Summer Chum Salmon in Hood Canal

Carrie K. Cook-Tabor

U.S. Fish and Wildlife Service
Western Washington Fishery Resource Office
Olympia, Washington

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ABSTRACT

Summer chum salmon (*Oncorhynchus keta*) returns to Hood Canal drainages have declined dramatically since 1968 and have reached critically low levels in recent years (1979-1993). Combined annual Hood Canal summer chum returns now constitute less than three percent of their former abundance. Of the 12 streams that have produced summer chum salmon in Hood Canal, only seven have had recent returns. This decline in abundance has prompted a petition to the National Marine Fisheries Service to list Hood Canal summer chum salmon as threatened or endangered and to designate critical habitat under the Endangered Species Act. Possible causes of the decline in abundance of summer chum salmon include: freshwater and estuarine habitat loss and degradation; overharvest in coho and chinook salmon terminal fisheries; overharvest in marine mixed stock fisheries; non-point pollution; hatchery fall chum interactions; estuarine predator-prey relations; and general changes in oceanic and estuarine conditions. Restoration efforts include the development of a memorandum of understanding between federal, state, and tribal fishery agencies on Hood Canal summer chum management, which is currently being written, and hatchery supplementation programs at Quilcene National Fish Hatchery and Lilliwaup Hatchery. Components of a recovery plan, outlining future research needs and fish hatchery guidelines, is proposed.

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GLOSSARY OF ACRONYMS

DNR	Washington Department of Natural Resource
DSHS	Department of Social and Health Services
EPA	Environmental Protection Agency
ESA	Endangered Species Act
GSI	Genetic Stock Identification
HCCC	Hood Canal Coordinating Council
MOU	Memorandum of Understanding
NMFS	National Marine Fisheries Service
PNPTC	Point No Point Treaty Council
Pro-salmon	Professional Resource Organization-Salmon
PSWQA	Puget Sound Water Quality Authority
PSCRBT	Puget Sound Cooperative River Basin Team
QNFH	Quilcene National Fish Hatchery
RSI	Remote Site Incubators
TFW	Timber Fish and Wildlife
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
UW	University of Washington
WDF	Washington Department of Fisheries
WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resource Inventory Area
WWFRO	Western Washington Fishery Resource Office

INTRODUCTION

Pacific salmonids (*Oncorhynchus* spp.) are an integral component of the Northwest, supporting industry, recreation and culture, but some stocks continuing existence is in jeopardy. Extensive losses in salmonid populations and habitats by hydropower, fishing, logging, mining, agriculture, pollution, and urban growth have occurred. Native salmon and steelhead considered extinct in California, Oregon, Idaho, Washington, and Nevada, include a minimum of 51 chinook salmon (*O. tshawytscha*), 15 coho salmon (*O. kisutch*), 9 sockeye salmon (*O. nerka*), 5 chum salmon (*O. keta*), 2 pink salmon (*O. gorbuscha*), 23 steelhead (*O. mykiss*), and 2 coastal cutthroat (*O. clarki*) stocks (Nehlsen et al. 1991). Two hundred and fourteen native naturally-spawning stocks were listed as at high or moderate risk of extinction or of special concern by the American Fisheries Society in 1991 (Nehlsen et al. 1991). Hood Canal summer chum salmon were included in the list of stocks at moderate risk of extinction by the American Fisheries Society and as "critical" in the 1992 Washington State Salmon and Steelhead Stock Inventory (WDF, 1993).

Summer chum salmon returns to Hood Canal drainages have declined dramatically since 1968 and have reached critically low levels in recent years (1979-1993). This decline in abundance has prompted a joint agency attempt, initiated in 1992, to protect and rebuild the summer chum returns. This low level of abundance also caused the Professional Resource Organization-Salmon (PRO-Salmon) and the Northwest chapter of Trout Unlimited to petition Hood Canal summer chum salmon as threatened or endangered and to designate critical habitat under the Endangered Species Act (ESA) (PRO-Salmon 1994).

The objectives of this report are: (1) to provide background information on the biology and historical numbers of summer chum salmon; (2) to provide the historical and current habitat information on the Hood Canal drainages supporting summer chum salmon runs; (3) to investigate the possible causes of the decline of these salmon runs; (4) to evaluate the listing probability of the Hood Canal stock under ESA; (5) to highlight the current summer chum program at Quilcene National Fish Hatchery (QNFH); and (6) to highlight the hatchery fall and summer chum interaction observation study done by U.S. Fish and Wildlife Service - Western Washington Fishery Resource Office (USFWS-WWFRO).

Historical Information

Hood Canal is an inland fjord of Puget Sound and is host to a number of anadromous salmonid species including chum salmon (*O. keta*), coho salmon (*O. kisutch*), chinook salmon (*O. tshawytscha*), coastal cutthroat trout (*O. clarki*), steelhead (*O. mykiss*), pink salmon (*O. gorbuscha*), Dolly Varden (*Salvelinus malma*), and some stray sockeye salmon (*O. nerka*) (Schreiner et al. 1977). Summer chum salmon have historically returned to atleast 12 streams within Hood Canal (Figure 1). Other Hood Canal drainages, such as Mission Creek and Skokomish River, may have also produced summer chum but escapements have been minimal or not well documented (M. Ereth, Skokomish Tribal Fisheries, N. Lampsakis, Point No Point, personal communication). Rivers on the eastern shore of Hood Canal (Big Beef, Dewatto, Tahuya, Union) have moderate gradients with low summer flows, while rivers on the western shore

(Hamma Hamma, Duckabush, Dosewallips) are steep, often with falls and cascades that limit anadromous fish migration. The Big and Little Quilcene Rivers also flow through rugged terrain, but have moderate gradients in their lower reaches.

Hood Canal summer run chum salmon differ from other local chum stocks genetically (Phelps et al., in press) and in Puget Sound marine migrational timing and escapement. They typically return earlier to Puget Sound terminal areas than other stocks (August to mid-September) (from Washington Department of Fisheries (WDF) commercial salmon harvest data (1968-1993)) and spawn earlier in lower reaches of the drainages. Most runs spawn between September 15 and October 20, with the exceptions of the Union River-origin summer chum salmon that spawn between August 15 and late September (Tynan 1992) and the Quilcene chum spawn timing of September 1 to early October (D. Zajac, USFWS-WWFRO, personal communication). In contrast, the earliest-timed fall chum salmon in Hood Canal return to spawning streams over a month later than the summer chum.

Summer chum salmon returns to Hood Canal drainages have declined dramatically since 1968 and have reached critically low levels in recent years (1989-1993). Combined annual Hood Canal summer chum returns now constitute less than three percent of their former abundance (Table 1; Figure 2). Prior to 1974, escapement information was gathered less often, therefor, estimates of former abundance may be slightly off. Of the 12 streams that have been known to produce summer chum salmon, only seven have had recent returns (Figure 3). Since 1988, Anderson and Big Beef Creeks have had no observed spawners and Dewatto River, Tahuya River, and John Creek have had no spawners observed since 1991 (Figure 4).

Chum Salmon Life History

Adult chum salmon commonly return to their natal streams at ages 3-5, and occasionally at age 2, to spawn from September through February. They typically spawn from the intertidal areas up to the lower 5 kilometers in Washington streams (Mason 1974) in water depths of < 1.3 m and in velocities of < 1 m/s (Caldwell and Caldwell 1987). It is suggested fall chum salmon favor the boundary between pools and riffles for spawning (Reiser and Bjornn 1979). After emerging from the redd, chum fry move into swift currents and rapidly emigrate at night from freshwater to shallow nearshore marine habitats where food is plentiful (Hoar 1951; Neave 1955; Parker 1971; Healey 1979). During their early marine migration, the main prey of Hood Canal juvenile chum (at 35 - 45 mm) are epibenthic crustaceans and eggs, insects, and zooplankton (Kaczynski et al. 1973; Feller and Kaczynski 1975; Schreiner et al. 1977). Chum salmon fry have been found to migrate offshore as they increase in size ($\geq$ 65 mm) and density (Bax 1983) and with spring runoff (Schreiner 1977). This offshore movement allows the now larger juveniles to exploit the abundant, larger neritic zooplankton consisting of gammarid amphipods, calanoid copepods, other macroinvertebrates, and fish larvae. It has been suggested that chum salmon fry migrate through Hood Canal in an average of 30 days (Salo et al. 1980).

POSSIBLE REASONS FOR DECLINE

Possible causes of the decline in abundance of summer chum salmon include freshwater and estuarine habitat loss and degradation, overharvest in coho and chinook salmon terminal fisheries, and overharvest in marine mixed stock fisheries (Nehlsen et al. 1991). Non-point pollution, hatchery fall chum interactions, estuarine predator-prey relations, and general changes in oceanic and estuarine conditions may also contribute to the decline in escapement.

Marine Mixed Fisheries

The overall magnitude of the impact of marine mixed stock fisheries on Hood Canal summer chum salmon is unknown. Millions of chum salmon are caught annually in Washington and British Columbia, with the majority taken in marine areas where different chum spawning populations are mixed (Graves 1989). Commercial troll and net fisheries in Canadian and U.S. waters, ranging from the Strait of Juan de Fuca to Admiralty Inlet, the Strait of Georgia, and the San Juan Islands, harvest summer chum incidentally in coho, chinook, sockeye, pink, and fall chum salmon directed fisheries (Tynan 1992; Pacific Salmon Commission Joint Technical Committee, 1994). Harvests estimates of Washington and Canadian summer chum in commercial fisheries in the San Juan Islands area fisheries have ranged from 62 in 1984 to 43,000 in 1976, with an average of 1,600 from 1990-1991. In 1992, the Washington State fall chum commercial fishery in the Strait of Juan de Fuca was delayed until October 18 (to minimize coho interceptions) and incidental summer chum catches totalled 127 fish (Pacific Salmon Commission Joint Technical Committee, 1994).

Incidental Harvest in Terminal Net Fisheries

In 1974, summer chum harvests, as incidental take in coho commercial net fisheries, began in Hood Canal. Hood Canal area management periods for summer/fall chinook and coho salmon overlap with summer chum return timing (Figure 5; Figure 6). Even though there is usually no allowable direct harvest of summer chum salmon, treaty and nontreaty commercial net fishers directed harvests towards summer chum in 1976 and 1977, when summer chum returns were extremely abundant (Figure 7). The fishery harvested an overall Hood Canal average of 57% of the summer chum from 1974 through 1991, with a peak harvest rate of 90% in 1987 (Figure 8). The cut off date used to determine if the chum salmon caught in the coho fishery are summer or fall chum salmon is highly disputed and WDF and PNPTC are trying to reach agreement and determine past harvest rates for individual management areas within Hood Canal. If fall chum salmon were indeed used in the determining summer chum salmon harvest rates in the coho fisheries, true harvest estimates may be quite different. Since 1991, the coho fishery has been severely restricted and harvest rates of summer chum salmon fell to 9% and 0.4% for 1992 and 1993, respectively.

Poaching

Illegal chum capture and retention have been observed in the Big Quilcene River, regardless of the presence of USFWS agency samplers or enforcement agents (WWFROb. 1992).

Marine Mammals

Harbor seals (*Phoca vitulina richardsi*) and California sea lions (*Zalophus californianus*) have been observed near river mouths in Hood Canal. Both of these marine mammals are opportunistic predators (Calambokidis et al. 1978; Everitt et al. 1981; Jeffries and Newby 1986). From February to May, 1993, California sea lions were observed in large numbers (22) for the first time off the Dosewallips River delta on floats placed there to entice harbor seals away from the shellfish beds. The sea lions were no longer present off the delta after June 1993 (Evenson and Calambokidis 1993). California sea lion populations have been increasing steadily and in other areas of Washington large numbers of California sea lions have quickly adopted a variety of structures, fed on returning adult salmonids, and have resisted removal (Steiger and Calambokidis 1986; Gearin et al. 1988). Future sea lion colonization of man-made floats and natural habitats within Hood Canal, and the possibility of increased predation upon adult returns, could pose a huge threat to the rehabilitation of summer chum salmon runs, but does not appear to be a negative factor thus far.

Harbor seals, historically found in Hood Canal, increased dramatically during the 1970s and early 1980s, less rapidly from 1984 to 1990, and have declined somewhat since 1990 (Calambokidis et al. 1985, 1988; Evenson and Calambokidis 1993). The average number of harbor seals at the Dosewallips State Park has been highest in the fall, coinciding with the summer chum return (Evenson and Calambokidis 1993). Harbor seals have been observed eating adult salmonids in Quilcene Bay and at the mouth of the Dosewallips, Duckabush, and Hamma Hamma Rivers (Calambokidis, Cascadia Research Collective, personal communication). Brown and Mate (1983) found that up to 7.2% of the total hatchery chum salmon in Whiskey Creek, Oregon was consumed by harbor seals. Knudsen et al. (1990) observed the feeding behavior of harbor seals in Quilcene Bay and was unable to rule out the possibility that seals were not consuming chinook salmon smolts.

Freshwater Habitat

Changes in the freshwater habitat of Hood Canal include diverted stream flow, instream and riparian habitat degradation, loss of instream spawning habitat, diminished water quality, increased stream temperature, and increased stormwater runoff. Increased stormwater runoff, due to forest practices (loss of vegetative ground cover) and urbanization (culverts, ditches, and impervious surfaces), has been a major factor in the degradation of Hood Canal drainages' water quality (Lucchetti and Furstenberg 1992; Puget Sound Cooperative River Basin Team (PSCRBT) 1992, 1993).

The majority of the Hood Canal watershed is forested and most of the land west of the canal is owned and managed by the U.S. Forest Service, the National Park Service, or Washington State Department of Natural Resources (DNR) (PSCRBT 1993). On the east side of Hood Canal, DNR manages state timberlands and landowners hold the majority of the remaining forest lands. Large private timberland holdings and Indian reservations are also found in the watershed. Hood Canal forested lands have been intensely harvested for over 100 years (Hood Canal Coordinating Council (HCCC) 1994). Forest management practices impact water quality and salmon production by increasing the siltation and sedimentation of redds, increasing stormwater runoff, shifting prey bases by shifting terrestrial plant life, and by increasing stream temperatures (Hall and Lantz 1969; Burns 1972; Moring and Lantz 1974; Beschta 1978; Reiser and Bjornn 1979; Bottom et al. 1985). The Tahuya River and other Kitsap Peninsula rivers, being low elevation streams orientated to full sun exposure and having higher base water temperatures, are more susceptible to timber harvesting effects (HCCC 1994).

Farming is also prevalent in the Hood Canal basin. In the northern Hood Canal watershed two-thirds of the farms are rated as having a moderate to high potential to impact water quality (HCCC 1994). Farming activity on Big Beef Creek, Tahuya River, and Union River has probably impacted water quality by bacterial contamination, nutrient loading, and sedimentation.

Habitat surveys of portions of the twelve Hood Canal summer chum salmon streams have been accomplished or are currently underway (Figure 9) (Tabor and Knudsen 1993). The types of stream surveys include USFS stream inventories, Timber Fish and Wildlife (TFW) ambient monitoring, coho supplementation surveys, and WDF physical habitat surveys. Habitat information of individual streams surveyed is summarized below (Williams et al. 1975; Tabor and Knudsen 1993; Pro-Salmon 1994).

Anderson Creek

Anderson Creek (Water Resource Inventory Area (WRIA) 15.0412) is 6.2 km long and summer chum utilize the lower 1.8 km. Land use is predominantly second growth forest, with residential homes in the lower 1.6 km. This creek is currently being surveyed by USFWS-WWFRO (TFW ambient monitoring) and some results of the survey are listed in Table 2. Anderson Creek appears to be fairly healthy in the lower mainstem. Residential and agricultural uses in this portion of the river are minimal, mature timber is the dominant streamside vegetation, and the preferred-sized spawning gravel for chum salmon is abundant (7-76 mm (Hale et al. 1985; Caldwell and Caldwell 1987)).

