Chinook Salmon – Trends in Abundance and Biological Characteristics

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Abstract: Chinook salmon, *Oncorhynchus tshawytscha*, the least abundant but largest in size of the five major Pacific salmon species, are widely distributed throughout the North Pacific Rim. Although precise numbers spawning in many rivers are little known, many stocks have only a small percentage of their historic abundance levels, and more than 50 stocks have become extinct. Over the past decade commercial catches have fluctuated between one and two million fish annually with an additional 0.6–0.9 million fish caught in recreational, subsistence, and aboriginal fisheries. About half of all commercial catches are made in the United States, particularly in Alaska and Pacific-Northwest states, with the remainder caught, in descending order, by Canada, Russia, and Japan. Within the U. S., nine fish populations are listed in Pacific-Northwest states as threatened or endangered, according to the Endangered Species Act (ESA). While no formal ESA-type listings occur in other areas, some populations in Canada and Russia are of special concern due to declining trends. Current trends in abundance are reviewed from different regions with a focus on stocks of concern but also including some stocks whose trends are relatively stable. While equivocal in improving the status of many depressed wild stocks, hatcheries are important in helping maintain fisheries and general abundance in some areas. Chinook salmon are characterized by high plasticity and life-history variability, as seen in their multiple age groups, diverse temporal migration behavior as they return to natal streams, distinct races with separate freshwater and ocean life-history behavior patterns, and red-fleshed and white-fleshed forms. Long-term declines in the average size and age of Chinook salmon appear to be continuing for some stocks and fisheries. The species may be establishing new populations and expanding its range into higher latitudes, possibly due to global warming and other climatic changes.

Keywords: Chinook salmon abundance, biological characteristics, hatcheries, range extension, reduced size and age

INTRODUCTION

Chinook salmon, *Oncorhynchus tshawtscha*, indigenous to the Pacific coast of North America and Asia are among the least abundant salmon populations but achieve the largest adult size of all Pacific salmon. The species is widely distributed with important spawning stocks ranging from central California in North America to the Bering Straits and southward along the Asian coast to the Amur River (Major et al. 1978). North of the Bering Straits, smaller runs occur in Alaska's Kotzebue Sound and possibly eastward into the Beaufort Sea along the north coast of Alaska and northern Canada (McPhail and Lindsey 1970; Hart 1973; McLeod and O'Neal 1983). While it is known that Chinook salmon range widely thoughout the Sea of Okhotsk, the Bering Sea, and northern portions of the North Pacific Ocean (Healey 1991), the southern limits of their oceanic distributions are more fragmented and less well known. Along the North American coast a few Chinook salmon have been recovered south of 40°N Latitude, including two coded, wire-tagged (CWT) fish caught by a groundfish fishery (see CWT database at http://www.rmis.org/cwt/cwt_qbe.html). Others have been captured by recreational fisheries off San Diego, California (Miller and Lea 1972) and Baja California, Mexico (Cruz-Aguero 1999).

Throughout their range, Chinook salmon show a wide diversity of life-history characteristics, including run-timing, variable ages of juvenile seaward migration and different oceanic behavior patterns. Maturing adults can enter natal streams over an extended period from February to December and are commonly referred to as winter, spring, summer, or fall runs. After emerging from natal gravels, juvenile Chinook salmon that are reared in fresh water but migrate to sea after only a few months are referred to as ocean-type salmon,

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whereas those that are reared in fresh water for one to two years before migrating to sea are referred to as stream-type salmon. These two life-history types also exhibit distinctly different oceanic migration patterns (Healey 1983; Hartt and Dell 1986).

Significant commercial fisheries for Chinook salmon are found along the North American coast near California, Oregon, Washington, British Columbia, and in southeastern Alaska, central Alaska, and Bristol Bay. Substantial freshwater fisheries may also occur in many rivers, including the Sacramento, Klamath, Columbia, Fraser, Skeena, Nass, Kuskokwim, Yukon, Kamchatka, and Bolshaya rivers.

In North America, a Pacific Salmon Treaty (PST) established in 1985 between the United States and Canada and amended in 1999 (http://www.psc.org/pubs/Treaty.pdf) plays a significant role in regulating fisheries for Chinook salmon from the mid-Oregon coast northward to the southeast of Alaska (Shepard and Argue 2005). The treaty, administered by the Pacific Salmon Commission (PSC), facilitated major rebuilding programs for depressed stocks through careful management and restricted harvest levels in many fisheries. The bilateral Chinook Technical Committee (CTC) oversees scientific assessments of stock status and establishes management protocols for Chinook salmon fisheries within areas of PSC jurisdiction.

Besides influencing commercial fisheries, Chinook salmon are important in many recreational, subsistence, and aboriginal fisheries throughout much of its range. The species is highly prized in both freshwater and marine sport fisheries due, in part, to its large size and relative scarcity compared to other salmon. Sport fisheries for Chinook salmon play an important role in tourism development in many areas and positively impact local economies. In rural areas and among native and aboriginal peoples, Chinook salmon have historically played a vital role in subsistence and ceremonies. From 2003 to 2004, the harvest of Chinook salmon in North American recreational, subsistence, and aboriginal fisheries exceeded 900 thousand fish (Table 1). The catch for PST-regulated fisheries in areas of the Pacific Northwest is documented in Anon. (2005b) for the years 1975–2004.

Table 1. Recent North American harvest of Chinook salmon by recreational, subsistence, and aboriginal fisheries (in thousands of fish).

Area	Recreational	Subsistence-aboriginal	Total
WOC[1]	371	NA	
BC[2]	193	18	
AK[3]	193	167[4]	
Totals	757	185	942

[1]Washington, Oregon, and California data from Bartlett (2005).
[2]British Columbia data from Irvine et al. (2005).
[3]Alaska data from Eggers (2005) and from Anon. (2005a) Subsistence Report.
[4]Subsistence-aboriginal data from Alaska are from 2003, all other data from 2004.

The role of hatcheries has been important to the history and legacy of Chinook salmon over the past century, especially in North America. For much of this history, Chinook salmon hatcheries were considered to be an acceptable means of mitigating many of the deleterious, anthropogenic causes of habitat loss, declining fishery catches, and depressed populations. In more recent times, however, hatcheries are seen not as an unequivocal solution to these issues, but as part of the problem.

For long periods of time, hatcheries were not adequately monitored or evaluated to measure their intended effects, and more recent scientific information has shown that past hatchery practices exacerbated many issues they were intended to solve (Anon. 1996a; Levin et al. 2001).

Although hatcheries remain controversial in many scientific circles, most hatchery programs now have implemented important changes in past practices and operate under more clearly defined objectives: to help rebuild depressed natural runs or to stabilize fisheries. Several Chinook salmon fisheries in North America are now only possible because of hatchery programs. In some rivers, hatchery fish comprise a majority of the fish population. For example, by 1987, hatchery-originating Chinook salmon dominated adult returns to the Columbia River, comprising 70% of the spring run, 80% of the summer run, and over 50% of the fall run (Anon. 1996a).

From the 1993 to 2001 brood years, between 250 and 298 million juvenile Chinook salmon were released annually from North American hatcheries. The state of Washington has the largest program, releasing up to 160 million juvenile Chinook salmon per year, followed by Canada, Oregon, California, Alaska, and Idaho (Table 2). Chinook salmon hatcheries in Russia occur on a much smaller scale. The Malkinski Hatchery in the lower reaches of the Bolshaya River currently is the nation's only hatchery for Chinook salmon. Annual releases from Malkinsky Hatchery, 1983–2004, ranged from 0.3–1.2 million juveniles (excluding 1989, a year of high mortalities in the hatchery).

In this report, we will consider current trends in abundance of certain stocks of Chinook salmon from around the Pacific Rim. Our focus will be on major stocks and stock groups that represent significant components of the species in different regions. This focus will include stocks at risk due to declining populations, and stocks that may be in danger of extinction, as well as some stocks that show stable or improving population tendencies. We focus on escapements of adults into natal spawning areas whenever possible, however, where escapement data is limited or unavailable, we use terminal fishery harvest data, although harvest data alone may not accurately reflect stock status.

