NOAA Technical Memorandum NMFS-NWFSC-73

Historical Population Structure of Pacific Salmonids in the Willamette River and Lower Columbia River Basins

February 2006

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

NOAA Technical Memorandum NMFS Series

The Northwest Fisheries Science Center of the National Marine Fisheries Service, NOAA, uses the NOAA Technical Memorandum NMFS series to issue informal scientific and technical publications when complete formal review and editorial processing are not appropriate or feasible due to time constraints. Documents published in this series may be referenced in the scientific and technical literature.

The NMFS-NWFSC Technical Memorandum series of the Northwest Fisheries Science Center continues the NMFS-F/NWC series established in 1970 by the Northwest & Alaska Fisheries Science Center, which has since been split into the Northwest Fisheries Science Center and the Alaska Fisheries Science Center. The NMFS-AFSC Technical Memorandum series is now being used by the Alaska Fisheries Science Center.

This document should be cited as follows:
Myers, J., C. Busack, D. Rawding, A. Marshall, D. Teel, D.M. Van Doornik, and M.T. Maher. 2006. Historical population structure of Pacific salmonids in the Willamette River and lower Columbia River basins. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-73, 311 p.

NOAA Technical Memorandum NMFS-NWFSC-73

Historical Population Structure of Pacific Salmonids in the Willamette River and Lower Columbia River Basins

James Myers, Craig Busack[1], Dan Rawding[2],
Anne Marshall[1], David Teel, Donald M. Van Doornik,
and Michael T. Maher

Northwest Fisheries Science Center
Conservation Biology Division
2725 Montlake Boulevard East
Seattle, Washington 98112

[1] Washington Department of Fish and Wildlife
600 Capitol Way North
Olympia, Washington 98501

[2] Washington Department of Fish and Wildlife Region 5
2108 Grand Boulevard
Vancouver, Washington 98661

February 2006

U.S. DEPARTMENT OF COMMERCE
Carlos M. Gutierrez, Secretary

National Oceanic and Atmospheric Administration
Vice Admiral Conrad C. Lautenbacher, Jr. USN (Ret), Administrator

National Marine Fisheries Service
William T. Hogarth, Assistant Administrator for Fisheries

Most NOAA Technical Memorandums NMFS-NWFSC are available online at the Northwest Fisheries Science Center web site (http://www.nwfsc.noaa.gov)

Copies are also available from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone orders (1-800-553-6847)
e-mail orders (orders@ntis.fedworld.gov)

Table of Contents

List of Figures

List of Tables

Executive Summary

The Population Identification Subcommittee of the Willamette-Lower Columbia Technical Recovery Team (WLC-TRT) convened in 2000 to review information relevant to the identification of historical, demographically independent populations (DIPs) of listed Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*O. mykiss*) and chum salmon (*O. keta*) within their recovery domain. In 2004 coho salmon (*O. kisutch*) were included in response to the proposed listing of lower Columbia River coho salmon under the U.S. Endangered Species Act.

These are the preliminary conclusions of the subcommittee:

- In the Lower Columbia River Chinook Salmon Evolutionary Significant Unit (ESU), 32 DIPs—23 fall and late fall runs and nine spring runs—existed historically.
- In the Upper Willamette River Chinook Salmon ESU, seven DIPs existed historically.
- In the Lower Columbia River Steelhead ESU, 23 historical DIPs were identified.
- In the Upper Willamette River Steelhead ESU, four historical DIPs were identified.
- In the Lower Columbia River Coho Salmon ESU, 24 historical DIPs were identified.
- No coho salmon DIPS existed historically in the upper Willamette River.
- In the Lower Columbia River Chum Salmon ESU, 17 historical DIPs were identified.
- No chum salmon DIPs existed historically in the upper Willamette River.

Providing the TRT with an historical perspective is seen as an essential first step in developing delisting criteria as part of an overall recovery strategy.

Results

Chinook Salmon

There was an extensive volume of information on Chinook salmon, more than any other species discussed. Abundance, age structure, and genetic information have been collected for nearly all major Chinook salmon-bearing rivers for several decades. Hatchery production information, including spawn timing, fecundity, and population transfers covers more than a century. Tagging studies undertaken at these hatcheries for nearly 40 years provided a wealth of information on oceanic migration patterns and homing fidelity.

Chinook salmon exhibit considerable diversity in major life history traits: run timing, spawn timing, and juvenile life history. Within the Lower Columbia River Chinook Salmon ESU, run timing was the predominant life history criteria used in identifying DIPs. Three distinct run times, spring, fall, and late fall, were identified. The distribution of populations with distinct run times varied among the three ecological subregions. Fall Chinook salmon historically were found throughout the Lower Columbia River Chinook Salmon ESU, while spring Chinook salmon historically were only found in the upper portions of basins with snowmelt driven flow regimes (western Cascade Crest and Columbia Gorge tributaries). Late fall Chinook salmon were identified in only two basins in the western Cascade Crest tributaries. In general, late fall Chinook salmon also matured at an older average age than either lower Columbia River spring or fall Chinook salmon, and had a more northerly oceanic migration route. Within the Upper Willamette Chinook Salmon ESU, only spring Chinook salmon historically were present, although fall-run fish have been introduced from outside of the ESU. Based on the analysis of Chinook salmon populations with minimal out-of-basin influence, basins encompassing more than 250 km^2 appeared capable of maintaining sustainable genetically distinct populations, which suggested demographic independence.

In the Lower Columbia River Chinook Salmon ESU, 32 historical DIPs (23 fall and late fall runs and nine spring runs) historically existed. In the Coast Range tributaries, seven fall Chinook salmon historical DIPs were identified. In the western Cascade Crest tributaries, 10 fall, two late fall, and seven spring Chinook salmon historical DIPs were identified. The construction of large impassable or partially passable barriers in the western Cascade Crest tributaries has led to the likely extirpation or amalgamation of several historical DIPs, complicating the characterization of historical populations. In the Columbia Gorge tributaries four fall and two spring Chinook salmon historical DIPs were identified. Historical life history and abundance information on specific populations generally was limited, with the exception of those populations that were associated with hatcheries or major fisheries. Within the Gorge tributaries, habitat degradation, especially the construction of Condit Dam on the White Salmon River and the flooding of tributaries upstream of Bonneville Dam, has extirpated at least one DIP and severely reduced the abundance of naturally produced fish in the remaining populations. Hatchery programs also have resulted in the introgression of nonlocal Chinook salmon populations. While these effects were seen in other ecological subregions, they were most pronounced in the Columbia Gorge.

In the Upper Willamette River Chinook Salmon ESU, seven historical DIPs were thought to have existed. All seven are contained within a single ecological subregion, the western Cascade Crest tributaries. The construction of several dams on tributaries to the Willamette River has eliminated much of the historical spawning habitat, resulting in an increasing reliance on hatchery production to sustain populations. Interhatchery transfers of eggs and fish within the Willamette River basin has resulted in the probable loss of between-population diversity. Analysis of contemporary populations marginally was useful in interpreting historical population characteristics. There also are several tributaries that drain the Coastal Range to the west in the upper Willamette River basin where spring Chinook salmon have been observed intermittently. Chinook salmon observed in these west-side tributaries are thought to have originated from one of the seven upper Willamette River DIPs, and although adults occasionally may reproduce successfully, these fish do not constitute a self-sustaining population.

Steelhead

The Lower Columbia River Steelhead ESU exhibits two distinct life history strategies: summer- and winter-run timing. In general, west of the Cascade Crest the winter-run timing is more common, while east of the Cascade Crest summer steelhead are found almost exclusively. Summer steelhead are somewhat analogous to spring Chinook salmon in that they utilize spring and summer flow conditions to access the upper portions of many river basins. Summer steelhead also return to freshwater well in advance of spawning, in contrast to winter steelhead that return from the ocean at an advance stage of maturation and spawn within a few weeks. Summer steelhead spawning areas in the lower Columbia River are found above waterfalls and other features that create seasonal barriers to migration. Where no temporal barriers exist, the winter-run life history dominates. The Cowlitz River, Clackamas River, and Sandy River basins are large drainages that support spring and fall Chinook salmon, but in the absence of temporal barriers only contain winter steelhead. Only winter steelhead historically existed in the Upper Willamette River Steelhead ESU, although summer steelhead have been introduced. Flow conditions over Willamette Falls allowed only late winter steelhead to ascend the falls prior to the construction of a fish ladder in the early 1900s.

Steelhead exhibit considerable variability in their age at ocean emigration and their age at first maturation (steelhead, unlike the Pacific salmon do not die after spawning). Much of this age structure variability exists within rather than between most populations; therefore it was of limited use in distinguishing between putative populations. There is a considerable genetic database available for steelhead in the lower Columbia and upper Willamette rivers. Except in areas where hatchery transfers potentially have obscured historical genetic differences between populations, this database was very useful in determining population structure. Steelhead undertake extensive oceanic migrations, however, in spite of large-scale tagging efforts, little is known of their migratory patterns. Tags from marked steelhead seldom are recovered in coastal fisheries, indicating that steelhead quickly move offshore where the probability of recovery is low. It is unclear from existing databases if run timing or population-specific migration patterns exist.

In the Lower Columbia River Steelhead ESU, 23 historical DIPs were identified. In the western Cascade Range tributaries ecological subregion, there were four summer and 14 winter steelhead historical DIPs. Within this subregion, the Cowlitz River basin historically was a major center of abundance and diversity, containing seven of the 14 winter steelhead DIPs. The Columbia Gorge tributaries historically contained three winter and two summer steelhead DIPs.

In the Upper Willamette River Steelhead ESU, four historical DIPs were thought to have existed. Resident and anadromous *O. mykiss* currently are found in a number of tributaries that drain the west side of the upper Willamette River basin. Analysis of historical observations, hatchery records, and genetic analysis strongly suggested that many of these spawning aggregations are the result of recent introductions and do not represent a historical DIP. It was recognized, however, that these tributaries may provide juvenile rearing habitat or may be temporarily (one or more generations) colonized during periods of high abundance. Similarly summer steelhead have become established in the McKenzie River, where historically no steelhead existed. Introduced McKenzie River steelhead were not considered in the identification of historical DIPs.

Criteria employed to designate the steelhead population boundaries were similar to those used for Chinook salmon. Some TRT members felt that because steelhead utilize more side-channel habitat than Chinook salmon, ascend farther upstream in most tributaries, and reside longer in their natal freshwater habitat, the geographic template size for distinct steelhead populations probably was smaller than the 250 km^2 for Chinook salmon.

Coho Salmon

Coho salmon historically existed throughout the Lower Columbia River Coho Salmon ESU. Early historical coho salmon population records are scarce, because coho salmon were not initially considered a desirable commercial species. With the decline of the Columbia River Chinook salmon runs in the early 1900s, more attention was given to coho salmon by commercial fisherman and state and federal biologists.

In response to increased sport and commercial harvest and declining habitat conditions, the hatchery production of coho salmon has expanded significantly throughout the ESU in the past 50 years. Hatchery stocks were exchanged routinely within the lower Columbia River, resulting in a homogenization of hatchery broodstocks. Habitat degradation, loss of accessible habitat, and overharvest also have reduced the abundance of naturally spawning coho salmon to critically low levels. As a result of the interactions between large runs of relatively genetically homogeneous hatchery fish and remnant naturally produced coho salmon populations, recent genetic analyses provide little information to discriminate populations. Much of the life history information collected from hatchery-origin fish or feral hatchery fish provides little insight into the characteristics of historical populations.

Coho salmon exhibit two major life history strategies: early and late timing. As with Chinook salmon and steelhead, run timing is correlated strongly with other important life history traits (spawn timing, habitat utilization, oceanic migration patterns). In general, late coho salmon spawn in smaller rivers or the lower reaches of larger rivers. Late-run fish also undertake oceanic migrations to the north of the Columbia River, extending as far as northern British Columbia and southeast Alaska. As a result, late coho salmon are known as “Type N” coho. Alternatively, early coho salmon spawn in the upper reaches of larger rivers in the lower Columbia River and in most rivers inland of the Cascade Crest. Historically early coho salmon also were found in the interior portion of the Columbia River basin, migrating as far as Kettle Falls on the Columbia River and into many of the lower Snake River tributaries. During their oceanic migration, early coho salmon migrate to the south of the Columbia River and are known as “Type S” coho salmon. They may migrate as far south as the waters off northern California. While the ecological significance of run timing in coho salmon is fairly well understood, it is not clear how important ocean migratory pattern is to overall diversity. Additionally, the correlation between ocean migration and run timing is somewhat tenuous.

The relative historical abundance of late run (Type N) and early run (Type S) life histories largely is unknown. The divergence of run times in coho salmon is not thought to be of a sufficient magnitude to warrant consideration as distinct populations. Within a basin, these distinct life history types are considered subpopulations, rather than distinct DIPs. Presently, no basins contain self-sustaining aggregations of both life history types. Thus it is not possible to understand the level of interaction or isolation between late and early run fish in the same basin. As self-sustaining populations are recovered, the dynamics of sympatric populations of early and late run coho salmon will be better understood.

In the Lower Columbia River Coho Salmon ESU, 24 historical DIPs were estimated. In the Coastal Range tributaries subregion, seven historical DIPs were identified. It was estimated that coho salmon in these DIPs would have included late-timed runs. In the western Cascade Range tributaries, 14 DIPs were thought to have existed. Many of these DIPs historically would have contained both early- and late-run coho salmon. In the Columbia Gorge subregion, three historical DIPs were identified. The majority of coho salmon in these DIPs likely would have exhibited an early-run life history. While there is considerable information about existing spawning aggregations in the lower Columbia River, the extensive programs of hatchery releases and interbasin transfers between hatcheries, in tandem with the small number of naturally produced fish, places some uncertainty on the population-specific historical accuracy of these DIP designations. In general, the coho salmon populations were considered more similar to steelhead populations than Chinook salmon, reflecting the tendency of coho salmon to use smaller tributaries and mainstem side channels for spawning and extended rearing.

Chum Salmon

Of the four species examined, information about historical and existing chum salmon populations is the most limited. This is in part because of the near extirpation of chum salmon in the 1940s, and the relatively low commercial value of the species. In the Lower Columbia River Chum Salmon ESU, the predominant life history type is the fall-run timing, although a summer chum life history also has been identified in the lower Columbia River. Chum salmon exhibiting additional run times may have been historically present, but were either extirpated or currently are at very low numbers.

Unlike other the species, chum salmon spawning aggregations were identified in the mainstem Columbia River. These aggregations generally were included in the DIP associated with the nearest river basin. Much of the structure of historical populations in the Columbia River Coho Salmon ESU was inferred using population boundaries derived for fall Chinook salmon. New information on chum salmon, especially genetic information, has been analyzed from recently sampled spawning aggregations. Although much of this information suggests that considerable genetic variation exists in the ESU, it is unclear whether this variation is representative of historical patterns or is the result of random genetic drift related to protracted declines in population abundance.

In the Lower Columbia River Chum Salmon ESU, an estimated 17 DIPs historically were identified. Seven historical DIPs, all fall runs, were identified in the Coast Range tributaries subregion. Eight historical DIPs, seven fall runs and one summer run, were thought to have existed in the western Cascade Range tributaries subregion. Fall and summer chum salmon DIPs in the Cowlitz River were considered distinct based on run timing and spawning habitat. Summer chum salmon appear to have migrated farther upstream in the Cowlitz River than fall chum salmon. In the Columbia Gorge tributaries subregion, only two fall chum salmon DIPs were identified.

Methods

By definition DIPs consist of one or more spawning aggregations that are linked sufficiently by an exchange of spawners such that they share a common demographic fate (McElhany et al. 2000). Effectively the criteria for demographic isolation are similar to those employed for reproductively isolation in establishing biological populations. As a biologically based subunit of ESUs, DIPs are useful components in recovery planning. The historical distribution of DIPs in each of the listed ESUs also provides a proven benchmark for sustainability. Understanding the distribution and characteristics of the historical DIPs that comprised an ESU may help recovery planners in setting criteria for recovery.

The authors relied on a number of types of information to identify historical populations. In general, there were six different types of information utilized:

1) geography,
2) migration fidelity,
3) genetic attributes,
4) life history patterns and morphological characteristics,
5) population dynamics, and
6) environmental and habitat characteristics.

Historical information on hatchery transfers and releases also was valuable in interpreting life history and genetic characteristics exhibited by present-day populations.

The historical population boundaries and designations provided are intended to be approximations of the range and diversity of populations for each species in the listed ESUs, not necessarily an exact reconstruction. The geographic population boundaries presented delimit the basin area accessible to adults for spawning. It is understood that many of the populations share areas for juvenile rearing, migration corridors, and ocean feeding.

In addition to defining the geographic boundaries of historical population, characterizing the biological characteristics of each population, especially life history diversity, was considered important. Changes in population life history characteristics may explain observed declines in productivity and abundance, especially when associated with habitat changes. In the absence of comprehensive historical studies of individual populations, information was gleaned from a number of sources. Biological surveys of salmon and steelhead populations in the Columbia River basin began in the 1850s with the U.S. exploring expeditions. These early documents gave general descriptions of the species found and identified areas where Native Americans had established seasonal fishing camps. In the 1880s, state and federal agencies began documenting commercial fishing and canning activities. This information was useful in estimating the regional abundance of many species prior to large-scale alterations in freshwater habitat and the initiation of hatchery operations. A number of biological surveys by the Bureau of Commercial Fisheries (the precursor of NOAA Fisheries Service) identified suitable sites for hatchery construction. These surveys focused on rivers with large numbers of salmon (primarily Chinook salmon), and included descriptions of run and spawn timing for Chinook salmon and other salmon species. During the early decades of the 1900s, much of the information concerning the biology and abundance of salmon and steelhead was collected at hatcheries throughout the Northwest. In general, however, historical documentation on the life history characteristics, distribution, or abundance of populations prior to 1940 is extremely limited.

Considerable biological information has been gathered during the past three decades, although there is some uncertainty in relating the biological characteristics and distribution of existing populations to those that existed historically in the same basins. This dilemma is due in part to the widespread transfer of eggs and fry between watersheds by state and federal agencies during the past 100 years. Habitat degradation and the creation or the removal of migration barriers also have altered the distribution and life history characteristics of many salmonid DIPs. Genetic information similarly is affected by artificial-propagation activities, except in those few basins where there has been little or no activity. Many of the geographic criteria for identifying historical DIPs were established using information from relatively unimpacted basins in the Pacific Northwest.

The boundaries for historical DIPs were in part established using information related to different isolating mechanisms: homing fidelity and migration timing. Homing fidelity was examined to estimate the extent of adult exchange among putative spawning populations. Analysis of the recoveries of adult marked hatchery fish suggests that there is little straying of adults beyond 50 RKM from their juvenile site of release, however, estimates derived from hatchery fish may be higher than naturally produced fish. Many of the recoveries also occurred at hatchery collection facilities where one-way traps collect "stray" fish that might have otherwise returned to the site of their release. Husbandry practices also can affect homing fidelity. Insufficient acclimation prior to release or inappropriate release timing can influence the likelihood of an adult accurately returning to its release site. Within a basin, temporal differences in return migration and spawn timing provided a mechanism for establishing demographically (and reproductively) isolated populations. Adult run timing often is coordinated with stream hydrology. For example, spring Chinook salmon return to freshwater when stream flows are high and normally impassable barriers (e.g., waterfalls or cascades) can be jumped. Similarly differences in maturation and spawn timing limit the potential for the interbreeding of spring and fall Chinook salmon in many basins. Major run-timing differences were used as one criterion in distinguishing DIPs.

Ecological subregions were identified because they describe major geographic areas within the ESUs with distinct ecological characteristics. For those traits where life history information was available, populations in different subregions did exhibit differences in life history diversity, even within a single run time. The authors concluded that the ecological conditions in these subregions historically created the conditions for the evolution of substantial differences in life history traits among endemic populations in the different subregions. Where historical life history information was absent, ecological subregions provided a useful tool for implying differences in life history traits. The TRT also has recognized the importance of these subregions in recovery planning. Ensuring that DIPs are recovered in each of the subregions provides a mechanism for conserving life history diversity to the ESU.

The TRT relied heavily on geographic and ecological information to establish proposed population and ecological subregion boundaries. Major stream features such as branching, cascades, falls, or canyons were considered as potential isolating mechanisms between populations. Basin area also was used a general criteria for establishing population boundaries. Analysis of less developed regions indicated that DIPs exist in basins that are sufficiently sized to provide reproductive isolation from other populations and exhibit adequate productivity to support sufficient numbers of fish and ensure long-term sustainability. This geographic template established minimum basin size guidelines for each species. Geographic characteristics such as elevation also were used as indicators of differences in stream hydrology (snow vs. rain influenced flows), streamside ecology, water temperature, and overall productivity. Ecological subregions were in part adapted from the U.S. Environmental Protection Agency's ecoregions (Omernik 1987). Ecoregions provided a simplified summary of environmental characteristics such as elevation, soil type, vegetative land cover, rainfall, and climate.

Overall the information utilized in the identification of historical DIPs contributes to our understanding of how these populations functioned. An understanding of the historical structure of each population, its abundance, and the interaction between historical habitat and life history characteristics provides a baseline for analyzing the present status of populations, the changes that have affected them, and, potentially, the actions that may be necessary to conserve or restore them.

In addition to identifying historical DIPs for listed ESUs in the lower Columbia River and upper Willamette River basins, maps were created for each DIP showing historical and current accessibility. Historical accessibility was based on maximum stream gradients ascended by each species. Current accessibility was based on presence as reported by state agencies and location of known barriers to migration (i.e. inaccessible culverts, screened access points, dams). Of the four species, chum salmon are most limited by stream gradients, coho salmon and Chinook salmon are intermediate (utilizing gradients up to 7%), and steelhead occupy the highest stream gradient areas (up to 12%). Except where major barriers exist (large culverts or impassable dams), there has not been a substantial change in the area accessible to fish; however, in many cases while the quantity of available habitat is unchanged, the quality of that habitat has been severely degraded. In some cases poor habitat conditions (high temperature or low flow) may effectively create seasonal barriers to migration that are not represented on the maps.

Acknowledgments

The authors wish to thank biologists from the Oregon Department of Fish and Wildlife, the Washington Department of Fish and Game (WDFW), the U.S. Fish and Wildlife Service, the U.S. Geologic Survey, and the National Marine Fisheries Service, who provided information and technical review.

Many of the genetic baseline samples are the result of fieldwork carried out by WDFW biologists and technicians. We thank WDFW Genetics Lab technicians from 1988 to 2001 who conducted lab operations and collected genetic data for the samples. WDFW current and former staff members Bruce Baker, Joe Hymer, Larry LeClair, Stevan Phelps, Jim Shaklee, and Sewall Young were principal researchers for genetic studies and contributed to sampling design, genetic data statistical analyses, and results interpretation and reporting. We also appreciate the work of John Sneva, who scale-aged many adult fish collected for genetic samples.

The authors also acknowledge the efforts of David Kuligowski, Northwest Fisheries Science Center (NWFSC), in the collection and analysis of many of the coho salmon genetics samples, and Laurie Weitkamp, NWFSC, for providing many of the coho salmon tissues for genetic analysis and for her generosity in allowing us to reprint large section of the coho salmon status review.

The authors also thank technical editors Andrea Jarvela, Winston Martin, and Gordon Sholtys.

Abbreviations and Acronyms

BRT	Biological Review Team
CWT	coded-wire tag
SCTC	Salmon Culture Technology Center
DIP	demographically independent population
EPA	U.S. Environmental Protection Agency
ESU	evolutionarily significant unit
GDU	genetic diversity unit
LRB	lower river bright
NFH	National Fish Hatchery
NMFS	National Marine Fisheries Service
NOR	natural-origin recruit
ODF	Oregon Department of Fisheries
ODFW	Oregon Department of Fish and Wildlife
PNRBC	Pacific Northwest River Basins Commission
PIT	passive integrated transponder
PSTRT	Puget Sound Technical Recovery Team
RKM	River kilometer
SASSI	Salmon and Steelhead Stock Inventory
SaSI	Salmon and Steelhead Inventory
TRT	Technical Recovery Team
UPGMA	unweighted pair group method with mathematic averages
URB	upriver bright
USBF	U.S. Bureau of Fisheries
USDOC	U.S. Department of Commerce
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geologic Survey
VSP	viable salmonid population
WDF	Washington Department of Fisheries
WDG	Washington Department of Game
WDFG	Washington Department of Fish and Game

Introduction

The goal of the Willamette-Lower Columbia Technical Recovery Team (WLC-TRT) is to identify historical and extant independent populations of salmonids in listed evolutionarily significant units (ESUs). Understanding population size and spatial extent is critical for the viability analyses, which are a necessary step in recovery planning and conservation assessments for any species. The Washington Department of Fisheries (WDF) et al. (1993) identified Salmon and Steelhead Stock Inventory (SASSI) populations in Washington,[1] and the Oregon Department of Fish and Wildlife (ODFW) (Kostow 1995) identified populations in Oregon. It is likely that, in many cases, the populations we identify will be the same as those identified by state agencies and tribal governments. Alternatively, different population identifications may result from several inherent differences in the population definitions employed and the underlying management purpose for each classification scheme. In the end, it is not possible to verify the accuracy of the historical populations presented in this technical memorandum. We do, however, present a likely scenario that can then be analyzed as part of recovery planning.

The populations ultimately identified are the historical demographically independent units (DIPs) for which the viability of extant populations will be estimated. These populations are the independent groups of fish whose historical and present conditions will be characterized in future papers. For each population, where possible, we will describe the historical abundance and productivity, life history and phenotypic diversity, and spatial distribution of spawning and rearing groups. We also estimate habitat capacity for each population under historical and present conditions. In the ultimate recovery goals expressed, the populations identified in this technical memorandum are those considered when answering the question: "How many and which populations are necessary for persistence of the ESU?"