Possible problems noted in the TFW survey include: 1) a high percentage of the lower 907 m has substrate under 5 mm in diameter (47.5%); and 2) proliferation of beaver dams near the creek's mouth. As mentioned earlier, egg-to-fry survival decreases as fines in the redds increase. Five beaver dams are currently located in the lower 2 km and may become a problem if they remain throughout the summer chum spawning season (Figure 10). In 1993, it is possible fall chum salmon would have had trouble navigating past a large beaver dam at the mouth of the creek (R. Tabor, USFWS-WWFRO, personal communication).

Big Beef Creek

Big Beef Creek (WRIA 15.0389) is 16.1 km long, is dammed 8.5 km upstream, and has a moderate gradient in the lower reach. Summer chum salmon have been found to spawn in the lower 8 km of the river. Land use includes second growth forest, a fisheries research station near the mouth, and residential home development, which is particularly dense near Lake Symington. Point No Point Treaty Council (PNPTC) conducted TFW ambient monitoring surveys in 1993 from the mouth to 13.8 km upstream.

Big Quilcene River

The Big Quilcene River (WRIA 17.0012) is 30.4 km long and is accessible to anadromous salmonids for approximately 12.2 km. No tributaries to this river are accessible to salmonids. A dam at river km 12.3 diverts water to the City of Port Townsend and a paper mill. The diversion causes diminished flows in the lower stream reaches during September and early October. The QNFH is located at the mouth of Penny Creek (WRIA 17.0014) at river km 4.5. A hatchery electric fish barrier blocks anadromous salmonids from April to January. Gradients are steep in the upper watershed where extensive logging has taken place. The gradient becomes moderate in the lower 4.8 km and summer chum salmon have been known to spawn in the lower 4.4 km. Other land uses include farming, ranching, second growth forests, and residences. The town of Quilcene is located near the river mouth.

Big Quilcene River was diked prior to 1970 between river km 3.2 and 4, resulting in scouring and loss of spawning gravel, and has been channelized recently within the lower kilometer. In the late 1970s a 100 meter log jam was removed in summer chum spawning area under permit. In 1991 over 600 meters of dike construction and channel excavation legally took place subsequent to dewatering of the summer chum spawning reach resulting from streambed agradation. The latest channelization took place illegally in 1993, when dike reconstruction and channel work were performed on over 500 meters of the chum spawning reach, destroying 29 percent of the summer chum salmon redds (D. Zajac, personal communication).

The U.S. Forest Service (USFS) has surveyed the majority of the Big Quilcene River and its tributaries and a TFW ambient monitoring survey was conducted on lower Tunnel Creek (WRIA 17.0034), a tributary.

Dewatto River

The Dewatto River (WRIA 15.0421) is 14 km long with a moderate gradient and good habitat for chum salmon in the lower 5.6 km. Summer chum salmon have been found to spawn in the lower 3.2 km of the river. Above this is a series of beaver dams. Land use is predominantly second growth forest, Christmas tree farms, and residences. The USFWS-WWFRO surveyed the river for possible coho supplementation in 1992 and PNPTC is currently surveying the lower 11.7 km of this river (TFW ambient monitoring).

Dosewallips River

The Dosewallips River (WRIA 16.0442) is 45.5 km long, with 167.4 km of tributaries that are mostly inaccessible to salmon. The upper watershed is located in the Olympic National Park and is very steep and rugged. A cascade at river km 22.5 may limit anadromous salmonid accessibility in low flows. The middle portion of the watershed lies in the Olympic National Forest and is periodically logged. The river remains in a steep-walled valley until it reaches the mouth. Summer chum salmon spawn in the lower 7.2 km of the river. Prior to 1970 the river was diked within the summer chum spawning areas, causing loss of habitat. Watershed land use includes second growth forest, recreational camp sites along 25.7 km of the mainstem, small farms, residences, and the Dosewallips State Park on the south bank of the mouth.

The town of Brinnon is located to the north of the river mouth. A USFS stream inventory habitat survey has been done on Rocky Brook (WRIA 16.0449), a tributary at river km 6. No habitat surveys are scheduled for the mainstem.

Walcott Slough, located just north of the Dosewallips River mouth, is short, spring fed, and flows through tidal marshes. This was the historical release and recapture site for QNFH fall chum salmon. However, the program was transferred entirely to QNFH recently.

Duckabush River

The Duckabush River (WRIA 16.0351) is 38.8 km long with numerous short and steep tributaries totalling 55 km. The upper watershed, like the Dosewallips River, lies deep in the Olympic National Park, has been minimally logged, and experiences seasonal recreational usage. The lower 5.6 km is accessible to salmon and summer chum have been observed spawning in the lower 3.7 km. A dike was constructed on the river prior to 1970 within the summer chum spawning reach, disrupting marine migration pathways and causing the loss of intertidal sloughs and nearshore shallow water habitat. Riprap bank protection projects on the river have channelized the lower chum spawning reaches, making them less stable and productive. Rural homes and dense recreational homesite development are found in the lower 6.4 km. Residences have impacted riparian vegetation in the lower 0.8 km. From 1911 to 1942 a federal fish hatchery operated on the Duckabush River, producing chum salmon. A coho supplementation habitat survey was conducted on mainstem reaches at river km 0.3 to 3.7 and 7.1 to 10.1. No other habitat surveys are scheduled.

Hamma Hamma River and John Creek

The Hamma Hamma River (WRIA 16.0251) is 28.6 km long with extensive tributaries, including John Creek (WRIA 16.0253), totalling 149.7 km. The headwaters lie in the rugged Olympic National Forest. A series of cascades and falls block anadromous salmonids 3.2 km above the mouth. The river below this point, of moderate-to-low gradient, is very productive. The Hamma Hamma River watershed land uses include past heavy logging and present selective logging in the lower 16 km, recreational usage, rural homes, and a farm near the river mouth. John Creek enters the Hamma Hamma River at river km 2.3 and experiences low summer flows and heavy winter floods from flash runoffs in the headwaters. John Creek is accessible to summer chum salmon in the moderately graded lower 2.9 km. In 1974 a project was completed to improve spawning gravel quality for chum salmon. No habitat surveys are scheduled for either watershed.

Lilliwaup Creek

Lilliwaup Creek (WRIA 16.0230) is 11.1 km long with 10 km of tributaries. The upper watershed was heavily logged in the past and is selectively logged at present. The town of Lilliwaup is located at the mouth of the creek and summer chum salmon accessibility ends at a large falls 1.1 km upstream from there. No habitat surveys are scheduled for Lilliwaup Creek.

Little Quilcene River

The Little Quilcene River (WRIA 17.0076) is 19.6 km long, with roughly half of the watershed residing in extensively logged areas of the Olympic National Forest. River gradient is steep in the upper watershed, becomes moderate in the lower 11.3 km, and flattens out in the lower 4.8 km. Land use includes second growth forest, camping facilities, farms, and numerous residences. The town of Quilcene is also near the mouth of the river. The Little Quilcene River is accessible to salmonids up to river km 10.6 and summer chum salmon have been found to use the lower 1.6 km. The Little Quilcene River is dammed at river km 11.4, is channelized within the lower 1.4 km, and experiences seasonal low flows and flooding. Water is diverted to the City of Port Townsend and a paper mill, reducing flows in the lower reaches in September and early October in low water years. Habitat surveys of the river include TFW ambient monitoring on the lower 8 river km and Howe Creek (WRIA 17.0090), USFS stream inventory above river km 8, and a coho supplementation survey on the lower 1.6 km of Ripley Creek (WRIA 17.0089).

Tahuya River

The Tahuya River (WRIA 15.0446) is 34 km long, has a moderate gradient, and is the largest stream draining the Kitsap Peninsula. Summer chum salmon spawn in the lower 4.8 km of the river. Land use includes second growth timber, Christmas tree farms, residences, and small farms. A commercial horse breeding and training facility on the Tahuya River floodplain has changed flooding patterns and has damaged riparian vegetation. PNPTC is currently surveying the river (TFW ambient monitoring).

Union River

The Union River (WRIA 15.0503) is 15.6 km long with a moderate gradient in the lower 10.8 km. Summer chum salmon spawn in the lower 10.8 km of the river. Physical habitat surveys and TFW ambient monitoring have been conducted on Courtney Creek (WRIA 15.0505) and Bear Creek (WRIA 15.0510) by WDF and PNPTC. Land use in the lower reaches is predominantly residential (City of Belfair) and farming. A diversion dam is located 10.9 km upstream of the mouth. The lower 10.3 river km and unsurveyed tributaries will be surveyed in 1994 by USFWS-WWFRO (TFW ambient monitoring).

Early Marine Environment

Chum salmon early marine life history is a critical period (Peterman 1978; Gallagher 1979; Salo et al. 1980). Marine conditions during early chum migration are believed to be important to overall growth and survival (Wickett 1958). Wide variations in growth and survival during early marine migration in Hood Canal have been seen. Bax et al. (1978) estimated considerable growth (30%) of hatchery fry in the first few weeks following release into Hood Canal. Salo et al. (1980) estimated 29% to 44% mortality of hatchery juvenile fall chum salmon in the first two days after release from Big Beef Creek in 1978 and 1979. Bax (1983) estimated 31% to 46% average daily mortality of hatchery-released juvenile chum salmon over four days.

Nearshore Estuarine Habitat

Hood Canal shorelines are classified as "Shorelines of Statewide Significance" under the 1972 Shoreline Management Act (SMA) Guidelines, and are to be protected for existing and future beneficial uses (SMA 1972). Chum salmon fry require nearshore habitats and environmental conditions conducive to rapid growth (Parker 1971; Healey 1979) and immediately begin feeding in the marine environment (Simenstad and Salo 1980). Bax et al. (1978) determined the abundance of chum fry was positively correlated with the size of shallow nearshore zones, and sublittoral eelgrass beds have been considered to be the principal habitat utilized by the smaller (<60 mm) juvenile chum salmon in Hood Canal (Simenstad et al. 1980). Construction, channelization, and other human actions along the shoreline degrade and destroy kelp and eelgrass beds, salt marshes, mud flats, and other nearshore habitats. Marine shoreline bulkheading has also reduced nearshore shallow habitat and riparian vegetation along Hood Canal. It is believed the size of Puget Sound vegetative nearshore estuarine habitats has declined enormously in the past 100 years (Puget Sound Water Quality Authority (PSWQA) 1991) and this loss may be contributing to the decline of summer chum.

A Coastal Zone Atlas, which includes maps of eelgrass for the majority of Hood Canal, was prepared in 1979 by the Washington State Department of Ecology. However, eelgrass at or near the mouth of the Skokomish River was not mapped because Indian reservations were excluded from this project. Infra-red photos were taken and data were confirmed by field surveys. DNR is currently monitoring nearshore environments, but has yet to complete a survey of Hood Canal (T. Mumford, DNR, personal communication). DNR and the Environmental Protection Agency's (EPA) Environmental Monitoring Systems Laboratory surveyed the type and areal extent of Puget Sound's nearshore habitats in 1992 using remote-sensing imagery, but these images have yet to be ground-truthed. Once the results of this survey are available, it will be important to determine to what extent eelgrass distribution and abundance have changed.

Marine Pollution

Pollutants, including high observed counts of fecal coliform bacteria, PCB's, Dieldrin, acids, metals, and organics (such as excess nitrogen from fertilizers), are found in Hood Canal. Pollution sources within the canal include failing on-site septic systems, contaminated storm water runoff, agricultural runoff, boats, and harbor seal fecal contamination. Hood Canal, a relatively narrow bay with a shallow sill near its entrance, is sensitive to pollution and many areas within the canal have violated federal water quality standards established by the EPA (Figure 11).

Hood Canal has also shown signs of eutrophication. The water circulation in this semi-closed canal is limited, causing waters to stratify. Nutrients and organic matter (sewage, pulp waste, farm animal waste) are not flushed out to sea quickly, creating conditions that, with stratification, help lead to algal blooms and depleted oxygen levels (≤ 7 mg/l) throughout much of Hood Canal (University of Washington (UW) 1954; Janzen and Eisner 1993; PSWQA 1993). In water-year 1992 one algal bloom or more per month occurred from February to October in South Hood Canal, and in April, May, and October in North Hood Canal (Janzen and Eisner 1993). At nearly all of the Hood Canal Puget Sound

Ambient Monitoring sites, oxygen depletion is a chronic problem (PSWQA 1993). Up until recent years, low dissolved oxygen problems have occurred in August and September, the months when summer chum are in their spawning migration, and fish kills (mostly perch) have occurred in the Tahuya area. Low dissolved oxygen levels have been found to reduce adult chum salmon swimming abilities and predator avoidance responses (Davis 1975).

Human and animal fecal contamination remains a problem throughout Hood Canal (HCCC 1994). Shifts in benthic and epibenthic phytoplankton and zooplankton species (prey of chum salmon fry) and abundance have been seen in fecal-contaminated areas (PSWQA 1993). Poorly drained soils, a high seasonal water table, failing or substandard systems, lack of monitoring systems, and poor regulatory responses to failures make on-site septic systems problematic throughout Hood Canal. Unfortunately, nearly all permanent and seasonal residences and businesses in the region have on-site septic systems for sewage disposal. Lynch Cove, Quilcene Bay, and Duckabush and Dosewallips deltas have experienced shellfish harvest closures within the last 10 years due to fecal coliform bacteria (due to harbor seals and/or septic systems) (Figure 12).

Consistently high levels of fecal coliform bacteria (>30 organisms/100g of shellfish) found in estuarine water and shellfish in Dosewallips State Park over the last three years have largely been due to harbor seals (Calambokidis et al. 1989; PSWQA 1993). Harbor seals inhabiting the Duckabush River delta have also contributed to the bacterial contamination found there (Calambokidis and McLaughlin 1987, 1988; Department of Social and Health Services (DSHS) 1988).

Prior to 1992, the large population of harbor seals hauling out in the Dosewallips River's sloughs and tidal flats dispersed feces upon reentering the water. Much has been done to try and lure these seals away from the sloughs and tidal flats of the river (Calambokidis et al. 1990; PSWQA 1993). In 1992, the State Parks and Recreation Department installed a fence to prevent seals from hauling out on a portion of the Dosewallips delta near shellfish beds, and water quality within the exclusion fence has improved (PSWQA 1993). Whether fecal contamination has had an important impact on Hood Canal summer chum is an interesting question. Summer chum, appearing to require nearshore marine habitats and environmental conditions conducive to rapid growth (primarily an abundance of select and preferred prey organisms) (Neave 1955), may indeed be affected if shifts in zooplankton to lesser desirable food organisms occur in these areas of fecal contamination. More work needs to be done to address this possible cause of summer chum salmon decline.

Salmonid Interactions

Fall chum salmon hatchery propagation began in the state of Washington in 1913 to increase harvest and rebuild declining populations (Washington Department of Fish and Wildlife (WDFW), hatchery records). Salmonids are currently reared in 7 Hood Canal hatcheries and have historically been released from nine sites (Figure 13). Other artificial propagation ventures in Hood Canal include remote site incubators (RSI), and coho and fall chinook salmon net pen rearing. An Equilibrium Brood Program was developed for the Hood Canal Management Plan (1989) and target production and release levels (±10%) are listed in Table 3. Since the implementation of the original plan in 1987, the average hatchery chum fry production has remained at or just below the target level of 39.7 million fry. All six Hood Canal hatcheries, including Hood Canal, George Adams, McKernan, Little Boston, Enetai, and Quilcene hatcheries produce fall chum salmon. Quilcene National Fish Hatchery and Lilliwaup Hatchery currently propagate summer chum salmon in an effort to stem the decline of Hood Canal summer chum salmon.