The intent of this review is to provide a snapshot of current trends in the abundance of Chinook salmon throughout its Pacific range and also to review some of the unique biological characteristics of the species.

Table 2. Numbers of juvenile Chinook salmon released from brood years 1993–2001 by Washington, Oregon, California, Idaho, Alaska, and British Columbia (BC)/Yukon (in millions of fish)[1].

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Washington	146.5	156.9	147.9	154.8	146.5	129.6	133.4	122.1	133.3
BC/Yukon	51.3	54.7	46.3	59.5	50.5	55.6	59.2	49.5	54.6
Oregon	49.9	45.3	40.3	30.8	30.5	28.2	23.5	25.1	27.9
California	29.1	33.4	38.9	32.6	47.7	33.4	28.9	33.4	29.3
Idaho	10.2	0.8	0.8	3.6	8.8	7.8	3.7	11.4	11.9
Alaska	8.5	6.4	8.3	8.1	7.9	8.7	8.8	8.6	8.6

[1]Data from Pacific States Marine Fish Commission RMIS Database.

TRENDS IN ABUNDANCE

Precise data on present numbers of Chinook salmon spawning in many rivers is not known, however, many populations were historically more numerous than they are today—particularly those populations in the U. S. Pacific Northwest. A long list of factors contributing to these declines includes major losses of spawning and juvenile rearing habitats due to logging, urbanization, and other developmental practices; over-fishing; water allocations for argricultural, mineralogical , urban, and other uses; and the presence of dams that block or compromise upstream and downstream migration patterns in addition to flooding spawning and rearing habitats.

Harvest data gleaned from the Food and Agriculture Organization of the United Nations (FAO) for different countries around the Pacific Rim indicate that catches of Chinook salmon averaging around 25,000 mt in 1950 had declined to about half that level by 2004 (Fig. 1). By 1950, many major runs of Chinook salmon had already diminished significantly in size from levels observed in the first half of the century (Mundy 1997; Lichatowich 1999). Over the past decade, Pacific Rim commercial catches of Chinook salmon have generally fluctuated between one and two million fish annually with over half of the catch coming from the U.S. and the remainder coming, in descending order, from Canada, Russia, and Japan. The U.S commercial catch is almost evenly divided between Alaska and Pacific Northwest states. Sharp declines in the Canadian commercial harvest in the mid 1990s were driven by conservation concerns for domestic salmon stocks, and were not reflective of corresponding declines in overall Canadian Chinook salmon abundance.

Washington-Oregon-Idaho-California (WOIC)

Trends in salmon abundance along North America's western coast have been the subject of several studies in recent years. In a detailed review of salmon stocks in Pacific Northwest states, Nehlsen et al. (1991) found that over 50 native stocks of Chinook salmon from Washington, Oregon, Idaho, California, Nevada, and British Columbia had become extinct. Most extinct British Columbian stocks were located above the Grand Coulee Dam (completed in 1941), which blocked runs into the upper reaches of the Columbia River Drainage.

The U.S Endangered Species Act (ESA) of 1973 has had a major impact on Chinook salmon management and conservation in the Pacific Northwest. During the 1980s, as it became more evident that many salmon stocks in the region were in various stages of decline and several were on the verge of extinction, scientists began exploring how ESA could be applied to threatened stocks of salmon. In response to petitions that called for various salmon populations to be listed under ESA, the National Marine Fisheries Service (NMFS) initiated coast-wide status reviews by Biological Review Teams (BRT) for each species (Kope and Wainwright 1998). Following principles developed in a series of policy decisions, NMFS determined that a salmon population or group of populations would be considered a distinct ESA listing if it represented an evolutionary significant unit (ESU) of the species (Waples 1991). By this definition, nine ESUs of Chinook salmon were ultimately listed as either threatened or endangered (Anon. 1996b). These listings included three ESUs from California, five from the Columbia River Basin, and one from Puget Sound (Table 3). Geographic drainages for some of these ESU groups have overlapping ranges (Fig. 2).

The first Chinook salmon population was listed under ESA in 1990 after the Sacramento River winter run past the Red Bluff Diversion Dam reached a record low count of 550 adults in 1989 (Nehlsen et al. 1991). The initial listing as "threatened" for this ESU was upgraded to "endangered" in 1994 (Table 3). Following the implementation of a recovery plan that includes fishery closures and hatchery fish supplementation the Sacramento River winter run Chinook salmon (Fig. 3) has begun to show modest improvements (Anon. 2004a; Killam 2005).

The Klamath River Drainage in northern California and southern Oregon historically had both spring and fall runs of Chinook salmon. Spring runs in this system now do not occur due to a series of hydro-dams and other factors (Hamilton et al. 2005). Fall run Chinook salmon in the Klamath

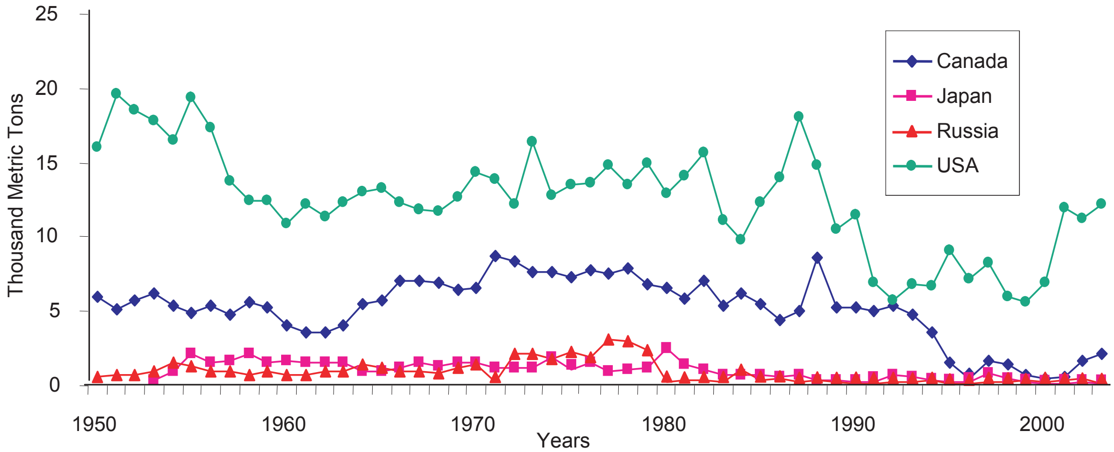

Fig. 1. Commercial harvest of Chinook salmon in metric tonnes by Canada, Japan, Russia, and United States, 1950–2003. Data from FAO.

