hare, 1994; Hare and Francis, 1995; Mantua *et al.*, 1997; Beamish *et al.*, 1998). Although hatcheries in Alaska have enjoyed considerable success during their first twenty-year history, because of these long-term cycles, a longer time horizon is likely needed, as suggested by Hilborn and Winton (1993) to properly evaluate this kind of enhancement program.

Changes in marine environments that influence ocean survival of young salmon can also affect freshwater life stages due to colder or drier winters reducing the survival of eggs and fry. Under these conditions hatchery salmon, while subjected to the same marine conditions as wild salmon, will have freshwater survival advantages due to controlled conditions during these life stages. As noted by Smoker and Linley (1997) the "...hatchery program was not developed to ameliorate poor marine survival. Rather, it was developed to ameliorate limitations of the freshwater environment...".

Some scientists now believe major environmental changes are underway and that the twenty-year high survival rate of Alaska salmon may be declining, due to climatic pattern shifts in the North Pacific Ocean (Klyashtorin, 1998; Klyashtorin and Rukholv, 1998; Noakes *et al.*, 1998; Welsh *et al.*, 1998). Evidence also suggests there may be a climate-driven inverse pattern of salmon production between Alaska and the West Coast (Hare *et al.*, 1999). Recent increases in numbers of West Coast salmon, therefore, could indicate a declining trend for Alaska salmon. However, the jury is still out on this issue for although Alaska's commercial catches did decline for three years following the record 1995 harvest, landings in 1999 reached 217 million fish, essentially matching the peak harvest year. Landings fell to 137 million salmon in 2000 (Fig. 1), but preliminary data for 2001 indicate a rebound to173 million fish (ADF&G, 2001). Although salmon resources in Alaska generally are still healthy, in some areas, notably Western Alaska including Bristol Bay, the Kuskokwim and Yukon River drainage, many stocks are badly depressed resulting in major economic hardships in those regions. Interestingly, these are areas with little or no enhancement effort.

Successes of Alaska's hatcheries has involved some controversy and the program has been critically challenged in two areas, the large pink salmon hatchery program in PWS and the chum salmon hatchery program in the Southeast region. Eggers *et al.* (1991) reviewed trends of wild-hatchery pink salmon interactions in PWS and raised concerns over declines in wild stock escapements and the ability to conduct fisheries on large hatchery runs concomitant with reaching target escapement goals for wild stocks. Hilborn (1992) also criticized pink salmon hatchery production in PWS suggesting the program was without merit and "...should be terminated". Kron (1995), however, revisited the issue of declining wild stock escapements in PWS and indicated that new analyses of available data suggested escapements were higher than previously thought and that they were consistent with long term, pre-hatchery levels. He further noted that large scale marking programs of PWS hatchery pink salmon were enabling managers to conduct fisheries while achieving escapement goals. A careful, contemporary and historic analysis of PWS fisheries and escapement patterns (Smoker and Linley, 1997) suggested there was no credible evidence that hatcheries have harmed wild stocks.

Hilborn (1999) asserted that PWS hatcheries have not increased pink salmon production above the current high levels in the Southeast region where there is minimal hatchery production of this species. In a more rigorous analysis Hilborn and Eggers (2000) argue that pink salmon hatchery program in PWS has essentially replaced wild stock production that would have occurred in the absence of hatcheries. Wertheimer *et al.* (2001), however, analyzed the same data sets along with other factors and concluded that PWS hatcheries were supplementing wild stock production with a net gain of 17.5-23.7 million pink salmon annually to fisheries in that region.

Some components of the Hilborn and Eggers (2000) argument included temporal comparisons of hatchery and wild pink salmon production in PWS with other regions. In PWS, as hatchery production was getting started, wild stock productivity was near record high levels. As hatchery production began increasing, wild stocks in PWS after a seven-year period of unusually high production (1979-1985), began declining while wild stock production in other regions continued at relatively high levels. This declining trend in PWS wild stocks persisted as hatchery production reached current high levels. Superficially this pattern gives the appearance of a possible cause and effect relationship between hatchery production and decline in wild stocks (Fig. 9).