Hood Canal fall chum salmon hatchery production increased from a mean of 12.7 million in the 1970s to 39.6 million in the 1980s, and 31.1 million from 1990 to date (Figure 14). With this increased production, fed fry have been released earlier in the spring and at smaller sizes than was common in the 1970s (Figure 15)(Kane 1994). These fed fry released would have been slightly larger than naturally produced summer chum and young salmon at a smaller size are generally less able to avoid predators, obtain food, and defend a territory (Parker 1971). It is suggested that the time and size at which fry leave the estuarine environment is also important in determining mortality in the subsequent coastal phase (Kayev 1981). Other studies suggest that the larger or faster-growing fry have higher survival rates during the early oceanic life history phase (Peterman 1987; Holtby et al. 1990). Southern Hood Canal hatcheries also began releasing unfed fall chum fry in Hood Canal streams in the 1980s.

In the springs of 1993 and 1994 the USFWS-WWFRO initiated weekly post-hatchery release surveys of juvenile chum relative abundance in Quilcene Bay (WWFRO 1994). In 1993 chum abundance was highest in April. The large numbers of fry (larger fry in large schools) observed throughout April in Quilcene Bay were consistent with the release of 30.2 million fall chum fed-fry between March 15 and April 20 from southern Hood Canal hatcheries. Surveyors hypothesize that small groups of fry seen in March and April, 1994, represented naturally produced fish emigrating in smaller groups than hatchery releases. Indirect or direct competition between hatchery produced fall chum and naturally produced summer chum is likely. It is possible the higher densities of small-sized hatchery released juveniles over-exploit the zooplankton population, thus limiting the foraging success of juvenile summer chum salmon in Hood Canal.

With 30.8 million hatchery fall chum fry released, on average, into Hood Canal since 1974 and the naturally spawned summer and fall chum produced in the canal, has the carrying capacity (in time or space) of Hood Canal been met or exceeded? One way of estimating carrying capacity is to examine the interaction of prey abundance, chum fry abundance, and chum fry outmigration rates. Juvenile chum salmon migration and habitat selection in Hood Canal have been found to be directly related to availability of preferred prey organisms (Simenstad and Salo 1980) and juvenile chum abundance (Bax 1983). Chum salmon have been found to associate with shallow nearshore waters and benthic prey until they reach approximately 65 mm in length, at which time they move into deeper waters and feed on benthic and planktonic prey (Simenstad et al. 1980; Healey 1982). It is believed the majority of west shore Hood Canal fall chum salmon fry migrate to the east shore before leaving the canal (Bax et al. 1977; Schreiner 1977).

Simenstad and Salo (1980) estimated a surplus carrying capacity (above the hatchery and naturally spawned fry of 1979), to provide optimum foraging, of 0.03 - 0.65 fish/m^2 biweekly in shallow, sublittoral habitats and 0.01 - 0.07 fish/m^2 in neritic habitats during peak zooplankton production. These estimates translate to a surplus carrying capacity of ½ to 1 million epibenthic feeding fry (≤ 65mm FL) biweekly in nearshore waters and 7 million in offshore waters. Thirty-nine million fall chum fry were released in Hood Canal in 1979, over 40 million in 1982, 1985, and 1986, and 62 million were released in 1984 (Figure 14). If these estimates are accurate, and the natural production and carrying capacity were similar from 1979 to 1986, (which may be too large of an assumption) Hood Canal may have indeed been overplanted with hatchery chum salmon fry, resulting in deleterious effects on the naturally spawned fall and summer chum salmon stocks.

There is currently little data, current or dated, available regarding the possible hatchery fall chum-natural summer chum interaction in Hood Canal. The USFWS-WWFRO is currently working to determine the possible interactions, by reviewing available data and collecting fry migrational timing and overlap, diet overlap, prey base, growth data, and others.

Oceanic Conditions

El Niño events in the last century, particularly the El Niño of 1982-83, coincide with abnormally low abundances of some salmon stocks (Pearcy 1992). In 1957 and 1958, during an El Niño, the average weight of coho salmon and the number of adult ocean landings were abnormally low (Wooster and Fluharty 1985). During El Niños, winds are greatly reduced, upwelling is ineffective in replenishing nutrients in the upper layers along the West Coast, and primary productivity remains low (Pearcy and Schoener 1987). Species abundance and distribution changes are also seen during El Niños. During weak upwelling years, salmon smolts are confined to upwelled water in a narrow nearshore zone where fewer prey are available to fish, bird and mammal predators (Pearcy 1992). Coho salmon abundance and survival have been positively correlated with strong upwelling years. The number of coho salmon that returned south of Willapa Bay in 1983 was 42% less than expected based on jacks returning the previous year (Fisher and Pearcy 1988). Chinook salmon returns to many Oregon and California streams were also greatly reduced that year. In 1985, 3 years following the largest warming event along the west coast of North America in this century, the waning Hood Canal summer chum escapement sharply declined (Table 1, Figure 2). We are currently experiencing an El Niño event and this occurrence and past ocean warming events may have pushed these depressed stocks, and in some cases particular broodyear cycles, to levels from which they have yet been unable to successfully rebuild.

RESTORATION EFFORTS

In 1993, the Washington Department of Fish and Wildlife and the Western Washington Treaty Indian Tribes began a process to develop the Washington State Salmon and Steelhead Wild Stock Restoration Initiative. The Initiative's goal is "to maintain and restore healthy wild salmon and steelhead stocks and their habitats in order to support the region's fisheries, economies, and other societal values" (WDF et al. 1993). In support of this goal, in 1992, prior to the return of Big Quilcene River summer chum, the USFWS-WWFRO, WDF, and PNPTC agreed to establish and implement management actions directed at protecting Quilcene Bay summer chum salmon (WWFROa. 1992). These actions included modifying gear and limiting areas open for coho fisheries to reduce incidental take of summer chum salmon and supplementing natural spawning with an enhancement program at QNFH. Releases were tagged to determine the success of supplementation, the genetic integrity of the stock, and the timing and distribution of the stock. A supplementation program on the Lilliwaup River also began in 1992.

The joint interim agreement regarding the run restoration program at QNFH includes the following objectives and provisions: (1) the summer chum program would attempt to rebuild the run(s) from the existing low level while preserving its genetic character; (2) the program would continue through at least three generations to succeed (12 years); (3) brood stock would be captured from the natural stock in the Big Quilcene River and in Quilcene Bay; (4) returning hatchery releases would be allowed to spawn in the river; (5) all brood stock would be sampled for GSI, scales, other biological characters, and for disease assessment; (6) the egg bank goal would be 400,000; (7) resulting hatchery fry would be released into the Big Quilcene River.

A memorandum of understanding (MOU) between PNPTC, WDFW, and the USFWS on Hood Canal summer chum management is currently being written. The parties have agreed to develop plans (interim and long term) by June 30, 1995. The plans will include escapement goals, harvest management restrictions, supplementation strategies, and tasks. Actions not currently mentioned in the proposed summer chum salmon MOU that should also be considered in the recovery plan are listed in Appendix A.

Quilcene National Fish Hatchery

Summer chum salmon were first reared at QNFH from 1912 to 1937. During this time broodstock were removed from various rivers in Hood Canal, raised at QNFH, and released into Quilcene River or elsewhere (QNFH log book). The Duckabush River (Station) Hatchery also raised summer chum salmon from 1911 to 1942, when the hatchery was closed. Stock transfers noted on the QNFH log book are listed in Table 4. The QNFH summer chum salmon program was terminated in 1938 when the lower Quilcene River was "modified" (as noted in the log book: the fish could no longer make it back to the hatchery, and Hood Canal summer chum runs were considered to be in generally good condition).

In 1992, as mentioned earlier, a new summer chum restoration program began at the QNFH to increase the number of returns to Quilcene Bay. Approximately one-half of the last 3 year's return to the Big Quilcene River was captured and spawned in the hatchery (Table 5). A total of 216,441 fed fry were released in April, 1993 into Quilcene Bay, and 24,784 in April, 1994. This program was immensely important in 1993, when a major portion of the Big Quilcene River containing summer chum redds was illegally bulldozed. The WDFW, PNPTC, and USFWS have agreed that the summer chum restoration program at QNFH should continue through three generations (until 2003).

Potential for Endangered Species Act Listing

The National Marine Fisheries Service (NMFS), when deciding to list a stock under the ESA, addresses the following questions: (1) Is the stock reproductively isolated from other conspecific population units?; and if so, (2) Does the stock represent an important component in the evolutionary legacy of the species? (Waples 1991). In determining whether the population is of substantial ecological and/or genetic importance to the species as a whole, the following questions are raised: (1) Is the population genetically distinct from other conspecific populations?; (2) Does the population occupy unique habitat?; (3) Does the population show evidence of unique adaptation to its environment?; and (4) If the population became extinct, would this event represent a significant loss to the ecological and/or genetic diversity of the species? If the above questions are answered affirmatively, a population or stock is considered to be an evolutionary significant unit (ESU) of the species and can be listed.

Hood Canal summer chum salmon are considered to be reproductively isolated from other chum salmon stocks due to differences in run timing (Tynan 1992). This reproductive isolation has probably led to the genetic differences seen between Hood Canal summer chum salmon and other chum salmon (Figure 16). Significant differences between Hood Canal fall and summer chum salmon in allelic counts at variable loci have been found (Phelps et al., in press). Whether each stream's summer chum salmon population is a genetically distinct stock is in question. A dendogram of Hood Canal stream populations sampled is pictured in Figure 17. The extremely low population sizes during genetic sampling and the considerable movement of chum salmon eggs around the Puget Sound region, of which some are listed in Table 4, may have confounded genetic results. The collections of summer chum salmon for WDFW's GSI study were made between 1985 and 1992, when these stocks were already at extremely low levels (Phelps et al., in press). As mentioned earlier, as the effective population size decreases, genetic drift increases, thus increasing the chance of finding genetic differences between populations that may have originally been very similar. Care needs to be taken in making conclusions on summer chum salmon GSI results.

RECOVERY PLAN ELEMENTS TO REBUILD WILD HOOD CANAL SUMMER CHUM SALMON

Once a stock is listed as threatened or endangered, the ESA requires both prevention from extinction and development of recovery plans, unless the Secretary of the Interior or the Secretary of Commerce finds that doing so would not promote the conservation of the species. The recovery plans must contain site-specific management actions necessary to achieve recovery of the species, objective criteria to determine whether progress has been made, and estimates of the time and funds needed to achieve the goals. All federal agencies are required to conserve listed species and follow recovery plan directives. With this in mind, the USFWS-WWFRO proposes these elements for the Hood Canal summer chum salmon recovery plan.

Habitat

The habitat recovery plan for Hood Canal summer chum salmon should follow the MOU for Hood Canal coho salmon (WDFW, PNPTC, and USFWS 1993). This MOU proposed the following: a review of current regulations protecting Hood Canal habitat, an inventory of freshwater habitat, a determination of the major sources of habitat degradation, and development and implementation of habitat recovery plans. Much of the habitat survey information on Anderson and Big Beef Creeks and the Tahuya, Union, Dewatto, Duckabush, Big Quilcene, and Little Quilcene Rivers will be available in the near future. Major habitat degradation and possible rehabilitation measures on surveyed streams need to be listed and addressed. Habitat surveys of John and Lilliwaup Creeks, the Hamma Hamma River, and the lower portions of the Duckabush and Dosewallips Rivers need to be undertaken.

Fishery Restrictions

Fishery restrictions, such as no-take in terminal or near terminal areas and time and gear changes to avoid incidental take in coho fisheries, should be implemented. At present there is a much diminished coho fishery in Hood Canal, which allows summer chum salmon some protection from terminal harvests. Once the coho fishery resumes, measures should be taken to minimize summer chum harvest. Fishery restrictions may be included in the summer chum MOU now under development.

Enhancement of Little and Big Quilcene River Stocks

QNFH may be able to help restore the depleted runs in the Quilcene drainages and, possibly, other Hood Canal streams. The egg-to-fry survival of salmonids is usually much higher in a hatchery or other artificial setup (egg boxes, streamside incubators) than in a natural redd (McNeil 1969; Bams 1967; Bailey et al. 1976; Smith et al. 1985). Maximizing genetic variability in the progeny and letting the natural environment select for the most fit individuals should remain primary goals. Proposed hatchery guidelines for summer chum enhancement are mentioned below and summarized in Appendix B.

Brood stock should continue to be obtained by randomly sampling spawners in the Quilcene Bay wild population in order to increase fitness and avoid inadvertent selection for body size, spawn timing, within-hatchery survival, etc. (Reisenbichler and McIntyre 1986). With this strategy, natural selection problems associated with localized oxygen depletion and metabolic waste buildup (Michael 1975). However, if accumulated waste cannot be easily removed from special incubation substrates, problems such as bacterial gill disease may result.

One example of the effective use of rugose substrate and cover was reported by Fuss and Johnson (1988). Coho salmon eggs (25,000) were placed in wire mesh baskets suspended in 4.5 X 0.3 X 0.015 m concrete troughs covered with plywood. Alevins dropped at hatching into 5 layers of 1.9-cm mesh (polypropylene plastic netting material) and were raised at a density of 5.6 alevins/cm^2. A similar set-up could be used at QNFH for summer chum salmon incubation. Other journal articles addressing the use of rugose substrate for salmonid incubation are listed in Appendix C.

Fraser et al. (1978) concluded that optimum marine survival of hatchery chum occurred when juveniles were released at the peak of the natural migration (which ensures an adequate food supply in the estuary and ocean), and at a relatively large size. Epibenthic sampling of Quilcene Bay and surrounding nearshore areas is recommended in determining release dates. Preferred prey items of chum salmon fry, such as epibenthic crustaceans, eggs, insects, and zooplankton, should be noted. Release of hatchery fry should occur at night on incoming tides as studies have indicated higher mortality if salmonid smolts and fry reach estuaries at low tide (Kenworthy et al. 1985).

To determine the number of eggs to collect and number of fry to be released (optimal stocking density), the quantity and quality of habitat and prey available (fresh and marine) for rearing the fry and smolts should be evaluated (Smith et al. 1985).

Enhancement of Other Hood Canal Stocks

Underescaped Streams

Whether one or more Hood Canal summer chum stocks are listed as an ESU to manage, QNFH, Hood Canal Hatchery, or Lilliwaup Hatchery could play very important roles in the rehabilitation of stocks in other drainages. These hatcheries could hold broodstock captured from the targeted streams until ripe, perform appropriate mating schemes, incubate eggs, and outplant fry, or place eggs in remote site incubators in depleted and barren drainages. Maximizing genetic variability in the progeny, increasing egg-to-fry survival in the hatchery and smolt survival in marine waters, and minimizing negative impacts on any remaining wild fish would continue to be primary goals.

Barren Creeks (Anderson Creek, Big Beef Creek, John Creek (a tributary to the Hamma Hamma River), and the Dewatto River)

Ways of restoring summer chum in barren creeks with the help of hatcheries include raising and outplanting fry, and seeding streams with RSIs containing eggs from Hood Canal broodstock held and spawned at the hatcheries. One particular approach to re-establish runs in drainages where summer chum have been extirpated would be to collect gametes from all of the Hood Canal drainages with established summer run chum salmon, perform all possible crosses among the sources, and outplant the progeny (Krueger et al. 1981).

This would be consistent with the goal of maximizing genetic variation in the progeny and letting nature select the fittest individuals. A "mixed" broodstock could be developed at Walcott Slough (if additions to the existing lease could be obtained from the owners) and used as an egg source. Capturing broodstock at Walcott Slough is relatively easy and the run could be terminated at the completion of the program.

Another approach would be to collect gametes from one or two geographically nearest drainages with established summer chum runs, as proximate populations are usually more similar than distant populations (Reisenbichler and McIntyre 1986), perform crosses, and outplant the progeny. However, using broodstock originating outside of Hood Canal or from the Union River may not be appropriate (Union River summer chum return a few weeks earlier and are thought to be genetically distinct from all other Hood Canal summer chum runs).