Definition of a Population

The definition of a population that we apply is set forth in the viable salmonid population (VSP) document prepared by the National Marine Fisheries Service (NMFS) for use in conservation assessments for Pacific salmonids (McElhany et al. 2000). In the VSP context, NMFS defines an independent population much along the lines of Ricker's (1972) definition of a stock. That is, an independent population is a group of fish of the same species that spawns in a particular lake or stream (or portion thereof) at a particular season and, which, to a substantial degree, does not interbreed with fish from any other group spawning in a different place or in the same place at a different season. For our purposes, not interbreeding to a "substantial degree" means that two groups are isolated to such an extent that exchange of individuals among the

[1] 2002 Salmon and Steelhead Inventory (SaSI) (WDFW 2003), an updated version of the 1993 SASSI document, is online at http://wdfw.wa.gov/mapping/salmonscape. The 1993 SASSI report was extensively utilized in the preparation of this document and is still widely available; therefore references to the 1993 SASSI were retained with notations where the newer 2002 SaSI population structure differed.

populations do not substantially affect the population dynamics or extinction risk of the independent populations over a 100-year period (McElhany et al. 2000). The exact level of reproductive isolation that is required for a population to have substantially independent dynamics is not well understood, but some theoretical work suggests that substantial independence will occur when the proportion of a population that consists of migrants is less than about 10% (Hastings 1993). Thus independent populations are units for which it is biologically meaningful to examine extinction risks that are intrinsic factors, such as demographic, genetic, or local environmental stochasticity. In general, the isolation conditions necessary to maintain demographic independence are not as strict as the conditions to maintain reproductive or genetic independence at the population level.

Structure above the Population Level

Just as there may be substructuring within a population, there may be structure above the level of a population. This is explicitly recognized in the designation of an ESU. An ESU may contain multiple populations that are connected by some small degree of migration, however, a population cannot be larger than an ESU. Thus organisms can be grouped in a hierarchical system in which we define the levels of individual, subpopulation, population, ESU, and finally species. Other hierarchical systems with more or fewer levels could be constructed. Although reproductive isolation forms a continuum, it probably is not a smooth continuum, and there is a biological basis for designating a hierarchy of subpopulations, populations, and ESUs.

A population is described as a group of fish that is isolated reproductively "to a substantial degree" (McElhany et al. 2000). As a criterion for defining fish groups, the degree of reproductive isolation is a relative measure, however, and can vary continuously from the level of fish pairs to the degree of reproductive isolation separating species. The population defined in this technical memorandum is therefore not the only biologically logical grouping that can be constructed.

Structure below the Population Level

Below the population level, for example, some fish groups may be isolated reproductively to some degree from other fish groups within the population, but they are not sufficiently isolated to be considered independent by the criteria adopted for this technical memorandum. These fish groups are referred to as subpopulations. Few populations have been studied sufficiently in depth to characterize their component subpopulations. The existence and interaction of subpopulations can have important consequences for characterizing a VSP, and population spatial structure is proposed as one of four key parameters for eventually evaluating the status of a population. Furthermore, subpopulations play an important role in the sustainability and evolution of populations.

Independent populations generally (but not always) will be smaller than a whole ESU and generally will inhabit geographic ranges on the scale of whole river basins or major subbasins that are relatively isolated from outside migration.

Conceptual Approach to Identifying Populations

The definitive information needed to identify populations is intergroup migration rates and the demographic consequences of those migration rates. In practice, information about straying of salmon between streams rarely is available. Our approach in identifying population structure is to use diverse sources of information that are proxies for understanding the degree of reproductive isolation between fish groups. Each type of information contributes to our understanding of population boundaries, but none alone provides us with much confidence in our answer. In the following six subsections we briefly outline the different information sources we used to help in identifying salmon populations. They are discussed in order of strength of inference we believe possible to make about population structure from each indicator, beginning with relatively high inference that can be made with geographic and migration-rate indicators. Depending on the particular data quality and the genetic and demographic history of salmon in different regions, the usefulness of these indicators in any one area can vary.

Geography

The boundaries of a salmon population will be defined in part by the spatial distribution of its spawning habitat. Physical features such as a river basin's topographical and hydrological characteristics dictate to a large degree where and when salmon can spawn and delimit the spatial area over which a single group of fish can be expected to interact. Geographic constraints on population boundaries (such as distance between streams) can provide a useful starting point, but geographic constraints will not generally support strong inferences at a fine scale (e.g., distinguishing separate populations within a small river basin). In addition, biogeographic characteristics and historical connections between river basins on geological time scales can be informative in defining population boundaries.

Migration Rates

The extent to which individuals move between populations will determine the degree of reproductive isolation and, therefore, demographic independence among sites. Estimates of stray rates are particular to the group of fish, season, and streams in which they are made, thus they provide useful information about straying under current conditions. In contrast, it is not possible to estimate the magnitude of their variation over long time periods (e.g., 100 years). Furthermore, there have been substantial changes in fish density within populations and geographic connectivity between populations during the past century. Migration rates usually are calculated using the recovery of tagged adults. Fish are tagged using a variety of external tags or internal coded-wire tags (CWTs) or passive integrated transponder (PIT) tags. Compared to mark-recapture and other direct estimates of straying, genetically based estimates of intergroup isolation can be used to better estimate straying that has occurred between fish groups integrated over longer time periods.

Genetic Attributes

Neutral genetic markers are useful in identifying salmon populations, because they indicate the extent of reproductive isolation among groups. Neutral markers can be difficult to interpret because patterns may reflect hatchery breeding practices or nonequilibrium conditions, so they should be interpreted with caution. Neutral and adaptive genetic differences among fish groups (as indicated by quantitative traits or molecular markers) are more difficult to document than discrete marker differences. Since the degree of isolation necessary to maintain genetic independence is much higher than that for demographic independence, genetic information will tend to give a more conservative measure of demographic population structure. That is, some populations that appear to be linked genetically may be largely independent demographically.

Patterns of Life History and Phenotypic Characteristics

Technically only those phenotypic traits based on underlying genetic variation (rather than environmentally induced variation) are informative in identifying populations (defined on the basis of reproductive isolation and demographic independence). Variations in spawning time, age at juvenile emigration, age at maturation, and ocean distribution are, to some degree, genetically influenced (Myers et al. 1998). Environmental conditions may restrict variability in the life history traits expressed. Hydrological conditions (i.e., water temperature, times of peak and low flows, etc.) influence the time of emigration and return migration and spawning. Conditions in many rivers (especially short coastal rivers) during the summer months do not provide suitable habitat for juvenile fish to extend their freshwater rearing beyond late spring. Similarly, if habitat is not available for returning adults to oversummer prior to spawning, the spring- or summer-run life history strategies would not be feasible. Phenotypic variation can be used as a proxy for genetically based variation, and it may indicate similarities in the selective environments experienced by salmonids in different streams. In some cases, similarities in phenotype may arise independently in distinct populations (e.g., spring run timing or possibly resistance to the parasite *Ceratomyxa shasta*). However, phenotypic differences in life history traits between populations (especially those that recently have diverged) could be the result of differences in habitat utilization and geographic separation.

Population Dynamics

Abundance data can be used to explore the degree to which demographic trajectories of two fish groups are independent of one another. All else being equal, the less correlated time series of abundance is between two fish groups, the less likely they are to be part of the same population. Complicating interpretation of correlations in abundance between fish groups is the potentially confounding influence of correlated environmental characteristics, such as shared ocean conditions or regionwide drought. Harvest effects also may result in correlations of abundance when distinct populations share oceanic and inshore migratory routes. Similarly, hatchery releases can confound any correlation between two populations, especially if the magnitude of releases is different and the relative contribution of hatchery fish to escapement is unknown or subject to a high degree of uncertainty. When fish groups that are in close proximity are not correlated in abundance over time, they are not likely to be linked demographically. The reverse is not always easy to argue—when correlations in abundance between fish groups are detected, more work is needed to rule out confounding sources of correlation.

Environmental and Habitat Characteristics

In identifying independent demographic populations, environmental characteristics can influence population structure in two ways. First, environmental characteristics can directly isolate populations. Thermal or flow conditions in a river can create migrational barriers that prevent interactions between populations (e.g., Willamette Falls and Lyle Falls). Second, environmental conditions may exert a selective influence on salmon populations, which in turn may influence the expression of life history characteristics. The strength of the correlation between habitat and life history characteristics may be related to homing fidelity and the degree to which populations in ecologically different freshwater habitats are effectively isolated reproductively. If immigrants are less fit, they will not contribute to the long-term demographics of the receiving population.

Identifying Historical Populations of Salmonids

The first goal of the WLC-TRT's Population Identification Subcommittee was to identify historical populations of salmonids in the listed ESUs. An understanding of the number, abundance, life history diversity, and distribution of historical populations is an important step in formulating recovery scenarios. It was understood that the historical organization and status of populations in an ESU were not static but dynamic, however, the historical structure does provide the only proven prototype of sustainability. It is not the WLC-TRT's task to restore historical conditions completely, but to determine in general the population structure necessary to restore the needed aspects of life history diversity, population distribution, and abundance in order to provide for a sustainable ESU into the foreseeable future.

Criteria for Identifying the Distribution of Historical Populations

The task of identifying historical populations in the lower Columbia River and upper Willamette River ESUs is challenging, because anthropogenic factors (e.g., hatchery operations, stock transfers, harvest effects, and habitat degradation and elimination) (Appendix A, pages 121–154) have influenced population structure and interaction significantly. Few extant populations in these ESUs provide information directly relevant to determining historical population structure and number (Appendix B, pages 155–160). Where available, information concerning salmonid populations in the Lower Columbia River and Upper Willamette River ESUs and others (primarily Puget Sound) was useful in developing a template for the general geographic and ecological characteristics of an independent population. A geographic template was developed to infer selective and isolating factors that may have led to DIPs in lieu of relevant biological information for historical salmonid populations. In general, four criteria were used to establish the distribution of historical populations:

1) documented historical use,
2) temporal isolation (different run or spawn timing),
3) geographic isolation (geographic template), and
4) basin-specific information (e.g., barrier falls).

In some instances presumptive populations that did not meet the criteria for DIPs, but that exhibited one or more of the characteristics of distinct populations, were designated as subpopulations. Subpopulation designations were intended to highlight areas where some level of population structuring may exist and where further study should be directed, rather than identify true biological subpopulations.

Geographic Template Criteria

For an independent population to persist in the face of environmental fluctuations it must maintain a sufficiently large population size. Whether an independent population must contain hundreds or thousands of individuals still is under debate, but at a minimum, hundreds of individuals are necessary. Thus one measure of the potential for a watershed to sustain an independent population is its size. Basin-size estimates generally were acquired from U.S. Geologic Survey (USGS) stream-gauge databases (Table 1). The size of a basin (square kilometers) and the topography of the river to which it belongs also may influence homing accuracy. The presence of a seasonal or complete migration barrier or barriers provides an added degree of reproductive isolation.

Minimum basin-size estimates were derived from the examination of other ESUs where native, naturally produced populations (primarily Chinook salmon [*Oncorhynchus tshawytscha*]) still exist. Additionally, boundaries between distinct populations could be inferred where rivers diverge into distinct major tributaries. Tributary basins, if large enough, may provide ecologically distinctive habitats and characteristic homing (olfactory) cues that promote the establishment of independent populations. For example, based on genetic analysis alone there are several isolated reproductively Chinook salmon groups in northern Puget Sound. The Nooksack River basin contains two populations of Chinook salmon, each of which represents a different WDFW genetic diversity unit (GDU), the north fork (743 km^2) and south fork (477 km^2) (Marshall et al. 1995).

Within the Stillaguamish River basin (1,774 km^2), the North Fork Stillaguamish River drainage covers 738 km^2 and contains a population of Chinook salmon with significant genetic and life history differences relative to Chinook salmon in the main stem and South Fork Stillaguamish River (Marshall et al. 1995). The Skagit River basin is the largest in Puget Sound (8,270 km^2), slightly larger than the Cowlitz River basin in the lower Columbia River basin, and presently contains as many as six DIPs. Historically the Skagit possibly contained an additional two or three (now extinct) independent populations (WDF et al. 1993). The Puget Sound Technical Recovery Team (PSTRT 2001) identified three spring-run populations in the Skagit River basin:

1) Cascade River (390 km^2),
2) Suiattle River (873 km^2), and
3) upper Sauk River (762 km^2).

Other basins that historically may have contained independent populations have basin areas larger than 250 km^2 (e.g., the North Fork Skokomish [304 km^2] and Dungeness rivers [524 km^2]). Basin productivity depends on a variety of factors other than size, however, it would require special circumstances for rivers with basin areas smaller than 250 km^2 to sustain a population large enough to be demographically independent under variable environmental conditions. Differences in life history characteristics among Chinook salmon, coho salmon (*O. kisutch*), chum salmon (*O. keta*), and winter and summer steelhead (*O. mykiss*) probably significantly influence the minimum basin size described above. These differences are discussed in the subsequent species sections.

Table 1. Lower Columbia River ESU tributary basin, distance from mouth of the Columbia River, and basin size.

Tributary basin	RKM[a]	Basin (km^2)[b]	USGS gauge
Lower Columbia River (coastal tributaries)	—	—	—
Lewis and Clark River	12.9	—	—
Youngs River	16.1	103.8	14251500
Wallooskee River	22.5	—	—
Klaskanine River	27.4	36.2	14252000
Chinook River	9.6	30.2	CBIC 1967
Deep River	32.3	32.4	CBIC 1967
Grays River	33.8	156.9	14250000
Big Creek	37.0	82.6	14248500
Bear Creek	40.0	8.6	14248700
Skamokawa Creek	54.7	45.0	14248000
Elochoman River	60.0	170.3	14247500
Plympton Creek	63.0	—	—
Clatskanie River	—	137.2	14247000
Beaver Creek	—	—	—
Mill Creek	85.2	73.3	14246500
Abernathy Creek	86.9	52.6	14246000
Germany Creek	90.1	59.3	14245500
Coal Creek	99.8	69.6	Hymer et al. 1992
Goble Creek	119.1	—	—
Tide Creek	120.6	—	—
Milton Creek	144.0	85.4	Willis et al. 1960
McNulty Creek	146.0	—	Willis et al. 1960
Scappoose Creek	150.0	152.7	Willis et al. 1960
Cowlitz River	106.2	6,420.4	14245150
Cispus River	+148.0	831.0	14231900
Tilton River	+102.0	403.9	14236500
Upper Cowlitz River	—	3,008.3	14235000
Ohanapecosh River	+214.0	261.5	14224000
Toutle River	+27.4	1,322.9	14242690
North Fork Toutle River (with Green River)	+20.9	735.2	14241101
North Fork Toutle River (without Green River)	+20.9	396.1	14241101
Green River	+41.8	339.1	14241000
South Fork Toutle River	+20.9	310.7	14241500
Coweeman River	+12.1	308.1	14245000
Kalama River	115.8	523.0	14223600
Little Kalama River	+21.9	29.8	CBIC 1967
Gobar Creek	+31.4	54.9	CBIC 1967
Lewis River	141.0	2,718.4	CBIC 1967
North Fork Lewis River	+8.0	1,892.5	14220500
Cedar Creek	+25.3	143.7	CBIC 1967
Muddy River	+96.7	349.5	14216350
East Fork Lewis River	+8.0	390.9	14216500
Willamette River	164.1	—	Willis et al. 1960
Johnson Creek	+29.0	134.1	04211550
Mount Scott and Kellogg creeks	+29.2	—	14211130

Table 1 continued. Lower Columbia River ESU tributary basin, distance from the mouth of Columbia River, and basin size.

Tributary basin	**RKM**[a]	**Basin (km^2)**[b]	**USGS gauge**
Willamette River continued			
Clackamas River	+39.9	2,4180.0	—
Mainstem and upper Clackamas River	—	—	—
Oakgrove Fork	—	>310.0	—
Collawash River	+131.5	>368.0	—
Salmon Creek	151.2	208.9	14144000
Sandy River	193.6	1,315.0	—
Bull Run River	+25.7	277.0	14140000
Little Sandy River	+46.3	—	14140500
Salmon River	+56.0	274.4	14135500
Zigzag River	+64.4	80.3	14131500
Washougal River	194.9	279.6	14143500
Mainstem Washougal River	—	—	—
Little Washougal River	+9.1	60.1	14144000
West Fork Washougal River	+23.1	78.5	14143000
Columbia Gorge tributaries	—	—	—
Mainstem Columbia River	—	—	—
Bridal Veil Creek	—	—	—
Wahkeena Creek	—	—	—
Hardy Creek	228.2	—	CBIC 1967
Hamilton Creek	229.0	30.5	—
Multnomah Creek	—	—	—
Moffer Creek	—	—	—
Tanner Creek	—	—	—
Eagle Creek	236.5	—	—
Rock Creek	243.0	106.1	CBIC 1967
Herman Creek	243.0	—	—
Gorton Creek	—	—	—
Viento Creek	—	—	—
Lindsey Creek	—	—	—
Phelps Creek	—	—	—
Wind River	249.4	582.5	14128500
Panther Creek	+6.9	106.1	CBIC 1967
Trout Creek	+17.4	78.4	CBIC 1967
Little White Salmon	260.7	346.9	14125500
Big White Salmon River	270.3	696.4	14123000
Rattlesnake Creek	+12.1	144.2	CBIC 1967
Trout Lake Creek	+41.8	179.4	CBIC 1967
Hood River	271.9	722.3	14120000
East Fork Hood River	+18.5	279.6	14115500
West Fork Hood River	+18.5	247.5	14118500

[a] Distances (RKM) are from the mouth of the Columbia River to the mouth of the tributary. Distances with a + indicate the distance from the mouth of the parent stream to branching of the tributary.

[b] Basin sizes were obtained from information describing USGS flow-monitoring stations (where given), otherwise, basin sizes were obtained from CIBC 1967, Willis et al. 1960, and Hymer et al. 1992.

Ecological Information

The fidelity with which salmonids return to their natal streams implies a close association between a specific stock and its freshwater environment. The selective pressures of different freshwater environments may be responsible for differences in life history strategies among stocks. Miller and Brannon (1982) hypothesized that local temperature regimes are the major factor influencing life history traits. If the boundaries of distinct freshwater habitats coincide with differences in life histories, it would suggest a certain degree of reproductive isolation. Therefore, identifying distinct freshwater, terrestrial, and climatic regions may be useful in identifying distinct populations. As a first step in identifying historical independent salmonid populations, the lower Columbia River was divided into three geographic/ecological subregions:

1) coastal,
2) western Cascades, and
3) Columbia Gorge (eastern Cascades).

Differences in geography, hydrology, precipitation, vegetation, and geology probably are substantial enough to have differentially selected for variations in life history strategy and provided the geographic separation for reproductive isolation. Within these large subregions, identifying historical independent populations is more problematical.

The U.S. Environmental Protection Agency (EPA) established a system of ecoregion designations (Figure 1) based on soil content, topography, climate, potential vegetation, and land use (Omernik 1987). These ecoregions are similar to the physiographic provinces determined by the Pacific Northwest River Basins Commission (PNRBC 1969). Similarly, there is a strong relationship between ecoregions and freshwater fish assemblages (Hughes et al. 1987). Also included in the physiographic descriptions for each region is information presented in PNRBC (1969), present-day water use information (USGS 1993), river-flow information (Hydrosphere Products, Inc. 1993), and climate data from the U.S. Department of Commerce (USDOC 1968).

Biological Data

Homing fidelity is a major determinant of population structure and plays a key role in defining a population’s geographic bounds. Migration rates (homing fidelity) were estimated using CWT-marked fish releases (primarily from hatcheries) (PFMC 2000). Spatial homing fidelity was measured as the relative proportion of freshwater recoveries that occurred in the river basin of origin. Methods for calculating migration (stray) rates followed that used by van der Haegen and Doty (1995). Freshwater recoveries of adults at hatcheries, fish traps, terminal (tributary) fisheries, and spawner surveys were considered in the migration estimation. Mainstem Columbia River recoveries (net and sports fisheries) were excluded from the analysis. In general, only CWT releases during the 1980s that produced more than 100 expanded freshwater recoveries were used. At least three CWT release groups were used for each release location. Only releases of fish that were produced from adults returning to that release site (hatchery) were considered. Since many hatcheries were founded originally by transfers from other sites, genetically determined aspects of their oceanic migration may reduce the precision with which they return to their “new” natal stream. Furthermore, many aspects of hatchery rearing and release programs probably reduce the homing fidelity of returning hatchery fish.

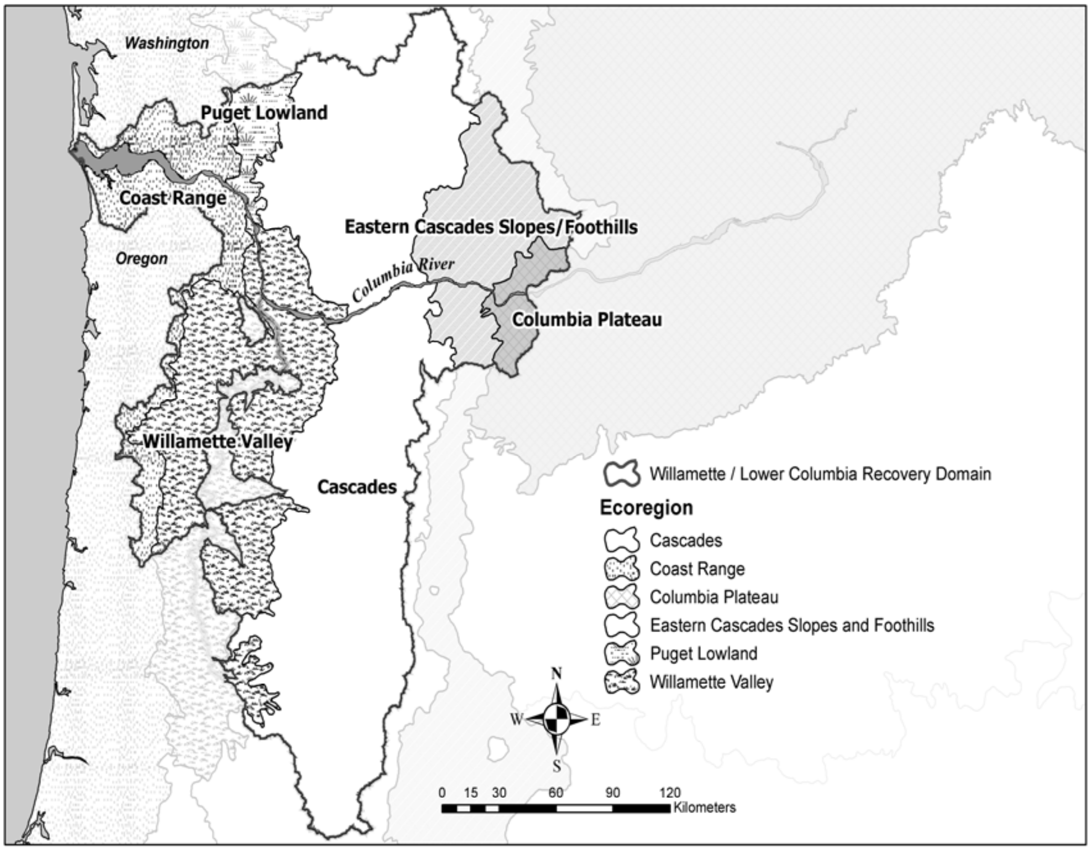


Figure 1. EPA Level III ecoregions for the lower Columbia and upper Willamette rivers.
Source: Omernik 1987.

Additionally, although the proportion of freshwater recoveries at a nonnatal site may be high, the impact on the population receiving the strays is related to the number of strays, the number of indigenous spawners, and the relative reproductive success of the strays.

The marine distribution of Chinook salmon groups was estimated through recoveries of CWT-marked fish in ocean fisheries. CWT information supports a strong genetic basis for ocean migration patterns. These patterns represent an important form of resource partitioning and are based on ancestral feeding routes that are significant to the evolutionary success of the species. To minimize variability in ocean conditions and fishery effort, recoveries were analyzed for a minimum of three groups from any release site. Only groups released from 1980 to 1989 that had at least 100 oceanic recoveries (expanded) were considered, and no groups from one site could be released during the same year. Recoveries were assigned to six regional oceanic areas:

1) Alaska,
2) British Columbia,
3) Washington coast,
4) Puget Sound,

5) Oregon coast, and
6) California coast.

The marine distributions were compared using hierarchical clustering analysis.[2] With few exceptions, groups came from hatchery populations, which may not be representative of historical populations depending on the history of stock transfers for each hatchery. Because of the difficulties in relating current oceanic distribution to historical patterns, this analysis was only used to ascertain whether general patterns of oceanic distribution were correlated to geographic proximity or life history similarities.

Analysis of scales from naturally spawning adults was utilized to identify similarities in age at marine emigration and maturation of proposed populations. This information was used with caution, because of the unknown origin of unmarked naturally spawning fish, the impact of harvest on age structure, and the modification or loss of habitats that would preclude specific juvenile life history strategies.

Historical documentation of fish presence and abundance (Table 2) was based on U.S. Fish and Wildlife Service (USFWS) surveys carried out in the 1930s and 1940s (Bryant 1949, Parkhurst et al. 1950) and additional reports by Mattson (1948 and 1955), Craig and Townsend (1946), Wallis (1961), and others. Hatchery and fisheries records also provided valuable insight into historical abundance and life history characteristics.

Hatchery operations in the lower Columbia and upper Willamette rivers have left a legacy of transplanted or homogenized stocks, with the exception of chum salmon. Very few remaining salmonid populations are unchanged by these activities. Thus it is difficult to estimate historical life history characteristics from fish that currently occupy river systems in this area.

Furthermore, because of the magnitude of hatchery releases, similarities or differences in abundance trends do not necessarily indicate demographic independence or lack thereof. Hatchery fish influence demographic data in three ways:

1. When present on natural spawning grounds, they inflate the abundance of naturally spawning fish.
2. Large releases of hatchery fish may reduce the survival of naturally produced juveniles.
3. They reduce estimates of natural productivity by adding more adults to the adult-to-spawner relationship.

Although the genetic analysis of spawning aggregations normally provides a quantitative method for establishing population boundaries, the influence of hatchery introgression and the reduced abundance of naturally spawning populations likely has dramatically affected the genetic structure of historical populations in the Columbia and Willamette rivers. Genetic analysis of contemporary populations (Appendix C, pages 161–192, Appendix D, pages 193–198) was useful is corroborating the population structure derived from other sources, especially when hatchery influence was minimal.