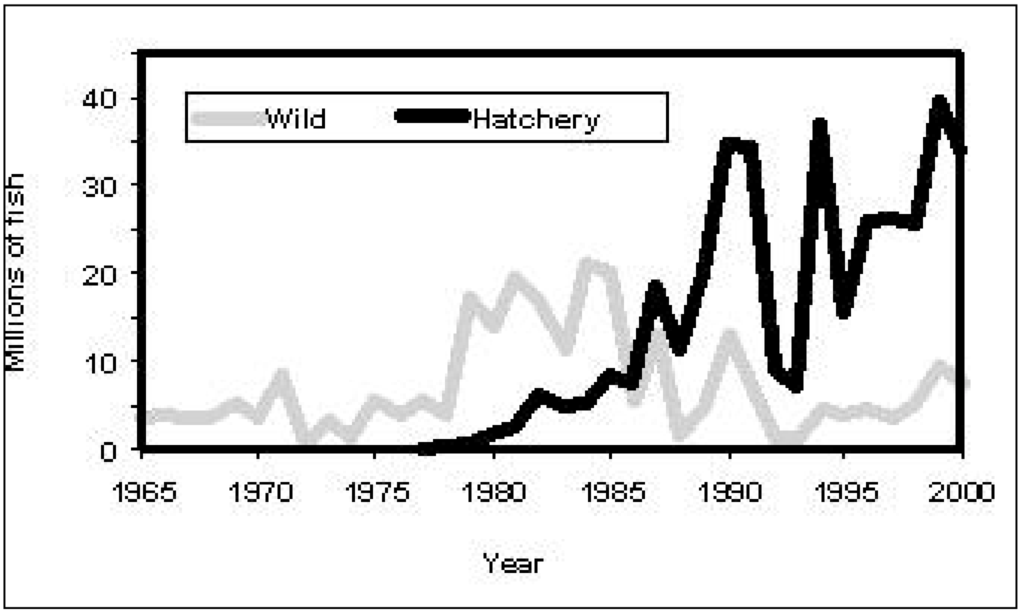

Figure 9. Commercial harvest of wild and hatchery pink salmon in Prince William Sound, Alaska between 1965-2000 (Wertheimer *et al.*, in press).

Another element of concern, as hatchery releases of juveniles in PWS increased, was whether decreases in productivity among wild stocks, expressed as adult returns per spawner, was the result of density-dependent responses to the large releases of hatchery fry. Hatchery survivals have been lower in 1986-1995, when hatchery fry releases were higher, relative to survivals in an earlier period (1977-1985), when hatchery releases of fry were smaller (Fig. 10).

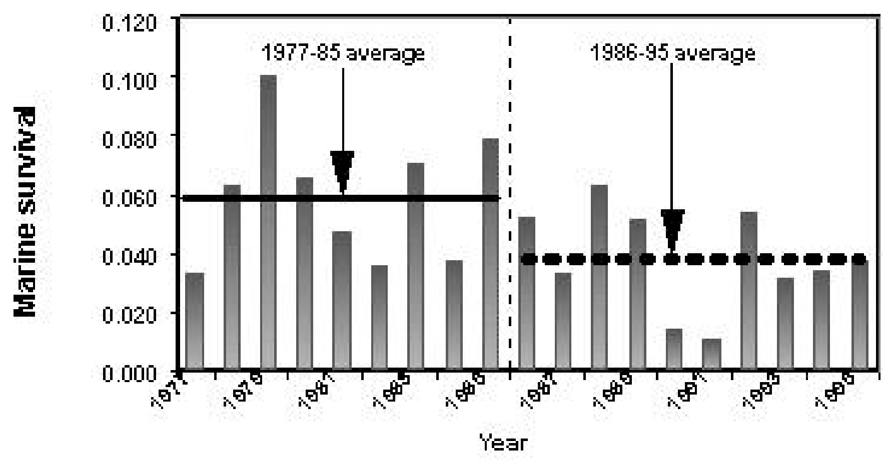

Figure 10. Marine survivals of pink salmon hatchery releases of fry in Prince William Sound, 1977-1995, showing two periods with different average values (Wertheimer *et al.*, in press).