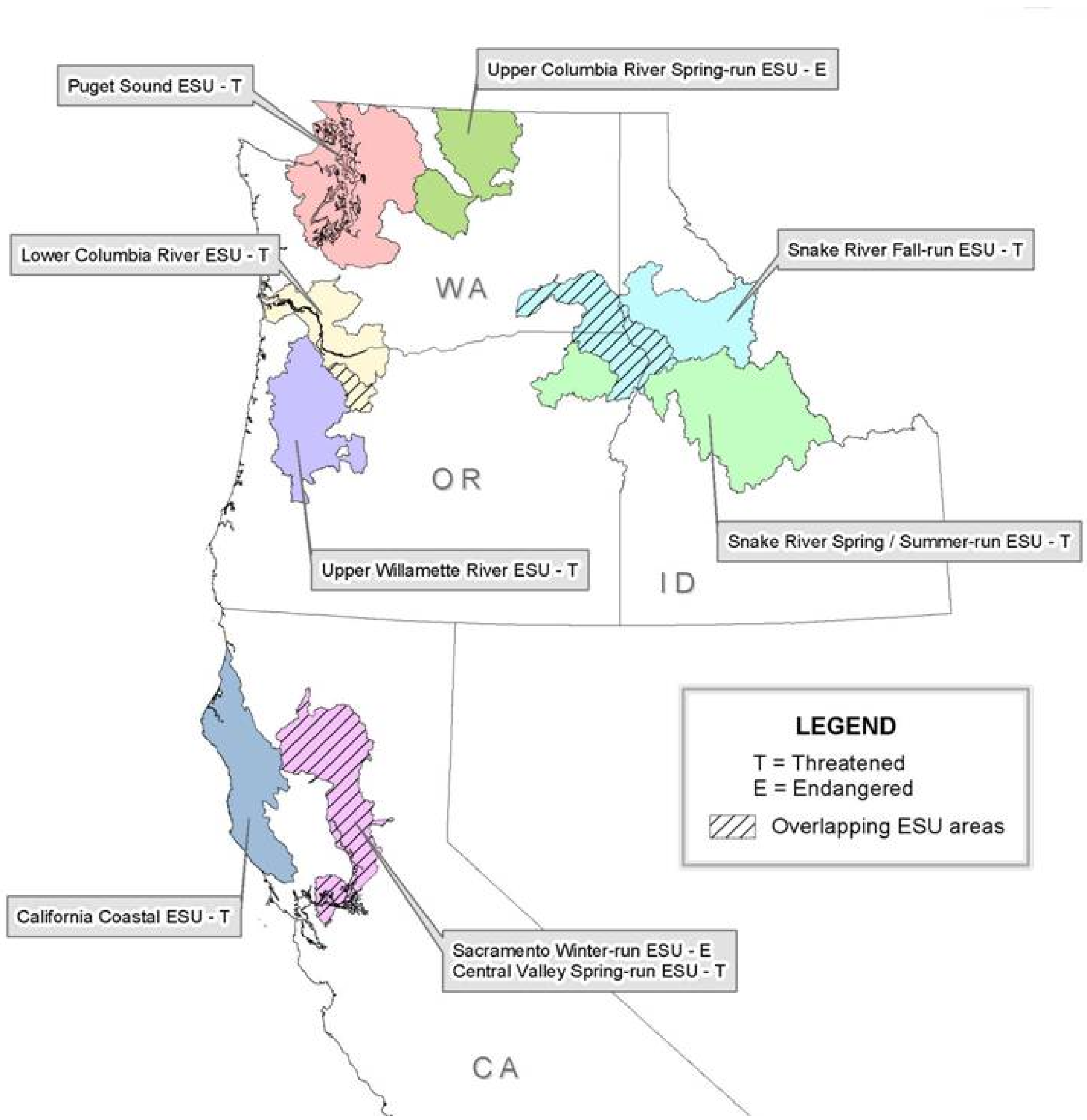

Fig. 2. Geographic drainages of nine Chinook salmon ESUs in the states of Washington, Oregon, Idaho, and California listed either as threatened or endangered under the U. S. Endangered Species Act of 1974. Map by Barbara Seekins, NOAA Fisheries.

Table 3. Threatened and endangered Chinook salmon in the Pacific Northwest listed under the Endangered Species Act (ESA) of the United States.

ESU[1] groups	Year endangered[2]	Year threatened[3]
Sacramento River Winter- Run ESU	1994	1990
California Central Valley Spring- Run ESU		1999
California Coastal ESU		1999
Lower Columbia River ESU		1999
Upper Wilamette River ESU		1999
Upper Columbia River Spring- Run ESU	1999	
Snake River Spring/Summer- Run ESU		1992
Snake River Fall-Run ESU		1992
Puget Sound ESU		1999

[1]ESU or evolutionary significant unit is defined by NMFS as a population that:
a) is substantially reproductively isolated from conspecific populations, and
b) represents an important component in the evolutionary legacy of the species.
[2]Endangered means ESU is in danger of extinction.
[3]Threatened means ESU is likely to become endangered.

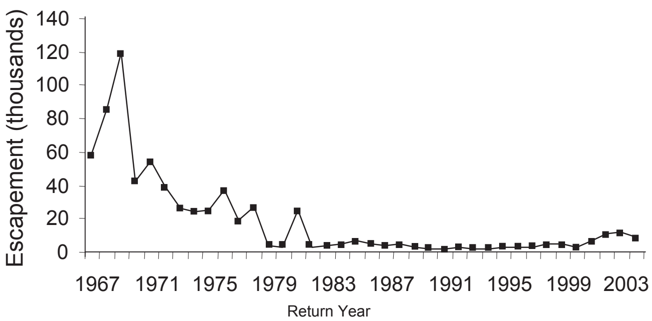

Fig. 3. Sacramento River Winter-Run Chinook salmon escapements, 1967–2004. Data from Calif. Dept. Fish Game.

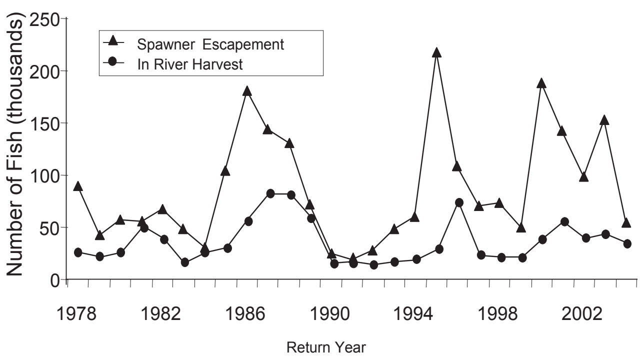

Fig. 4. Escapement and in-river harvest of Klamath River Fall-Run Chinook salmon, 1978–2004. Data from U.S. Fish and Wildlife Service.

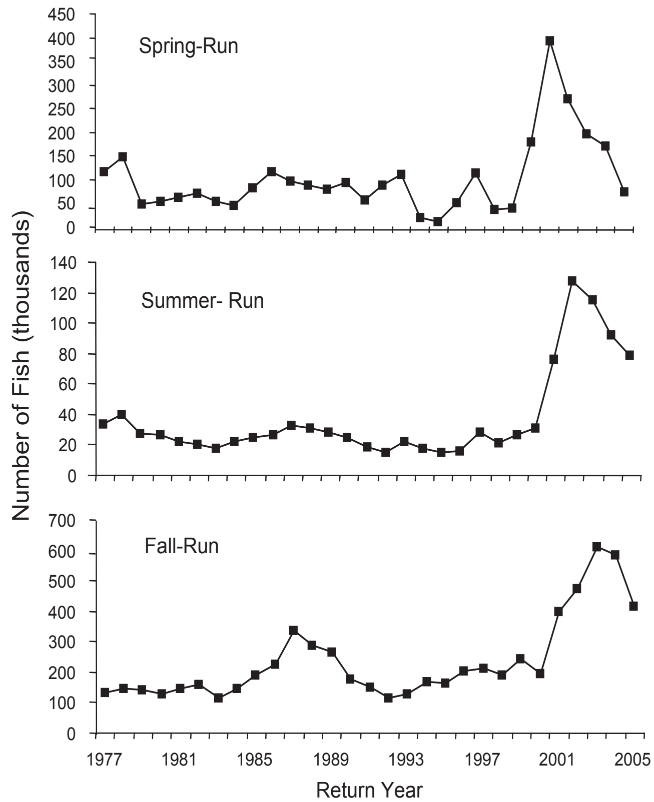

Fig. 5. Counts of Spring-, Summer-, and Fall-Run Columbia River Chinook salmon adults past Bonneville Dam, 1977–2005. Data from Columbia River Data Access in Real Time (DART) system (http://www.cbr.washington.edu/dart/adult.html).

River system was not listed under ESA by the BRT, however; this ESU is of concern because of its fluctuations and frequently low escapements. Current runs of Chinook salmon into the Klamath River drainage system are characterized by significant recreational and subsistence fisheries on the river (Fig. 4).