[2] JMP 3.0, Statistical Analysis System Institute, Cary, NC.

Table 2. Chinook, chum, and coho salmon and steelhead historical natural escapement estimates for lower Columbia River ESU tributaries.[a]

Tributary basin	Chinook	Coho	Chum	Steelhead
Lower Columbia River (coastal tributaries)	—	—	—	—
Lewis and Clark River	—	rpt[b]	rpt	10
Youngs River	rpt	rpt	rpt	rpt
Wallooskee River	—	—	—	—
Klaskanine River	rpt	rpt	rpt	12
Chinook River	rpt	rpt	—	—
Deep River	nv[c]	nv	nv	nv
Grays River	34	>100	6,286	>100
Big Creek	rpt	rpt	rpt	rpt
Bear Creek	—	rpt	rpt	—
Skamokawa Creek	—	obs[d]	rpt	obs
Elochoman River	—	371	158	7
Plympton Creek	—	rpt	rpt	—
Clatskanie River	rpt	rpt	rpt	rpt
Beaver Creek	—	rpt	rpt	rpt
Mill Creek	—	rpt	rpt	1
Abernathy Creek	—	—	92	obs
Germany Creek	—	obs	obs	obs
Coal Creek	—	—	rpt	rpt
Tide Creek	—	—	rpt	rpt
Goble Creek	—	—	—	—
Milton Creek	—	rpt	rpt	rpt
McNulty Creek	nv	nv	nv	nv
Scappoose Creek	60	rpt	rpt	rpt
Cowlitz River basins	—	—	—	—
Cispus River	130	120	—	obs
Tilton River	212	407	—	rpt
Upper Cowlitz River	—	—	—	—
Ohanapecosh River	rpt	rpt	—	—
Toutle River	rpt	rpt	rpt	obs
North Fork Toutle River (without Green River)	—	—	—	—
Green River	—	—	—	—
South Fork Toutle River	—	—	—	—
Coweeman River	1,746	2	rpt	rpt
Kalama River	20,000[e]	1,422	rpt	37
Lewis River	rpt	rpt	rpt	rpt
North Fork Lewis River	259	7,919	259	—
Muddy River	—	—	—	—
East Fork Lewis River	40	1,166	—	—
Willamette River basins				
Mainstem and upper Clackamas River	obs	obs	—	obs
Oakgrove Fork	—	—	—	—
Collawash River	—	—	—	—
Johnson Creek	rpt	—	—	rpt
Salmon Creek	19	16	rpt	rpt
Sandy River	—	—	—	—
Bull Run River	—	—	rpt	rpt

Table 2 continued. Chinook, chum, and coho salmon and steelhead historical natural escapement estimates for lower Columbia River ESU unit tributaries.[a]

Tributary basin	Chinook	Coho	Chum	Steelhead
Willamette River basins continued				
Little Sandy River	—	—	—	—
Salmon River	rpt	rpt	—	rpt
Zigzag River	—	—	—	rpt
Washougal River	rpt	rpt	—	539
Mainstem Washougal River	—	—	—	—
Little Washougal River	—	—	—	—
West Fork Washougal River	—	—	—	—
Columbia Gorge tributaries	—	—	—	—
Mainstem Columbia River	—	—	—	—
Bridal Veil Creek	—	—	—	—
Wahkeena Creek	—	—	—	—
Hardy Creek	—	—	—	—
Hamilton Creek	—	—	—	rpt
Multnomah Creek	—	—	—	—
Moffer Creek	—	—	—	—
Tanner Creek	rpt	—	—	—
Eagle Creek	rpt	—	—	—
Rock Creek	rpt	—	—	rpt
Herman Creek	rpt	—	—	—
Wind River	200	—	—	obs
Gorton Creek	—	—	—	—
Little White Salmon River	rpt	—	—	rpt
Viento Creek	—	—	—	—
Lindsey Creek	—	—	—	—
Big White Salmon River	—	—	—	—
Hood River	rpt	—	—	rpt
East Fork Hood River	—	—	—	—
West Fork Hood River	rpt	—	—	rpt

[a] The numbers presented represent fish counted during surveys and are not expanded to estimate run size. Surveys did not necessarily correspond to the time of peak spawning. USFWS Columbia River surveys were done intermittently from 1936 to 1946 (Bryant 1949, Parkhurst et al. 1950).
[b] Rpt stands for species presence reported to the survey teams by local biologists.
[c] Nv stands for not validated.
[d] Obs stands for juveniles or adults that were observed but not enumerated.
[e] The hatchery superintendent reported that 13,000 Chinook had been collected at the hatchery rack and another 7,000 passed over the rack to spawn naturally in 1936.

Population Boundaries for Fish and Habitat

In describing the population boundaries, two types of maps were generated for each population. One map delineates the area of a basin that is used for spawning and initial rearing, that portion of the basin that the fish directly occupy. A second map delineates the entire basin, a portion of which is occupied by fish from the population. This second map identifies the watershed that influences stream habitat conditions in the occupied portion of the basin. It is

Table 3. Species-specific stream gradient utilization and barrier passability. Dark gray denotes gradients used for spawning and rearing, gray denotes gradients used for passability, white denotes gradients that act as barriers for upstream passage for each species or life history strategy. Source: WDFW 2000.

Species	**Gradient strata (%)**						
	0–1	1–3	3–5	5–7	7–12	12–16	16–20
Chum salmon							
Pink salmon (*O. gorbuscha*)							
Coho salmon							
Sockeye salmon (*O. nerka*)							
Chinook salmon							
Steelhead							
Cutthroat trout (*O. clarkii*) (anadromous)							
Bull trout (*Salvelinus confluentus*)							
Trout							

important to consider, historically and contemporarily, conditions in headwater areas and the impact on the abundance and life history strategies of downstream fish assemblages.

Fish-based population boundaries include different information to identify accessible stream reaches. Tribal, state, and local management agencies used direct observations of fish presence where possible. In lieu of direct observation, we used stream gradients to identify passage barriers. These species-specific gradient barriers are based on estimates described in Table 3 (WDFW 2000). Historical major barriers also were utilized to define fish access. Seasonal barriers such as Willamette, Shearers, Dougan, Salmon, and Punchbowl falls limited access to specific run times for some species. Habitat-based population boundaries are based on the USGS level 6 hydrological unit codes (HUCs).

All populations included multiple level 6 HUC basins. Population habitat and historical presence maps are presented in Appendix E (pages 199–311).

Chinook Salmon

Life History

Chinook salmon—also referred to as king, spring, quinnat, Sacramento, California, or tyee salmon—is the largest of the Pacific salmon (Netboy 1958). The species distribution historically ranged along the west coast of North America from the Ventura River in California to Point Hope in Alaska, and in northeastern Asia from Hokkaido, Japan, to the Anadyr River in Russia (Healey 1991). Chinook salmon also have been reported in the Mackenzie River area of northern Canada (McPhail and Lindsey 1970). The Lower Columbia River and Upper Willamette River Chinook Salmon ESUs exist near the center of the species' North America distribution.

Of the Pacific salmon, Chinook exhibit arguably the most diverse and complex life history strategies. Healey (1986) described 16 age categories for Chinook salmon, seven total ages with three possible freshwater ages. Two generalized freshwater life history types were initially described by Gilbert (1912):

1) stream Chinook salmon that reside in freshwater for a year or more following emergence, and
2) ocean Chinook salmon that migrate within their first year.

Healey (1983 and 1991) has promoted the use of broader definitions for ocean type and stream type to describe two distinct races of Chinook salmon. Using Healey's definition, Chinook salmon native to the lower Columbia and upper Willamette rivers are considered to be ocean type (Myers et al. 1998).

Juvenile Emigration

Ocean-type juveniles enter saltwater during one of three major phases. Immediate fry migrate to the ocean soon after yolk resorption, at 30–45 mm in length (Lister et al. 1971, Healey 1991). In most river systems, however, the majority of ocean-type emigrants are represented by fry that migrate at 60–150 days posthatching and fingerlings that migrate in the late summer or autumn of their first year. When environmental conditions are not conducive to subyearling emigration, ocean-type Chinook salmon may remain in freshwater for their entire first year, emigrating to the ocean during their second spring. Distance of migration to the marine environment, stream stability, stream flow and temperature regimes, stream and estuary productivity, and general weather regimes have been implicated in the evolution and expression of specific emigration timing.

The majority of naturally produced fall Chinook salmon from the lower Columbia and lower Willamette rivers emigrate to the marine environment as subyearlings (Reimers and Loeffel 1967, Howell et al. 1985, Hymer et al. 1992, Olsen et al. 1992, WDF et al. 1993). A portion of returning adults whose scales indicate a yearling smolt migration may be the result of extended hatchery-rearing programs rather than natural volitional yearling emigration (Table 4). It also is possible that modifications in the river environment altered the duration of freshwater residence. The natural timing of spring Chinook salmon emigration similarly is obscured by hatchery releases of spring Chinook salmon juveniles late in their first autumn or early in their second spring. Age analysis based on scales from naturally spawning spring adults from the Kalama and Lewis rivers indicated a significant contribution to escapement by fish that entered saltwater as subyearlings (Hymer et al. 1992). This subyearling smoltification pattern also may be indicative of life history patterns for the Cowlitz River spring run, because the Kalama and Lewis rivers have received considerable numbers of transplanted fish from the Cowlitz River. Life history data from the Clackamas and Sandy rivers is very limited, and transplantation records indicate that these rivers have received overwhelmingly large numbers from the Upper Willamette River Spring Chinook ESU (Nicholas 1995).

Recent analysis of scales from adults returning to the upper Willamette River basin indicated that the majority of fish had emigrated to saltwater as yearlings (Table 5 and Table 6). This estimate is biased by the overwhelming hatchery contribution to escapement, more than 90% of total escapement (Myers et al. 1998). Hatchery fish are released late in their first autumn or second spring (Nicholas 1995, Willis et al. 1995). Scales sampled from returning adults in 1941 indicated that the fish had entered saltwater no earlier than the autumn of their first year (Craig and Townsend 1946). Mattson (1963) found that returning adults that had emigrated as fingerling (subyearling) smolts made up a significant proportion of the 3-year-old age-class, with fingerling emigrants making up a smaller proportion of the older age-classes.

Studies have indicated that Willamette River spring Chinook salmon have a physiological smoltification window during their first autumn. Large numbers of fry and fingerlings have been observed migrating downriver from the Willamette River and its tributaries (Craig and Townsend 1946, Mattson 1962, Howell et al. 1988). Based on the examination of scale patterns from returning adults, it appears that these fry do not immediately enter the estuary or do not survive the emigration. Emigrating fry were affected severely by high water temperatures and industrial waste discharges in the lower Willamette River throughout much of the twentieth century, especially during periods of low river flow in late spring and early summer (Craig and Townsend 1946, Mattson 1962, USGS 1993). More recently, fry migrants constituted a relativeall proportion of the smolt emigration (compared to the artificially propagated fingerling and yearling contribution), thus their potential contribution to returning adults should be quite low. In a 1998 offshore study, subyearling Willamette River spring-run juveniles were identified through genetic mixed-stocks analysis in the Columbia River plume.[3] Alternatively, many of these fry migrants could have been rearing in the Columbia River prior to emigrating to the marine environment (Craig and Townsend 1946, Mattson 1962).

[3] D. Teel, Northwest Fisheries Science Center, Seattle, WA. Pers. commun., January 2000.

Table 4. Age structure for the Lower Columbia River Chinook Salmon ESU.

	Age designation[a]										
	Subyearling migrants					Yearling migrants					
Collection site/run	2.0	3.0	4.0	5.0	6.0	2.1	3.1	4.1	5.1	6.1	**Source**
Klaskanine River fall	0.000	0.306	0.694	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Olsen et al. 1992
Plympton Creek fall	0.084	0.708	0.193	0.016	0.000	0.000	0.000	0.000	0.000	0.000	Olsen et al. 1992
Big Creek fall	0.013	0.371	0.567	0.044	0.000	0.000	0.000	0.004	0.000	0.000	Olsen et al. 1992
Gnat Creek fall	0.006	0.651	0.283	0.030	0.030	0.000	0.000	0.000	0.000	0.000	Olsen et al. 1992
Lewis and Clark River fall	0.050	0.469	0.481	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Olsen et al. 1992
Grays River fall	0.137	0.294	0.510	0.057	0.000	0.000	0.000	0.000	0.000	0.000	Hymer et al. 1992
Elochoman River fall	0.132	0.501	0.340	0.027	0.000	0.000	0.000	0.000	0.000	0.000	Hymer et al. 1992
Cowlitz River spring	0.000	0.000	0.000	0.000	0.000	0.175	0.100	0.528	0.191	0.006	Hymer et al. 1992
Cowlitz River fall	0.032	0.165	0.580	0.193	0.004	0.001	0.016	0.008	0.000	0.000	Hymer et al. 1992
Coweeman River fall	0.015	0.007	0.312	0.645	0.022	0.000	0.000	0.000	0.000	0.000	Hymer et al. 1992
Kalama River late fall[b]	0.029	0.330	0.424	0.162	0.000	0.000	0.009	0.036	0.009	0.000	Hymer et al. 1992
Lewis River late fall[b]	0.132	0.196	0.419	0.212	0.008	0.000	0.003	0.018	0.009	0.001	Hymer et al. 1992
Lewis River fall	0.123	0.193	0.468	0.202	0.005	0.000	0.004	0.000	0.004	0.000	Hymer et al. 1992
Washougal River fall	0.022	0.198	0.628	0.151	0.000	0.000	0.000	0.001	0.000	0.000	Hymer et al. 1992
Sandy River late fall[b, c]	0.043	0.182	0.533	0.236	0.005	0.000	0.000	0.000	0.000	0.000	Fulop unpubl. data
Sandy River fall	0.026	0.283	0.592	0.100	0.000	0.000	0.000	0.000	0.000	0.000	Fulop unpubl. data

[a] Age information is based on scales recovered from naturally spawning Chinook salmon. In the age designation numeral (X.Y) in the column headings, X is the age at maturation, and Y is the age at ocean emigration (0 = subyearling, 1 = yearling).

[b] Late fall or bright.

[c] Juvenile age structure was not available for Sandy River fish, but it is assumed to be mostly subyearling migrants (partially based on data presented in Howell et al. 1985).

Table 5. Chinook salmon CWT-recovery distribution in ocean fisheries.[a] Source: Bishop 1995 and PSMFC 2000.

Hatchery stock (release site)/run	Alaska	British Columbia	Washington coast	Puget Sound	Oregon coast	California
Grays River fall	0.10	0.62	0.20	0.00	0.07	0.00
Elochoman River fall	0.07	0.46	0.22	0.06	0.17	0.02
Big Creek fall (SAB[b])	0.00	0.31	0.15	0.03	0.43	0.09
Big Creek fall	0.05	0.63	0.27	0.00	0.05	0.00
Cowlitz River spring	0.05	0.44	0.32	0.06	0.11	0.00
Cowlitz River fall	0.12	0.44	0.23	0.02	0.18	0.00
Kalama River fall	0.10	0.72	0.16	0.00	0.02	0.00
Lewis River late fall	0.19	0.54	0.12	0.03	0.09	0.02
Lewis River summer	0.19	0.46	0.29	0.00	0.06	0.00
Washougal River fall	0.08	0.63	0.24	0.00	0.06	0.00
Bonneville Hatchery fall	0.00	0.55	0.24	0.08	0.11	0.00
Spring Creek fall	0.05	0.47	0.24	0.13	0.11	0.00
South Santiam River spring (1)[c]	0.30	0.55	0.14	0.00	0.01	0.00
North Santiam River spring (1)[c]	0.42	0.40	0.17	0.00	0.01	0.00
McKenzie River Hatchery spring (0)[d]	0.52	0.41	0.07	0.00	0.00	0.00
McKenzie River Hatchery spring (1)[c]	0.41	0.48	0.09	0.00	0.02	0.00
Clackamas River spring (1)[c]	0.24	0.47	0.20	0.00	0.09	0.00
Clackamas River spring (1990s)[e]	0.46	0.23	0.11	0.00	0.18	0.02
North Santiam River spring (1990s)[e]	0.77	0.21	0.01	0.00	0.00	0.00
South Santiam River spring (1990s)[e]	0.67	0.23	0.09	0.00	0.01	0.00
McKenzie River Hatchery spring (1990s)[e]	0.59	0.25	0.10	0.00	0.02	0.05
Upper Columbia River fall	0.33	0.62	0.02	0.02	0.01	0.00

[a] CWT Chinook salmon were released from hatcheries in the lower Columbia and upper Willamette rivers. Recoveries for each release site are based on at least three release groups, each of which had at least 100 tag recoveries (expanded) in ocean fisheries. Except where noted, all tagged groups were released between 1980 and 1989.

[b] SAB stands for select area bright fall run (Rogue River).

[c] 1 stands for yearling release.

[d] 0 stands for subyearling release.

[e] 1990s stands for yearlings released, 1990–1994.

Table 6. Age structure for spring populations in the Upper Willamette River Chinook Salmon ESU.

			Age designation[a]										
			2-year-old		3-year-old		4-year-old		5-year-old		6-year-old		
Collection site	**Year**	**No. of fish**	2.0	2.1	3.0	3.1	4.0	4.1	5.0	5.1	6.0	6.1	**Source**
Lower Willamette River (sport fishery)	1946–1951	590	—	—	0.017	0.015	0.082	0.148	0.055	0.554	0.001	0.101	Mattson 1963
Willamette River (sport fishery)	1970–1977	8,936	—	—	—	0.024	—	0.484	—	0.476	—	0.016	Collins 1980
Willamette River (sport fishery)	1978–1988	13,070	—	—	—	0.018	—	0.559	—	0.412	—	0.011	Bennett 1988
Willamette River (escapement[b])	1968–1980	—		0.080	—	0.025	—	0.448	—	0.434	—	0.014	Bennett 1987
Clackamas River (sport fishery)	1979–1988	3,033		—	—	0.045	—	0.668	—	0.285	—	0.003	Bennett 1988
Clackamas River (escapement)	1976–1980	—		—	—	0.039	—	0.649	—	0.307	—	0.005	Bennett 1987
North Santiam River (spawning grounds)	1996–1997	125[c]		0.000	—	0.000	—	0.414	—	0.555	—	0.020	Lindsay et al. 1997
McKenzie River (spawning grounds)	1996–1997	63[d]		0.000	—	0.000	—	0.444	—	0.556	—	0.000	Lindsay et al. 1997

[a] Age information is based on scales recovered from returning adults. In the age designation numeral (X.Y) in the column headings, X is the age at maturation, and Y is the age at ocean emigration (0 = subyearling, 1 = yearling, 2 = 2-year-old smolt, etc.).

[b] Escapement estimates based on age data from hatchery and naturally spawning adults.

[c] Fish exhibiting subyearling emigration (N = 50) were classified as fall Chinook salmon and not included, all but two were 3-year-old fish.

[d] Does not include marked hatchery fish.

Ocean Distribution

Ocean-type Chinook salmon tend to migrate along the coast, while stream-type Chinook salmon appear to move far off the coast into the central North Pacific Ocean (Healey 1983 and 1991, Myers et al. 1984). Studies of prerecruit fish (<71 cm) in the marine fisheries off southeastern Alaska indicate that differences in migration speed, timing, and growth were related to the life history type, age, and general geographic origin of the stocks (Orsi and Jaenicke 1996). The causal basis for these differences is unknown, but for the more northerly (stream-type) populations the differences may be based on poor coastal feeding conditions during past glacial events.

Marine CWT recoveries for lower Columbia River ESU stocks tend to occur off the British Columbia and Washington coasts, with a small proportion of tags recovered from Alaska (Table 5). Marine recoveries of CWT-marked Willamette River spring-run fish occur off the British Columbia and Alaska coasts, with a much larger component (>30%) of recoveries from Alaska relative to lower Columbia River ESU stocks (Table 5). Age of release (subyearling versus yearling) does not appear to influence the general oceanic distribution of fish (Myers et al. 1998).

Return Migration

The timing of return to freshwater, and ultimately spawning, provides a temporal isolating mechanism for populations. Furthermore, return timing is often correlated with spawning location. Salmonids that return in the early spring often take advantage of high flows from snowmelt to access the upper reaches of many rivers. Differences in return migration timing provide a geographic isolating mechanism.

The freshwater component of the adult return migratory process is under significant genetic influence. The underlying genetic influence on run timing was initially demonstrated by Rich and Holmes (1928), when spring Chinook salmon from the McKenzie River in Oregon were reared, marked, and released from a predominantly fall-run watershed. The transplanted Chinook salmon displayed no apparent alteration in their normal time of return or spawning, although there was an apparent decrease in homing fidelity. Subsequent stock transplantations further substantiated the heritable nature of run timing. Heritability estimates for return timing among early and late returning pink salmon runs in Alaska, for example, were 0.4 for females and 0.2 for males (Gharrett and Smoker 1993). In one experiment, upriver fall Chinook salmon were captured and spawned and the subsequent progeny reared and released from a downriver site (McIsaac and Quinn 1988). A significant fraction of the returning adults from the upriver bright progeny group bypassed their rearing site and returned to their “traditional” spawning ground, 370 km farther up the Columbia River. This migration pattern may be related to the relative timing of freshwater entry and spawning rather than a geographic sense of where the salmon’s traditional home is. Returning to the home stream may reflect local adaptation and reproductive isolation.

Run designations are based on when adults enter freshwater, however, distinct runs also may differ in degree of maturation at river entry and spawning time. Early spring (stream-maturing) Chinook salmon tend to enter freshwater as immature or bright fish, migrate upriver (holding in suitable thermal refuges for several months), and finally spawn in late summer and early autumn. Late fall (ocean-maturing) Chinook salmon enter freshwater at an advanced stage of maturity, move rapidly to their spawning areas on the main stem or lower tributaries, and spawn within a few days or weeks of freshwater entry (Fulton 1968, Healey 1991). Summer-run fish show intermediate characteristics of spring and fall runs, spawning in large- and medium-sized tributaries and not showing the extensive delay in maturation exhibited by spring Chinook salmon (Fulton 1968). There is no record of summer-run fish historically spawning within the ESU boundaries of the lower Columbia or upper Willamette rivers. All temporal runs, especially those that migrate into freshwater well in advance of spawning, utilize resting pools. These pools provide an energetic refuge from river currents, a thermal refuge from summer and autumn high temperatures, and a refuge from potential predators (Berman and Quinn 1991, Hockersmith et al. 1994). Furthermore, utilization of resting pools may maximize the success of the spawning migration through decreases in metabolic rate and potential reduction in susceptibility to pathogens (Bouck et al. 1975, Berman and Quinn 1991). Therefore, the existence or absence of resting pools may be an important determinant in the success of certain run times in specific basins.

Run timing is in part a response to stream-flow characteristics. Rivers such as the Klickitat or Willamette historically had waterfalls that were impassable to upstream migration, except during late winter or spring high flows, while other falls are passable only during low flows (WDF et al. 1993). For example, low river flows on the southern Oregon coast during the summer result in barrier sandbars that block migration. The timing of migration and ultimately spawning must be cued to the local thermal regime. Eggs must be deposited at a time that will ensure fry emerge during the following spring, when river or estuary productivity is sufficient for juvenile survival and growth. The strong association between run timing and ecological conditions made this trait useful in considering potential ESU boundaries.

The fall run currently is predominant in the lower Columbia River, although historically, spring-run fish may have been nearly as numerous. Fall-run fish return to the river in mid-August and spawn within a few weeks (WDF et al. 1993, Kostow 1995). These fall Chinook salmon often are called tules, they are distinguished by their dark-skin coloration and advanced state of maturation at the time of freshwater entry. Tule fall Chinook salmon populations historically may have spawned from the mouth of the Columbia River to the White Salmon and Hood rivers. There is substantial disagreement on whether fall Chinook salmon historically existed in the lower Klickitat River. Among other fall-run populations, a later returning component of the fall Chinook salmon run exists in the Lewis and Sandy rivers (WDF et al. 1993, Kostow 1995, Marshall et al. 1995). Because of the longer time interval between freshwater entry and spawning, Lewis and Sandy rivers fall Chinook salmon are less mature at freshwater entry than tule fall Chinook salmon at river entry, they are commonly termed lower river brights (Marshall et al. 1995). Presently a number of other fall Chinook salmon in the lower Columbia River are referred to as brights. Hatchery records and genetic analyses indicate that these fish are the descendants of introduced fall Chinook salmon from the Rogue River (Oregon coast) and the upper Columbia River (Priest Rapids Hatchery). Except for late fall runs in the Lewis and Sandy rivers, we know of no information to indicate that this life history form historically was present anywhere in the Lower Columbia River Chinook Salmon ESU.

Spring Chinook salmon in the lower Columbia River, like those from coastal stocks, enter freshwater in March and April, well in advance of spawning in August and September. An Oregon Department of Fisheries (ODF) report stated that "this variety is known the world over as the 'Royal Chinook,' and may truly be called the king of the salmon. Those taken from the Columbia River during the months of April, May and June are claimed to be superior to any found elsewhere" (ODF 1900).

Fish migrations historically were synchronized with high rainfall or snowmelt periods to provide access to upper reaches of most tributaries where fish would hold until spawning (Fulton 1968, Olsen et al. 1992, WDF et al. 1993). Early fishery biologists recognized the relationship between flow and run timing: "Another peculiarity in connection with the habits of this species of salmon is that they will not enter any stream which is not fed by snow water ..." (ODF 1900).

Willamette Falls (RKM 42) historically limited access to the upper Willamette River, thus it defines the boundary of a distinct geographic region. High flows over the falls provided a window for returning Chinook salmon in the spring, while low flows prevented fish from ascending the falls in the autumn (Howell et al. 1985). Returning Willamette River spring Chinook salmon enter the Columbia River in February and March, but they do not ascend Willamette Falls until April and May. The migration past the falls generally coincides with a rise in river temperatures above 10°C (Mattson 1948, Howell et al. 1985, Nicholas 1995). Spawning generally begins in late August and continues into early October, with spawning peaks in September (Mattson 1948, Nicholas 1995, Willis et al. 1995).