Correlation analyses of hatchery marine survivals to hatchery fry releases, however, strongly suggested a density-independent response to marine conditions (Fig. 11) indicating that other factors caused the decline in wild stock productivity in PWS (Wertheimer *et al.*, in press).

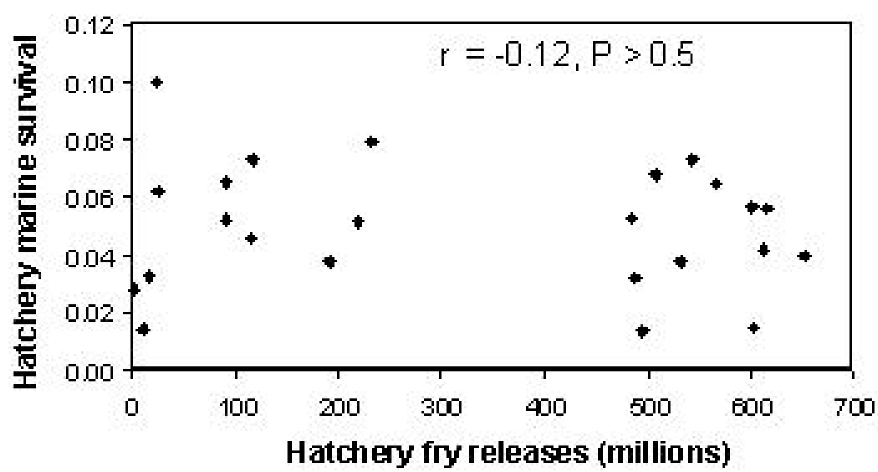

Figure 11. Correlation of Prince William Sound hatchery pink salmon marine survivals from hatchery fry releases during the 1975-1998 brood years (Wertheimer *et al.*, in press).

In further analyses Wertheimer *et al.*, (in press) examined a suite of eleven concurrent biophysical variables related to PWS pink salmon production, including releases of hatchery fry and numbers of wild spawners, in a stepwise regression model. Data for some variables was only available for restricted time intervals. These analyses found that hatchery survival, as an index of environmental conditions affecting wild stock survival, was the most significant factor that alone accounted for 49-60% of variability in wild stock productivity. Variables representing other marine environmental conditions, PWS zooplankton index (representing availability of pink salmon prey) and Gulf of Alaska sea surface temperature (SST) were also important functions in explaining the variation in wild stock productivity. Based on these analyses, Wertheimer *et al.* (in press) concluded that pink salmon hatcheries in PWS provide a net gain of up to 25.3 million fish per year. They also noted that under certain worst case conditions there might be up to a 4.5 million annual wild stock yield loss due to hatchery releases. However, even under these conditions there still was a 20.8 million net gain in available pink salmon for fishery harvest in the region. Therefore, while some other regions in Alaska continued to have high wild stock productivity after the1986 decline in wild stocks began in PWS (Fig. 9), biophysical variables affecting PWS are the major causes of wild stock declines rather than displacement from hatchery production. This conclusion is also consistent with a study by Pyper *et al.* (2001) that found that environmental processes affecting temporal variation in survival rates of pink salmon operate at regional spatial scales rather than larger ocean-basin scales.

Controversy over Southeast Alaska chum salmon hatchery production involves speculation that hatchery fish from this region during their marine life history somehow have a competitive and deleterious impact on wild chum salmon productivity in Kuskokwim and Yukon River systems. Some fishermen and civic leaders from Western Alaska have argued that a reduction in chum salmon hatchery production in the Southeast Region would help Western Alaska stocks recover. This rationale is based on the overlap in oceanic distribution of stocks from these two regions during part of their marine life cycles. Chum salmon stocks from Western Alaska rivers currently are at very depressed low levels, however, causes for this decline are largely unknown. Preliminary indications suggest ecological changes in the Bering Sea ecosystem may have significant negative impacts on juvenile salmon from Western Alaska rivers during early sea life. New freshwater and marine research programs are being implemented to better understand causes of chum salmon declines in this region. However, presently there is no credible evidence that Southeast hatchery chum salmon have a deleterious impact on Western Alaska stocks.