Problems associated with the use of hatcheries as off-site broodstock holding and egg rearing facilities may include disease transfer, inadvertant imprinting of fry on hatchery water, and lack of space to rear summer chum.

Objective Criteria to Judge Progress of Recovery Actions

The recovery program will be considered a success if self-sustaining summer chum salmon runs, which are genetically viable, are re-established in the 12 Hood Canal drainages. Return rates, mean and variance of time of return, spawn timing, age composition of spawners, and GSI analysis can be used to assess the success of the hatchery programs.

Time and Money Needed to Achieve Recovery

To estimate funding needed to achieve recovery of Hood Canal summer chum salmon, much more information is needed. Every task outlined in this report requires funding. The number of tasks addressed and the number of summer chum runs to be recovered will determine the funds needed. Costs associated with the hatcheries include holding facility improvement, or reduction in coho production at QNFH to accomodate chum, construction of isolation units for imported eggs (to meet disease zone requirements), and the normal costs associated with rearing fish. The estimated time required to complete the recovery of Hood Canal summer chum salmon runs is difficult to determine. An interim hatchery supplementation program, such as for the Big and Little Quilcene Rivers, should continue for a minimum of four consecutive years (or one complete brood cycle). However, this program may continue indefinitely due to the instability of chum salmon spawning grounds in both the Big and Little Quilcene Rivers. Once a self-sustaining "wild" summer chum salmon run has been established in Quilcene Bay, the QNFH may be needed to periodically supplement the run.

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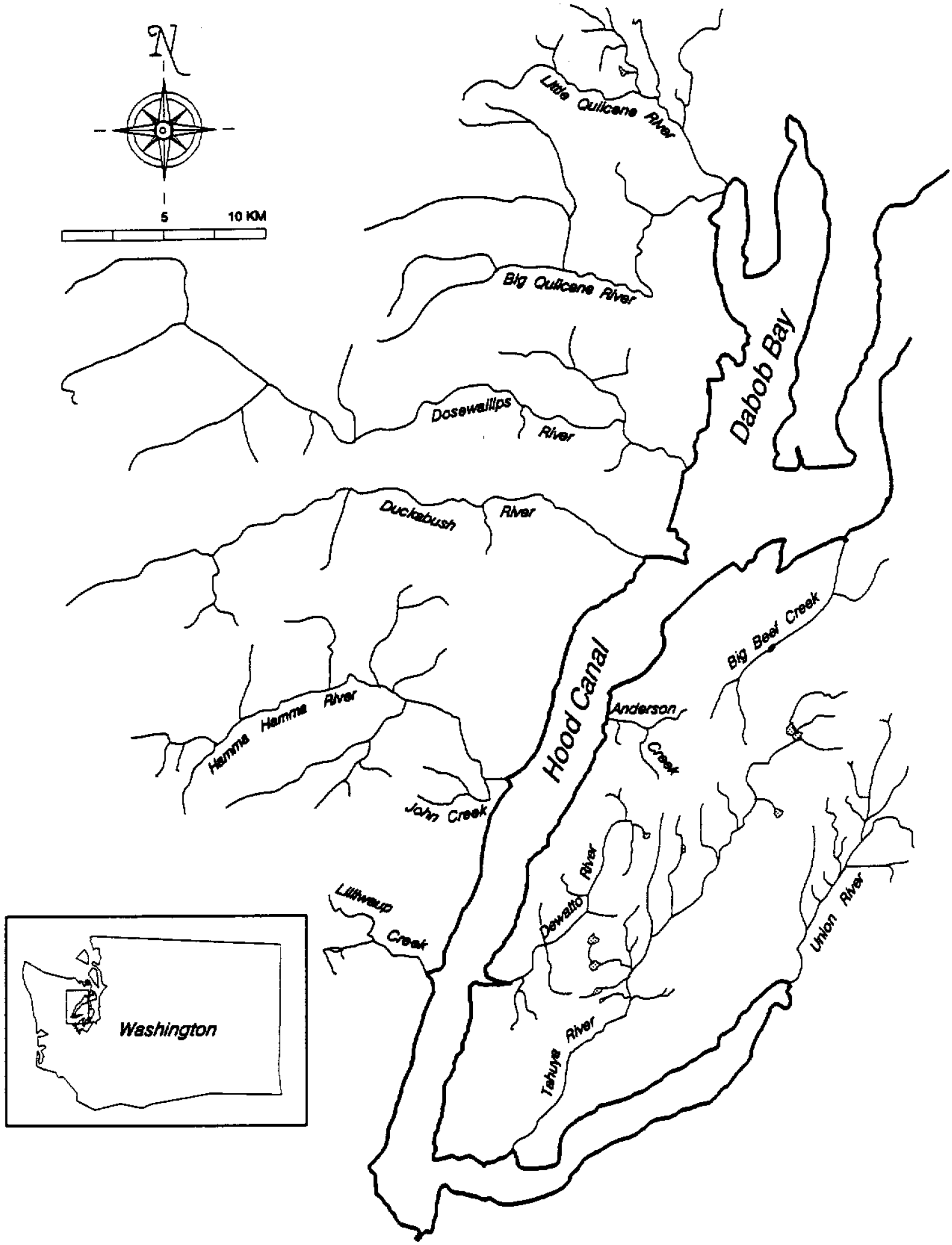

Figure 1. Map of Hood Canal streams producing summer chum salmon runs, past and present.

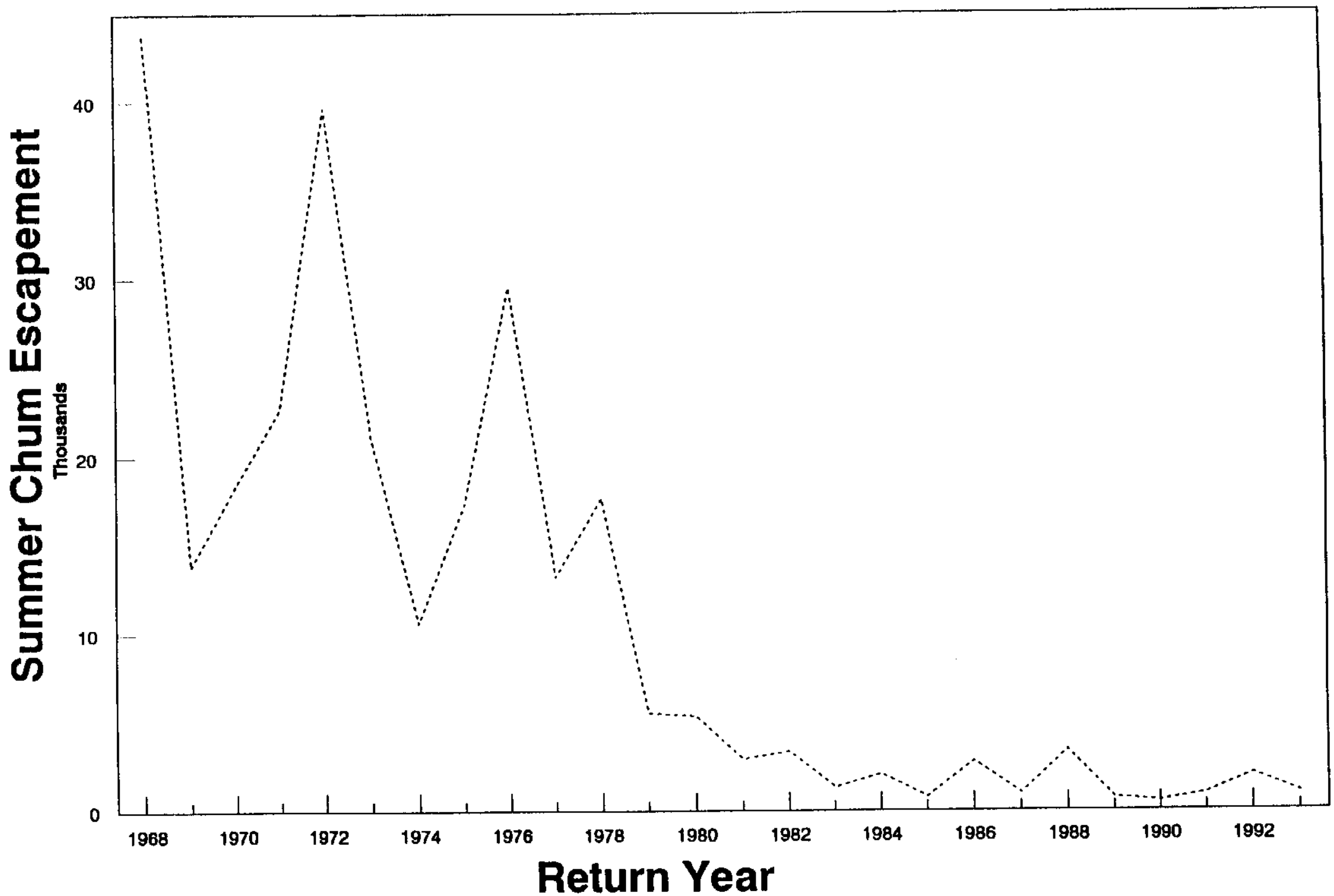

Figure 2. Summer chum escapement in Hood Canal, since 1968. Source: Washington Department of Fish and Wildlife, unpublished data.

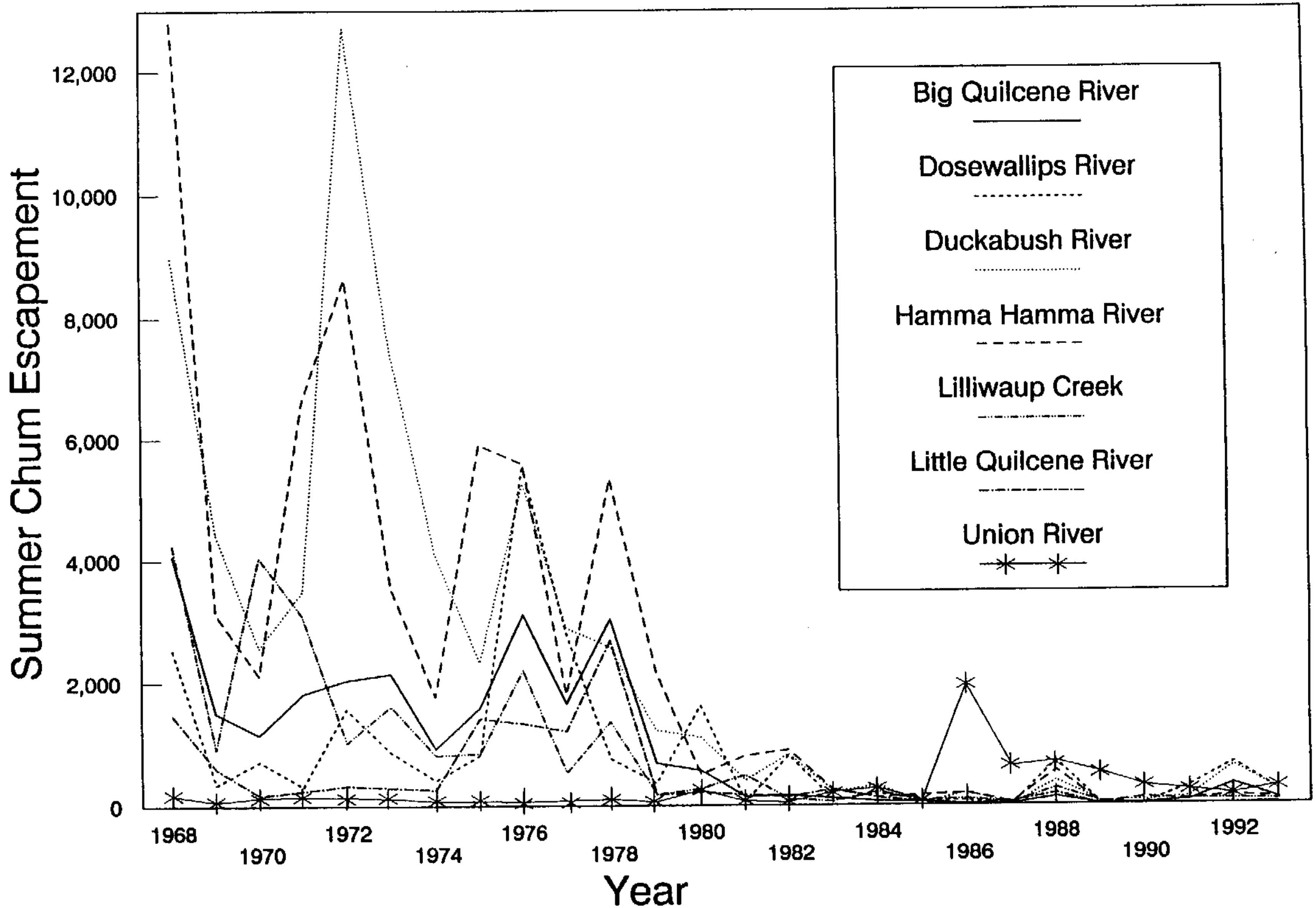

Figure 3. Hood Canal summer chum escapement (1968-93) in streams with recent returns (1991-93). Source: Washington Department of Fish and Wildlife, unpublished data.

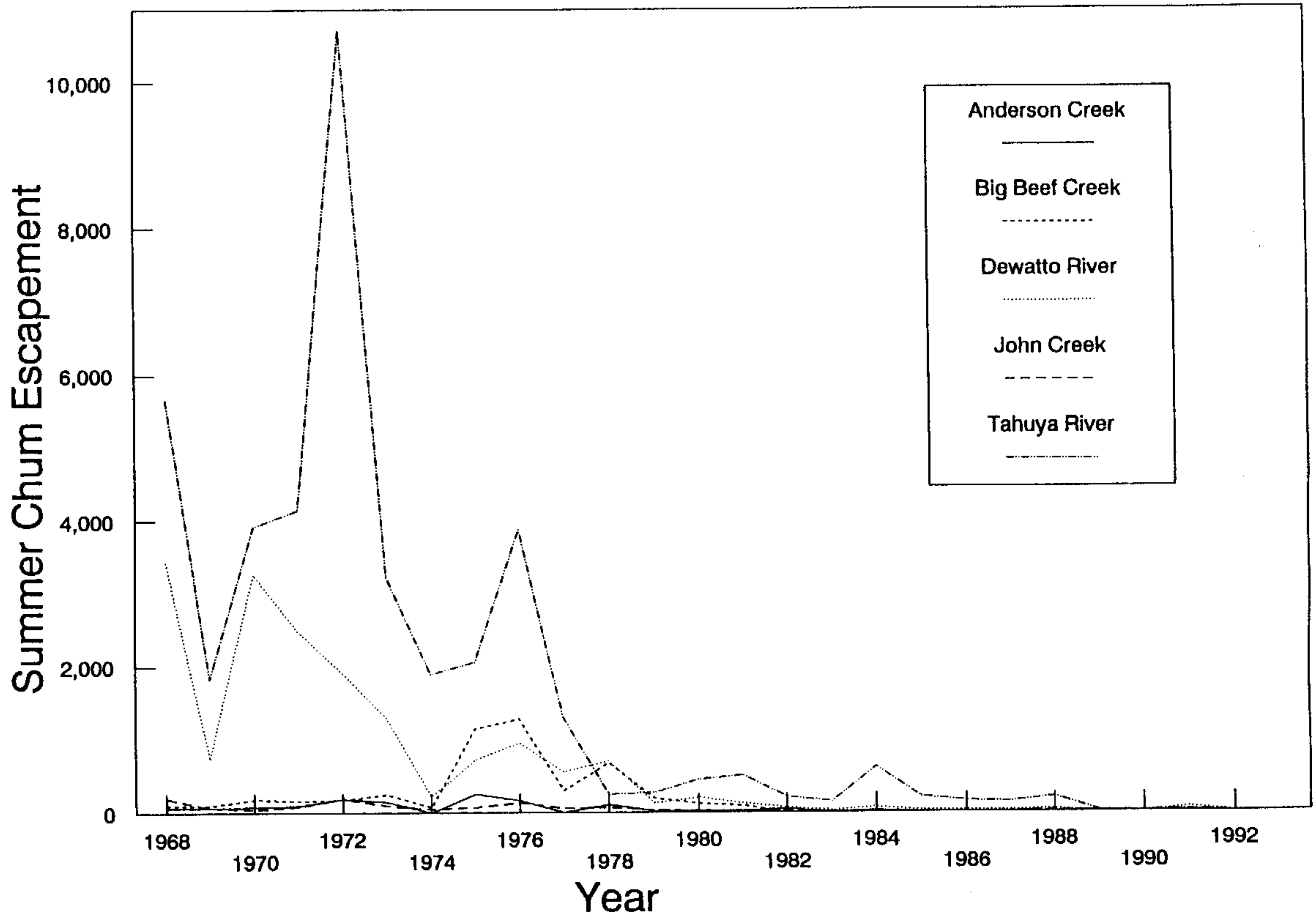

Figure 4. Hood Canal summer chum escapement (1968-93) in streams with no recent returns (1991-93). Source: Washington Department of Fish and Wildlife, unpublished data.