Run timing was used as a criterion for distinguishing independent populations. Freshwater entry timing differences resulted in geographic separation, because of flow-related access windows at barrier falls or cascades. Furthermore, spring Chinook salmon utilize upper watershed areas with distinct thermal regimes, resulting in spawn timing (and possibly embryonic development) differences relative to fall-run fish in the same watershed.

Age at Maturation

Adults return to tributaries in the lower Columbia River predominately as 3- and 4-year-olds for fall-run fish and 4- and 5-year-olds for spring-run fish. This may be related to the predominance of yearling smolts among spring-run stocks. In general Willamette River spring Chinook salmon mature in their fourth and fifth years, with slightly more 4-year-old fish. Historically 5-year-old fish comprised the dominant portion of the run (Mattson 1963).

Differences in age at maturation were of limited use in distinguishing independent populations. It is possible that older, larger fish are more successful at ascending barriers, or younger, smaller fish may be able to utilize off-side-channel habitat more effectively, however, no conclusive information substantiates this, and age structure was highly variable in most populations. Given the high degree of hatchery intervention in most river systems, the intensity of selective forces on many life history traits may have been reduced or redirected to an unknown degree.

Lower Columbia River Chinook Salmon ESU
Historical Independent Populations

Coast Range Tributaries

The Coast Range tributaries region extends from the mouth of the Columbia River to Coal Creek (RKM 99.8) on the Washington side and Scappoose Creek (RKM 140) on the Oregon side (Figure 2). Chinook salmon spawning in this region were placed in seven population clusters, based on historical population abundance estimates and watershed size.

Coast Range tributaries are relatively short, less than 40 km (Table 1). The lower reaches tend to be low gradient, slow-moving systems that are under tidal influence. Many tributaries enter the Columbia River through a series of sloughs that offer little usable spawning habitat. The rivers and creeks drain low elevation hills, with peaks less than 1,000 m. Rainfall averages 200–240 cm per year. In the absence of substantial snowpack or groundwater sources, the river flows are correlated strongly with rainfall (peak flows occur in December and January), and summer flows can be very low (low flows occur in August). Presently, there are no naturally spawning spring Chinook salmon in this subregion, and given the relatively short length of these rivers and creeks and their rainfall-dominated hydrology, there is little suitable habitat for spring Chinook salmon. It is unlikely that distinctive run times or geographically isolated populations could have developed in one of these systems. Furthermore it is possible that during extended periods of poor ocean conditions or extremes in climate (floods or droughts) many of the smaller systems experience short-term extirpations.

The distribution of historical populations in this portion of the lower Columbia River was initially derived using the geographic clustering of the watersheds listed (those historically known to contain Chinook salmon). In some cases it is unclear whether Chinook salmon historically were present (Table 2). For example, spawner surveys in the 1930s and 1940s documented Chinook salmon in the Chinook River. However, a hatchery was established in the watershed in 1894 using adults captured in the mouth of the Columbia River, and the fish observed are most likely descendants of those hatchery fish. Jordan (1904) quotes H. S. Davis, who described the Chinook River as "a small sluggish stream [that] has never been frequented by Chinook salmon, although considerable numbers of silver and dog salmon enter it late in the fall." The Washington Department of Fish and Game (WDFG 1916) suggested that the Chinook River did not have an indigenous Chinook salmon population prior to establishment of the hatchery run. Marshall et al. (1995) suggested that many rivers in this region did not support Chinook salmon populations.

The Chinook River basin was not included in any of the DIPs identified in this stratum, but it was identified as an area that may provide an intermittent contribution to the stratum overall. In his surveys of Pacific coast fisheries, Collins (1892) specifically lists the Lewis and Clark River and Youngs River as supporting runs of Chinook salmon. Gilbert and Evermann (1895) noted that "fish of the fall run enter the Columbia a short time only before they are ready to spawn. So far as we now know, the majority of these turn directly into streams near the mouth

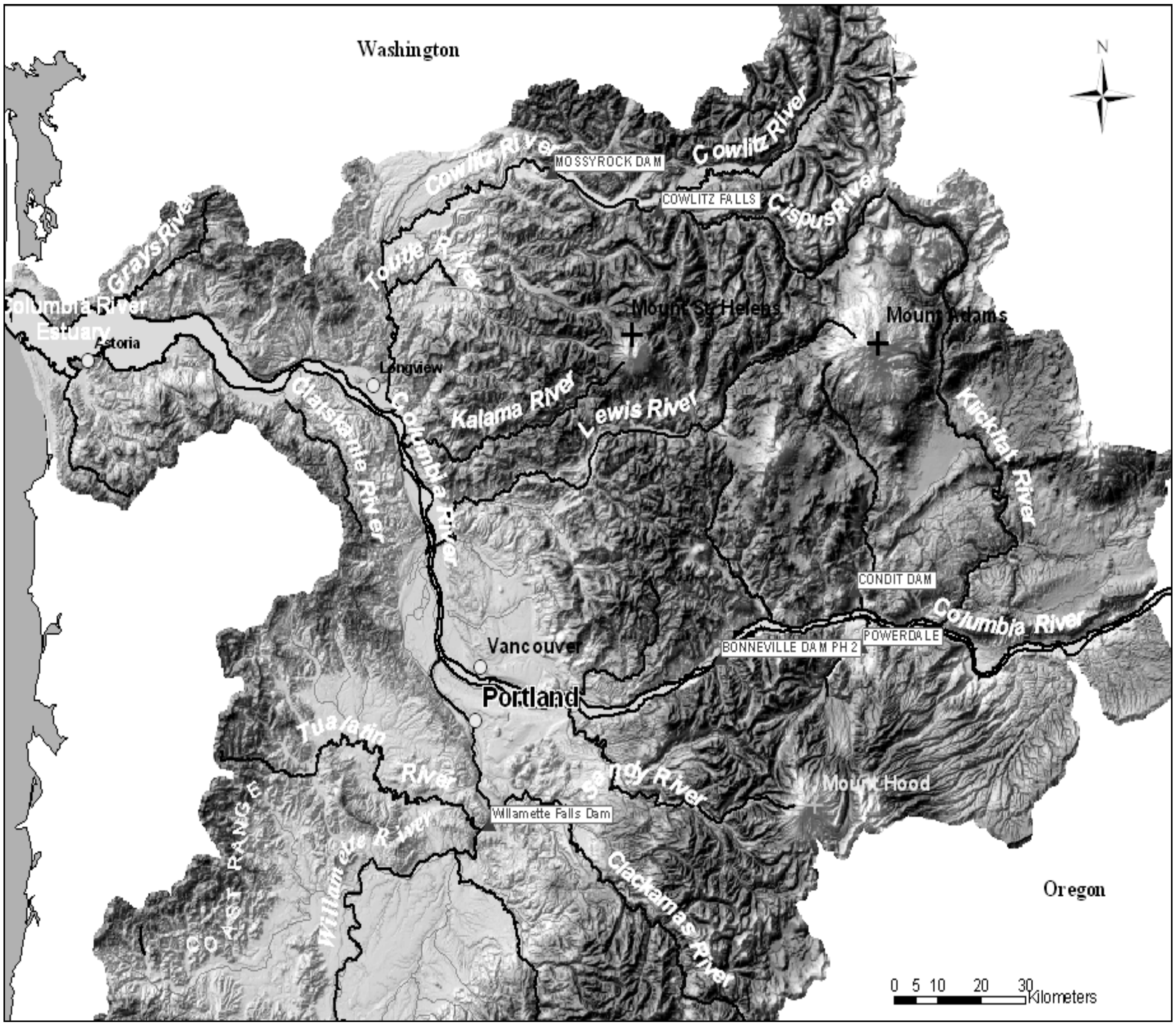


Figure 2. Lower Columbia River basin.

of the river and spawn a short time after their entrance into the Columbia." R. E. Clanton, master fish warden of Oregon, suggested locating a hatchery near the falls on the Youngs River because "very few Chinook enter this stream" (Clanton 1911). The absence of detailed historical documentation may be related to the emphasis on fisheries (and studies) targeting spring Chinook salmon during the late 1800s and early 1900s. In contrast to the spring run, fall Chinook salmon entered freshwater at an advanced stage of maturation, and there was initially little demand for these poor quality fish. Spring Chinook salmon sold to salmon packers in 1894 for $.05 a pound, whereas fall Chinook salmon and chum salmon sold for $.03–.05 per fish (Smith 1895). The preference for spring Chinook salmon also influenced hatchery policies. "The opinion also prevails that the fish hatched from the eggs of the fall run will return to the river in the fall and be the undesirable fish, and the hope is general that no attempts will be made to propagate the late fish, but that the efforts will be centered on the spring and summer broods, which alone are suitable for canning" (Smith 1895).

Chinook salmon studies were conducted on Gnat Creek in Oregon from 1956 to 1962 (Willis 1962). In 1955 construction of a weir on the lower portion of the creek enabled biologists to enumerate and measure returning adults, as well as sample emigrating juveniles, except during high flow periods. During the study, average Chinook escapement was only 39 fish. Peak juvenile outmigration by subyearling juveniles was observed during February and March, no yearling migrants were observed.

Genetic analysis was limited because of the large numbers of hatchery-origin fish released into these basins from outside the specific watershed (Appendix C, Table C-6 and Table C-7, pages 177–178). Straying between these spawning aggregations was estimated using CWT recoveries from naturally spawning fish, fish returning to hatchery racks, or fishery recoveries from the tributaries. It is believed that there was a high degree of exchange between all the populations in the smaller coastal tributaries of the lower Columbia River, but less so between populations in this region and those in other regions within the lower Columbia River ESU. For example, of the freshwater recoveries of marked fish released from the Grays River Hatchery, only 32.3% were recovered in the Grays River basin, 10.3% in Skamokawa Creek, 23.0% in the Elochoman River, 33.0% in Big Creek, and less than 1.0% of recoveries were upstream of the Cowlitz River (Figures 3, 4, and 5). Low levels of homing fidelity also were observed for fish released from the Abernathy Creek Salmon Culture Technology Center (SCTC), and the Elochoman River and Big Creek hatcheries. In general, a significant proportion (>10%) of the freshwater recoveries occurred within 50 km of the release site. These rates may be substantially higher than historical levels because of:

- use of mixed-origin lower Columbia River ESU fish by most hatchery programs,
- poor water quality or low attraction flows in many of the rivers or hatcheries, and
- attraction of fish to assemblages of fish (i.e., fish in hatchery holding ponds).

Additionally, fish that enter hatchery traps or are intercepted in terminal fisheries are considered strays, despite the fact that fish naturally often hold temporarily in nonnatal streams or may test tributaries for homing cues. In general, fall Chinook salmon spawn in the lower reaches of the tributaries, just above the extent of tidal influence (Parkhurst et al. 1950, Merrell 1951). This may increase the likelihood of movement by spawning adults between basins.

Life history information (spawn timing, age at maturation, ocean migration) was relatively useful, given the degree of hatchery transplantation and the high apparent rate of interchange (Figures 3, 4, 5, 6 and 7, Table 7, also see Appendix A, Table A-1). There were slight differences in peak spawning time for populations in this subregion, and presently there is considerable overlap in spawning distribution for populations in this subregion (Figure 8). Similarly, there is no clear overall trend in age at maturation. However, fall-run fish from the Grays and Klaskanine rivers and Big Creek tend to cluster together in the unweighted pair group method with arithmetic averages (UPGMA) dendrogram (Figure 9, Table 7) for the Lower Columbia River Chinook Salmon ESU, as do fall Chinook salmon from Plympton and Gnat creeks and the Lewis and Clark and Elochoman rivers. Analysis of CWT recoveries in marine fisheries was not informative in life history distinctions beyond the level of run timing (Figure 10), except that ocean recovery distribution was similar among hatcheries that had exchanged large numbers of fish.

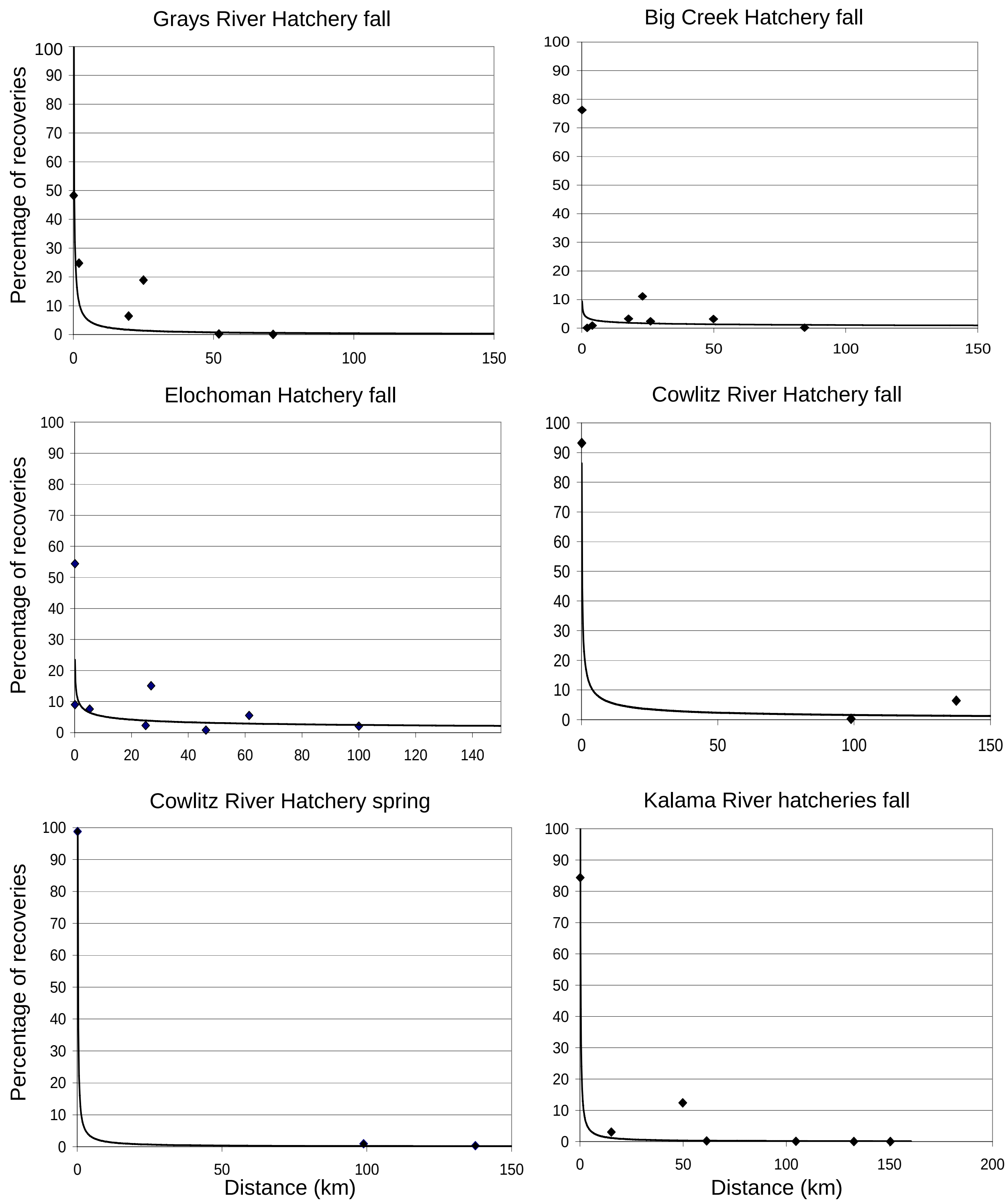


Figure 3. Incidence, as a percentage of all freshwater recoveries, and distance of adult recovery to juvenile release location of Chinook salmon returning to the lower Columbia River. Each graph represents the averaged results from at least three CWT groups (each with at least 100 freshwater recoveries) released from a specific hatchery, 1980–1990. Source: PSMFC 2000, Fuss et al. 1994, and van der Haegen and Doty 1995.

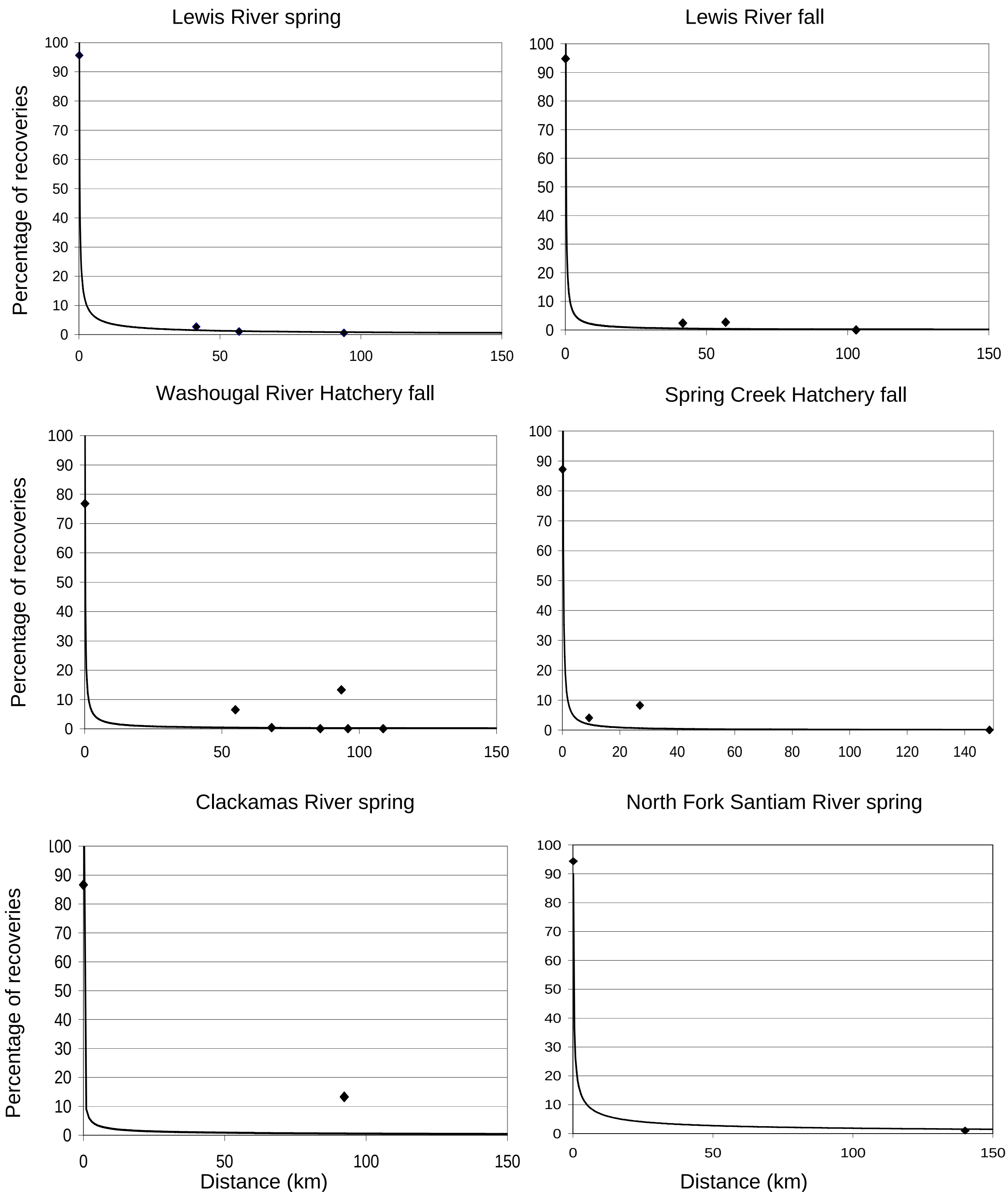


Figure 4. Incidence, as a percentage of all freshwater recoveries, and distance of adult recovery to juvenile release location of Chinook salmon returning to the lower Columbia River. Each graph represents the averaged results from at least three CWT groups (each with at least 100 freshwater recoveries) released from a specific hatchery, 1980–1990. Source: PSMFC 2000, Fuss et al. 1994, and van der Haegen and Doty 1995.

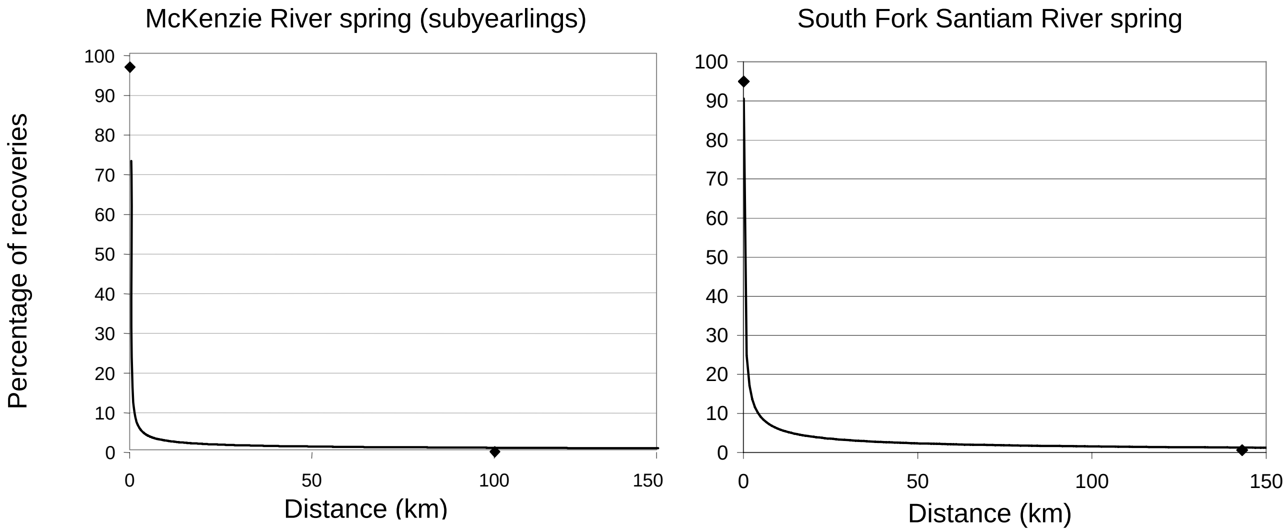


Figure 5. Incidence, as a percentage of all freshwater recoveries, and distance of adult recovery to juvenile release location of Chinook salmon returning to the lower Columbia River. Each graph represents the averaged results from at least three CWT groups (each with at least 100 freshwater recoveries) released from a specific hatchery, 1980–1990. Source: Source: PSMFC 2000, Fuss et al. 1994, and van der Haegen and Doty 1995.

Very little information is available for the cluster of populations from Tide Creek to Scappoose Creek, other than that indicating fall Chinook salmon historically were present in most of these systems. Fall Chinook salmon were thought to spawn in Milton Creek during the late 1950s (Willis et al. 1960). Scappoose Creek is the only basin that contains enough habitat to potentially sustain large numbers of fish (Table 1). Willis et al. (1960) reported that 100 fall Chinook salmon were observed spawning in the 2 two miles of Scappoose Creek. Ecologically, the Oregon tributaries that drain the Coast Range are different from the larger Washington tributaries (e.g., the Cowlitz and Kalama rivers) that drain the Cascade Range (Figure 1).

The seven DIPs proposed (listed at the end of this subsection) in this region are distinct based solely on geographic separation. In general, genetic information from recently collected fish is of limited value because of the high proportion of hatchery fish on the spawning grounds (Figures 6 and 7) and the large numbers of nonnative hatchery fish introduced into the region (Appendix A, Table A-1).

The DIPs in this technical memorandum represent, in the absence of definitive historical documentation, the most probable scenario for the coastal tributaries stratum. We have assumed that homing fidelity was substantially higher than currently is observed in hatchery populations. Additionally, anecdotal information suggests that fish tend to orient along the riverbank, and in the lower Columbia River a fish was more likely to stray to an adjacent system rather than across the river. It is reasonable to assume that distinct independent populations did not exist on a scale smaller than the seven populations. It also may be reasonable to assume that because of

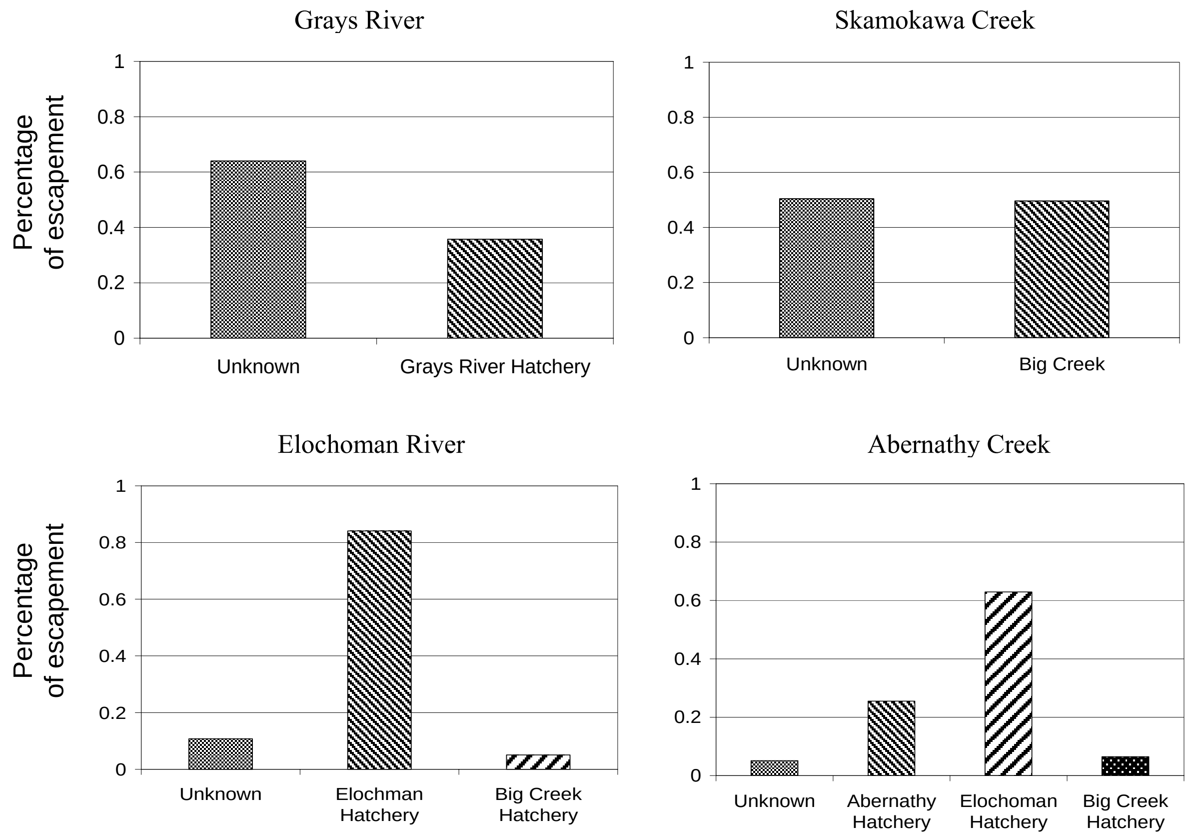


Figure 6. Estimated origin of naturally spawning Chinook salmon in Columbia River tributaries based on recoveries of adults in spawner surveys. Unknown fish may consist of naturally produced (unmarked) fish or unmarked hatchery fish for which no CWT were recovered. Source: Harlan 1999.

geographic and ecological factors, at a minimum these clusters formed one independent population on each side.