Statewide, the major problem faced by Alaska's salmon industry is a continuing decade-long decline in commercial value of salmon caught in fisheries. Over a recent thirteen-year period, 1988-2000, commercial catches of Alaska salmon have averaged around 145 million fish with15-40% of this harvest derived from hatcheries. The ex-vessel values paid to fishermen during this period, however, have steadily declined from over 500 million dollars annually to 250 million dollars (Fig. 12).

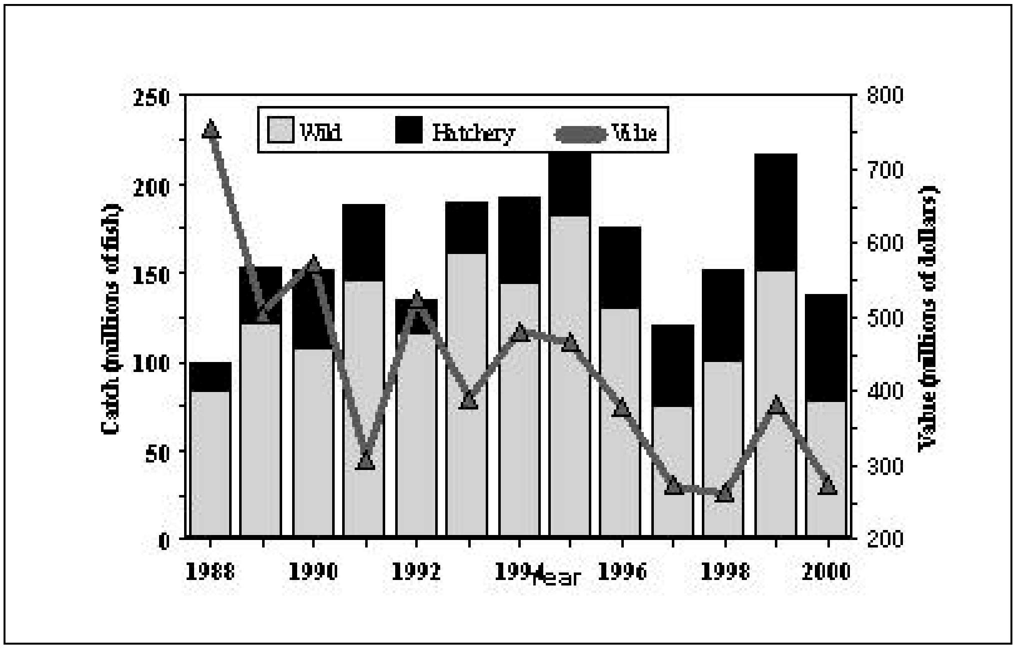

Figure 12. Statewide contributions of wild and hatchery salmon in Alaska commercial fisheries and ex-vessel values paid to fishermen, 1988-2000.

Many factors interact to determine prices paid to salmon fishermen in capture fisheries. Most important has been the overall supply and demand economics driven by continued increases in world supplies of farmed salmon produced by many countries (Knapp, 1998). While worldwide capture fisheries for salmon since 1985 have remained relatively stable at around 600,000-900,000 t annually, farmed salmon production has grown steadily during the same period from around 50,000 t to over one million t in 2001 (Fig. 13). For the first time, farmed production exceeded capture fisheries in 1998, and there is no indication of any change in this increasing availability of farmed salmon (Knapp, 2001). The negative impacts of this trend on the value of commercial salmon fisheries in Alaska and in Japan (Kaeriyama and Urawa, 1993) have created serious economic hardships in capture fisheries for salmon throughout the North Pacific Rim.

As recently as 1982 Alaska salmon held the dominate share (45%) of the total world supply of salmon, but fifteen years later, in spite of a period of record high commercial catches, Alaska's share had dropped to 19% of world supplies (Spiess, 1998). There are more salmon available today in commercial markets than ever before as world salmon production approaches two million tons. However, in spite of a generally negative economic outlook for commercial salmon fisherman based on capture fisheries, the Alaska enhancement program, focused on regional aquaculture associations and private sector involvement is currently providing significant, positive impacts to regional economies (McDowell, 2001; DIPAC, 2001).