There are over 40 dams in the Columbia River Basin, and the first dam encountered by salmon returning from their ocean migration is Bonneville at river kilometer (Rkm) 235. Daily counts of upstream-migrating salmon and other anadromous fishes passing through this dam provide the

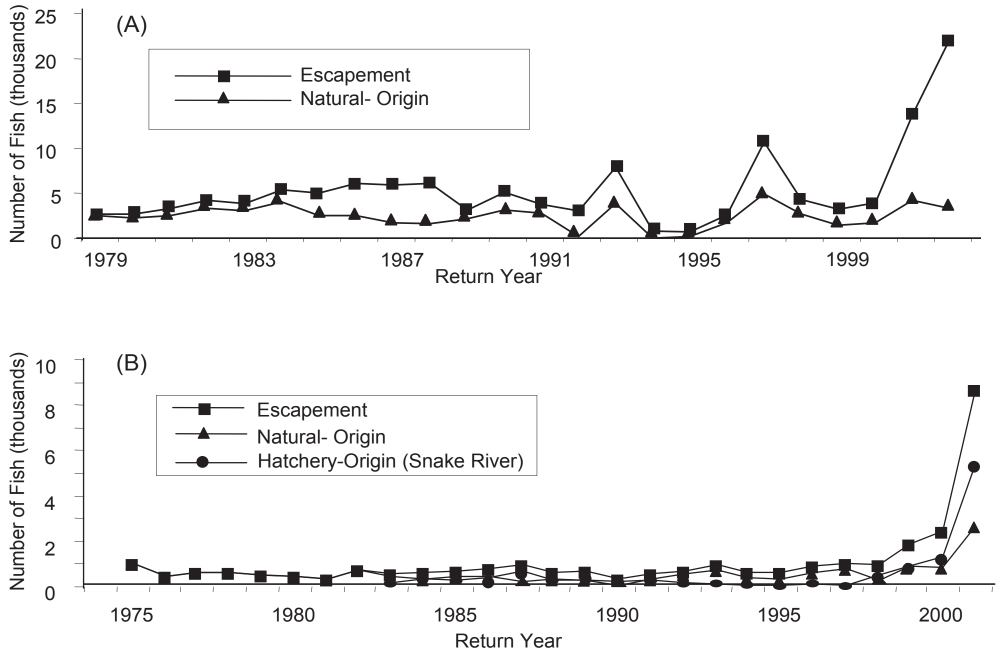

Fig. 6. Escapements of Snake River Chinook salmon past Lower Granite Dam: (A) total escapement and natural origin escapement of Summer-Run, 1979–2002; (B) total escapement, natural origin escapement, and Snake River hatchery origin Fall-Run, 1975–2001. Data from Anonymous (2003a, Figs. A.2.1.1 and A.2.2.2).

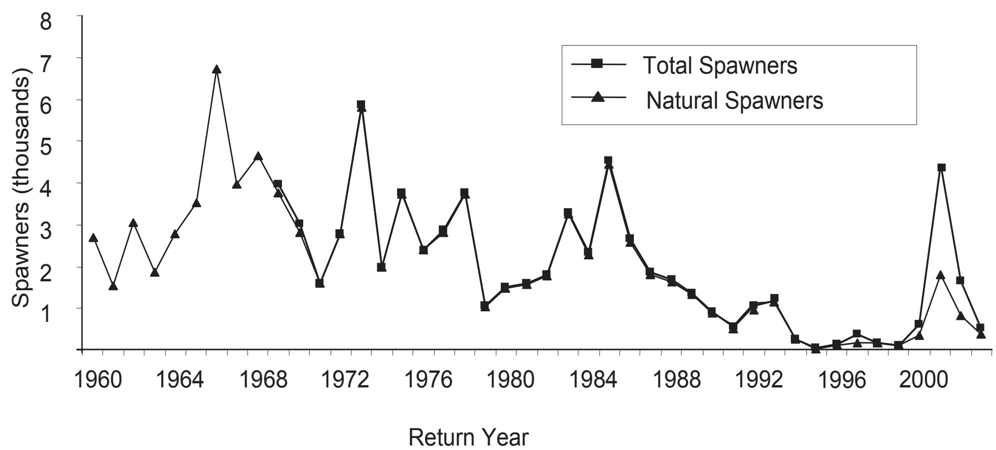

Fig. 7. Estimated number of Chinook salmon spawners in the Wenatchee River, a key indicator stock for the Upper Columbia River Spring-Run ESU, 1960–2003. Data from Anonymous (2003a, Fig. A.2.3.1).

number of each species returning to the river each year. Chinook salmon counts at Bonneville Dam are maintained under the DART system (http://www.cbr.washington.edu/dart/adult.html) in a temporal mode representing run-timing of spring-, summer-, and fall-run fish. Bonneville Dam counts of Chinook salmon are usually designated “spring run fish” from March through May, “summer run fish” from June through July, and “fall run fish” from August through November. Chinook salmon counts at Bonneville Dam from 1977–2005 show a significant increase in returns beginning in 2000 and 2001. However, more recently counts have begun to decline, especially for spring- and summer-run fish (Fig. 5).

The Lower Granite Dam, located on a major tributary of the Columbia River at Snake River Rkm 173, is the last major dam salmon pass before reaching the remaining available spawning grounds in the Snake River Basin. Counts of Chinook salmon at this dam provide assessments on the status of two ESA-listed groups: Snake River spring/summer-run and Snake River fall-run ESUs. Counts of Chinook salmon passing the Lower Granite Dam are evaluated by BRT groups to determine what portion of total escapement is comprised of hatchery salmon and and what portion of natural-origin salmon (Anon. 2003a). The principle of “natural origin” includes both wild salmon and naturally spawning salmon that may have some measure of hatchery parentage. The distinction between hatchery- and natural-origin salmon is drawn because ESA seeks to foster rebuilding programs with naturally spawning fish and, where possible, to minimize the influence of hatcheries. Snake River summer-run Chinook salmon escapements past the Lower Granite Dam illustrate the differences between total escapement and natural-origin fish (Fig. 6A). When monitoring the Snake Rive fall-run escapement, one of the more contentious Columbia Basin listings, BRT assessors track an additional level of escapement by distinguishing hatchery-origin fish from Snake River stocks (Fig. 6B). Unfortunately, current BRT assessments past the Lower Granite Dam do not include Snake River stock calculations for the most recent years (2003–2005).

Wenatchee River Chinook salmon represent one of the last vestiges of the large Upper Columbia River spring run ESU that was all but totally extirpated with the completion of the Grand Coulee Dam in 1941. BRT estimates of Chinook salmon spawning in the Wenatchee River show a long, steady decline that, even with hatchery supplementation, now includes only a few hundred natural-origin fish (Fig. 7).

British Columbia–Yukon

In a review of Chinook salmon in British Columbia and the Yukon Territory, Slaney et al. (1996) identified from a total of 866 stocks 17 stocks as extinct and 60 others at high or moderate risk of extinction. Slaney's stocks at risk included, among others, some populations near West Vancouver Island, the Strait of Georgia, and certain Fraser River stocks. Concern over declines in population remains today. Canada currently has a two-step system for listing stocks at risk of extinction. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is a committee comprised of representatives from government, academia and other non-governmental organizations, which assesses the risk of a species' extinction. It can then recommend that the federal government place the endangered species under the legal protection of the Species at Risk Act (SARA). If the recommendation is accepted, COSEWIC formulates a recovery plan. COSEWIC's determinations of stock status are somewhat different from those definitions used by Slaney et al. (1996). Presently, there are no Chinook salmon stocks listed under SARA in Canada. Henderson and Graham (1998) attributed overall increases in spawning escapements of Chinook salmon in British Columbia in the late 1980s and 1990s to implementation of the Pacific Salmon Treaty as well as other actions taken in Canada to address domestic conservation concerns. This general increase in abundance has continued since the new regulations were implemented.