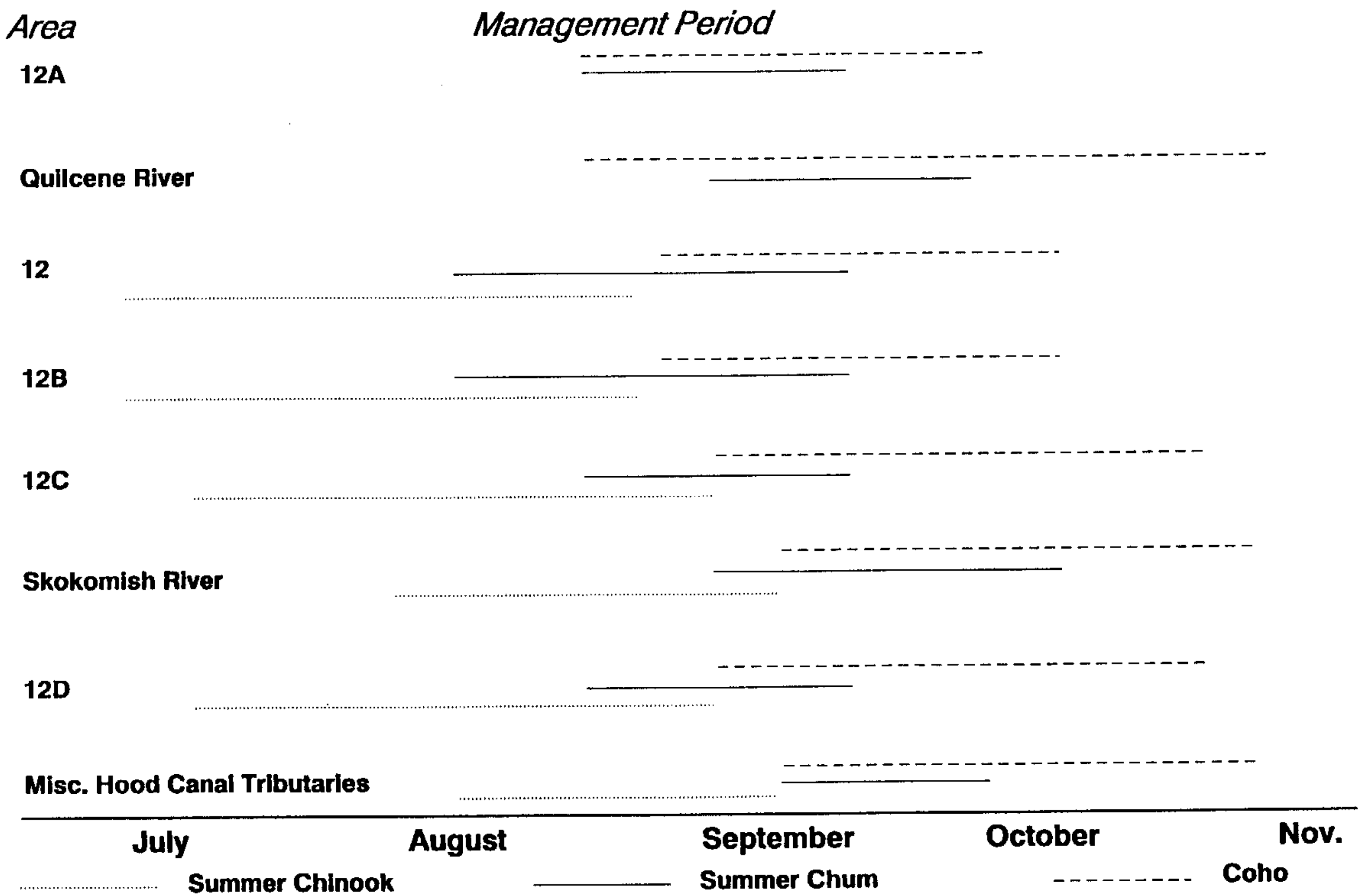

Figure 5. Hood Canal area summer chinook salmon, summer chum salmon, and coho salmon management periods (Hood Canal Salmon Management Plan, 1993, revision under review). Figure 6 locates designated management areas in Hood Canal.

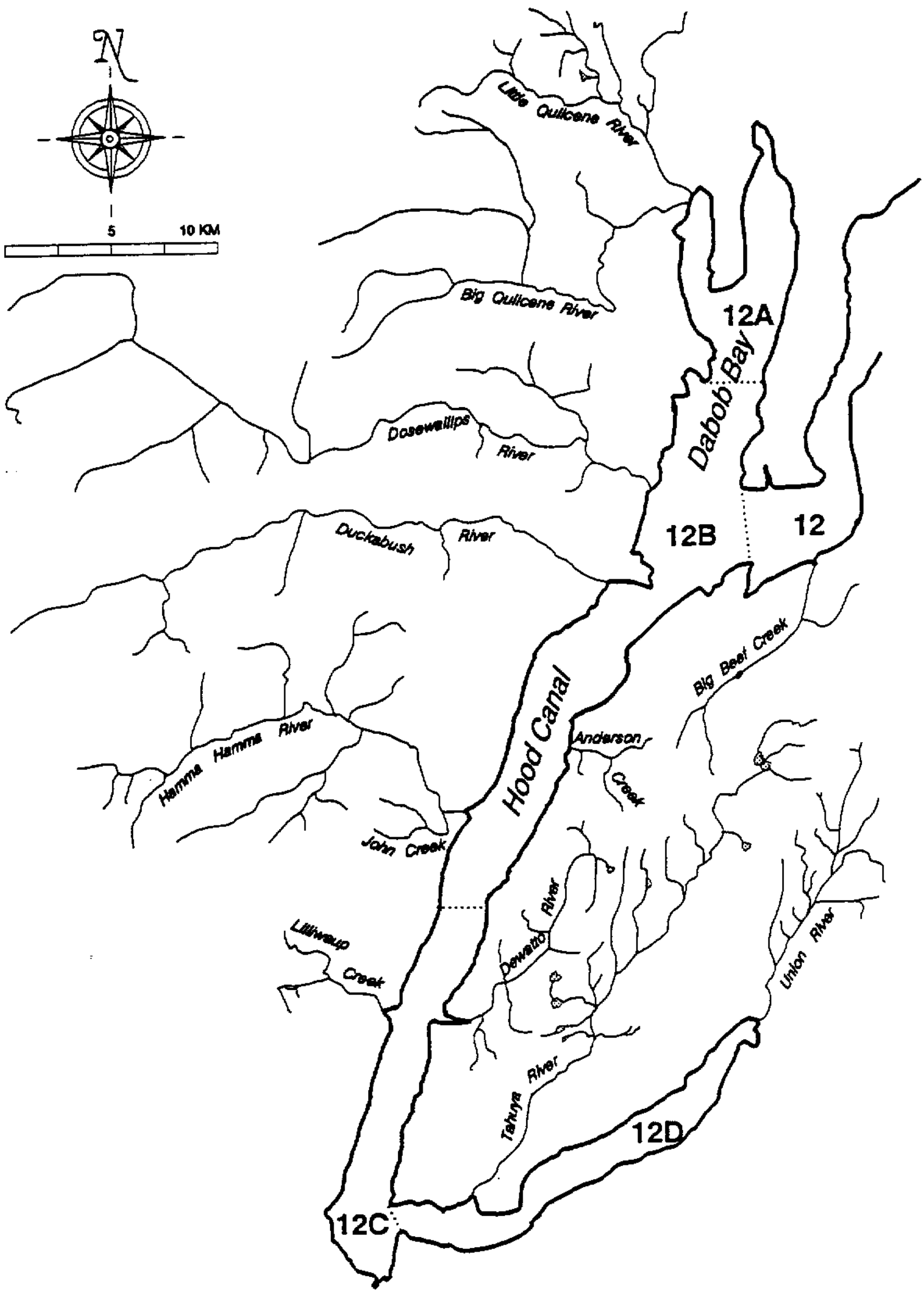

Figure 6. Hood Canal salmon fishery management areas (Hood Canal Salmon Management Plan 1985).

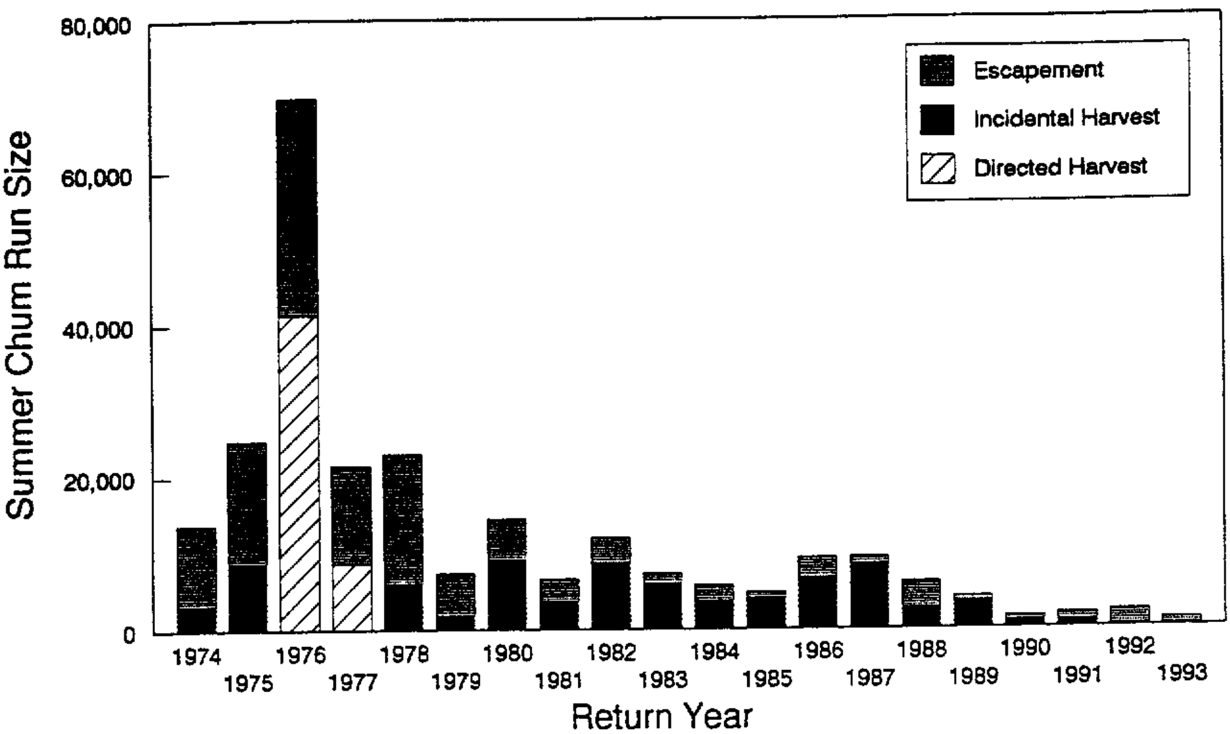

Figure 7. Estimated Hood Canal summer chum salmon run size, escapement and harvest in treaty and nontreaty commercial net fisheries. Source: WDFWS "PSSUM" reports by catch accounting period, 1970-93.

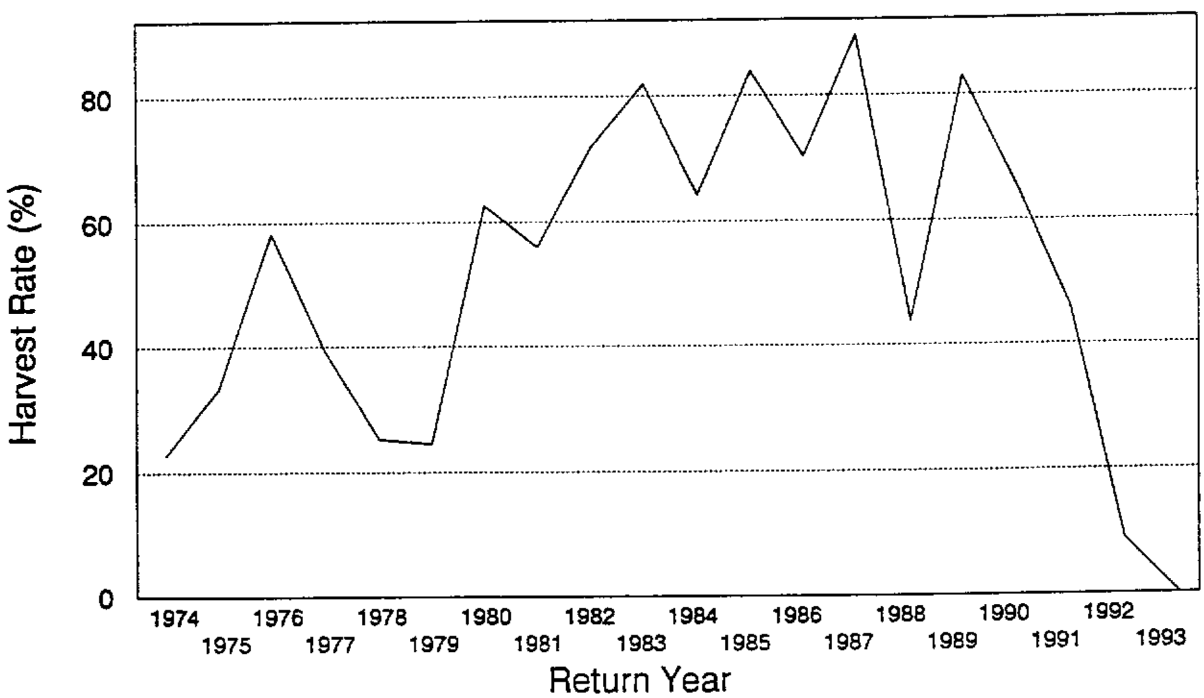

Figure 8. Estimated Hood Canal summer chum salmon harvest rate in treaty and nontreaty commercial net fisheries. Source: WDFWS "PSSUM" reports by catch accounting period, 1970-93.