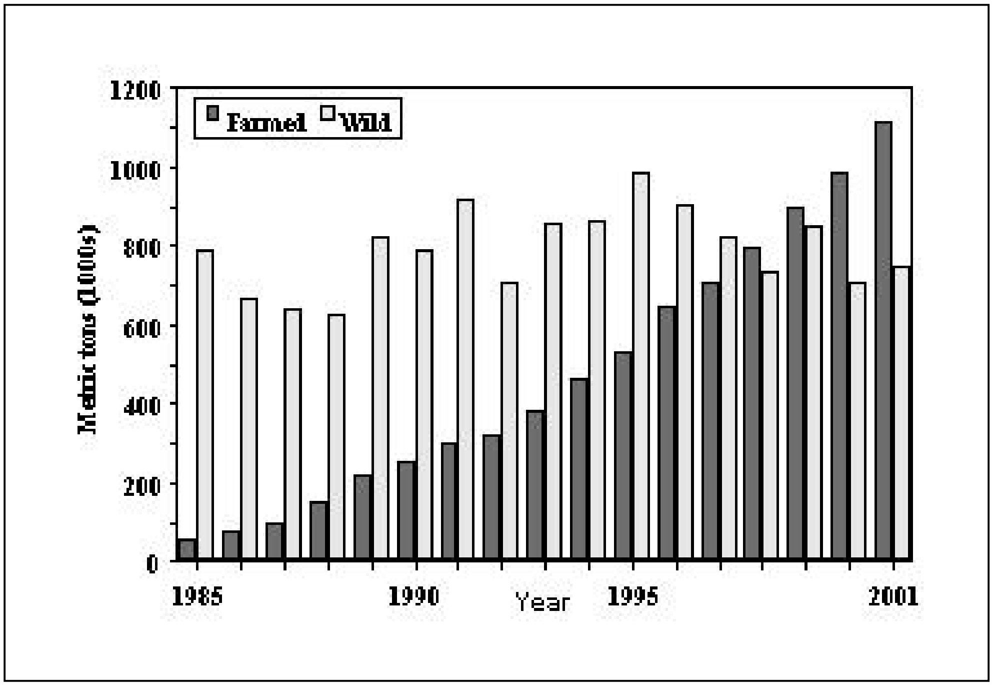

Figure 13. Worldwide production of farmed salmon and wild salmon caught in capture fisheries, 1985-2001. Wild salmon in this context includes fish from enhancement and hatchery programs. Data from 2001 are provisional.

Conclusions

Alaska salmon runs and the fisheries that depend on them are unique in that nowhere else around the Pacific Rim does such a relatively large and successful hatchery program coexist with abundant and healthy wild stocks of salmon. Salmon populations in Alaska, in general, are strong, healthy, and currently are at or near record high levels (Burger and Wertheimer, 1995; Baker *et al.*,1996; Wertheimer, 1997; ADF&G, 2001), in spite of sharp fluctuations in some stocks in some regions in some years (Kruse, 1998). After two decades of operations in several regions Alaska hatcheries are successfully making meaningful contributions to fisheries with little, if any, evidence of significant, detrimental impacts either on the environment or on wild stocks.

Salmon management in Alaska is strongly directed by law, policy, and regulation to maintain adequate wild stock escapements and preserve existing pristine habitats. Even if no hatchery fish are involved, management policies are directed at reaching target escapement goals for wild runs rather than any predetermined harvest goal for the benefit of fisheries. Escapement-based management and strong habitat laws preventing catastrophic habitat losses, together with a carefully implemented and conservative hatchery program, are key hallmarks of Alaska's commitment to maintaining healthy salmon runs and fisheries that depend on these resources (Holmes and Burkett, 1996).

The current successful hatchery program is playing a significant role in helping meet this commitment. Only time will tell if the present favorable balance between wild and hatchery salmon production will continue into the future. Alaska's modern hatchery program started with the onset of higher salmon survivals due to favorable conditions in the marine environment. It is essential to continue this program along with ongoing research and careful evaluation to correctly assess its effectiveness when long-term cyclic and environmental influences change to less favorable conditions.

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