Fortunately, the Fraser River, unlike the Columbia River, has no main-stem dams to impede migration of salmon stocks throughout the basin. Like Columbia River salmon, Fraser River Chinook salmon cycle through as spring-, summer- and fall-run types. As in the Columbia River, each of these runs is comprised of many individual stocks that exist at different levels of stability or decline. Ocean age .2 and age .3 spring-run Chinook salmon escapements of stream-type spawners in the Fraser River show similar escapement trends but exhibit different levels of abundance, whereas ocean age .3 summer-run fish from both stream and ocean-type spawners show similar escapement trends and similar abundance levels (Fig. 8). Both spring-run and summer-run Chinook salmon show a decline in escapements from recent highs in the Fraser River. Fall-runs have demonstrated considerable year-to-year fluctuation (between 100 and 200 thousand fish)

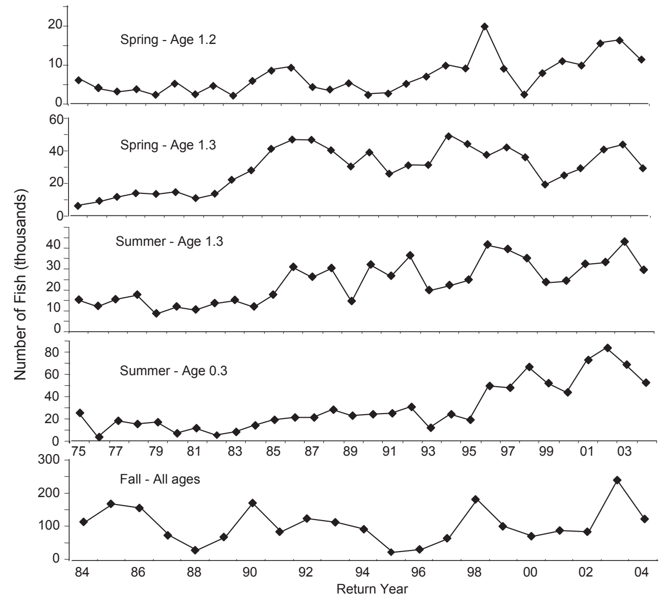

Fig. 8. Escapements of Fraser River Chinook salmon, Spring- and Summer-Run by life-history type,1975–2004, and Fall-Run, 1984–2004 (Anonymous 2005b).

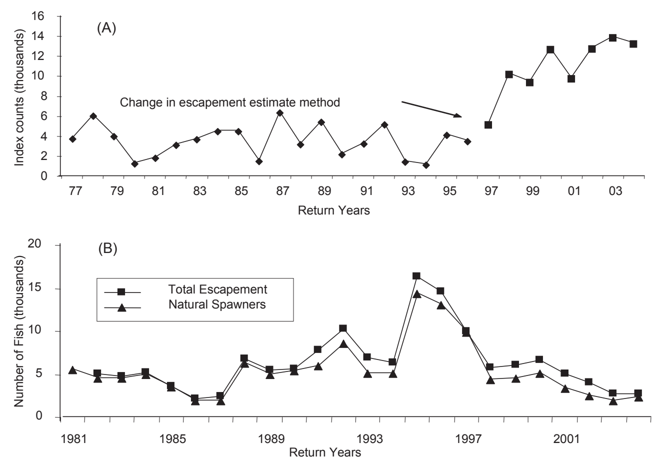

Fig. 9. Escapements of Fall-Run Chinook salmon in the Strait of Georgia: (A) an index of escapements for a group of stocks in the upper strait, 1977–2004; (B) escapement in the Cowichan River in the lower strait, 1981–2004 (Anonymous 2005b).

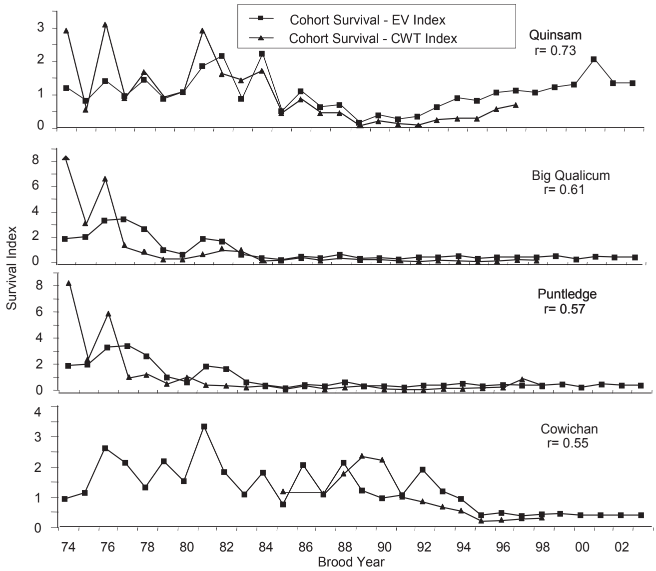

Fig. 10. Chinook salmon EV and CWT cohort survival indices for Strait of Georgia hatcheries, 1974–2003, including Quinsam Hatchery in the upper strait and Big Qualicum, Puntledge, and Cowichan Hatcheries in the lower strait. EV indices are scalers generated by the PSC coastwide Chinook salmon model which reflect annual variability in natural mortality in the initial year of ocean residence while CWT indices represent survival of CWT-marked releases to age two. Standardized EV scalers are plotted for complete and incomplete broods, while only completed brood values are plotted for CWT survivals; the r value is the correlation coefficient between the two indices, which indicates that the two generally track one another. Data from CTC files.

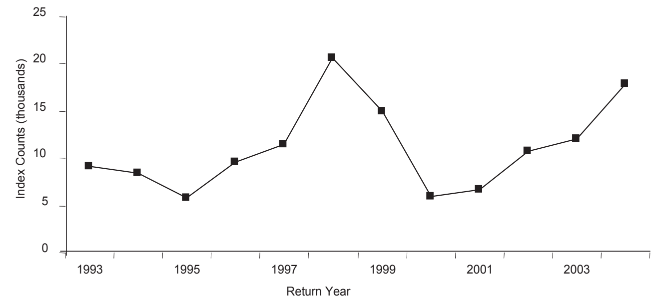

Fig. 11. Escapement index counts of Chinook salmon for 14 West Vancouver Island streams, 1993–2004 (Anonymous 2005b).

with no clear long-term trend (Fig. 8). The Harrison River stock, which comprises the vast majority of this stock group, represents one of the largest single Chinook salmon stocks in the Pacific Northwest.

Perhaps the most recent conservation concern in Canada is Chinook salmon in the Strait of Georgia. While CTC assessments indicate low abundance levels throughout the Strait of Georgia, there are discernable regional differences between the Upper Georgia Strait (UGS; relatively higher) and the Lower Georgia Strait (LGS; relatively lower), in population trends, and in survival rates (Anon. 2003b, 2004b). Generally difficult to enumerate, the UGS group consists largely of stocks heavily influenced by glacial runoff. While there is evidence that the UGS group has increased in abundance since the late 1990s, this observation may be confounded by a concurrent change in enumeration methodology for this stock group (Fig. 9A). The LGS stock group, however, has undergone continuous declines over the past decade. The stock group's status is primarily monitored via returns to the Cowichan River, which has traditionally been the largest single stock within the stock group. The Cowichan River is monitored for total escapement and natural spawners, because hatchery-origin fish may also spawn in the river. Escapements to the Cowichan have declined precipitously since the mid-1990s (Fig. 9B).

A difference in the status of Chinook salmon in UGS and LGS is also apparent in the survival trends of hatchery smolts released in the two regions. The survival rate for smolts released at Quinsam Hatchery in UGS is measured by coded wire tag (CWT) recoveries and an environmental variable (EV) scaler index generated by the PSC coast-wide model (Anon. 2004c); these measurements indicate an improving survival trend since the early 1990s (Fig. 10). In contrast, survival rates among three LGS hatchery stocks (Big Qualicum, Puntledge, and Cowichan) show considerable decline for both CWT and EV indices—in some cases, since the early 1980s—and have remained at these low levels ever since (Fig. 10). These comparisons illustrate a puzzling difference in the status of Chinook salmon in the two regions of the Strait of Georgia. Possible factors that could be contributing to the present condition include: overfishing by commercial and recreational fisheries, changes in the environment (Beamish et al. 2004), shifts in abundance, changes in predators' and competitors' behavior (Beamish and Neville 2000; Beamish et al. 2003), and differences in migration patterns.

One possible difference in survival patterns in the UGS and LGS areas could be the amount of time juvenile and immature Chinook salmon spend in the Strait of Georgia. According to Healey (1980) numerous juvenile, ocean-type Chinook salmon remain in the LGS throughout much of their first ocean year, and, judging from sport fishery catches, juveniles remain plentiful in the LGS during their second ocean year (Argue et al. 1983). However, CWT recovery information indicates that the majority of these fish are from the LGS. Furthermore, based on CWT recoveries of Quinsam-hatchery Chinook salmon, UGS stocks, unlike LGS stocks, are far-north-migrating and are generally intercepted outside the Georgia Strait, suggesting that some deleterious factors within the Strait of Georgia have led to population declines in the lower Strait of Georgia.