Individual population maps are in Appendix E (pages 199–311), and strata are presented in Figure 10. Letter designations indicate possible subpopulation designations within the numbered populations. Populations identified in WDF et al. (1993) as a SASSI stock are indicated.

1. Youngs Bay fall (Figure E-22)
    a. Lewis and Clark River
    b. Youngs River
    c. Wallooskee River
    d. Klaskanine River

2. Grays River fall (SASSI) (Figure E-12)
    a. Deep River
    b. Grays River

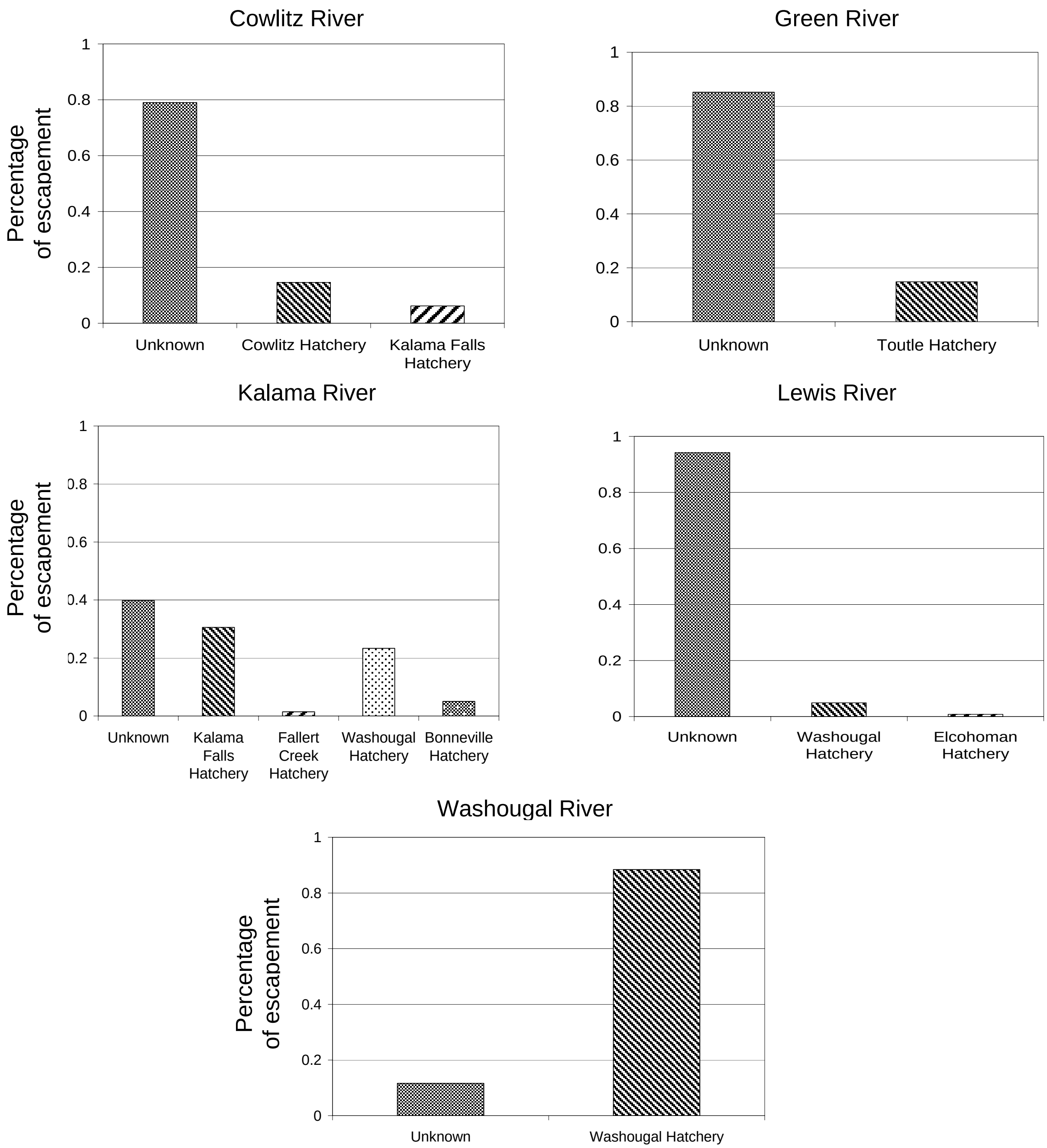


Figure 7. Estimated origin of naturally spawning Chinook salmon in Columbia River tributaries based on recoveries of adults in spawner surveys. Unknown fish may consist of naturally produced (unmarked) fish or unmarked hatchery fish for which no CWT were recovered. Source: Harlan 1999.

Table 7. Summary of the number and source of juveniles released into selected rivers in the Lower Columbia River and Upper Willamette River Chinook Salmon ESUs through 1995. Source: Myers et al. 1998.

Water body	Run	Native/ local[a] (%)	ESU releases		
			Inside[b]	Outside	Total
Chinook River	Fall	0.477	0.518	0.006	17,621,483
Youngs River	Fall	0.000	0.618	0.382	1,245,379
Grays River	Fall	0.269	0.731	0.000	83,901,280
Big Creek	Fall	0.611	0.363	0.027	202,843,377
Elochoman River	Fall	0.654	0.345	0.001	120,559,102
Cowlitz River	Fall	0.926	0.074	0.000	164,273,295
Toutle River	Fall	0.635	0.365	0.000	87,615,600
Kalama River	Fall	0.941	0.046	0.012	235,348,662
Lewis River	Fall	0.762	0.184	0.054	21,785,757
Clackamas River	Fall	0.000	0.913	0.087	60,051,486
Washougal River	Fall	0.485	0.508	0.007	172,296,250
Sandy River	Fall	0.067	0.933	0.000	32,815,098
Tanner Creek	Fall	0.000	0.911	0.089	673,455,947
Hood River	Fall	0.000	1.000	0.000	2,656,380
Cowlitz River	Spring	0.959	0.027	0.014	71,004,079
Toutle River	Spring	0.996	0.004	0.000	2,672,655
Kalama River	Spring	0.881	0.119	0.000	10,367,665
Lewis River	Spring	0.621	0.322	0.057	15,809,691
Sandy River	Spring	0.151	0.189	0.660	14,533,110
Molalla River	Spring	0.000	0.000	0.000	10,987,335
Santiam River	Spring	0.793	0.191	0.016	193,191,761
North Santiam River	Spring	0.673	0.313	0.014	113,735,118
South Santiam River	Spring	0.700	0.300	0.000	39,619,551
McKenzie River	Spring	0.967	0.027	0.007	218,331,567
Middle Fork Willamette River	Spring	0.311	0.654	0.035	57,693,187

[a] Releases designated as "native/local" include the progeny of nonnative fish (and their descendants) that returned to a local hatchery and were incorporated into the hatchery broodstock.

[b] Inside includes the proportion of fish that originated from within the ESU, not including the local population.

3. Big Creek fall (Figure E-2)
    a. John Day River
    b. Mill Creek (Oregon)
    c. Big Creek
    d. Bear Creek
4. Elochoman River fall (Figure E-9)
    a. Skamokawa Creek (SASSI)
    b. Elochoman River (SASSI)

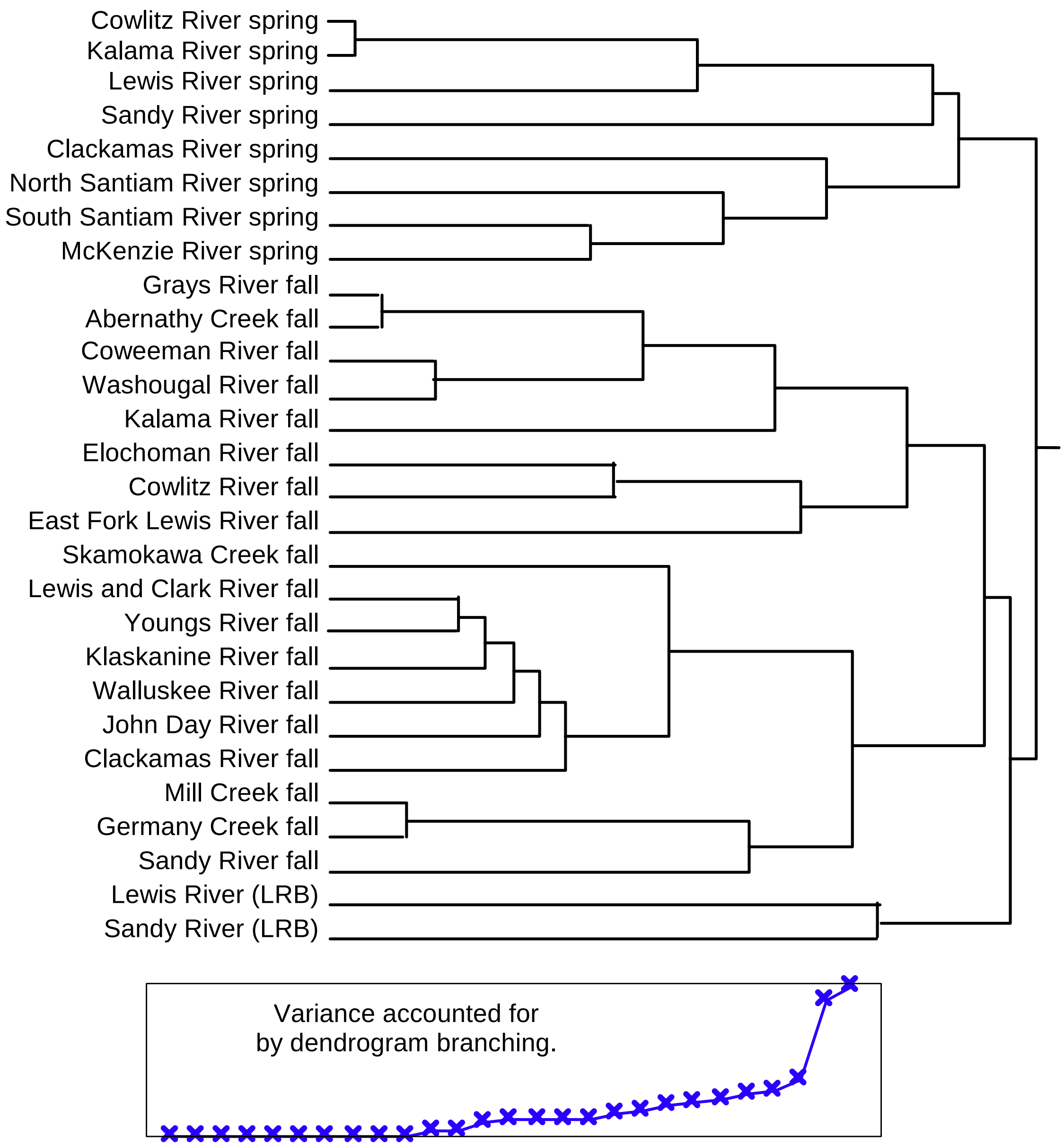


Figure 8. Standardized dendrogram for migration timing and spawning for Lower Columbia River and Upper Willamette River Chinook Salmon ESU stocks (top). Distributions for each stock were based on estimated time of freshwater entry (by week) and time of peak spawning activity (by week). Migration and spawning time were based on data from various sources compiled during the 1980s. The contribution of each branch to overall variation is presented in the lower figure. LRB stands for lower river brights. Source: Meyers et al. 1998.

5. Clatskanie River fall (Figure E-5)
   a. Plympton Creek
   b. Clatskanie River
   c. Beaver Creek

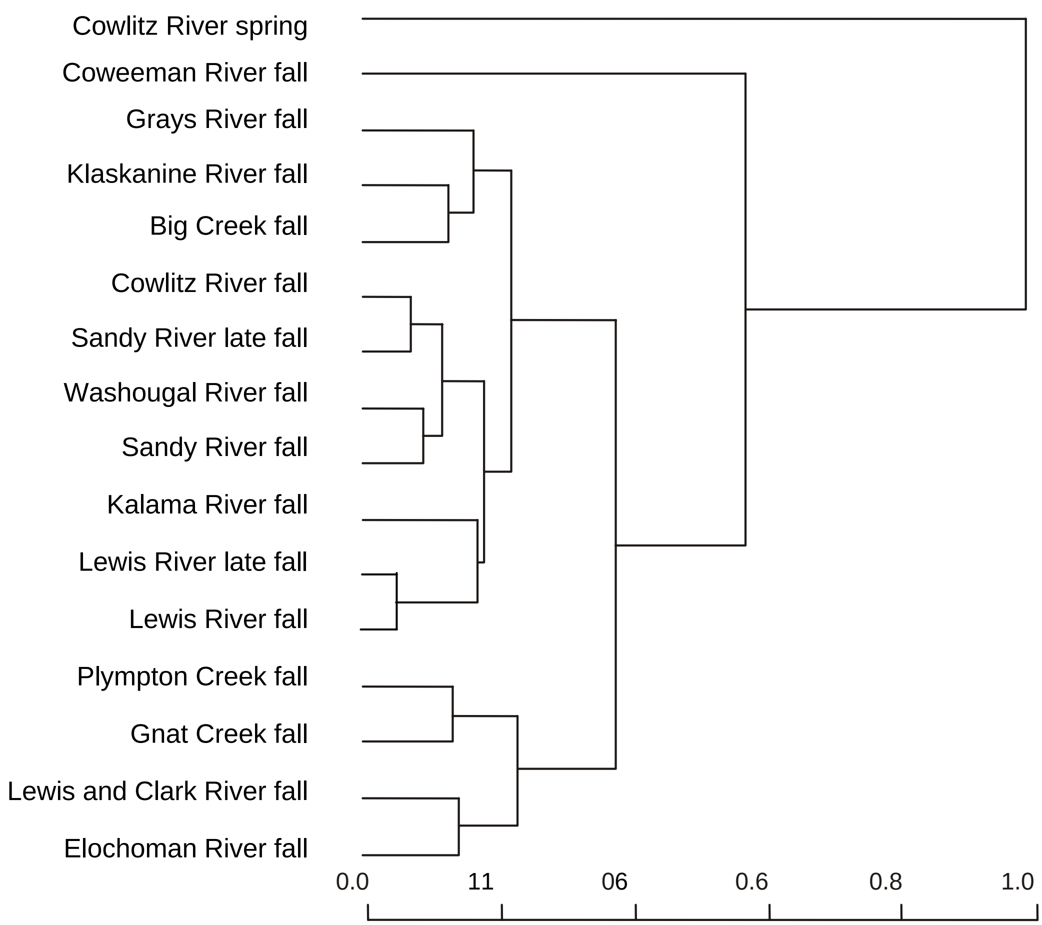


Figure 9. UPGMA dendrogram for Lower Columbia River Chinook Salmon ESU based on percentage overlap in spawner age distributions (age at maturation and age at ocean emigration). Age structure is based on scales from naturally spawning fish. Difference represents the proportion of total variance accounted for by differences in age structure between clusters of populations at different branch points. Source: Myers et al. 1998.

6. Mill Creek (Washington) fall (Figure E-16)
   a. Mill Creek (SASSI)
   b. Abernathy Creek (SASSI)
   c. Germany Creek (SASSI)
   d. Coal Creek

7. Scappoose Creek fall (Figure E-19)
   a. Tide Creek
   b. Goble Creek
   c. Milton Creek
   d. McNulty Creek
   e. Scappoose Creek

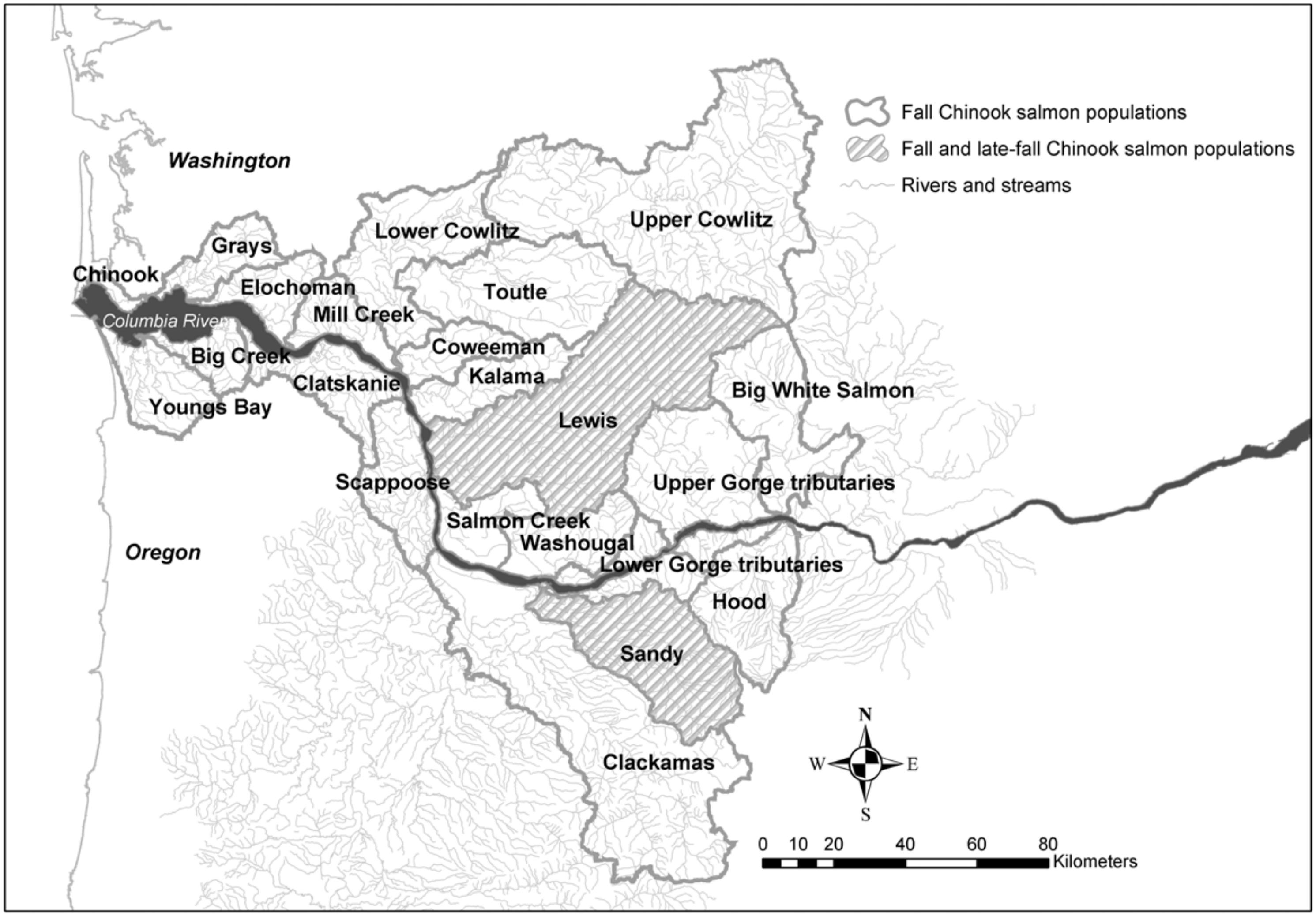


Figure 10. Historical fall DIPs in the Lower Columbia River Chinook Salmon ESU.

Western Cascade Range Tributaries

Rivers in the western Cascade Range are larger than those found in the coastal region, with headwaters high in the Cascade Mountains. Many rivers are more than 100 km long, with basins covering 1,000 km^2 or more (Table 1). Snowmelt and groundwater sources are substantial and maintain good year-round flows and cool water temperatures. River flows peak in December or January and sustain at least 50% of peak for six months or more. The lower reaches of rivers are relatively low gradient, but high gradient sections are common in the middle and upper reaches. Elevation plays a relatively important role in delineating the boundaries of EPA ecological regions (Figure 1).

This region extends from the Cowlitz River (RKM 106.2) to the Washougal River (RKM 194.9) on the Washington side and from the Willamette River (RKM 162.5) to the Sandy River (RKM 193.6) on the Oregon side. There appears to have been several major spawning aggregations in this region, based on historical population abundance information and watershed size (Table 1 and Table 2).

Considerable biological information is available for populations in this region. More importantly, this information is less affected by hatchery influences relative to populations in the coastal region. This is due in part to the larger size of Chinook salmon populations, making them more resilient to the effects of hatchery transfers. Several populations have had little or no direct hatchery influence (e.g., Coweeman River fall run, Lewis River late fall run or runs, and Sandy River late fall run) (Table 7, also see Appendix A, Table A-1) and give some indication of the historical diversity in genetic and life history characteristics.

Three basic life history types of Chinook salmon are found in this region: spring run, early fall run (tule), and late fall run (bright). Spring Chinook salmon historically were found in the Cowlitz, Kalama, Lewis, and Sandy rivers, tule fall-run fish were found throughout the region, and late fall-run fish were found in the Lewis and Sandy rivers. Spring-run fish in the Clackamas River are part of the Upper Willamette River Chinook Salmon ESU and are discussed in that ssubsection. Spring and early fall-run spawning adults historically were separated geographically and temporally, whereas the early fall- and late fall-run spawners primarily were separated temporally. Rivers in this region also provide sufficient habitat for juvenile Chinook salmon to extend their rearing through the summer months.

Analysis of scales collected from naturally spawning fall-run adults indicated that a small proportion (<10%) of fish do not emigrate until their second spring. Spring-run fish probably emigrated as subyearlings and yearlings. However, recent scale collections are biased heavily by releases of primarily yearling hatchery fish. It is apparent that spring-run juveniles in this region are capable of emigrating to saltwater during their first year, in contrast to spring-run populations upstream of the Cascade Crest, which appear to be obligate yearling migrants. In 1955 and 1956, juvenile Chinook salmon were sampled emigrating from the upper Cowlitz River basin as fry during their first spring, as fingerlings during the autumn, and as yearling smolts during their second spring (Stockley 1961). The majority of downstream migrants were fry and the temporal mode of emigration took place during June. However, it is not known whether these fry were migrating to the ocean or to downstream rearing sites. Analysis of ocean distribution, based on the CWT recovery location and age, indicates that only the Lewis River late fall run of Chinook salmon was distinct, with a more northerly distribution (Table 4, Figure 11). Late fall-run populations in the Lewis and Sandy rivers also tend to mature at an older age than early fall (tule) Chinook salmon (Table 5).

Fall and spring Chinook salmon in the Cowlitz River are similar genetically to populations in the Kalama and Lewis rivers. This similarity may be because of the geographical proximity of the rivers. However, in the case of spring-run populations, this similarity is more likely related to the infusion of Cowlitz Hatchery spring Chinook salmon into the hatchery programs in the Kalama and Lewis rivers (Appendix C, pages 161–192). Dams on the Cowlitz and Lewis rivers have eliminated migration access to the majority of historical spring-run spawning habitat. Genetic analysis of spring Chinook salmon from the Sandy River indicates that they are intermediate genetically between spring-run fish in the Lewis and upper Willamette rivers (Appendix C). Any present association between fish in the Sandy and upper Willamette rivers is due, in part, to extensive introductions of Willamette River fish into the Sandy River (Table 7).

Genetic similarities between spring- and early fall-run fish may be because of the monophyletic nature of temporal runs in lower Columbia River tributaries (Myers et al. 1998). Alternatively, there may have been natural hybridization between the temporal runs, because of the loss of geographic separation following dam construction or artificial hybridization in the hatchery because of the overlap in spawning time between the runs (Marshall et al. 1995, Myers et al. 1998). Cowlitz, Kalama, and Lewis rivers spring Chinook salmon are all part of WDFW's middle and lower Columbia spring Chinook salmon GDU (Marshall et al. 1995).

Migration between basins in this region is substantially lower than between populations in the coastal region (Figures 3, 4, and 5). This may be because of a higher degree of homing fidelity for fish returning to larger basins. Overall, for the hatchery releases analyzed from this region, more than 90% of the freshwater recoveries occurred in their natal river basin, and there were few recoveries of any significance beyond 25 km from the release site (Figures 3, 4, and 5).

Suckley (1858) cited reports of "banks and sand bars of the Cowlitz River—a stream emptying the Columbia at a comparatively short distance from the ocean—lined with dead and dying salmon." Gilbert and Evermann (1895) reported that quinnat (Chinook) salmon were obtained from the Cowlitz River in great numbers. Fall Chinook salmon populations still exist in the Cowlitz River basin, although much of the current escapement is the result of hatchery production. The Cowlitz River Historically was the primary producer in the Lower Columbia River Chinook Salmon ESU (Bryant 1949), however, little information is available on the size of various tributary runs prior to the 1940s. In 1946 WDF and WDG estimated that 14,000 fall Chinook salmon were spawning in the Cowlitz River above the proposed site of Mayfield Dam (RKM 84), representing a total run of 63,612.