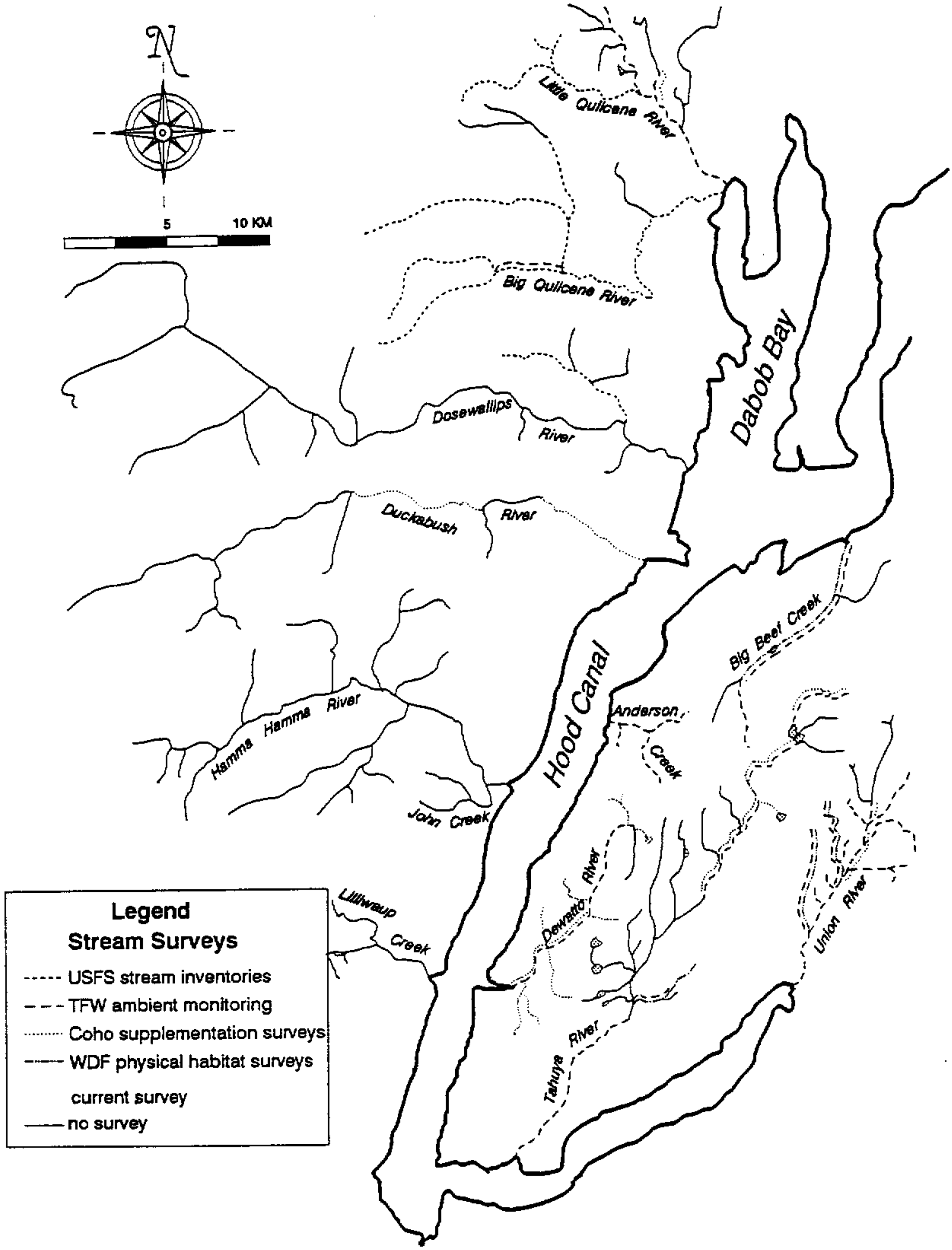

Figure 9. Hood Canal stream habitat surveys, past and present (Tabor and Knudsen 1993).

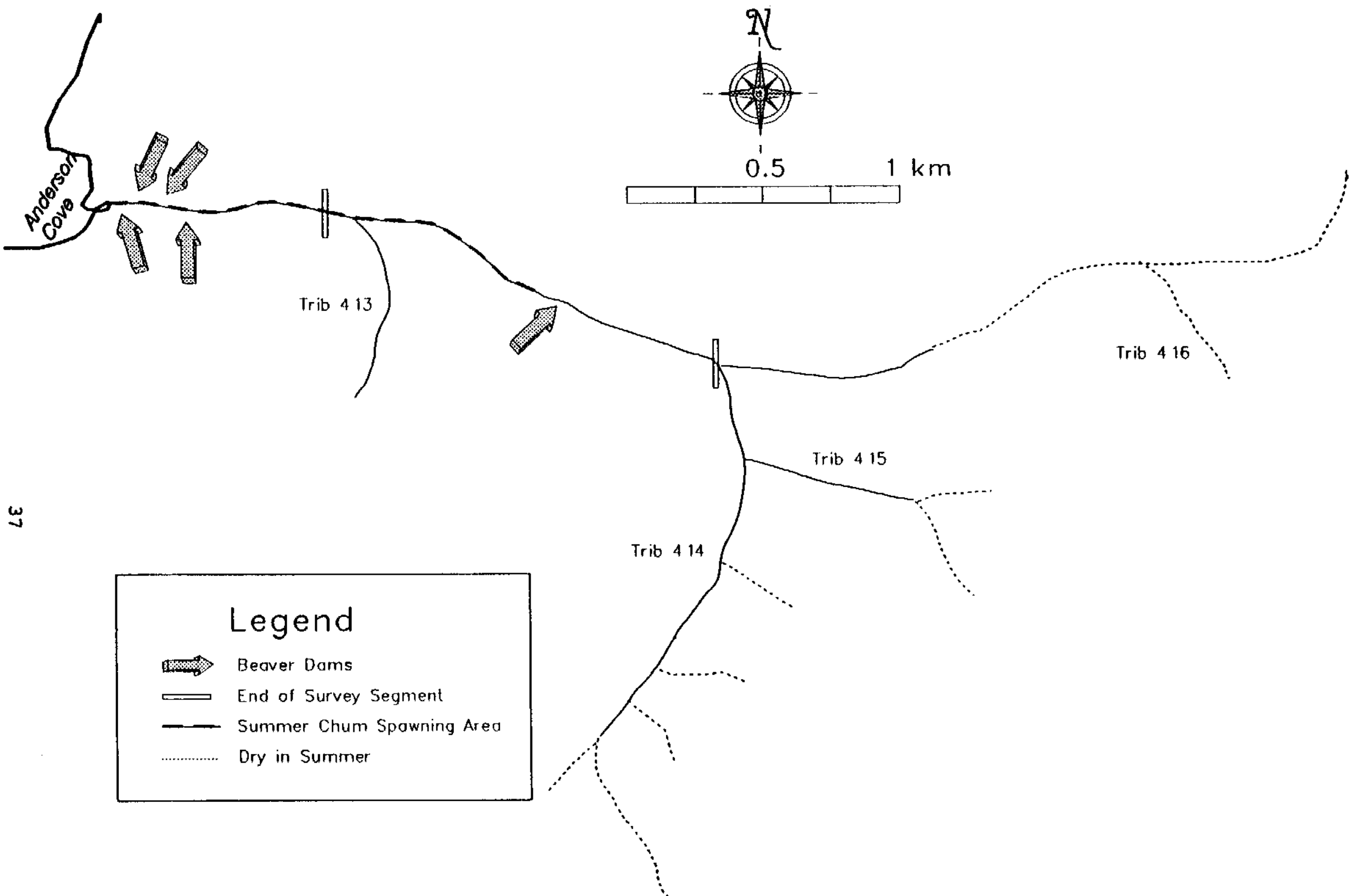

Figure 10. Anderson Creek summer chum spawning area and beaver dams located in 1994 (USFWS-WWFRO, unpublished data).

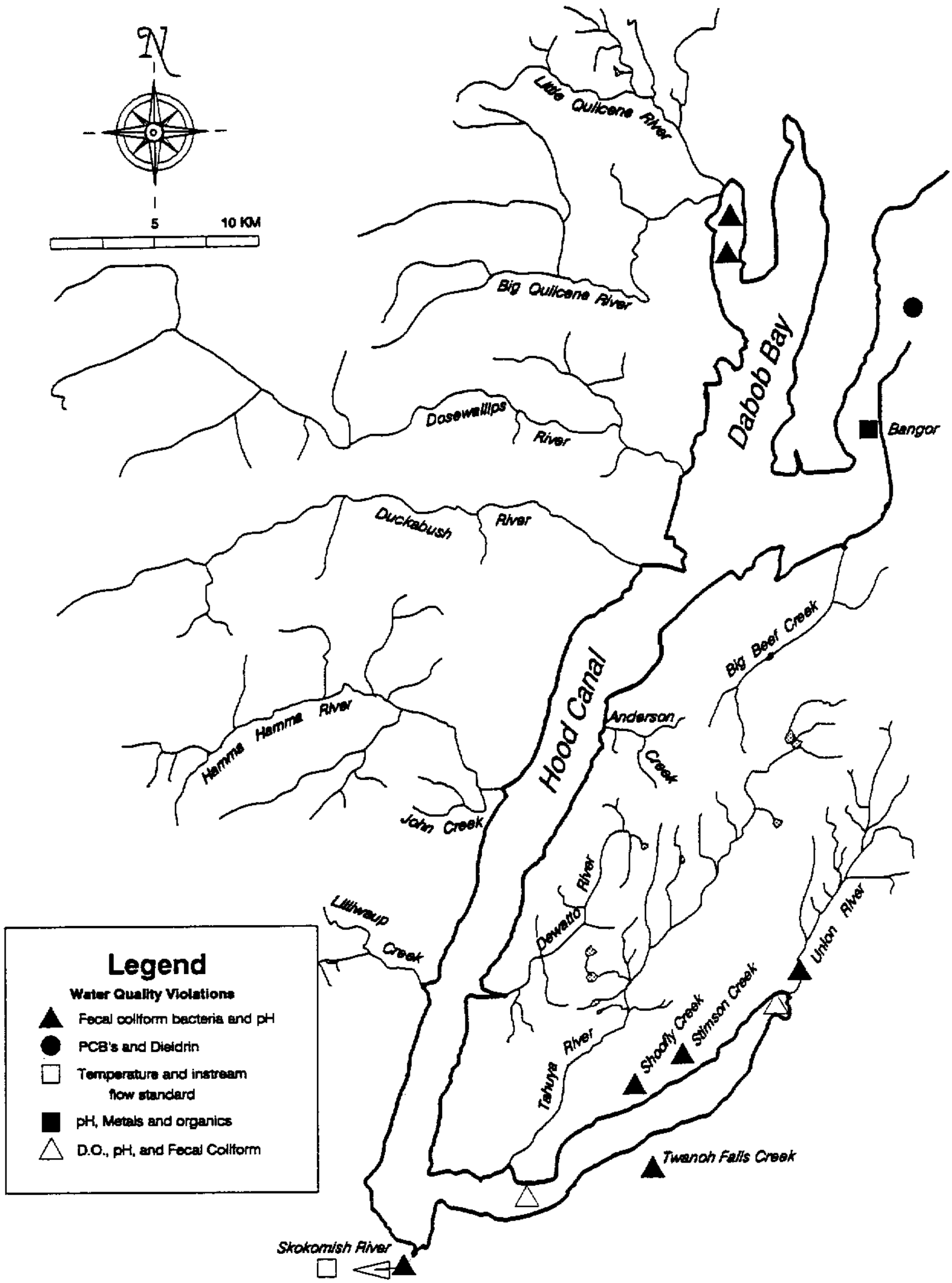

Figure 11. State and Federal water quality violations in Hood Canal, 1992-93 (PSWQA 1993; WSDE 1994).

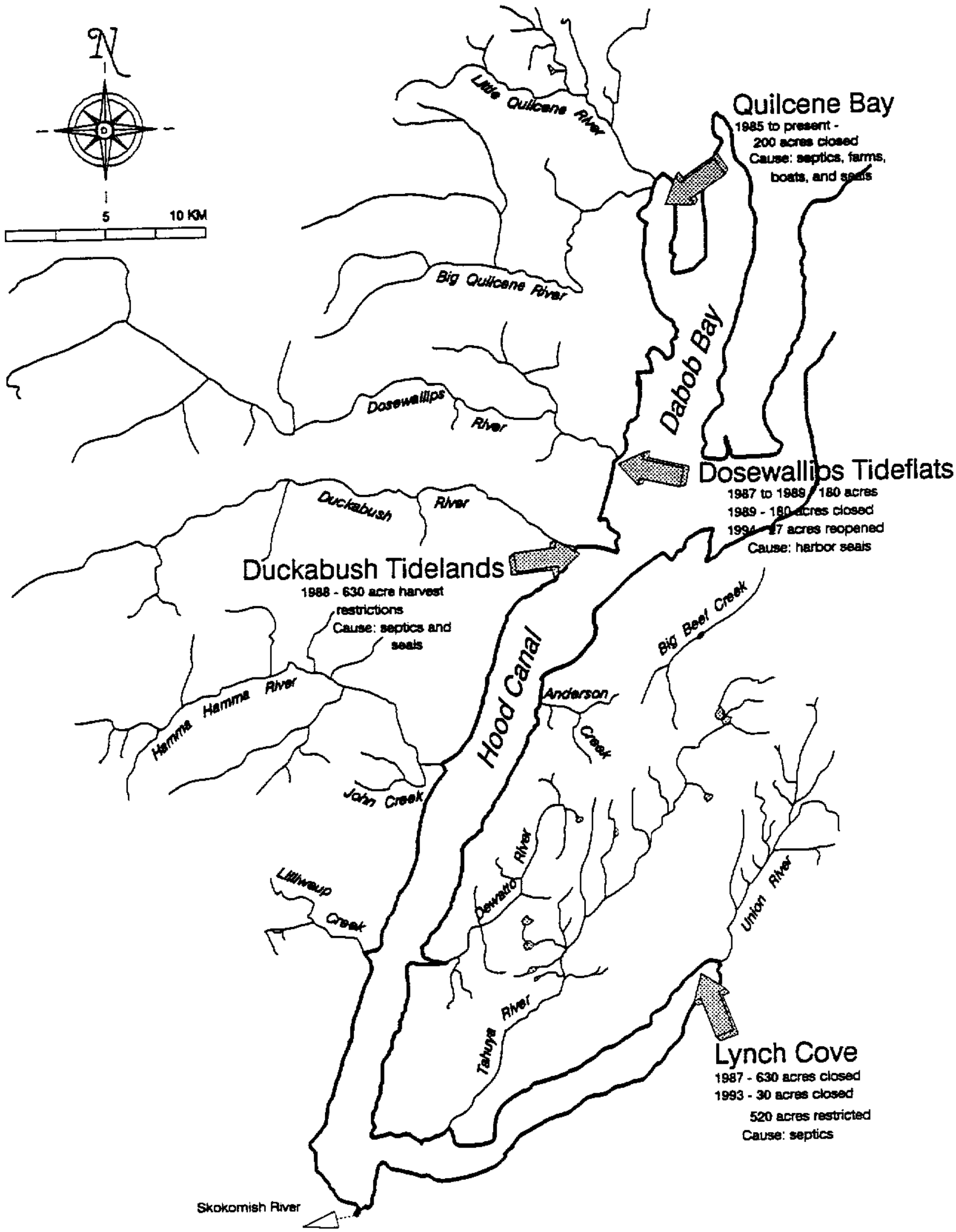

Figure 12. Shellfish closures in Hood Canal due to coliform bacteria (1985 to present) (WSDE 1994).