Beamish and Neville (2000) identified spiny dogfish and river lampreys as major predators of juvenile Chinook salmon in the Strait of Georgia. They estimated that 1.4 million spiny dogfish ate the equivalent of all 7.7 million juvenile Chinook and coho salmon released from local hatcheries

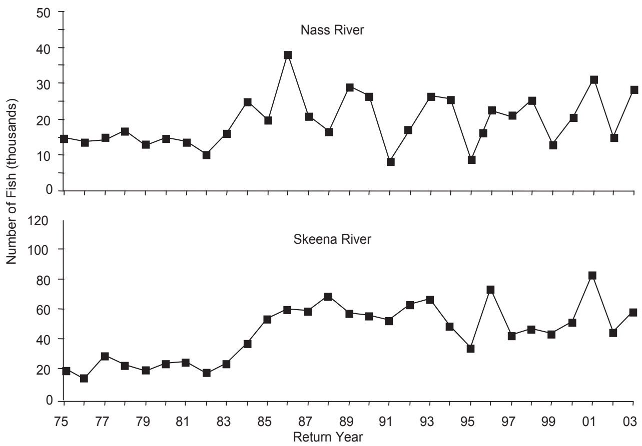

Fig. 12. Chinook salmon escapements for the Skeena and Nass rivers in northern British Columbia, 1975–2003 (Anonymous 2005b).

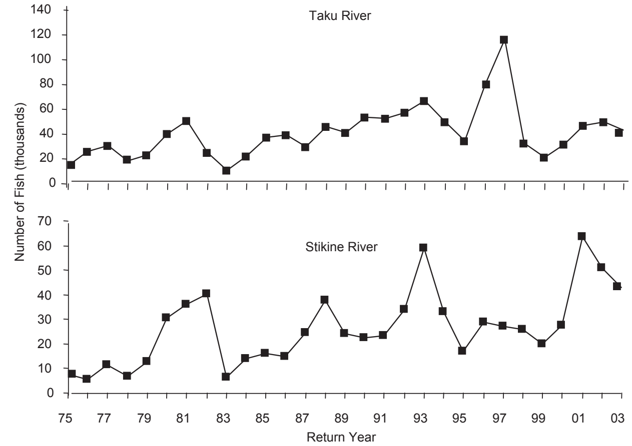

Fig. 13. Chinook salmon escapements for the Taku and Stikine rivers in southeastern Alaska, 1975–2003 (Anonymous 2005b).

in 1988, and that 3.0 to 3.9 million river lampreys killed 20 million and 18 million juvenile Chinook salmon in 1990 and 1991, respectively (Beamish and Neville 2000). Ford and Ellis (2005) found that fish-eating killer whales residing in the Strait of Georgia have a strong preference for Chinook salmon throughout much of the year, especially in the LGS. Ford and Ellis (2005) suggested that this preference for Chinook salmon could influence the year-round distribution patterns of resident killer whales within the Strait of Georgia. Selective predation is only one factor that may cause differences in the survival rates of LGS and UGS Chinook salmon stocks.

Another Chinook salmon stock group of conservation concern in British Columbia is found on the west coast of Vancouver Island. This group consists of several dozen small, coastal fall-run populations. A 14-stream index is used to monitor the abundance of this stock group (Anon. 2003b; 2004b). While this index shows modest increases in the last four years (Fig. 11), these populations are still of concern because several individual stocks in the group remain at very low levels.

In general, the abundance of Chinook salmon stocks in central and northern British Columbia has been relatively stable. This stability is illustrated by Nass and Skeena river returns, the two largest stock aggregates in northern British Columbia. While returns to the Nass have remained stable, those to the Skeena have improved since the signing of the PST (Fig. 12).

Alaska

In contrast to declining trends in Chinook salmon's abundance in WOIC and some areas in British Columbia, most salmon populations throughout Alaska are stable. Baker et al. (1996) identified 63 spawning aggregates of Chinook salmon in southeastern Alaska and, of the 31 groups with sufficient data for evaluation, they found only one that exhibited a declining escapement trend. Burger and Wertheimer (1995) and Wertheimer (1997) found that commercial harvests of Alaskan Chinook salmon have remained relatively stable over time when compared to harvests of other species. In southeastern Alaska, the Chinook salmon fishery is dominated by commercial trolling, and a large portion of the harvest in the region originates from more southerly, non-Alaska stocks. Harvesting of the region's Chinook salmon is regulated by catch limits and treaty oversight. Although Chinook salmon are the first to return to Alaska's rivers each year, commercial fisheries are normally allowed to target only those fish in terminal areas of a few river systems (Heard and Anderson 1999). After a lengthy period of fishery closures and stock rebuilding under PSC oversight, limited commercial gill-net fisheries were allowed in 2005 to target Chinook salmon returning to the Stikine and Taku rivers.

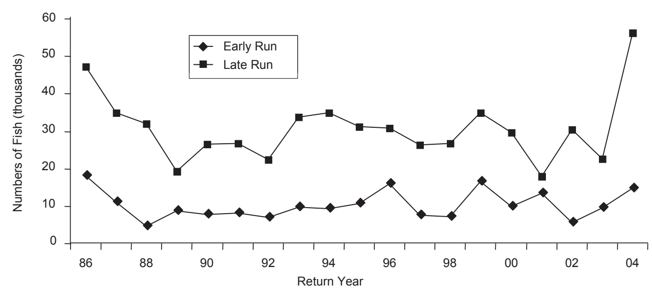

Fig. 14. Chinook salmon escapements for the Kenai River in south-central Alaska, 1986–2004. Data from ADF&G Sport Fish Division.

Escapement trends for stock groups in two of southeastern Alaska's largest drainages (Taku and Stikine rivers) show relatively stable patterns (Fig. 13). These trans-boundary rivers originate either in British Columbia or the Yukon Territory and fall under PSC oversight. In the Cook Inlet region of south-central Alaska, Kenai River Chinook salmon that support a major in-river sport fishery participate in early and late runs, spawning in upper and lower portions of the

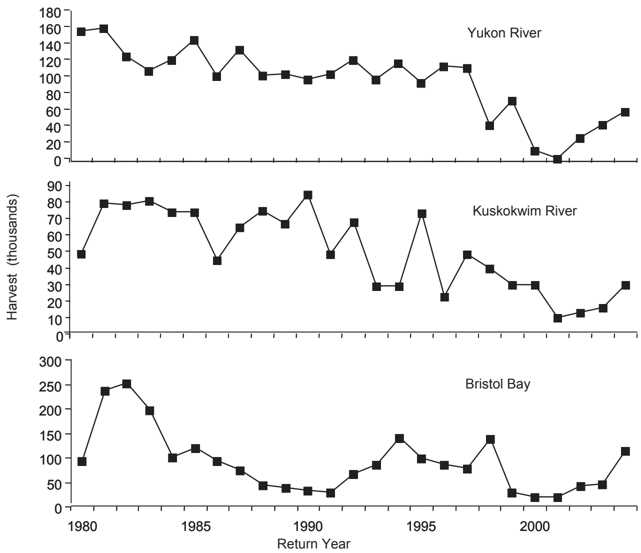

Fig. 15. Chinook harvest from Bristol Bay and from the Kuskokwim and Yukon rivers in western Alaska, 1980–2004. Data from ADF&G Commercial Fish Division.