Fall Chinook salmon in the Coweeman River represent one of the few remaining populations in the ESU sustained through natural production. In 1951 it was estimated that 5,000 spawning fall Chinook were in the Coweeman River, with a total spawning escapement of 31,000 fall Chinook salmon throughout the Cowlitz basin (WDF 1951). Recently escapement into the Coweeman River has averaged 800 fish. However, there has been minimal contribution to escapement by hatchery strays (ODFW 1998). Fall Chinook salmon populations in the Toutle

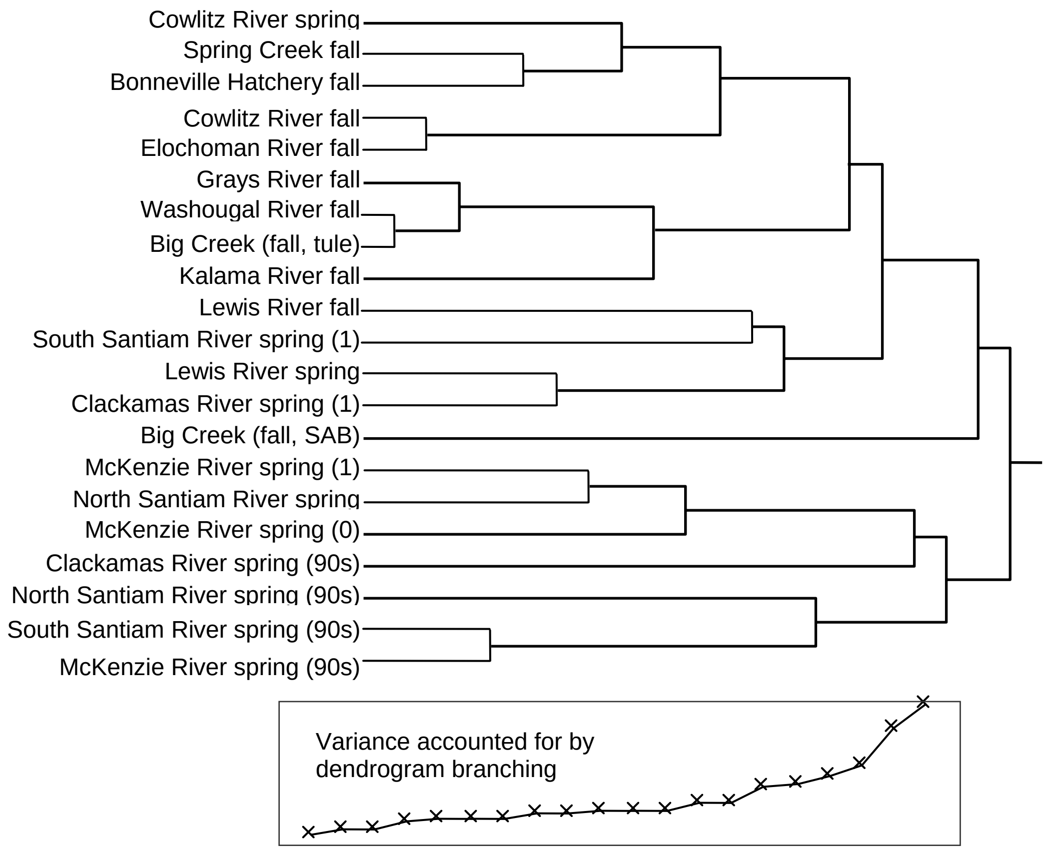


Figure 11. Standardized dendrogram of CWT ocean-recovery distributions for hatchery populations in the Lower Columbia River and Upper Willamette River Chinook Salmon ESUs. Distributions for each stock were based on at least three release groups (with 100 ocean recoveries [expanded]). Unless indicated, all groups were released from 1981 to 1990: 0 represents subyearling release, 1 represents yearling release, 90s represents release groups from 1991 to 1994, SAB represents Rogue River fall Chinook salmon released from Big Creek. The contribution of each branch to overall variation is presented in the lower figure. Source: Meyers et al. 1998.

River basin nearly were extirpated as a result of the Mount St. Helens eruption in 1980. Chinook salmon runs were reestablished in the basin by natural recolonization and introductions of fish from the Cowlitz Salmon Hatchery.

In the Cowlitz River spawner surveys, Bryant (1949) found fall-run fish spawning as far upriver as the lower reaches of the Tilton and Cispus rivers (RKM 102 and RKM 148, respectively) (WDF 1951). Evermann and Meek (1898) reported that fall Chinook salmon entered the Toutle River in "considerable numbers," and could be expected after 1 September. Fall Chinook salmon also were observed in the Toutle River (RKM 27.4) and Coweeman River (RKM 12.1) basins. Given the distinctiveness of the existing Coweeman River fall Chinook salmon population relative to the mainstem Cowlitz River fall population or populations (which is heavily influenced by hatchery releases), we propose that historically distinct populations of fall Chinook salmon existed in the Coweeman, Toutle, and mainstem Cowlitz rivers. Possibly more than one population existed in the mainstem Cowlitz River, with the steep canyons that existed near the site of the present-day Mayfield Dam providing some degree of geographic separation. Furthermore, given the large size of the Toutle River basin (1,200 km^2), distinct populations also may have existed in the North and South Fork Toutle rivers (Table 1).

Substantial numbers of naturally spawning spring Chinook salmon returned to the Cowlitz River basin through the 1960s. Geographically, the Cispus, Tilton, upper Cowlitz, and Toutle rivers are large enough to have had enough production capacity to be self-sustaining. Habitat capacity estimates for these basins ranged from the thousands to tens of thousands of fish (Bryant 1949). In 1946 the spawning escapement for spring Chinook salmon in the Cowlitz River basin above the then-proposed Mayfield Dam site was estimated to be 9,000 fish. Adjusting for harvest, this estimate represented a total run size of 32,490 fish (WDF and WDG 1946). WDF (1951) estimated that the spawning escapement for the entire Cowlitz River basin was 10,400 spring Chinook salmon, with 8,100 spawning in the Cispus River, 400 in the upper Toutle River, 200 in the Tilton River, and 1,700 in the upper Cowlitz River. Peak spawner counts for the Ohanapecosh (upper Cowlitz) and Cispus rivers averaged 145.2 and 140.6 for the years 1950–1962, based on index survey areas of 5.6 km and 40 km, respectively (Birtchet and Meekin 1962). There may have been three or more independent populations of spring Chinook salmon in the Cowlitz River basin. The Cispus and upper Cowlitz rivers appear to have the geographic and abundance criteria necessary to have supported independent populations. It is less clear whether habitats in the Tilton River and Toutle River basins are suited to spring Chinook salmon life history needs. In contrast to the Cispus River and upper Cowlitz River basins, the Tilton River basin lacks extensive mainstem spawning areas and is not influenced glacially. Thus there is some uncertainty whether spring Chinook salmon in the Tilton River constituted their own historical DIP, or they were part of either the Cispus River or upper Cowlitz River DIPs.

The Toutle River basin is large enough geographically to have sustained a spring population, but it may have lacked the persistent cold-water sources that normally distinguish spring Chinook salmon spawning habitat. Gilbert and Evermann (1895) described the Toutle River as being highly suitable for establishing a salmon hatchery (they based this assessment on reports of a large run of salmon in the river and observed water conditions, 15°C on 27 August). Evermann and Meek (1898) reported that salmon were present in the Toutle River in August, but residents indicated that the run increased after 1 September. If spring Chinook salmon were present they would have been located in headwater areas at the time of the survey. Furthermore, it is unlikely that residents could have observed returning spring Chinook salmon during high spring flows. Bryant (1949) reported a number of large, spawned-out Chinook salmon carcasses on 4 September 1940 in Coldwater Creek, a tributary to the North Fork Toutle River. Based on the advanced state of deterioration, the author speculated that the fish spawned and died before mid-August.

The Kalama River historically had and currently maintains a very large population of fall Chinook salmon. Although only a small spring-run population exists in the Kalama River, anecdotal information suggests that the run was once considerably larger (WDF 1951). There is, however, considerable debate on this matter. Although a hatchery was established in the Kalama River basin in 1895 (located 7 km from the town of Kalama, Washington), the site was upstream of the primary fall Chinook salmon spawning ground (WDFG 1902). Geographically, there are few large tributaries to the Kalama River, and none has the capacity to support a spawning aggregation large enough to be considered an independent population.

The Lewis River currently supports three temporal Chinook salmon runs, a spring run, early fall run, and late fall run. The early fall Chinook salmon return primarily to the East Fork Lewis River in August and September, and they spawn from late September to November (Marshall et al. 1995), although early fall Chinook salmon also are observed in the North Fork Lewis River. Draft versions of this document combined early fall Chinook salmon in the Lewis River with those in Salmon Creek, however, based on the professional opinion of local biologists, these two basins were split into separate DIPs. There is some evidence that Salmon Creek supported a salmon run of some note. John Crawford, Washington State superintendent of hatcheries stated, "About 6 miles from Vancouver flows a stream called Salmon Creek, so named from the fact that it was a favorite stream for spawning salmon. Every species of the Pacific Coast salmon, except the blueback (or sockeye) spawned in both Salmon Creek and the Lewis River" (Crawford 1911). Late fall Chinook salmon return to the North Fork and East Fork Lewis rivers from August to October, and spawning extends from October to January. Evermann and Meek (1898) reported that Chinook salmon were not seen in the Lewis River until after 10 August (the beginning of the closed fishing season). Marshall et al. (1995) report Chinook salmon spawning as late as April. A late fall Chinook salmon population also exists in the Sandy River (Oregon), and it is genetically similar to the Lewis River populations. In 1906 Crawford visited the Lewis River to establish a new hatchery (WDFG 1907). He surveyed some 16 km upstream of Woodland, Washington, on 3 September and 2 October (peak spawning time for early fall Chinook) but did not observe any Chinook salmon. This suggests that early fall Chinook salmon might not be native to the Lewis River. An alternative explanation is that river conditions were not conducive to surveying salmon in the lower river.

Spring Chinook salmon historically were found in the North Fork Lewis River, however, access to historical habitat was eliminated following the construction of Merwin Dam (RKM 31) in 1931. Evermann and Meek (1898) reported that river conditions in the South Fork [East Fork] Lewis River were very different from the north fork, and that only fall Chinook salmon were present. WDFG (1913) reported that the majority of spring Chinook salmon spawning occurred in tributaries to the Muddy Fork (also called "The Muddy") of the Lewis River. Furthermore, there was little apparent spawning by fall Chinook salmon above the hatchery location (Cedar Creek). In April 1926 WDF biologists surveyed the confluence of the Muddy Fork and North Fork Lewis River (WDFG 1928). They observed a "goodly number" of large steelhead spawning in addition to spring "royal" Chinook salmon. During the summers of 1926 and 1927, hatchery personnel returned to the site and were able to capture and spawn 48 and 72 female spring Chinook salmon, respectively (273,000 and 407,050 eggs). There are no distinctive geographic features or major tributaries that suggest more than one spring-run independent population existed in the Lewis River.

Fall Chinook salmon also were native to the lower Willamette River and its principal tributary, the Clackamas River. A tule fall run existed in the lower Clackamas River until the 1930s, when poor water-quality conditions below Willamette Falls presented a barrier to returning fall Chinook salmon (Parkhurst et al. 1950, Gleeson 1972). Stone (1878) reported intercepting salmon on 1 September 1877 just above Clear Creek (RKM 13), which "appeared to lack a week or two yet of being ripe." Ripe fish were observed by Stone (1878) on 12 September 1877, with fish spawning above and below the Clear Creek site. In 1902 following construction of a new weir across the river, 10,018,000 fall Chinook salmon eggs were collected between 22 September and 8 November 1902 (Titcomb 1904). Egg collection peaked on 15 October 1902, when 412,000 eggs were taken from 94 females. Dimick and Merryfield (1945) reported that these fish entered the Willamette River in September and October and spawned soon after entering the Clackamas River. Willis et al. (1960) speculated that fall Chinook salmon spawned throughout the length of the Clackamas River and in nearly all accessible large tributaries. Fall Chinook salmon from lower Columbia River hatchery stocks were introduced into the Clackamas River from 1952 to 1981 to reestablish the run. Available data on fall Chinook salmon in the Clackamas River were collected after reestablishment of the run and therefore were of little use in characterizing the historical run. Fall Chinook salmon probably spawned in the lower reaches of the Clackamas River and other Willamette River tributaries below Willamette Falls (e.g., Johnson and Abernathy creeks), they may have collectively comprised a single demographic population.

The Washougal River is 59 km long and drains a basin of 413 km^2. Salmon (RKM 23) and Dougan falls (RKM 34) may have been migration barriers to fall Chinook salmon during low water periods. The majority of Chinook salmon currently spawn in a 6-km reach below Salmon Falls. Parkhurst et al. (1950) estimated that sufficient habitat existed below Salmon Falls for approximately 5,000 pairs of spawning salmon. The Washougal River branches into the Little Washougal and West Fork Washougal rivers. However, neither tributary appears to be large enough to maintain independent populations of fall Chinook salmon. Estimates of stray rates for fish released from the Washougal Hatchery are relatively high, with 27% of the recoveries in basins other than the Washougal (Figures 3, 4, and 5). Given the large number of nonnative, fall Chinook salmon released from the Washougal Hatchery, this may not be reflective of an historical homing fidelity. Despite the potential influence of hatchery transfers, fall Chinook salmon sampled from the Washougal River were different genetically from fish from other basins. Furthermore, there is a general correlation between the geographic proximity of other basins and the genetic similarity among fish spawning in those basins. Historically, fall Chinook salmon returning to the Washougal River most likely constituted an independent population.

Fall and spring Chinook salmon are native to the Sandy River. As in the Lewis River, there are two types of fall Chinook salmon: early returning (tule) fall run and late returning (bright) fall run. There is some debate about whether the tule fall-run fish are native to the basin or are descendants of hatchery releases from lower Columbia River hatcheries. The late fall-run returns in September and October and spawns throughout December and January (Howell et al. 1985). There are reports of a winter run in the Sandy River, although Kostow (1995) suggested that the run has been extirpated. It also is possible that the winter Chinook salmon observed are the “tail-end” of the late returning fall-run fish. Late returning brights in the Lewis River have been observed spawning in April (Marshall et al. 1995). The run of late-returning fall-run fish historically may have exceeded 5,000 fish, compared with a recent survey (1997) that observed 1,125 adults (Whisler et al. 1998). There has been no artificial supplementation of the late-returning fall run. Genetic analysis indicates a strong association between Lewis and Sandy rivers late fall Chinook salmon, and that these two populations form a cluster within the general group of other ESU populations in the lower Columbia River.

The Sandy River historically had a very large run of spring Chinook salmon (Table 8). Total run size for the Sandy River basin may have been in excess of 12,000 fish (Mattson 1955).

Table 8. Salmon escapement estimates for Sandy River tributaries.[a] Blank spaces indicate no estimates provided.

Species/tributaries	Historical[b]	1954[c]	1995[d]	1998[e]
Chinook salmon				
Spring run				
Mainstem Sandy River	5,000	750	1,900	2,606
Salmon River	2,000	<50		
Zigzag River	Fair	Unknown		
Bull Run River	5,000	200		
Little Sandy River	Unknown	0		
Fall run				
Mainstem Sandy River	10,000	2,500		700
Salmon River	500	0		
Bull Run River	Unknown	500		
Gordon Creek	Unknown	200		
Chum salmon				
Mainstem Sandy River	Unknown	200		<100
Beaver Creek	Unknown	<100		
Coho salmon				
Mainstem Sandy River	15,000	3,000		261
Bull Run River	5,000	400		
Little Sandy River	Good	Few		
Salmon River	Good	300		
Zigzag River	Good	Unknown		
Gordon Creek	Good	250		
Cedar Creek	Unknown	500		
Beaver Creek	Unknown	250		
Steelhead				
Mainstem Sandy River	20,000	6,000		584
Bull Run River	5,000	400		
Little Sandy River	Good	Few		
Salmon River	2,000	600		
Zigzag River	Excellent	200		
Gordon Creek	Good	400		
Cedar Creek	Unknown	400		
Beaver Creek	Good	300		

[a] Numbers estimate naturally spawning escapement and may include hatchery-reared Chinook salmon.

[b] Mattson 1955.

[c] Mattson 1955.

[d] Nicholas 1995.

[e] Chinook salmon estimate based on a five-year average (ODFW 1998), coho salmon data for 1998, Marmot Dam (Weitkamp et al. 2001), steelhead counts for 1998, Marmot Dam wild counts (Chilcote 2001a).

Mattson (1955) estimated that the Sandy River main stem and tributaries sustained large numbers of spring Chinook salmon: Bull Run (5,000), Salmon (3,000–4,000), and mainstem Sandy (3,000–5,000) rivers. The ODF (1903) described the Salmon River "as a natural spawning stream from its confluence with the Sandy River to its source." The Salmon River was described as being a "very good stream for the early run of Chinook salmon, being second to the Clackamas" (ODF 1900).

Genetic analysis of naturally spawning spring-run fish from the Sandy River suggested that this population is intermediate between Upper Willamette River Chinook Salmon ESU and Lower Columbia River Chinook Salmon ESU spring-run populations (NMFS 1998a). Furthermore, there was little genetic resemblance between the spring- and bright fall-run fish in the Sandy River basin. In other lower Columbia River ESU and Coast Range basins, different run times in a basin tend to have evolved from a common source. The Sandy River basin is a deviation from this pattern, although it is probable that the existing spring run is not representative of the historical population. Microsatellite DNA data indicated that Sandy River spring Chinook salmon genetically are distinguishable from the Clackamas Hatchery spring-run broodstock, however, the degree of differentiation was much less than that between spring runs in the Sandy and Yakima rivers. Bentzen et al. (1998) concluded that although some interbreeding between the Upper Willamette River Chinook Salmon ESU and Sandy River stocks has occurred, the Sandy River population still retains some of its original genetic characteristics. The NMFS Biological Review Team (BRT) concluded that although fish from the Upper Willamette River Chinook Salmon ESU probably have interbred with indigenous spring-run fish in the Sandy River, this population still retains some genetic characteristics from the native population (NMFS 1998a).

Information about life history characteristics for spring-run fish from the Sandy River basin is limited. Hatchery collections of spring Chinook salmon in the Salmon River began in 1896. Fish were observed spawning from mid-July to early September, somewhat earlier than spring-run fish in the Cowlitz, Kalama, and Lewis rivers. During the first year of operation (1896), the hatchery collected 2.6 million eggs (@ 5,000 eggs/female = 520 females [Craig and Suomela 1940]). In 1901, 413 Chinook salmon females were spawned between 18 July and 3 September, with peak spawning occurring between 15 and 24 August 1901 (ODF 1903). Fall Chinook salmon also were observed migrating as far as the hatchery weir on the Salmon River (Mattson 1955). A few fall Chinook salmon were spawned between 1 and 16 October 1904 (ODF 1904).

A distinct population of spring Chinook salmon certainly existed in the Sandy River basin. It is unclear, however, whether spawning aggregations in the Salmon, Zigzag and Bull Run rivers constituted independent populations or subpopulations. Late fall Chinook salmon were separated temporally and geographically from spring-run fish. Since the late fall-run fish spawn in the lower portions of the Sandy River, it is unlikely that more than one population existed. There is some uncertainty regarding the historical existence of early fall Chinook in the Sandy River basin.

Individual population maps are in Appendix E (pages 199–311), and strata are presented in Figure 10 and Figure 12. Letter designations indicate possible subpopulation designations

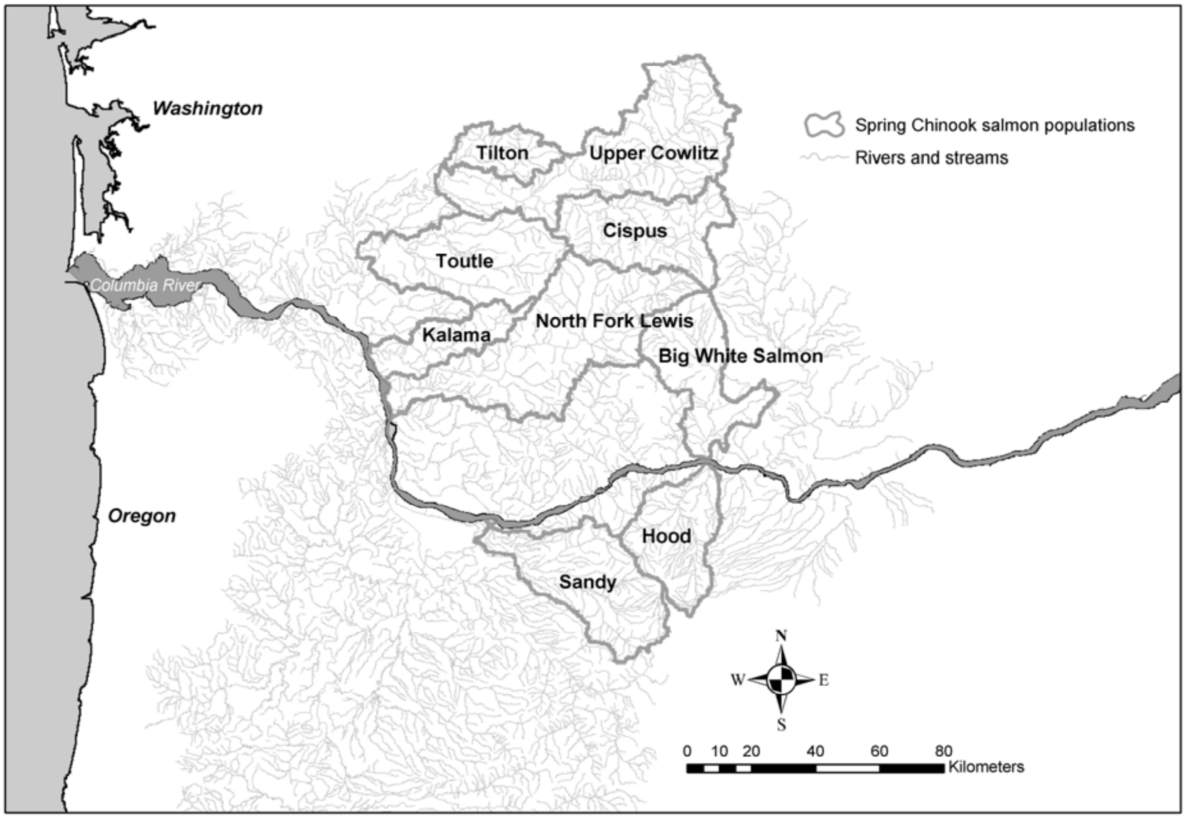


Figure 12. Historical spring DIPs in the Lower Columbia River Chinook Salmon ESU.

within the numbered populations. Populations identified in WDF et al. (1993) as a SASSI stock are so indicated. (Numbering sequence continued from the list of populations on page 33.)

8. Upper Cowlitz River fall run (SASSI) (Figure E-8)
9. Lower Cowlitz River fall run (SASSI) (Figure E-7)
10. Coweeman River fall run (SASSI) (Figure E-6)
11. Toutle River fall run (Figure E-20)
    a. North Fork Toutle (Green) River fall run (SASSI)
    b. South Fork Toutle River fall run (SASSI)
12. Upper Cowlitz River spring run (SASSI) (Figure E-26)
13. Cispus River spring run (Figure E-25)
14. Tilton River spring run (Figure E-31)

15. Toutle River spring run (Figure E-32)
    a. North Fork Toutle (Green) River spring run
    b. South Fork Toutle River spring run

16. Kalama fall run (SASSI) (Figure E-14)

17. Kalama spring run (SASSI) (Figure E-28)

18. Lewis River early fall run (Figure E-15)
    a. North Fork Lewis River early fall run
    b. East Fork Lewis River early fall run

19. Lewis River late fall run (brights) (Figure E-15)
    a. East Fork Lewis River late fall run (SASSI)
    b. North Fork Lewis River late fall run (SASSI)

20. Lewis River spring run (SASSI) (Figure E-29)

21. Salmon Creek early fall run (Figure E-17)

22. Clackamas River fall run (Figure E-4)

23. Washougal River fall run (SASSI) (Figure E-21)

24. Sandy River early fall run (Figure E-18)
    a. Bull Run River early fall run
    b. Little Sandy River early fall run
    c. Mainstem Sandy River early fall run

25. Sandy River late fall run (Figure E-18)

26. Sandy River spring run (Figure E-30)
    a. Bull Run River spring run
    b. Salmon River spring run
    c. Mainstem Sandy River spring run

Columbia Gorge Tributaries

The Columbia Gorge tributaries region extends from east of the Washougal River (RKM 194.9) through the White Salmon River (RKM 270) on the Washington side and from east of the Sandy River (RKM 193.6) to the Hood River (RKM 272) on the Oregon side. Rivers in this region of the Lower Columbia River Chinook Salmon ESU are influenced heavily by the steeply sloped sides of the Columbia Gorge. Most streams are relatively short. Impassable falls limit accessible habitat to less than a half mile on most small creeks. Larger rivers contain falls or a series of cascades in their lower reaches, which may present migrational barriers during all or most of the year. Physiographically, this region marks a transition between the high rainfall areas of the Cascades and the drier areas to the east. Stream flows can be intermittent and water temperatures can be limiting, especially during the summer.

Little information is available about the Chinook salmon populations that historically inhabited this region. The majority of the river systems historically had little accessible habitat for Chinook salmon. Much of the habitat that historically was available was inundated with the filling of the Bonneville Pool. Furthermore, after nearly a century of hatchery releases from a variety of sources into this region there may be little resemblance between fish currently utilizing many of the smaller creeks and those that historically were present. Shipherd Falls on the Wind River eliminated access to all but the lower 5 or 6 km of the river. Little is known about the fall run that utilized this area. U.S. Bureau of Fisheries (USBF) hatchery records indicate that several million eggs were collected annually.

The Big White Salmon River (RKM 270) historically supported runs of spring and fall Chinook salmon prior to the construction of Condit Dam (RKM 4) in 1913 (Fulton 1968). Evermann and Meek (1898) observed the beginning of the tribal fishery at the mouth of the Big White Salmon River. Hatchery records indicate that fall Chinook salmon in the Little and Big White Salmon rivers began spawning in early September, with peak egg collections in the later part of the month (21 September 1901), 12,840,700 eggs were collected in 1901 (Bowers 1902). Anadromous fish historically may have been able to ascend the Big White Salmon River as far as Trout Lake (RKM 45.4) (WDF 1951). LeMier and Smith (1955) evaluated the capacity of the Big White Salmon River to support salmon if passage were provided. Under conditions existing in 1955, they estimated the river could support 732 spring Chinook salmon and 452 fall Chinook salmon. It should be noted that conditions in the Big White Salmon River were degraded substantially in 1955 relative to historical levels. Additionally, LeMier and Smith (1955) interviewed a long-time resident who was unable to confirm the presence of spring Chinook salmon in the basin.