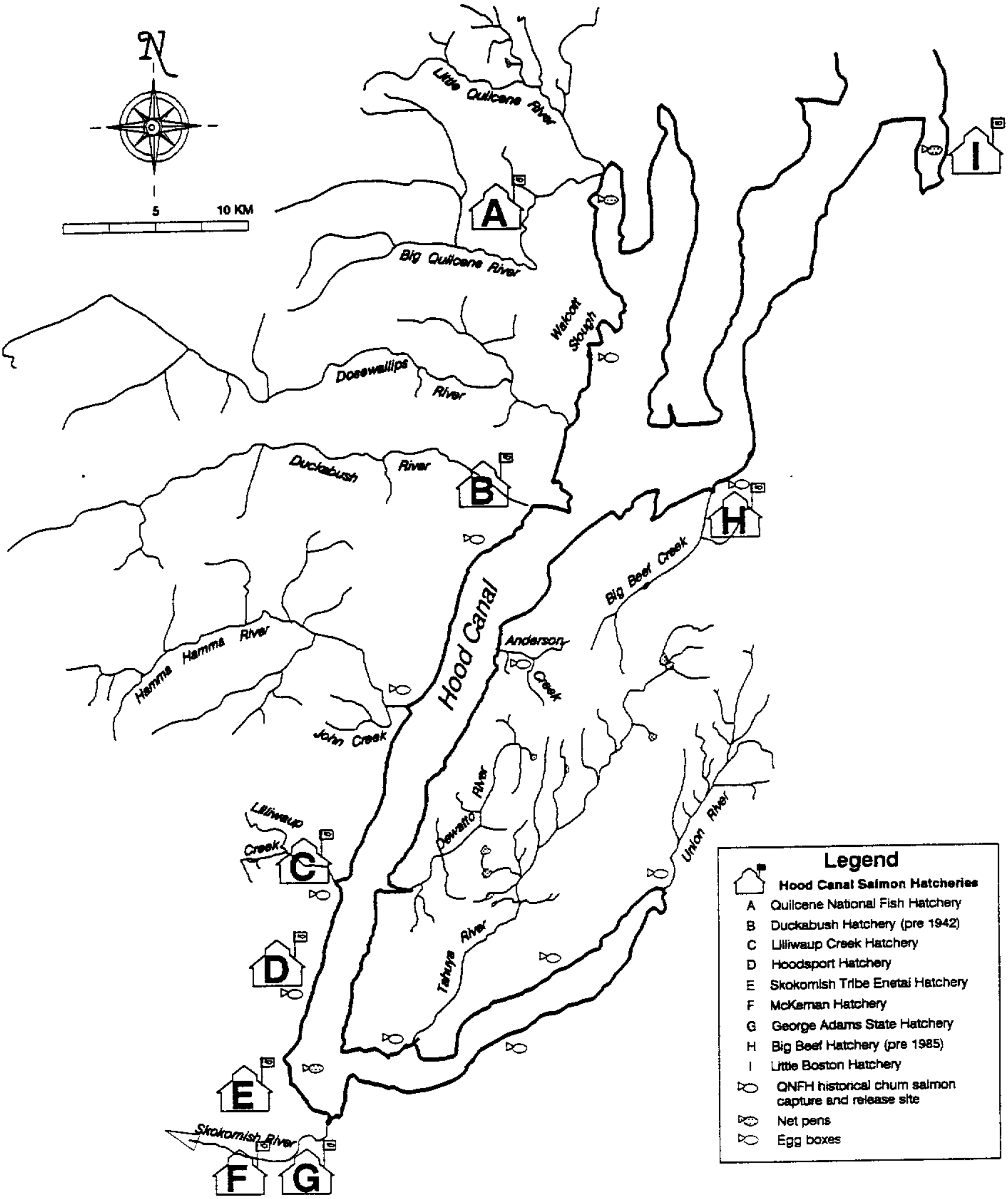

Figure 13. Hood Canal salmon hatcheries, net pen operations, and egg boxes.

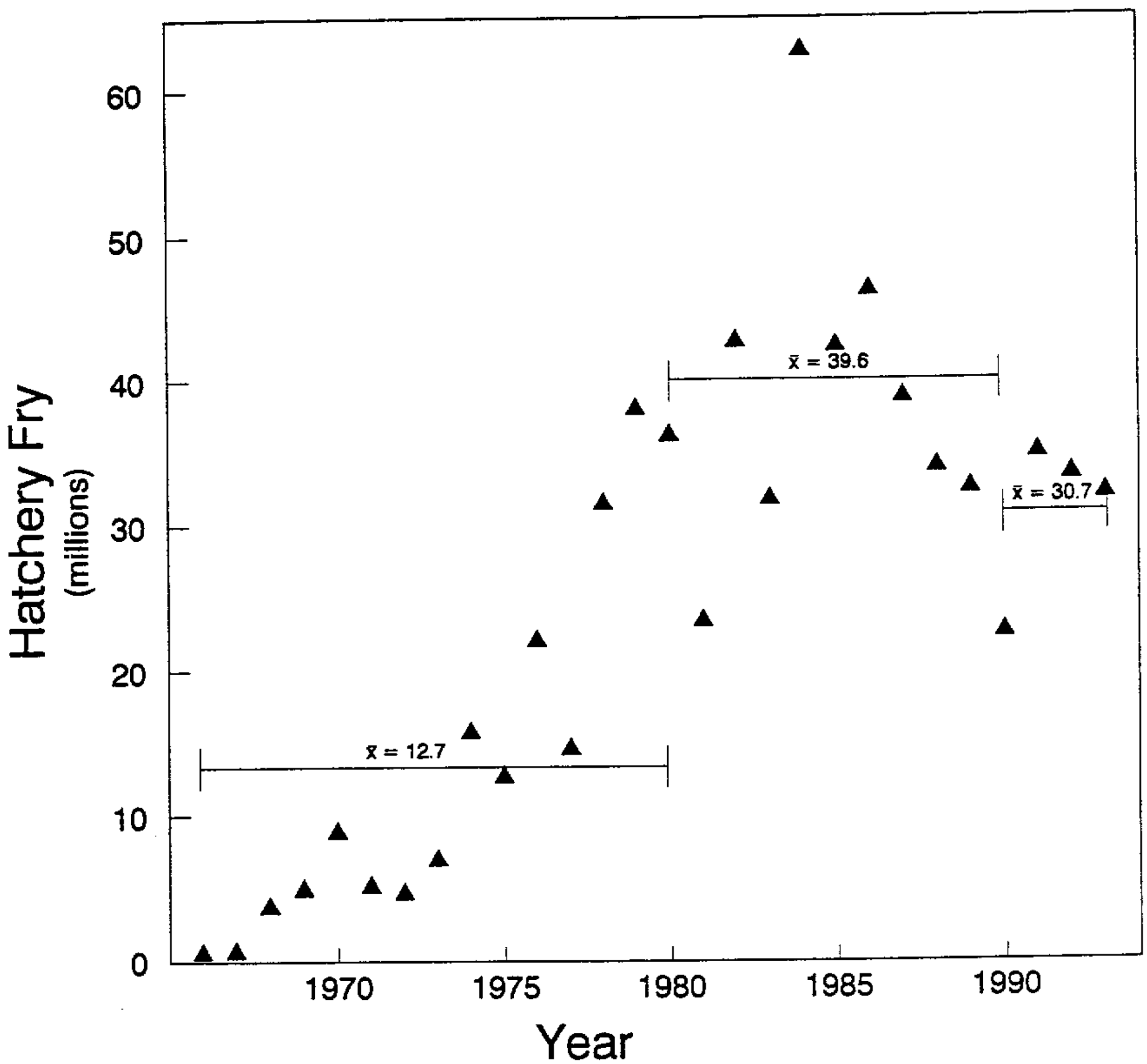

Figure 14. Number of hatchery fall chum fry released in Hood Canal (1966-1993) (Pacific States Marine Fish Commission releases database).

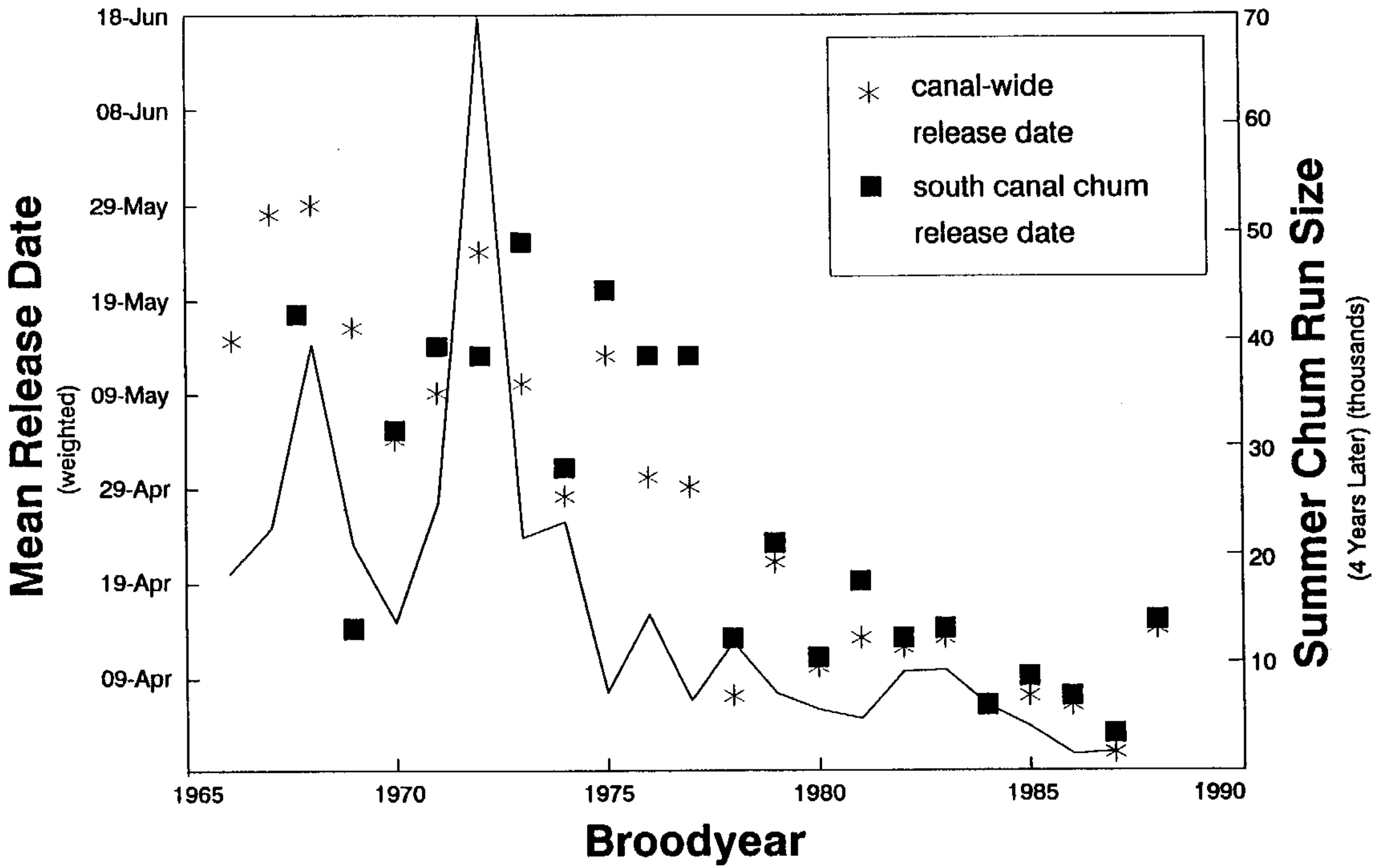

Figure 15. Hatchery fall chum salmon fry release date and summer chum salmon run size four years later (Kane, 1994, unpublished).

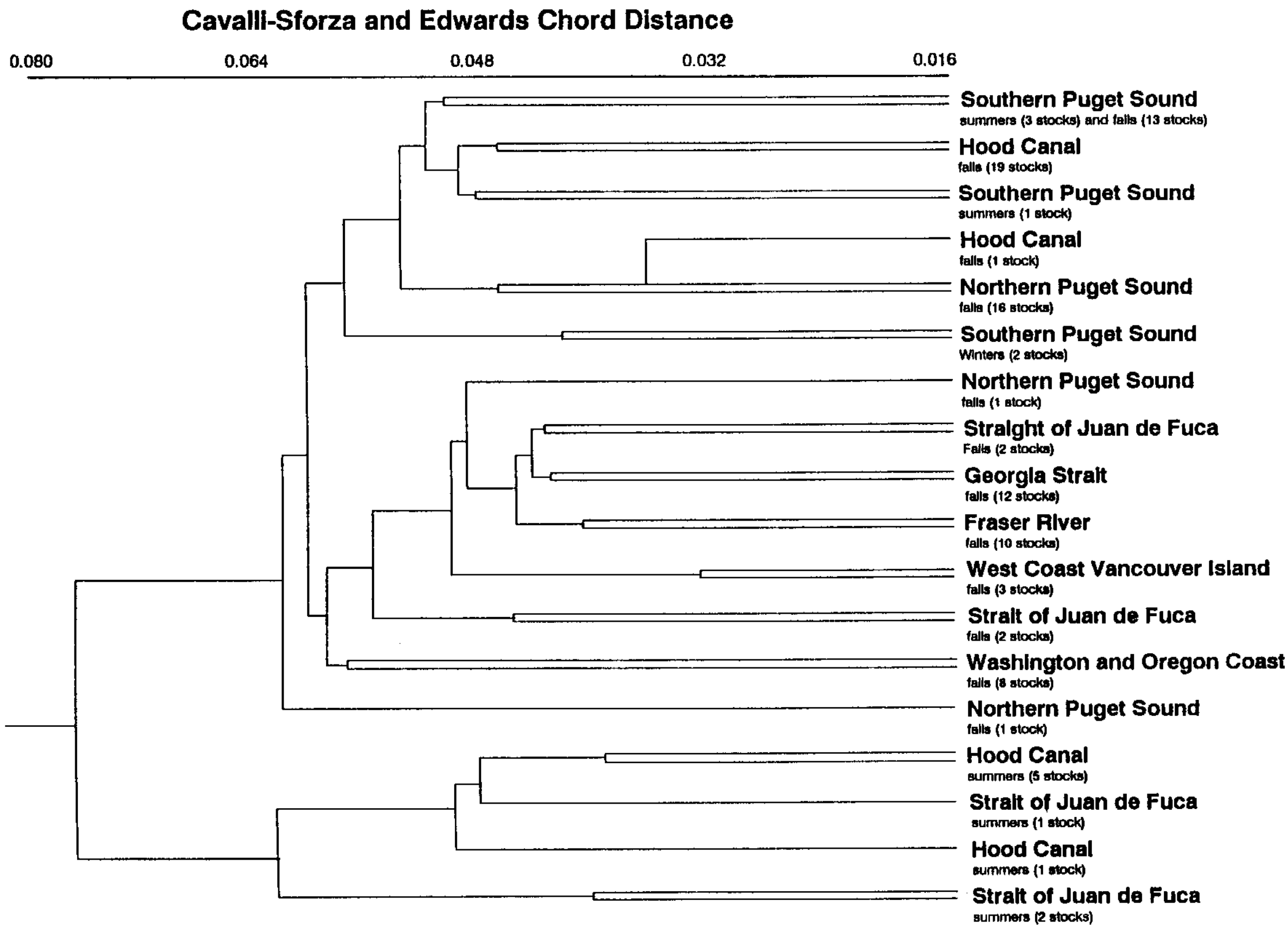

Figure 16. Dendogram depicting Cavalli-Sforza and Edwards (1967) chord distance among chum populations sampled in Washington (adapted from Phelps et al., in press).