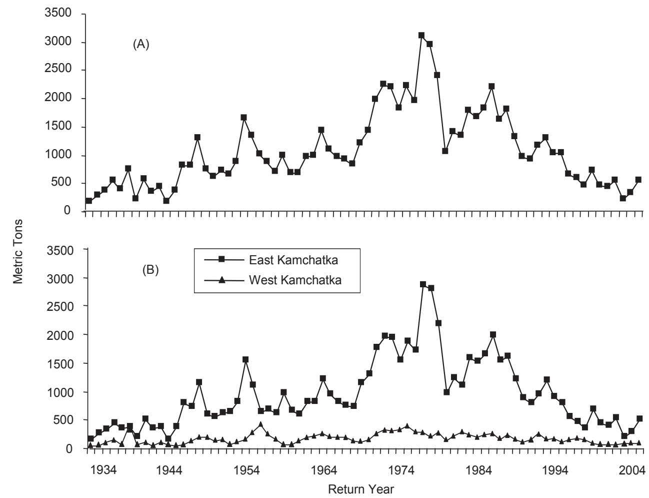

Fig. 16. Chinook salmon harvest from the Kamchatka Peninsula in Russia, 1934–2005: (A) total harvest; (B) harvest from east and west Kamchatka. Data from SakhNIRO.

drainage. Escapements to both run segments show relatively stable trends (Fig. 14).

Western Alaska represents the region in Alaska where there is most concern over trends in abundance of Chinook salmon. Long-term data sets on escapements in this region are somewhat spotty, therefore, harvest data are used to assess trends, although these data may not reflect true abundance trends. Harvest data from Bristol Bay, and the Kuskokwim and Yukon rivers all suggest declining abundance (Fig. 15). Although overall harvests in Bristol Bay show a downward trend, the commercial fishery mainly targets Nushugak River stocks that are still thought to be relatively healthy. Declining catches in both the Kuskokwim and Yukon rivers is a matter for concern for rural Alaskans living in these regions. Chinook salmon runs into the Yukon River, another transboundary river originating in Canada and managed under a separate treaty annex, were so low in 2001 that no commercial fishery was allowed. One area of concern regarding the present status of stocks in the Kuskokwim and Yukon rivers is the Chinook salmon by-catch made from these systems by groundfish trawl fisheries in the Bering Sea.

Russia

On the Asian side of the Pacific Rim, harvest data are also used to look at trends in abundance because precise escapement data is limited. Radchenko (1998) reviewed abundance trends in Russian Chinook salmon and reported that commercial catches had declined from a peak of 3,000 mt in the 1970s to 600 mt in the late 1990s. Commercial catches declined further to 200 mt by 2003 but have begun rebounding in the last two years to their current levels above 500 mt (Fig. 16). Although Chinook salmon fisheries are found on both the east and west coast of the Kamchatka Peninsula, 80–90% of Russia's total catch comes from eastern Kamchatka, and primarily from the Kamchatka River, whereas catches from western Kamchatka are mostly from the Bolshaya River. Radchenko (1998) suggested that there were several small, unexploited stocks in western Kamchatka that could increase the commercial catch up to 100 mt if exploited. In recent years, the total run—catch plus escapement—of Chinook salmon off both the east and west coasts of the Kamchatka Peninsula has been estimated by Shevlyakov to be at 170–190 thousand fish annually. Only in a few smaller rivers (Koly, Pymta, and Kikhchik) have adult escapements been at favorable levels in recent years. The major river systems (Kamchatka and Bolshaya) appear to have had inadequate escapements over the past decade due to intense fishing and increased in-river poaching.

The run timing of Chinook salmon returning to spawn in Russian rivers follows a late spring/summer-run pattern. In the Kamchatka River the commercial fishery begins operating shortly after the ice breaks up in May, and its operation peaks in June (Vronskiy 1972). Chinook salmon in the Kamchatka River also migrate in early and late runs. Some early-run fish may enter the river in spring before the ice is out. The run timing of the early run extends from late May to mid-June with spawning occurring from mid-June through August and peaking in late July to early August. Run timing of the late run extends from early July to late August with spawning occurring from mid-August to mid-September and peak spawning occurring in late August. Stream-type Chinook salmon are typical of populations in Asia although some under-yearling juveniles do migrate to sea from Kamchatka Peninsula rivers. However, adult returns for such stocks are extremely poor.

BIOLOGICAL CHARACTERISTICS

Chinook salmon are an extremely plastic species with the most diversified and complex life history among Pacific salmon. The species has many unique biological characteristics including highly evolved and diversified run timing (Waples et al. 2004) with adults entering rivers and spawning in almost every month of the year, exhibiting stream-type and ocean-type life-history forms with different freshwater and oceanic migration behavior patterns (Healey 1983), and some having both red- and white-fleshed forms (Godfrey 1975; Hard et al. 1989).

The coastal region of northern British Columbia and southeastern Alaska (54°–56°N) represents a transition area where populations with ocean-type life histories generally predominate to the south whereas stream-type life histories predominate to the north (Healey 1983). Upriver populations from longer trans-boundary rivers that penetrate the coastal mountain range in southeastern Alaska exhibit stream-type life histories in fresh water. These populations also display more extensive oceanic migration patterns characteristic of stream-type biology. Other populations of Chinook salmon from shorter rivers restricted to the coastal regions of southeastern Alaska also exhibit stream-type life history in fresh water (i.e. yearling smolts). In contrast, however, while at sea these coastal populations tend to exhibit an ocean-type life-history behavior by foregoing distant open oceanic migrations and instead remaining in coastal waters. Such transitional behavior in fresh water and marine life histories could result from a predisposition for ocean-type life history based on genetic origin modified by environmental constraints requiring extended freshwater rearing at higher latitudes. Guthrie and Wilmot (2004) speculated that cooler northern climates could cause this type of a life-history shift. Gharrett et al. (1987) suggested that, based on the intermediate genetic composition of Chinook salmon populations, the salmon in the region could have come from two different refuges in their post-glacial colonization. Based on current life-history behavior patterns, it seems likely that under such a scenario, coastal populations seaward of the coastal mountain range in southeastern Alaska arose from ancestral ocean-type parents, while longer-migrating, upriver populations (i.e. in the Taku, Stikine, and Alsek rivers) arose from stream-type parentage.

An important life-history characteristic in Chinook salmon is long-term change in size and age. Ricker (1980) pointed out that Chinook salmon had decreased in average size by 50% or more during the twentieth century. Potential contributing causes include the selective effects of fisheries, changes in oceanic environments, habitat loss, dams such as the Grand Coulee that eliminated entire runs of large fish, and the prevalence of contemporary hatchery production in many areas. According to Ricker (1980, 1981), fisheries—especially troll fisheries—which capture both immature and maturing fish, ultimately bring about a decrease in proportions of older, larger fish in spawning populations and an increase in younger, smaller fish. Ricker believes that declines resulted from a progressive deterioration of the genetic basis for maturation at older ages. A somewhat-related process may also be underway when hatchery-produced fish return at a reduced size per age and earlier in run-timing in comparison with naturally spawned fish. Increased maturation timing in hatchery fish is partly due to accelerated growth of juveniles in the hatchery environment (Larson et al. 2004). In some supplementation programs, however, hatchery males and females are returning not only earlier but also at smaller sizes than naturally-spawned fish in both Chinook salmon (Anon. 2004a; Pearsons et al. 2004), and in steelhead (Mackey et al. 2001).

In a later study Ricker (1995) noted that, by the early 1990s, declines in size of Chinook salmon catches (particularly 1951 through 1975) had been fully reversed or at least arrested in many but not all areas. Dramatic reversals were

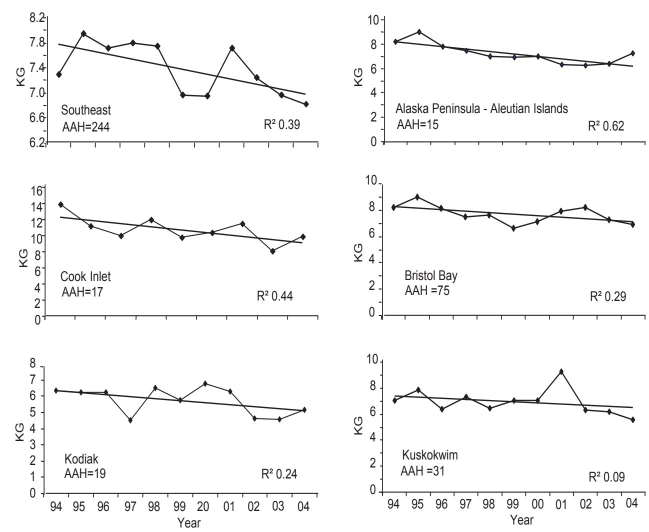

Fig. 17. Average weights of Chinook salmon caught in regional Alaska fisheries, 1994-2004. AAH is average annual harvest in thousands of fish for each region. R^2 values measure how well the regression line fits data in the trend line. Data from ADF&G Commercial Fish Division.