Fall-run fish from the Big White Salmon River were used to establish the nearby Spring Creek National Fish Hatchery (NFH) broodstock in 1901 (Hymer et al. 1992). Although a number of different hatchery stocks were transferred to the Spring Creek NFH, this stock still is most closely affiliated with other Lower Columbia River Chinook Salmon ESU fall-run populations (NMFS 1999b). The Spring Creek NFH stock of fall Chinook salmon still may retain some historical genetic and life history characteristics. The life history characteristics of fall Chinook salmon from the Spring Creek NFH differ somewhat from other Lower Columbia River Chinook Salmon ESU stocks. Furthermore, Spring Creek NFH fall Chinook salmon are somewhat distinct genetically from the cluster of Lower Columbia River Chinook Salmon ESU populations. Historical information would indicate that all of the fall-run populations exhibited an early fall-run (tule) life history. Existing late fall (bright) Chinook salmon that spawn in this region appear to be the descendants of hatchery transfers from populations in the upper Columbia River (Marshall et al. 1995).

Fall and spring Chinook salmon are native to the Hood River basin. Large runs of Chinook salmon historically existed in the Hood River basin. However, these runs have declined dramatically and, despite supplementation efforts, remain at critically low levels. Fish from the Round Butte Hatchery (Deschutes River, Middle Columbia River Chinook Salmon ESU spring run) currently are being released into the Hood River basin as part of a reintroduction program.

Fish from the Round Butte introductions and their descendants are not considered part of the Lower Columbia River ESU. Differences in water conditions in the East and West Fork Hood rivers may have provided a selective force for local adaptation, resulting in differences in spawning time and other factors. There is some question as to whether large numbers of spring Chinook salmon were ever in the East Fork Hood River. Differences in timing and duration of peak flows, temperature, and headwater sources between the Hood and White Salmon rivers probably limited any substantial gene flow between the two rivers.

A number of smaller creeks (RKM 194–270) in this region would have provided spawning habitat for fall Chinook salmon from Columbia River. With the exception of the White Salmon and Hood rivers, no single creek appears to provide enough habitat or the geographic separation necessary to support a DIP. Evermann and Meek (1898) observed "considerable numbers" of Chinook salmon in the Little White and Big White Salmon rivers and Eagle and Tanner creeks. No Chinook salmon were observed at the mouth of the Big White Salmon River during a visit on 6 August 1896, but "quite a number" were observed during a return visit on 4 September 1896, at which time Native Americans already had established fishing camps (Evermann and Meek 1898). A salmon culture station was established on the Little White Salmon River in 1896, and during its first year of full operation (1897), 12 million eggs were collected (@ 5,000 eggs/female = 2,400 females). Eagle Creek was described by ODF (1903) as "rocky and full of boulders [but] its waters are perfect and even in the state in which it is at present it is sought after by the July and August Chinooks for spawning purposes." Bowers (1902) reported that Chinook salmon had entered Eagle and Tanner creeks by 18 September 1901 and that enough fish were present to provide 2–3 million eggs (@ 5,000 eggs/female = 600 females). Furthermore, these spawning areas would be susceptible to flooding by the Columbia River, and many may have occasionally suffered short-term extinctions in the past.

Evermann and Meek (1898) noted that Hamilton and Hardy creeks, which normally contained a "good many salmon," were blocked to salmon by large quantities of wood. Also included are fall Chinook salmon that historically may have spawned in the mainstem Columbia River. There is substantial evidence that Chinook salmon historically (and presently) spawned in the mainstem Columbia River upstream of the site of the former Celilo Falls (Fulton 1968), however, little historical documentation exists for spawning populations in the main stem below the falls. Stone (1878) reported that the fall Chinook salmon frequently spawned on the "sand beds" of the main river, within 80.5 km of the sea (approximately the limit of tidal influence in the Columbia River). There are aggregations of early fall and late (bright) fall Chinook salmon and chum salmon currently spawning below Bonneville Dam in the vicinity of Ives Island (van der Naald et al. 2001). Although the original source of these spawning fish is unclear, the ability of salmon to use mainstem habitat is well established. The late fall Chinook salmon appear to be related most closely to the upriver fall Chinook populations (summer and fall runs from the Upper Columbia River Chinook Salmon ESU), and are probably the progeny of hatchery strays (Marshall 1998, NMFS 1998a). Whether historical flow conditions in the main stem would have created similar situations is unknown. Additionally, if mainstem spawning were a significant component of the ESU, the relationship between fish spawning in the main stem and nearby tributaries would need to be established.

Individual population maps are in Appendix E (pages 199–311), and strata are presented in Figure 7 and Figure 9. Letter designations indicate possible subpopulation designations within the numbered populations. Populations identified in WDF et al. (1993) as a SASSI stock are so indicated. (Numbering sequence continued from the list of populations on page 44.)

27. Columbia River lower Gorge tributaries fall run (Figure E-10)
    a. Mainstem Columbia River
    b. Bridal Veil Creek
    c. Wahkeena Creek
    d. Hardy Creek
    e. Hamilton Creek
    f. Multnomah Creek
    g. Moffer Creek
    h. Tanner Creek
    i. Eagle Creek
    j. Rock Creek

28. Columbia River upper Gorge tributaries tule fall run (Figure E-11)
    a. Main stem
    b. Herman Creek
    c. Wind River (SASSI)
    d. Gorton Creek
    e. Little White Salmon River
    f. Viento Creek
    g. Lindsey Creek
    h. Phelps Creek

29. Big White Salmon River tule fall run (SASSI) (Figure E-3)

30. Big White Salmon River spring run (Figure E-24)

31. Hood River fall run (Figure E-13)

32. Hood River spring run (Figure E-27)
    a. West Fork Hood River

Upper Willamette River Chinook Salmon ESU Historical Independent Populations

The Willamette River basin historically provided sufficient spawning and rearing habitat for large numbers of spring Chinook salmon (Table 9). The predominant tributaries to the Willamette River that historically supported spring Chinook salmon, including the Molalla (RKM 58), Calapooia (RKM 192), Santiam (RKM 174), McKenzie (RKM 282), and Middle Fork Willamette (RKM 301) rivers, all drain the Cascade Range to the east (Figure 10) (Mattson 1948, Nicholas 1995). There are no direct estimates of the size of Chinook salmon runs in the

Table 9. Chinook salmon escapement estimates for Willamette River tributaries.[a]

Tributary	1936–46[b]	1947	1960[c]	1995[d]	1999[e]
Fall run					
Clackamas River	—	—	—	—	—
Spring run					
Clackamas River	800	—	433	1,000	818
Willamette Falls	—	45,000	—	—	—
Tualatin River (Gales Creek)	rpt[f]	—	—	—	—
Molalla River basin	—	550	—	Insignificant	—
Molalla River	993	500	—	—	—
Pudding River (Abiqua Creek)	200	50	—	—	—
North Santiam River basin	—	2,830	2,100	<300	—
Little North Santiam River	500	380	287	—	11 redds
North Santiam River	2,200	2,450	—	—	176 redds
South Santiam River basin		1,300	—	Insignificant	—
South Santiam River	392	1,100	—	—	15 redds
Thomas and Crabtree creeks	155	200	—	—	—
Calapooia River	20	30	—	—	—
McKenzie River (above racks)	250	4,780	—	1,000	—
Blue River	rpt	—	—	—	—
Middle Fork Willamette River basin	—	2,550	—	Insignificant	—
Middle Fork Willamette River	500	2,490	—	—	—
Fall Creek	rpt	60	—	—	—

[a] Numbers estimate naturally spawning escapement and may include hatchery-reared Chinook salmon.

[b] Parkhurst et al. 1950.

[c] Willis et al. 1960.

[d] Nicholas 1995.

[e] Schroeder et al. 2000.

[f] Rpt stands for reported.

Willamette River basin prior to the 1940s (Table 9). Wilkes (1845) estimated that the fishery at Willamette Falls could yield up to 800 barrels (122,000 kg) of salmon. Collins (1892) reported that 16,874 salmon (138,060 kg) were shipped to Portland, Oregon, from the Willamette Falls fishery in April and May 1889. This estimate would not include tribal harvest or harvest that was shipped to markets other than Portland. Clanton (1911) reported that 8 tons (7,272 kg) of salmon (888 fish) were confiscated in a single night on 22 April 1910 from fishermen fishing below Willamette Falls. McKernan and Mattson (1950) presented anecdotal information that the Native American fishery at Willamette Falls may have yielded 909,000 kg of salmon (100,000 fish @ 9.09 kg). Mattson (1948) estimated that the spring Chinook salmon run in the 1920s may have been five times the existing run size of 55,000 fish (in 1947) or 275,000 fish, based on egg collections at salmon hatcheries.

Prior to the laddering of Willamette Falls, passage by returning adult salmonids (RKM 37) was only possible during winter and spring high flow periods. The early run timing of Willamette River spring Chinook salmon relative to other Lower Columbia River Chinook Salmon ESU spring-run populations is viewed as an adaptation to flow conditions at Willamette Falls. Chinook salmon begin appearing in the lower Willamette River in February, but the majority of the run ascends Willamette Falls in April and May, with a peak in mid-May. Wilkes (1845) reported that the salmon run over the falls peaked in late May. Low flows during the summer and autumn months prevented fall-run salmon from reaching the upper Willamette River basin. Since the Willamette Valley was not glaciated during the last epoch (McPhail and Lindsey 1970), the reproductive isolation provided by the falls probably has been uninterrupted for a considerable time. Willamette Falls may have been formed by the receding waters of the Bretz Floods (12,000–15,000 years before present) (Nigro unpubl. data). This isolation has provided the potential for significant local adaptation relative to other Columbia River populations. Mattson (1963) discussed the existence of a late spring Chinook salmon that ascended the falls in June. These fish were apparently much larger (11.4–13.6 kg) and older (presumably 6-year-olds) than the earlier part of the run. Mattson (1963) speculated that this portion of the run "intermingled" with the earlier run fish on the spawning ground and did not represent a distinct run. The disappearance of the June run in the 1920s and 1930s was associated with the dramatic decline in water quality in the lower Willamette River. Similarly, the extirpation of the fall run in the Clackamas River during this time period was associated with pollution in the lower Willamette River. The migration of spring Chinook salmon over Willamette Falls currently extends into July and August (overlapping with the beginning of the introduced fall run of Chinook salmon), however, present-day salmon ascend the falls via a fish ladder. Passage over the falls historically may have been marginal in June because of diminishing flows, and only larger fish would have been able to ascend.

The juvenile life history characteristics of Upper Willamette River Chinook Salmon ESU spring-run populations appear to be highly variable. Mattson (1962) determined that fry emerge from February to March, although sometimes as late as June (Table 9). Emigration from the tributaries into the mainstem Willamette River occurred in three distinct phases:

1) late winter to early spring as fry,
2) fall to early winter (October through December) as fingerlings, and,
3) late winter to spring (February through early May) as yearlings.

Dimick and Merryfield (1945) reported that large numbers of fry were observed in the mainstem Willamette River from February through early April. It is possible that emigration also occurred during the summer, but pollution (specifically eutrophication and hypoxia) in the lower Willamette River from the 1920s to 1940s may have extirpated that life history form. In general, Chinook salmon returning to the upper Willamette River basin currently mature at 4 and 5 years old (Table 6).

Spring Chinook salmon populations in the upper Willamette River basin and Clackamas River have been influenced strongly by extensive hatchery transfers of fish throughout the Upper Willamette River Spring Chinook ESU for nearly 100 years (Table A-3). Much of the genetic diversity that existed between populations has been homogenized. Historical spawning times can be inferred from hatchery records, but much of the life history data that was collected in the

1940s already was biased by hatchery operations. Ecologically, all major spring-run-bearing waters drain the Cascades to the east and share the same Level IV EPA ecoregions. Historical population distribution for the spring Chinook salmon in this region was determined using biogeographic information, life history information, and historical estimates of abundance and habitat productivity.

The Willamette River basin covers approximately 29,800 km^2 (11,500 mi^2). Major tributaries include the Clackamas, Molalla, Santiam, Calapooia,[4] McKenzie, and Middle Fork rivers (Cascade Range), and the Tualatin, Yamhill, Luckiamute, Marys, and Long Tom rivers (Coast Range) (Figure 13, Table 10). The basin is composed of 30% valley floor (below 154 m) and 60% Cascade Range foothills and slopes (up to 3,000 m), the remaining area consists of part of the Coast Range (up to 1,200 m). The Upper Willamette River Chinook Salmon ESU differs biogeographically from many other ESUs in the Pacific Northwest in that it was not glaciated during the late Pleistocene. Climatically, a rain shadow effect, similar to the one influencing the Puget Sound lowlands, limits rainfall to about 120 cm per year, with minimum rainfalls in July, August, and September. River flows peak in December and January and are sustained at 50% of peak flow for 6 or 7 months of the year. Low flows occur in August and September, although the volume is generally 20% of the peak flow. Summer flows in the Coast Range tributaries are especially low because of the general absence of any substantial snowpack, and these tributaries historically may never have sustained Chinook salmon populations (Dimick and Merryfield 1945).

The Clackamas River historically contained spring Chinook salmon, but relatively little information about that native run exists. ODF (1903) reported that “the Clackamas River is, as has always been conceded, the greatest salmon breeding stream of water that our state affords.” Barin (1886) observed a run of Chinook salmon that “commences in March or April, sometimes even in February.” Smith (1895) estimated that 140 tons of Chinook were caught in the Clackamas River between April and May 1893 (127,270 kg @ 10.34 kg = 12,302 fish). Abernethy (1886) reported that some 3,500 Chinook salmon were caught in the Clackamas River between 10 April and 10 July 1885, however, he noted that no fishing was done in the river in March when the run was apparently very large. There are various accounts of when the spring-run adults spawned in the Clackamas River. Barin (1886) mentioned fish spawning in September, although his observations were in the vicinity of Clear Creek (RKM 13). He most likely observed fall-run fish spawning. The U.S. Fish Commission operated two hatcheries, one on the upper Clackamas River at Oak Grove Fork (RKM 95) and the other on the lower Clackamas River (RKM 6). Eggs were collected at the upper Clackamas station beginning 17 July and ending 26 August, with some 5 million eggs collected (Ravenel 1898). At the lower Clackamas station, ripe fish were not collected until 15 September and by 7 November 1897 only spawned-out fish were collected (Ravenel 1898). Murtagh et al. (1992) suggested that fish collected at the lower Clackamas station probably were fall (tule) Chinook salmon. The State of Oregon took over operation of the upper Clackamas station at the turn of the century and spawned 1,121 female spring Chinook salmon between 12 July and 4 September 1901, with peak

[4] The Calapooia River (Willamette River basin) also is spelled Calapooya in a number of historical documents. It should not be confused with the Calapooya River in the Umpqua River basin.

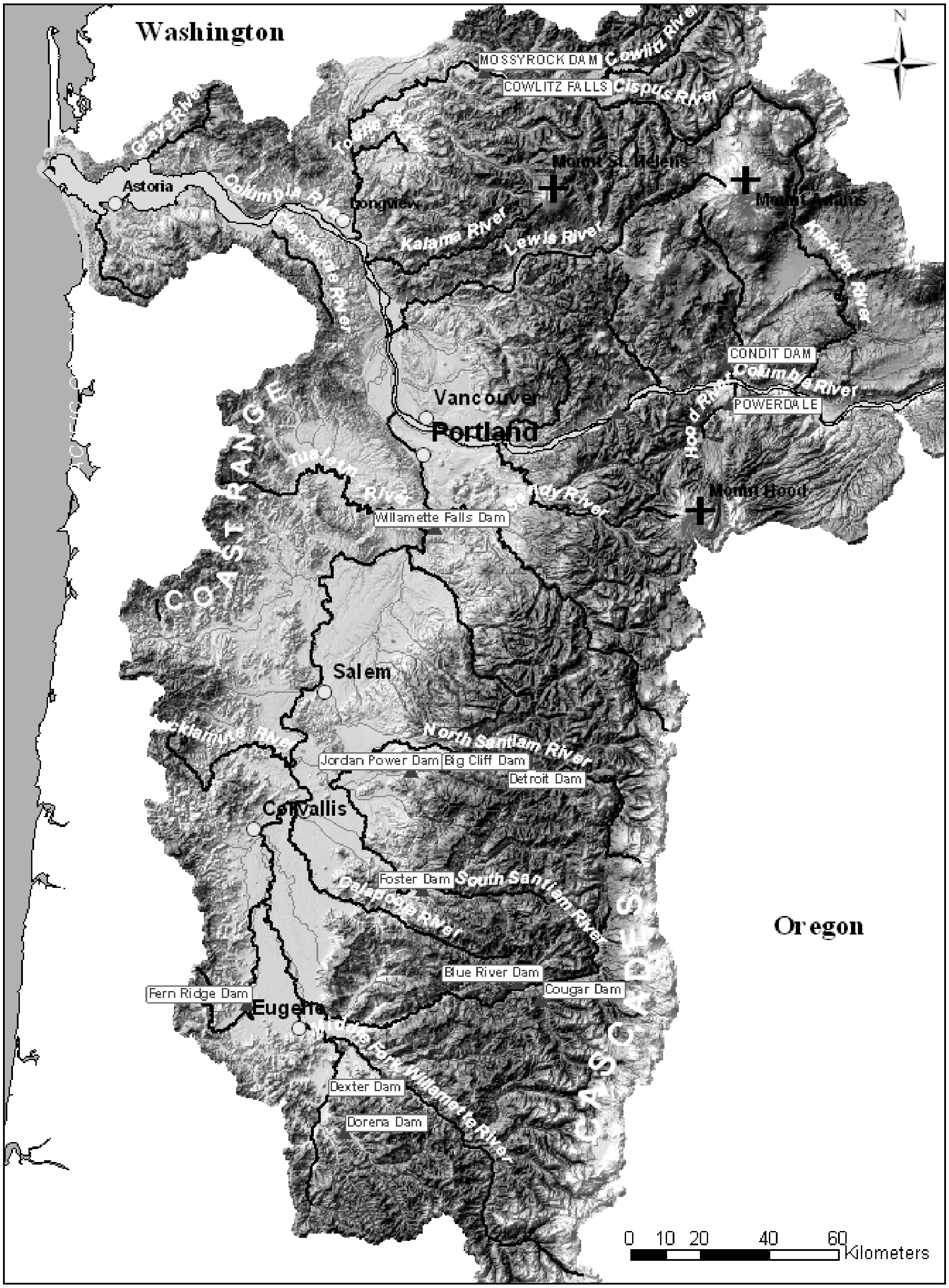


Figure 13. Willamette River basin.

spawning occurring between 2 August and 16 August 1901 (ODF 1903). Naturally spawning spring Chinook salmon currently spawn from September to October (Olsen et al. 1992).

Table 10. Willamette River tributary distance (RKM) from river mouth and basin size (km^2).

River basin	RKM[a]	Basin (km^2)	USGS gauge
Willamette River (mouth of Columbia River to Willamette River)	162.5	—	—
Clackamas River	39.9	2,418	14211000
Collawash River	—	>368	14208300
Oakgrove Fork	—	320	14209000
Molalla River	57.9	2,273	—
Molalla River	+0.0[b]	901	14200000
Pudding River	+1.2	1,372	14202000
Santiam River	173.6	4,730	—
North Santiam River	173.6+18.8	1,905	14184100
Breitenbush River	+91.7	280	14179000
North Santiam River above Detroit Dam	+91.7	558	14178000
Little North Santiam River	+45.1	290	14182500
South Santiam River	173.6+18.8	>1,657	—
South Santiam River above Foster	173.6+18.8	449	14185000
Middle Santiam River	+67.6	741	14186000
Quartzville Creek	+79.7	256	14185900
Calapooia River	192.3	968	14173500
McKenzie River	281.6	3,366	14159000
Mohawk Creek	+16.1	458	14165000
Blue River	+88.5	277	14162200
South Fork McKenzie River	+93.3	>539	14159500
Horse Creek	+103.0	386	14159100
Middle Fork Willamette River	304.1	3,495	14152000
Fall Creek	+17.7	>481	14151000
North fork of Middle Fork Willamette River	+57.9	637	14147500
Salt Creek	+66.0	293	14146500
Middle Fork Willamette River above Oakridge	—	668	14144800

[a] Distances (RKM) are given from the mouth of the Willamette River to the mouth of the tributary, unless otherwise noted.

[b] Distances with a plus (+) sign are from the mouth of a tributary to its secondary tributary.

The majority of historical spring Chinook salmon production probably came from the mainstem Clackamas and Collawash rivers (Willis et al. 1960). The Warm Springs Tribe considered the Big Bottom area of the Collawash River (a tributary to the upper Clackamas River) to contain the choicest salmon spawning grounds. Only the lower 3.8 km of the North Fork Clackamas River, 1 km of South Fork Clackamas River, and 4.8 km of the Oak Grove Fork were accessible (Willis et al. 1960).

Genetic analysis of naturally produced fish from the upper Clackamas River by NMFS indicated that this stock was similar to hatchery stocks from the upper Willamette River basin (Appendix C, pages 161–192) (Myers et al. 1998). This finding agrees with an earlier comparison of naturally produced fish from the Collawash and upper Willamette rivers hatchery stocks (Schreck et al. 1986). Fish introduced from the upper Willamette River have introgressed significantly into, if not overwhelmed, spring-run fish native to the Clackamas River basin and obscured any genetic differences that existed prior to hatchery transfers.

ODFW (1998) suggested that spring-run fish returning to the upper Willamette River basin historically may have strayed into the Clackamas River when conditions at Willamette Falls prevented upstream passage. Therefore similarities between Clackamas River and Upper Willamette River Chinook Salmon ESU spring-run fish may reflect an historical/evolutionary association between the two groups, rather than a recent artifact of human intervention. Recoveries of returning adults released from the Clackamas River have occurred at a number of sites outside this river. This may reflect the introgression of other Upper Willamette River Chinook Salmon ESU spring-run hatchery stocks into the Clackamas Hatchery, the relative downriver location of the releases (compared to historical spawning sites), or other aspects of the propagation of these fish prior to release.

The Molalla River is located above Willamette Falls, 50 km from the mouth of the Willamette River (Figure 13). By 1903 the abundance of Chinook salmon in the Molalla River already had decreased dramatically (ODF 1903). Surveys in 1940 and 1941 recorded 882 and 993 spring Chinook salmon, respectively (Parkhurst et al. 1950). Craig and Townsend (1946) collected a number of juveniles moving downstream from the Molalla River. Mattson (1948) estimated the run size to be 500 in 1947 (Table 9). In 1940, 200 spring Chinook salmon were observed in Abiqua Creek (Pudding River) during surveys (Table 8) (Parkhurst et al. 1950). Parkhurst et al. 1950 estimated that there was sufficient habitat in the Molalla to accommodate at least 5,000 salmon adults (Figure 10). Dimick and Merryfield (1945) reported that spring Chinook salmon spawn from early September into October, but some spawning may take place in the Clackamas and Molalla rivers as early as late July.

Spring Chinook salmon are native to the Santiam River basin. The Oregon Fish Commission (OFC) attempted egg-taking operations in 1906 and 1909, but it was not until 1911 that adults were captured for spawning (Wallis 1963c). The hatchery rack was located near Jefferson, Oregon, below the confluence of the North Santiam and Breitenbush rivers and below most of the natural-spawning areas (except for the Little North Santiam River). It was general hatchery policy to capture as much broodstock as possible. In 1911, 1.5 million eggs were collected. The largest egg collection was 13.2 million eggs in 1934 (@ 3,200 eggs/female = 4,125 females) (Wallis 1963c). The estimated run size for the entire North Santiam River basin was 2,830 in 1947 (Mattson 1948). Within the North Santiam River, the principal spawning areas were located from 2 km above the town of Stayton, Oregon, up through the Breitenbush River (Mattson 1948). Between 1911 and 1960, the overwhelming majority of hatchery fish released into the North Santiam River basin came from adults captured in the watershed. Other introductions came from the South Santiam River, McKenzie River, and Willamette River hatcheries (Wallis 1963b). Parkhurst et al. (1950) estimated that there was sufficient habitat in the North Santiam River to accommodate at least 30,000 salmon adults.

The earliest recorded observation of spawning occurred at the North Fork Santiam River hatchery rack on 22 August 1947, which is earlier than was observed at the McKenzie or Middle Willamette rivers hatchery racks (Mattson 1948). These spawning differences were ascribed to lower temperatures at the Santiam racks relative to other sites. During 1998 spawner surveys, no redds were observed prior to 1 September (Lindsay et al. 1999), 115 redds were observed in the

North Santiam River, and an additional 39 redds were observed in the Little North Santiam River.

Juvenile spring Chinook salmon historically began downstream emigration at various ages and sizes. Studies by Craig and Townsend (1946) in 1941 indicated that juveniles in the North Santiam River began moving downstream in March, soon after emergence. There appeared to be more or less continuous emigration through summer and autumn, with no previous-year juveniles present in tributaries by March of the following year. Analysis of scales from adults returning to the North Santiam River indicated that only 10% (six of 65) had entered the ocean as subyearlings, suggesting that a large proportion of juveniles observed emigrating downstream overwintered in the mainstem Willamette or Columbia rivers (Mattson 1963) (Table 6).

Genetic analysis of naturally produced juveniles from the North Santiam River indicated that the naturally produced fish were related most closely to, although still significantly distinct from, other naturally and hatchery produced spring Chinook salmon from the upper Willamette and Clackamas rivers (Appendix C, pages 161–192) (NMFS 1998a). Recoveries of returning fish occur primarily in the North Santiam River (95%) (Figures 3, 4, and 5), and there are few recoveries outside the upper Willamette River basin.