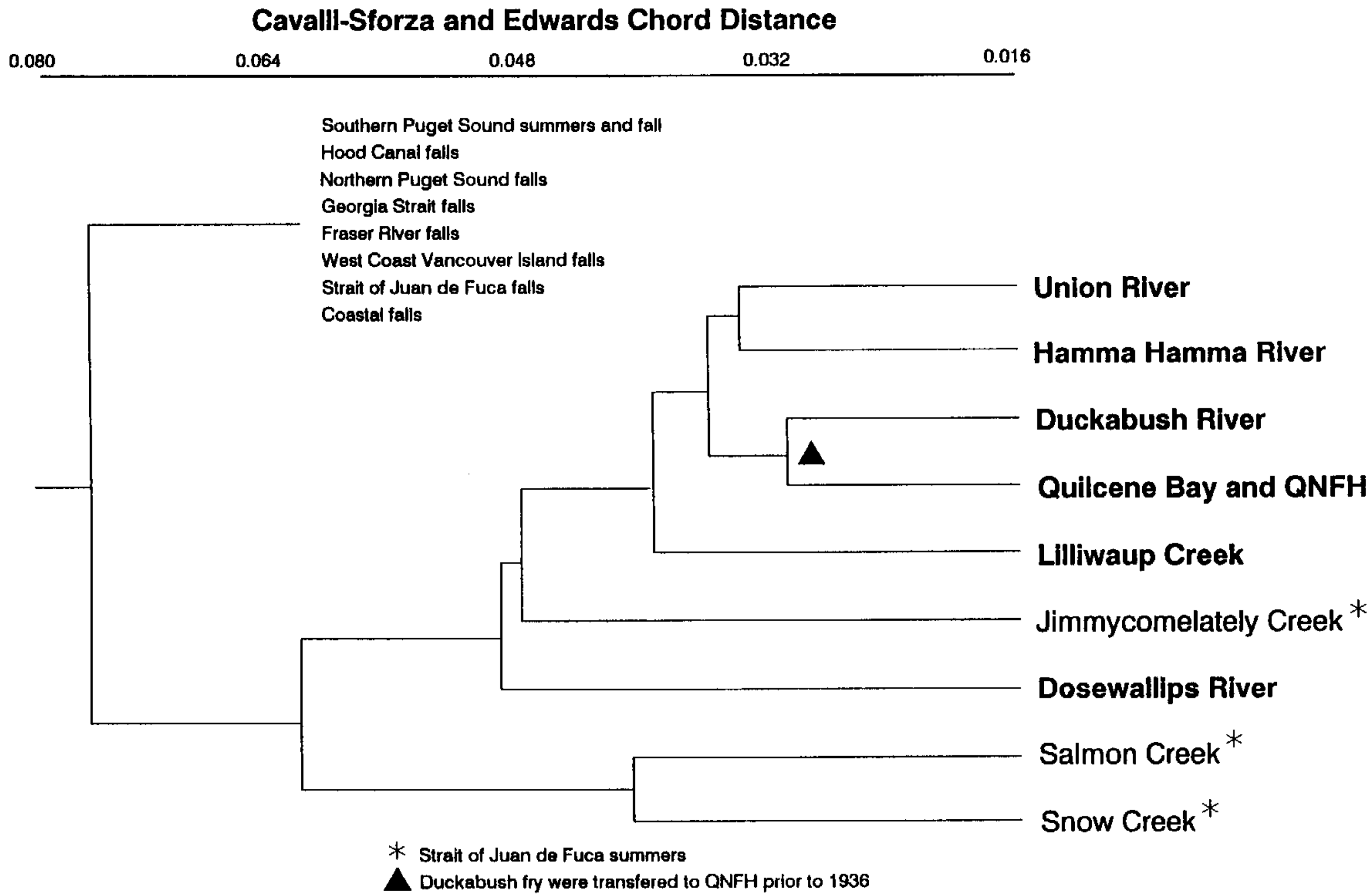

Figure 17. Dendogram depicting Cavalli-Sforza and Edwards (1967) chord distance among Hood Canal summer chum populations sampled (adapted from Phelps et al., in press).

Table 1. Hood Canal summer chum salmon escapement, 1968-1993. Source: Washington Department of Fish and Wildlife, unpublished data.

Year	John Creek	Anderson Creek	Big Beef Creek	Union River	Little Quilcene River	Dewatto River	Dosewallips River	Lilliwaup Creek	Big Quilcene River	Tahuya River	Duckabush River	Hamma Hamma River	Total
1968*	195	68	100	169	1,474	3,425	2,537	4,247	4,074	5,663	8,968	12,800	43,720
1969*	64	65	100	63	600	740	342	918	1,508	1,834	4,442	3,133	13,809
1970*	44	77	178	134	172	3,263	726	4,046	1,152	3,924	2,568	2,122	18,406
1971*	84	92	159	142	245	2,495	311	3,094	1,822	4,147	3,495	6,589	22,675
1972*	185	185	177	136	321	1,918	1,580	1,022	2,047	10,714	12,705	8,639	39,629
1973*	96	146	244	111	296	1,303	863	1,616	2,148	3,229	7,495	3,556	21,103
1974*	50	0	75	70	258	220	411	814	924	1,900	4,100	1,772	10,594
1975	75	251	1,152	71	1,421	730	822	844	1,599	2,066	2,337	5,906	17,274
1976	133	169	1,281	59	1,342	955	5,561	2,206	3,114	3,877	5,258	5,594	29,549
1977	60	0	302	76	1,211	555	2,806	532	1,662	1,303	2,895	1,811	13,213
1978	70	105	680	99	2,689	709	758	1,365	3,037	250	2,574	5,333	17,669
1979	30	20	191	56	174	125	359	180	690	270	1,226	2,183	5,504
1980	26	20	123	241	210	206	1,624	273	567	450	1,105	500	5,345
1981	10	20	90	63	172	125	60	492	139	511	403	797	2,882
1982	21	50	0	42	140	63	800	100	163	214	826	899	3,318
1983	4	0	0	200	251	26	73	50	107	144	211	236	1,302
1984	5	20	22	272	117	70	180	217	61	633	316	126	2,039
1985	2	0	0	73	50	29	81	81	45	214	34	169	778
1986	4	0	0	1,954	12	25	69	102	15	153	198	194	2,726
1987	1	0	6	622	54	25	16	40	15	141	13	43	976
1988	15	0	0	700	181	31	713	268	129	204	589	556	3,386
1989	1	0	0	521	5	4	30	43	5	13	52	21	695
1990	1	0	0	303	0	0	17	5	11	14	58	108	517
1991	4	0	0	229	5	56	286	79	58	21	115	79	932
1992	0	0	0	154	10	0	667	81	330**	0	625	132	1,999
1993	0	0	0	284	12	0	218	65	89**	0	218	94	980
Mean	45	50	188	263	439	658	843	876	981	1,611	2,416	2,438	10,808

* Escapement information may be questionable (N. Lampsakis, PNPTC, 1994).

** Broodstock in QNFH not counted (in river estimates only).

Table 2. Anderson Creek substrate composition, land use, and streamside structure in summer chum spawning areas (USFWS-WWFRO, TFW ambient monitoring data).

Habitat Unit	Category	Subcategory	Stream Segment Lower 907 m	907 m - 1807 m
Dominant Sediment[a]	Fines (<0.01 mm)		8.7	3.0
	Sand (0.2-5 mm)		38.8	9.4
	Gravel (5-64 mm)		52.5	51.7
	Cobble (64-254 mm)			35.8
Land Use and Streamside Structure[b]	Private Woods	Young Timber		15.8
		Mature Timber	11.5	2.8
	Timberlands	Shrub/Seedling	1.5	
		Young Timber	1.8	5.9
		Mature Timber	50.0	52.4
	Agricultural	Young Timber		1.8
		Mature Timber		5.3
	Residential	Grass/Forb		0.8
		Shrub/Seedling		0.7
		Pole/Sapling		4.3
	Livestock	Grass/Forb		4.3
	Roads	Shrub/Seedling		1.3
		Young Timber		1.0
		Mature Timber	4.7	3.6
	Wetlands	Grass/Forb	1.9	
		Shrub/Seedling	4.9	
		Young Timber	0.5	
		Mature Timber	23.2	

[a] Dominant sediment is defined as the substrate composing ≥50% of the streambed. Values given are percentage of area of stream length surveyed.

[b] Values given are percentage of stream length surveyed.

Table 3. Hood Canal salmon artificial propagation facilities and production numbers (in millions) agreed upon in the 1989 Production Evaluation MOU.

Facility	Fall Chum	Summer Chum	Sum/Fall Chinook	Spring Chinook	Coho	Steel-head	Pink
Quilcene National Fish Hatchery	2.2			0.2	0.5		
Hoodsport Hatchery	15.0		0.8		0.04		1.0
Enetai Hatchery (Skokomish Tribe)	2.5		0.62	0.19			
George Adams State Hatchery	5.0		3.73		0.65		
McKernan Hatchery	10.0		0.6				
Little Boston Hatchery	0.95						
Area 12A net pens					0.36		
Port Gamble Bay net pens	1.8				0.4		
Hoodsport Egg Boxes:	1.5						
Other egg boxes:							
Anderson Creek	0.15						
Caldervin Creek	0.15						
Eagle Creek	2.0						
Fulton Creek	0.5						
John Creek	0.5						
Johnson Creek	1.0						
L. Lilliwaup R.	0.5						
Stimson Creek	0.15						
Twanoh Creek	0.15						
Union River	0.15						
Total Hood Canal production agreed upon	44.05	N/A	5.75	0.39	1.95	N/A	1.0
Yearly hatchery production agreed upon[a]	35.65	N/A	5.75	0.39	1.95	N/A	1.0
Reported average yearly production of Hatcheries	34.3 6.2	0.12 0.09	8.95 2.86	0.34 0.05	1.78 0.57	0.02 0	?
(Brood Year)	(87-93)	(92-93)	(87-92)	(87-91)	(87-91)	(87)	

[a] This includes Quilcene National Fish Hatchery, Walcott Slough, Hoodsport Hatchery, Enetai Hatchery, George Adams Hatchery, McKernan Hatchery, and Little Boston Hatchery.

Table 4. Historical transfers of Hood Canal summer chum salmon noted in the Quilcene National Fish Hatchery log book.

Year	Broodstock	# of Eggs	# of Fry[a]	Release Site[b]
1919	Duckabush	652,000		Big and/or Little Quilcene Rivers
1921	Such Slough	1,100,000		Big and/or Little Quilcene Rivers
1925	Duckabush	170,000		Big or Little Quilcene Rivers
1926	Duckabush	2,696,000		Big and Little Quilcene Rivers
1927	Dosewallips	329,000		Big and Little Quilcene Rivers
1927	Duckabush		1,000,000	Big and Little Quilcene Rivers
1927	Duckabush	2,959,000		Big and Little Quilcene Rivers
1928	Duckabush		1,500,000	Walcott Slough
1928	Duckabush	1,890,000		Big and Little Quilcene Rivers
1929	Duckabush	3,606,000		Big and Little Quilcene Rivers

[a] The egg to fry survival and fry releases were not noted in many cases.
[b] Release site distinction between the Big and Little Quilcene Rivers was not made (other than "and" or "or").

Table 5. Summer chum salmon broodstock program at Quilcene National Fish Hatchery.

Year	Broodstock (♂ + ♀)	in River Spawners (♂ + ♀)	In Hatchery Program (%)	# of Fry Released
1992	412	330	56	216,441
1993	35	89	28	25,000
1994	298	326	48	375,000
Total	745	745	50	616,441

APPENDICES

Appendix A. Other tasks, not proposed in the MOU, needed in the restoration of Hood Canal summer chum salmon.

Task 1. Obtain USGS low flow data for Big Beef Creek and Duckabush River and determine if flow patterns are correlated with summer chum salmon population abundances.

Task 2. Evaluate the potential return and impact of California sea lions in the Dosewallips delta, and possibly other areas.
- 2.1 Monitor if and when the sea lions return.
- 2.2 Remove the float in the Dosewallips delta if these structures are used by the sea lions.
- 2.3 Evaluate food habits of the sea lions to identify any impacts on summer chum salmon.

Task 3. Evaluate the possibility of transplanting adult summer chum salmon from viable Hood Canal runs to reaches of barren streams suitable for spawning.

Task 4. Continue to evaluate the possibility of hatchery fall chum / natural summer chum interactions.

Task 5. Define a time-of-release and/or a size-at-release to maximize adult returns and minimize domestication.
- 5.1 Monitor weekly zooplankton abundance to determine optimal release time.
- 5.2 Determine natural emigrational peaks.
- 5.3 Evaluate size-at-release and adult survival via coded-wire tagging.

Task 6. Maintain contact with the Estuarine Nearshore Habitat inventory program at DNR (Tom Mumford (206) 902-1079) to catalog Hood Canal nearshore habitats and changes, as they relate to summer chum salmon life history.

Task 7. Evaluate the standing stock of epibenthic and neritic zooplankton (and abundance of other preferred prey organisms) and note any major shifts or trends in abundance and sizes of these populations, as they affect summer chum salmon.

Task 8. Use past, present, and future TFW ambient monitoring (by USFWS, PNPTC, and NWIFC) to evaluate chum salmon spawning habitat and possible rehabilitation measures.

Appendix B. Suggested hatchery guidelines for the restoration of summer chum.

Broodstock Collection

I. Big and Little Quilcene Rivers
   A. Select broodstock randomly from the native population.
   B. Remove broodstock from the wild population over the entire spawning period, as spawn timing is inherited.
   C. Avoid size selection on broodstock.
   D. May use hatchery produced returns to mate with wild individuals, if not enough "wild" individuals are available.
   E. Choose similar-sized mates to enhance survival of progeny.
   F. Avoid pooling milt.
   G. Avoid collecting more than 50% of the native population for the hatchery program.
   H. Spawn one female to one male unless low numbers return, in which case mix and partitioned eggs into N (N = number of available males to be used) lots to be fertilized with milt.

II. Dosewallips, Duckabush, and Hamma Hamma Rivers and Lilliwaup Creek
   A. Same as I (A-F) above.
   B. If the target drainage's returns are insufficient, choose broodstock from the geographically nearest drainage supporting a viable summer chum salmon run and mate with native fish.
   C. Hold broodstock at QNFH, Hood Canal Hatchery, or Lilliwaup Hatchery until ripe.

III. Barren Creeks
   A. Same as I (C,E, and F) and II (C) above.
   B. Capture broodstock from:
      1. The two geographically nearest drainages in Hood Canal with viable runs and cross-mate.
      2. All Hood Canal drainages with viable runs and randomly mate.
      3. A combination of 1 and 2.

Egg Incubation

I. All Hatchery Reared Fish
   A. Incubate eggs in substrate and covered with a light-inhibiting material.
   B. Place eggs at a density, depending upon dissolved oxygen levels, fine sediment, water veolcity, etc., to ensure maximum survival.

II. Within Target Streams
   A. Place eggs in egg boxes (RSIs or others) within the target stream.

Appendix B. (continued)

Fry Release Strategies

I. On-Station
   A. Release fry on an incoming tide within 30 days following total yolk absorption.
   B. Release fry in lower stretches of the target stream, chosen to maximize imprinting and fry suvival.
   C. Feed fry frequently until released.

II. Off-Station
   A. Employ egg boxes (such as remote site incubators) so fry emerge and emigrate volitionally, and transport-related stress is avoided.
   B. Ensure water source for remote site incubation is suitable (i.e., the water source is reliable, free of silt and debris, and the temperature regime is suitable) so that incubation survival is maximized and the timing and pace of emergence is more natural.

Appendix C. Journal articles addressing use of rugose substrate incubators for salmonids.

Bams, R.A. 1982. Experimental incubation of chum salmon (*Oncorhynchus keta*) in a Japanese-style hatchery system. Canadian Technical Report of Fisheries and Aquatic Sciences 1101:1-65.

Kapuscinski, A.R., and J.E. Lannan. 1983. On density of chum salmon (*Oncorhynchus keta*) eggs in shallow matrix substrate incubators. Canadian Journal of Fisheries and Aquatic Sciences 40:185-191.

Kepshire, B.M. 1980. Pacific salmon alevin incubation densities and alevins/dm^2 incubator area in Intalax saddle plastic substrate at Alaskan hatcheries. Pages 109-117 *in* Proceedings of the North Pacific Aquaculture Symposium. Alaska Department of Fish and Game, FRED Division, Juneau, Alaska.