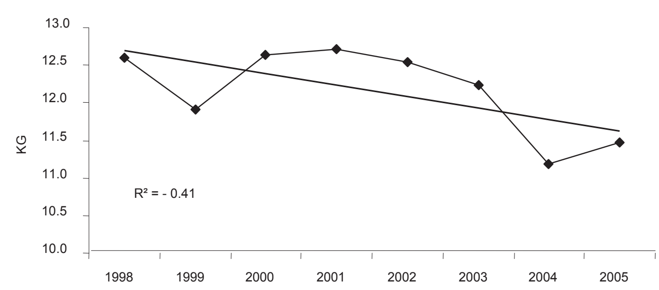

Fig. 18. Average weights of the 30 largest Chinook salmon caught in a May sport fishing derby near Juneau, Alaska, 1998–2005. R^2 measures how well the regression line fits data in the trend line. Data from Tlingit-Haida Central Council.

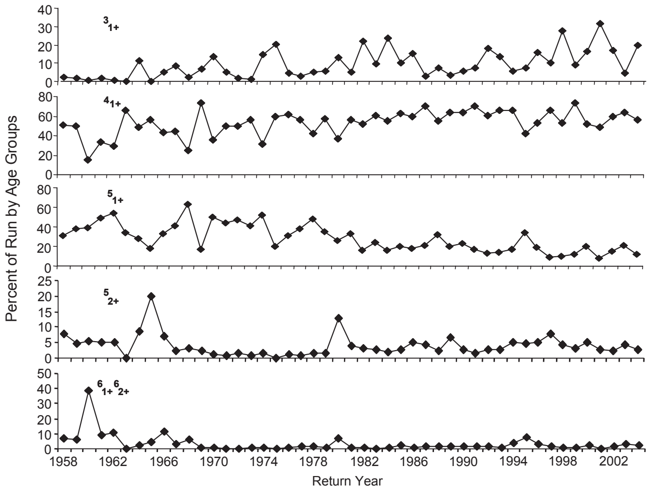

Fig. 19. Composition of Kamchatka River Chinook salmon by life-history types, 1958–2004. Data from KamchatNIRO.

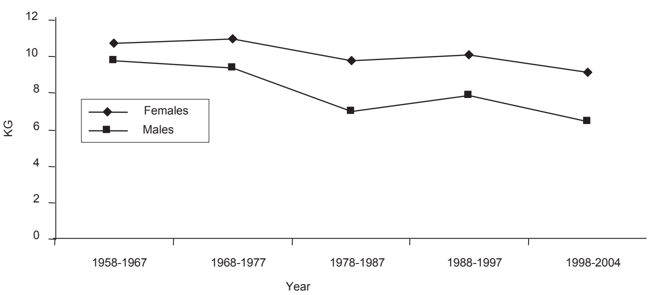

Fig. 20. Average weight of Kamchatka River Chinook salmon spawners by decade, 1958–2004. Data from KamchatNIRO.

evident in Canadian troll catches in Areas 1 and 5, but less so in Area 12. Dominated by troll fisheries, all Chinook salmon gear catches in southeastern Alaska showed similar improvements in size, whereas all gear catches in Puget Sound showed only minor improvement. Ricker expressed puzzlement over possible causes of these size reversals in certain areas. He indicated that changes in fishing regulations and minimum size limits are of special importance for troll fisheries since many Chinook salmon are caught while still growing rapidly, and he suggested that the factor or factors responsible for the size reversal might be apparent if age composition data were available (Ricker 1995).

Bigler et al. (1996) found that seven of nine individual or aggregate populations of Chinook salmon between 1975 and 1993 had decreased in average size. The increase in average size observed by two commercial troll fisheries in California and British Columbia may have been the result of changes in fishery regulations (e.g. size limits were increased in British Columbia's troll fisheries in 1987). The average weights of Chinook salmon in several Alaskan commercial fisheries from 1994 to 2004 continue to show declines (Fig. 17). A recreational fishery for Chinook salmon in the vicinity of Juneau, Alaska, primarily targets returning Taku River spawners during the month of May. The average size of the largest 30 fish caught from 1998 to 2005 show a declining trend (Fig. 18). From 1958 to 2004, the percentage of older Chinook salmon in the Kamchatka River has decreased while the percentage of younger fish has increased (Fig. 19). These dramatic changes in age structure are accompanied by modest decreases in the average size of returning fish, a trend that is more pronounced in males than females (Fig. 20).

CONCLUSIONS

The present population of Chinook salmon stocks from around the Pacific Rim varies considerably according to different geographic regions. For example, in the U.S. Pacific Northwest states of Washington, Oregon, Idaho, and California, where nine stock groups are currently listed by the ESA as threatened or endangered species, many wild stocks remain at or near record low levels. Other stocks in this area are already extinct due to a long list of contributing factors, including over-fishing; loss of spawning and rearing habitats; impediments to upstream or downstream migration due to river dams; watershed logging; water allocations for farming, mining and navigation; and generalized industrialization and urbanization throughout the region. Over time, recovery programs for some ESA-listed stock groups in the Sacramento and Columbia rivers are beginning to cause minor improvements.

While no Chinook salmon stocks are legally protected under the Canadian COSEWIC and SARA programs, some stocks in southern British Columbia, especially in the Lower Strait of Georgia and West Vancouver Island, are of special concern. The status of stocks in central and northern British Columbia are either stable or improving, due, in part, to conservation measures implemented since the PST was signed in 1985.

Chinook salmon stocks throughout most of Alaska are comparatively stable with the exception of stocks in the Kuskowim and Yukon rivers in the western part of the state. The by-catch of these stocks in Bering Sea groundfish trawl fisheries is an issue of concern. Stocks in the southeastern portion of Alaska have also benefited from PST conservation and managerial oversight.

As reflected by harvest trends, Russian stocks of Chinook salmon on the Kamchatka Peninsula have declined from 3000 mt in the 1970s to around 500 mt currently. Russia's two major river systems (Kamchatka and Bolshaya) appear to have had serious declines in escapement size over the past two decades due to intense fishing and in-river poaching.

Historically, hatcheries have played significant, and often controversial, roles in many Chinook salmon issues—especially in the U.S. Pacific Northwest and southern British Columbia. The use of hatcheries to mitigate anthropogenic-caused declines in wild stocks is now viewed as counter-productive to the long-term health and genetic diversity of salmon species. Nevertheless, many hatcheries today are implementing important changes in past practices and operate under more clearly defined objectives to help rebuild depressed wild runs or to help support certain fisheries. Hatcheries continue to play a major role in many important Chinook salmon populations and fisheries.

The selective harvesting of both immature and older, larger Chinook salmon in various fisheries, habitat loss, the extirpation of certain stocks of large fish, variable growth conditions in marine environments, some hatchery practices, and long-term environmental changes may all be interacting to cause significant long-term reductions in the average size and age of Chinook salmon .

Given the complex life history and plasticity exhibited by Chinook salmon, it is not surprising that this species may be responding to warming climatic conditions in Arctic environments by expanding its range into new regions, especially into the Beaufort Sea drainages of North America. Previous accounts of collections have been reported for the Mackenzie River (Mcleod and O'Neil 1983) and the Coppermine River (Hart 1973) in the Canadian Arctic. Other recent developments suggest that the species is also becoming more prevalent in Arctic regions of Alaska. These developments include recent catches of 20–25 adult Chinook salmon annually by subsistence fisheries in Elson Lagoon near Point Barrow (C. George, Dept. of Wildlife Mgmt., North Slope Borough, P.O. Box 69 Barrow, AK 99723, pers. comm.) and the collection of four adult Chinook in Ublutuoch River, a tributary stream near the mouth of the Coville River, AK, in 2004 (Moulton 2005).

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