Spring Chinook salmon are native to the South Santiam River. Egg collection activities began in 1923, when a weir was placed across the river near the town of Foster, Oregon (Wallis 1961), well below the natural holding and spawning areas (Mattson 1948). River conditions did not allow the weir to be put in place until June, and it is possible that a considerable portion of the run already had moved upstream. Wallis (1961) noted that the inefficient operation of the weir often allowed a number of adults to move upstream. In some years the weir was not put in place at all. Escapement to the South Santiam River was estimated to be 1,300 in 1947 (Mattson 1948). Spawning also was reported by Mattson (1948) in Thomas Creek (above the Jordan Dam), and Crabtree Creek (above the state hatchery). Chinook salmon were observed as far upstream as Tamolitsh Falls (Craig and Townsend 1946, Mattson 1948). Wallis (1961) estimated that because of poor husbandry practices, releases from the South Santiam Hatchery did not significantly contribute to escapements. In fact the hatchery may have been mining returning naturally produced adults for broodstock each year.

There is little historical information about the life history characteristics of spring Chinook salmon from the South Santiam River. Juvenile studies by Craig and Townsend (1946) indicated more or less continuous downstream migration of fish from the time of emergence through the winter. Other life history characteristics are assumed to be similar to other populations in the upper Willamette River basin. In 1976 Foster Dam (RKM 77) blocked access to nearly all historical spring Chinook salmon spawning areas (Middle Santiam River, Quartzville Creek, and South Santiam River [Mattson 1948]).

A population of spring Chinook salmon historically existed in the Calapooia River. Parkhurst et al. (1950) estimated suitable habitat for 9,000 fish (Figure 10), although Willis et al. (1960) estimated the run at only 100–500 fish. Parkhurst et al. (1950) reported the 1941 run was approximately 200 adults, Mattson (1948) estimated the run at 30 in 1947. More recently, Nicholas (1995) considered the run extinct, with limited future production potential.

Spring Chinook salmon are native to the McKenzie River basin. Historical natural spawning areas included the mainstem McKenzie River, Smith River, Lost Creek, Horse Creek, South Fork McKenzie River, Blue River, and Gate Creek (Figure 11) (Mattson 1948, Parkhurst et al. 1950, ODFW 1990). ODF (1903) surveyed much of the McKenzie River to site a hatchery and collection rack. The report stated: "It has been generally reported by settlers and those living along the river that salmon can be seen spawning during the months of August and September all along the river, but principally from Leaburg post office up to its source." The McKenzie River currently is the only basin above Willamette Falls to sustain any level of natural production. The McKenzie River Hatchery (RKM 52), which began egg collections operations in 1902, had a peak collection of 25.1 million eggs in 1935 (Wallis 1961) from an estimated 7,844 females (@ 3,200 eggs per female). Mattson (1948) estimated 4,780 adults returned to the McKenzie River, which constituted 40% of the entire run above the Willamette Falls. Parkhurst et al. (1950) estimated there was suitable habitat for 80,000 fish in the entire McKenzie River basin. In 1958 the OFC survey observed 3,198 Chinook salmon redds in the McKenzie River basin (Willis et al. 1960).

The construction of Cougar Mountain Dam (RKM 101) in 1963 eliminated 56 km of spawning habitat on the South Fork McKenzie River. The south fork generally was believed to be the best salmon-producing stream in the McKenzie River drainage (USFWS 1948). Mattson (1948) reported that the principal spawning area in the south fork was located 7–13 km from the mouth. In 1956, 805 Chinook salmon redds were observed in the south fork (Willis et al. 1960). The Blue River Dam (1968, RKM 88) prevented access to an additional 32 km of spawning habitat.

McKenzie River spring Chinook salmon historically began spawning in mid-August through mid-October, with peak spawning occurring around 10 September (Willis et al. 1995). In 1902 the McKenzie River Hatchery spawned 138 females between 19 August and 20 October, peaking in mid-September (ODF 1903). Mattson (1963) reported that a female was spawned as early as 14 August 1935 at the McKenzie River Hatchery. Stream surveys in the McKenzie River observed redds as early as 15 August and as late as 20 October. Juveniles were observed moving downstream beginning in February and continuing throughout the year (Craig and Townsend 1946, Cramer et al. 1996). Analysis of scales from adults returning to the McKenzie River in 1947 indicated that 13.5% (eight of 59) entered the ocean as subyearlings (Mattson 1963).

Genetic analysis of juveniles from the McKenzie River indicated that the naturally produced fish were related most closely to other natural and hatchery produced spring Chinook from the upper Willamette and Clackamas rivers (Appendix C, pages 161–192) (NMFS 1998a). Based on the recoveries of CWT fish released from the McKenzie River Hatchery, very little straying is apparent, with more than 97% of all freshwater recoveries occurring in the McKenzie River basin.

The Middle Fork Willamette River also supported historical populations of spring Chinook salmon. Spawning aggregations were in Fall Creek, Salmon Creek, North Fork Middle Willamette River, mainstem Middle Fork Willamette River, and Salt Creek (Mattson 1948, Parkhurst et al. 1950). Based on records (1909–present) from the Willamette River Hatchery (Dexter Ponds), the largest egg collection, 11,389,000 in 1918 (Wallis 1962), corresponds to

3,559 females (@ 3,200 eggs/female). Mattson (1948) estimated the middle fork run size to be 2,550 in 1947.

The construction of Lookout Point and Dexter dams (RKM 328) in 1953 eliminated access to almost 345 km of salmon habitat (Cramer et al. 1996). Only the Fall Creek basin remains accessible to anadromous salmonids. Although Parkhurst et al. (1950) estimated the Fall Creek basin could support several thousand salmon, by 1938 the run already had been depleted severely. In 1947 the run had dwindled to an estimated 60 fish (Mattson 1948). Construction of the Fall Creek Dam (1965) included fish passage facilities, but efficient passage is only possible during high flow years (Connolly et al. 1992). Nicholas (1995) concluded that the native spring-run population was extinct, although some natural production, presumably by hatchery-origin adults, may still occur.

Studies of juvenile emigration from the Middle Fork Willamette River in 1941 indicated that downstream migration occurred on a more or less continuous basis from March through autumn (Craig and Townsend 1946). Genetic analysis of naturally produced juveniles from the Dexter Ponds trap indicated that the fish were related most closely to other naturally and hatchery produced spring Chinook from the upper Willamette and Clackamas rivers (Appendix C, pages 161–192) (NMFS 1998a).

Dimick and Merryfield (1945) reported occasional sightings of adult Chinook salmon in west-side tributaries of the Willamette River (draining the Coast Range), however they concluded that these fish were accidental strays and that several years of extensive sampling had failed to observe any young salmon. Parkhurst et al. (1950) also failed to observe Chinook salmon in any tributaries draining the Coast Range during their surveys in the 1930s and 1940s, despite a number of efforts to introduce spring Chinook salmon into the west-side tributaries. USFWS (1948) reported that suitable spawning gravel existed in the lower Row River and Mosby Creek. Additionally, based on interviews with "older residents," spring Chinook salmon did occur in the Row River but apparently were exterminated by flash dams constructed during logging operations. The USFWS (1948) concluded that there were no anadromous fish in either the Long Tom or Luckiamute rivers. Reports of Chinook salmon in west-side tributaries have continued to the present, however, it is unlikely that spawner abundance in any of these tributaries constitutes a DIP.

There is little life history or genetic information for Willamette River spring Chinook salmon populations that is not potentially influenced by artificial propagation programs, migration barriers, and habitat destruction or degradation. In a comparison of the size and age structure of spring Chinook salmon returning to hatcheries in the upper Willamette River, Mattson (1963) observed a larger proportion of 3-year-old jacks returning to the Willamette Hatchery on the Middle Fork Willamette River: 19.3%, relative to the McKenzie River (7.6%) or North Santiam River hatcheries (10.6%) (Table 6). Mattson (1963) noted some discrepancy in the identification of jacks at the different hatcheries. Differences in hatchery-rearing protocols could easily have affected the age structure of returning fish. There was no apparent difference in the body size of fish returning to the McKenzie or North Santiam rivers, although the sample sizes were rather small (18–33 fish) (Mattson 1963).

The size of the Willamette River and its constituent tributaries, combined with the preference of spring Chinook salmon to spawn in headwater areas, provides a strong geographic mechanism for reproductive and demographic isolation. Current straying rates for hatchery-reared Willamette River Chinook salmon indicate a high degree of homing fidelity. Therefore, it is possible that there were a number of historical DIPs in the Upper Willamette River Chinook Salmon ESU.

Individual population maps are in Appendix E (pages 199–311), and strata are presented in Figure 14. Letter designations in the following list indicate possible subpopulation within the numbered populations.

1. Clackamas River (Figure E-35)
    a. Collawash River
    b. Upper Clackamas River

2. Molalla River (Figure E-37)
    a. Molalla River
    b. Pudding River

3. North Fork Santiam River (Figure E-38)
    a. Breitenbush River
    b. Marion Fork
    c. Little North Santiam River
    d. Mainstem North Fork Santiam River

4. South Fork Santiam River (Figure E-39)
    a. South Fork Santiam River
    b. Middle Fork Santiam River
    c. Quartzville Creek

5. Calapooia River (Figure E-34)

6. McKenzie River (Figure E-36)
    a. Mohawk Creek
    b. Blue River
    c. South Fork McKenzie River
    d. Horse Creek

7. Middle Fork Willamette River (Figure E-40)
    a. Fall Creek
    b. North fork Middle Fork Willamette River
    c. Salt Creek
    d. Mainstem Middle Fork Willamette River

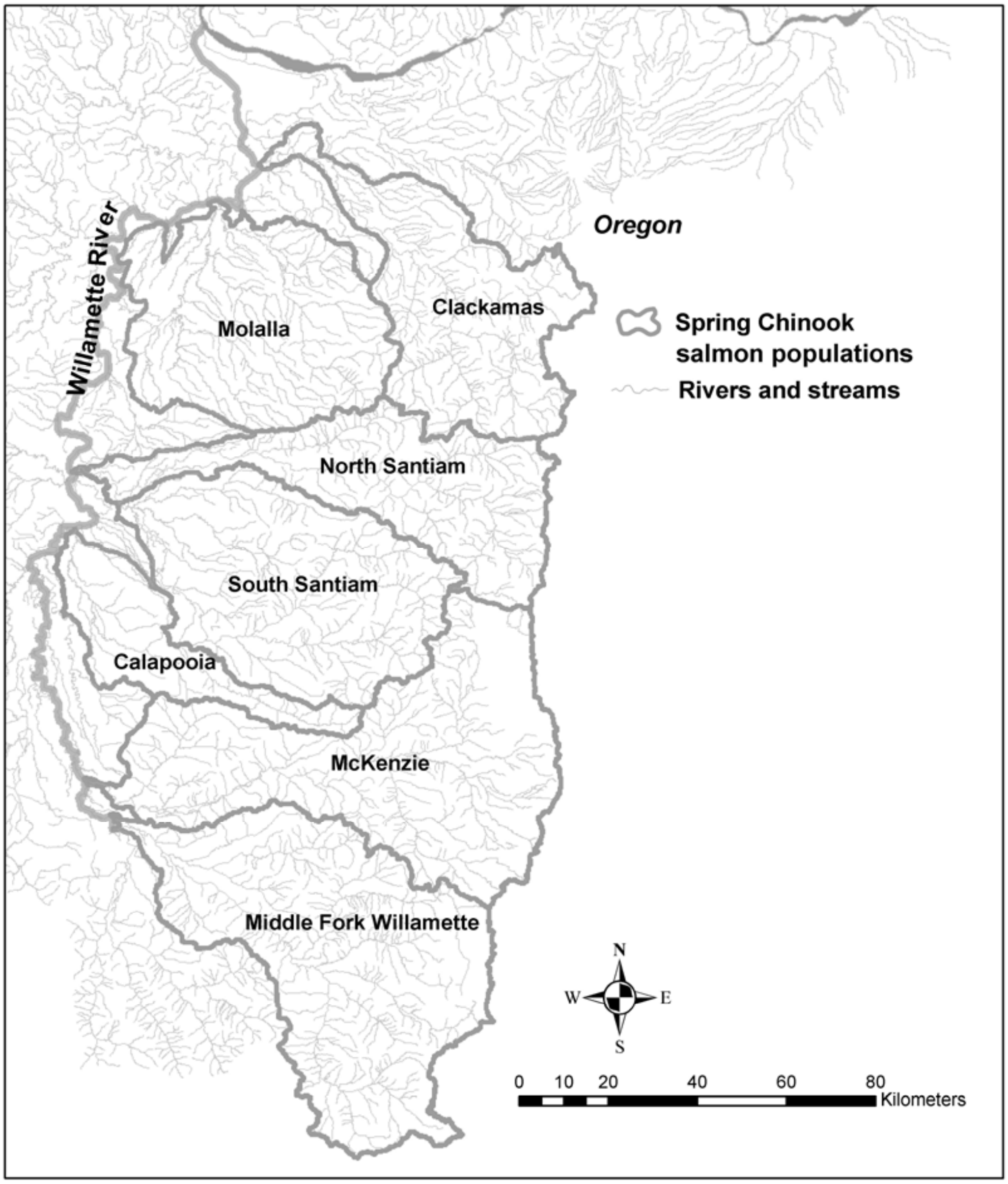


Figure 14. Historical spring DIPs in the Upper Willamette River Chinook Salmon ESU.

Steelhead

Life History

The life history of steelhead is highly variable. In the lower Columbia River, at first spawning most wild steelhead are 4–6 years of age, 50–91 cm in length, and 2–8 kg in weight (Table 11). However, they can attain the age of 9 years and reach lengths of more than 100 cm (12 kg) (Busby et al. 1996). Steelhead may spawn more than once, although the frequency of repeat spawners is relatively low. At least nine different initial and 13 different repeat age-classes were identified for the Lower Columbia River Steelhead ESU (Leider et al. 1986).

Two distinct races of steelhead, summer and winter runs, historically were and currently are found in the lower Columbia River. However, while summer- and winter-run life history types currently exist in the Upper Willamette River Steelhead ESU, only winter steelhead were present historically. The life histories of summer and winter steelhead overlap considerably. Both rear in freshwater for 1–4 years prior to smolting, select similar habitat for freshwater rearing, and spend 1–4 years in the ocean. However, substantial differences separate these races at adult freshwater entry: degree of sexual maturity at entry, spawning time, and frequency of repeat spawning.

Each year the majority of naturally produced summer-run fish from the Lower Columbia River Steelhead ESU enter freshwater between May and October. These fish are sexually immature upon return to their natal streams. Fish spawn between January and June, with peak spawning between late February and early April (Leider et al. 1986, Busby et al. 1996). The repeat spawner rate is about 5.9% for wild summer steelhead (Hulett et al. 1993). In contrast wild winter steelhead enter freshwater as sexually mature fish between December and May. Spawning occurs between February and June, with peak spawning time in late April and early May, almost two months later than wild summer steelhead (Leider et al. 1986, Busby et al. 1996). The repeat spawner rate for wild winter steelhead is 8.1% on the Kalama River, double that of wild summer steelhead (Hulett et al. 1993).

On average, there is a two-month difference in peak spawning time between winter and summer steelhead, although there is probably an overlap in the spawning distribution (Busby et al. 1996). Furthermore, within the same watershed, winter and summer steelhead spawn in geographically distinct areas. Summer steelhead populations occur above barrier falls, which are generally impassable during the winter-run migration. Watersheds that historically had summer steelhead populations include the Kalama, North Fork Lewis, East Fork Lewis, Washougal, Wind, and Hood rivers (Figure 2). The long duration of prespawning holding in freshwater may result in a high mortality, putting summer steelhead at a competitive disadvantage relative to winter steelhead. Therefore, in basins where winter and summer steelhead are present, the

Table 11. Primary (most common) and secondary age-structure patterns reported for populations in the Lower Columbia River and Upper Willamette River Steelhead ESUs.

Population[a]	Run type[b]	Age structure (frequency)[c]				Sample size	Source
		Primary		Secondary			
Toutle River	o	2/2	(0.73)	2/3	(0.11)	37	Howell et al. 1985
Cowlitz River	o	2/2	(0.55)	2/3	(0.34)	56	Howell et al. 1985
Kalama River	o	2/2	(0.65)	2/3	(0.18)	1,363	Howell et al. 1985
Kalama River	s	2/2	(0.67)	2/1	(0.17)	909	Howell et al. 1985
Willamette River	o	2/2	(0.92)	3/2	(0.08)	141	Howell et al. 1985
Clackamas River	o	4	(0.71)	5	(0.26)	na	Chilcote 1997
Sandy River	o	4	(0.71)	5	(0.26)	na	Chilcote 1997
Washougal River	s	2/2	(0.71)	2/1 & 2/3[d]	(0.14)	7	Howell et al. 1985
Wind River	s	2/2	(0.58)	2/3	(0.26)	19	Howell et al. 1985
Hood River	o	2/2	(0.58)	2/3	(0.19)	1,018	Olsen et al. 1994
Hood River	s	2/2	(0.65)	3/2	(0.16)	467	Olsen et al. 1994
Klickitat River	s	2/2	(0.75)	2/1	(0.14)	148	Howell et al. 1985

[a] Populations generally are arranged from north to south.

[b] O represents ocean maturing (winter run), s represents stream maturing (summer run).

[c] The frequency of occurrence in the sample is shown in parentheses. Format used is freshwater age/ocean age at first spawning migration.

[d] Both age structures are equally common.

summer steelhead life history strategy appears only to be able to persist above barrier falls that exclude winter steelhead. Because summer steelhead return to specific areas above barrier falls, they may require a higher homing fidelity relative to Chinook salmon or winter steelhead. Winter and summer steelhead prefer to spawn in smaller streams and side channels as compared to Chinook salmon. This may result in a finer level of population structuring than occurs in Chinook salmon. Utilizing smaller stream systems also provides more spawning and rearing habitat for steelhead than may be available to Chinook salmon. These factors suggest that the minimum basin size for steelhead may be smaller than the 250 km^2 derived for Chinook salmon.

Phelps et al. (1997) examined the relationship between coastal summer and winter steelhead populations. In their genetic analysis, the summer and winter runs within the GDU were more closely related to each other than to collections from other GDUs, indicating that the run-timing characteristics evolved from a single evolutionary line within each basin. However, significant differences in allele frequencies indicate that summer and winter runs in the same basin should be treated as separate populations. Sharpe et al. (2000) detected significant genetic differences between Kalama River wild winter and summer steelhead, confirming the earlier work by Phelps et al. (1997).

Parkinson (1984) indicated that significant differences in genetic variation were observed among steelhead populations in adjacent streams, and this pattern of variation supports the view that steelhead are subdivided into a large number of semi-isolated populations. Analysis of the historical distribution of summer steelhead in the lower Columbia River indicates that self-sustaining populations were present in relatively small drainage areas, such as the East Fork Lewis River above Horseshoe Falls (130 km^2). The East Fork Lewis River summer steelhead population is considered isolated reproductively from adjacent spawning populations in the Kalama (93.3 km distant), North Fork Lewis (109.4 km), and Washougal (138.4 km) rivers. It is unclear whether the larger basins, such as the Kalama, Wind, Washougal, and North Fork Lewis rivers, supported more than one summer steelhead population. However, the East Fork Lewis River population is an indication that steelhead populations may persist in drainages as small as 130 km^2, half the minimum drainage area estimated for Chinook salmon.

In identifying historical independent populations of steelhead, the lower Columbia River was divided into two geographic/ecological subregions, the western Cascade Range and Columbia Gorge. The Lower Columbia River Steelhead ESU does not include the coastal areas of the Columbia River basin or the White Salmon River (Busby et al. 1996).

There has been considerable discussion about incorporating resident rainbow trout (*O. mykiss*) into steelhead populations. In general, resident and anadromous life histories are considered components of a population unless they have been isolated reproductively from each other because of life history differences or long-standing natural barriers. For example, rainbow trout in the McKenzie River (McKenzie redsides) have been identified as being genetically distinct from winter steelhead in the Upper Willamette River Steelhead ESU (NMFS 1999a), although the mechanisms for this isolation are unclear. The expression of a nonmigratory (residual) life history strategy may be important to long-term persistence of steelhead populations, especially during periods of poor ocean conditions or in the event of otherwise catastrophic short-term barriers to anadromous migrations. Many of the issues related to resident/anadromous population are the result of anthropogenic activities (e.g., dams, stock transfers, etc.) and do not affect the designation of historical population boundaries. Overall, the effect of resident rainbow trout on population boundaries and estimates of historical or present-day abundances probably is relatively minor. The relationship between resident and residual rainbow trout is discussed in greater detail in Kostow (2003).

Cutthroat trout appear to be the predominant resident salmonid throughout the lower Columbia and upper Willamette rivers. Where resident cutthroat and rainbow trout are sympatric, cutthroat trout appear to have a competitive advantage. For example, Dimick and Merryfield (1945) suggested that the cutthroat trout "has the greatest overall distribution of any of the salmonids in the Willamette River system. In some areas the distribution overlaps that of the rainbow trout. In many of the small creeks, the cutthroat trout is present while the rainbow is entirely lacking." There are a number of basins where impassable structures have been built, and self-sustaining resident or residualized populations have been established above the barriers. There appears to be a close genetic association between these residualized populations and the anadromous steelhead population below the structure. This relationship may be of interest for recovery efforts that may wish to utilize this genetic reserve. Maps presented in this technical memorandum reflect historical access and include these residual areas. Finally, where long-standing natural barriers exist, independent resident populations of *O. mykiss* may occupy upstream areas. These resident populations generally are isolated reproductively and demographically from the downstream anadromous populations discussed in this technical memorandum: they are not included in the population distribution maps (Appendix E, Figures E-41–E-71).

Lower Columbia River Steelhead ESU
Historically Independent Populations

Western Cascade Range Tributaries

Rivers in this region are larger than those found in the coastal region, with headwaters high in the Cascade Mountains. Many rivers are more than 100 km long, with basins covering 1,000 km^2 or more. Snowmelt and groundwater sources are substantial and maintain good year-round flows and cool water temperatures. River flows peak in December or January and sustain at least 50% of peak for 6 months or more. The lower reaches of these rivers are relatively low gradient, but high gradient sections are common in the middle and upper reaches.

This region extends from the Cowlitz River (RKM 106.2) up to and including the Washougal River (RKM 194.9) on the Washington side and from the Willamette River (RKM 162.5) up to and including the Sandy River (RKM 193.6) on the Oregon side. In considering historical population abundance estimates and watershed size (Figure 1), it was concluded that this region contained several major populations.

In general, little life history information is available to distinguish steelhead populations other than traits associated with winter and summer run timing (NFMS 1998b). Historical references to steelhead rarely made any distinction between summer and winter runs. The majority of steelhead are believed to have emigrated to saltwater as 2-year-old fish and returned to spawn as 4-year-old adults (e.g., having spent 2 years in the ocean). The ability of steelhead to ascend waterfalls and cascades has given them a wide distribution in many basins that are not readily accessible to other anadromous salmonids. There is a considerable genetics database for the Lower Columbia River Steelhead ESU. However, a number of the naturally spawning and hatchery populations have been influenced strongly by transfers of fish from Puget Sound hatcheries (Puget Sound Steelhead ESU), the Big Creek Hatchery (Southwest Washington Steelhead ESU), and the Skamania Hatchery (Phelps et al. 1995). Winter steelhead populations in this ESU that have been subjected to extensive introgression by Puget Sound steelhead (Chambers Creek Hatchery) transfers display an earlier run and spawn timing compared to native or “late” winter steelhead.

Despite the large size of the Cowlitz River basin, the absence of seasonal barrier falls probably precluded the evolution of a summer steelhead run. Late winter steelhead appear to have been present throughout the basin. In addition to the late winter steelhead, Bryant (1949) reported “spring” steelhead in Lake and Lunch creeks, spawning in June and July, rather than in April and May for late winter steelhead. There historically were at least 20,000 winter steelhead in the Cowlitz River (Hymer et al. 1992). The Cowlitz River basin covers approximately 6,000 km^2 and drains the slopes of Mount Rainier, Mount St. Helens, and Mount Adams (Table 1). The construction of Mossyrock and Mayfield dams eliminated approximately 50% of the historical spawning habitat. WDF and WDG (1946) estimated the steelhead spawning escapement above the Mayfield Dam site at 11,000 fish (including harvest, this represented a total run of 22,000 fish). The eruption of Mount St. Helens in 1980 dramatically altered habitat in the Toutle River basin. However, naturally spawning populations still exist in the lower mainstem Cowlitz River, Coweeman River, and Toutle River basins. Based on the observed distribution of steelhead throughout the basin in the 1930s and 1940s (Table 2), it was concluded that suitable habitat was available (Table 1) and geographically arranged in a way that a number of large, independent steelhead populations could have existed historically in the Cowlitz River basin.

Analysis of allozyme variation indicates that there are significant differences between late native winter steelhead in the mainstem Cowlitz, Green (North Fork Toutle), and South Fork Toutle rivers (Appendix C, pages 161–192) (Phelps et al. 1997). The mainstem Cowlitz River population may represent the homogenized genetic resources of all winter-run populations from the upper and lower Cowlitz, Cispus, and Tilton basins. Samples from Green River (Cowlitz River basin) steelhead clustered with hatchery samples known to be influenced strongly by introductions of Chambers Creek (Puget Sound) winter steelhead. Therefore, Green River winter steelhead may not be representative of the historical population.

Summer and winter steelhead are native to the Kalama River basin. A waterfall (Lower Kalama Falls) at RKM 17.7 historically may have been accessible only during periods of low flow. A set of high falls at RKM 56.3 (e.g., Kalama Falls) marks the limit of upstream migration.[5] The entire Kalama River basin covers 523 km^2, with 226 km^2 of basin lying between Lower Kalama and Kalama falls. In the absence of major geographic features, such as tributaries and others, it was estimated that only one independent population of summer and winter steelhead existed in the Kalama River basin.

Summer and winter steelhead are native to the Lewis River basin. A large part of the historical spawning habitat on the North Fork Lewis River was blocked following construction of the Ariel-Merwin (1931), Yale (1953), and Swift (1958) dams. For a number of years prior to the construction of the Yale Dam, adult steelhead were passed over the Ariel Dam to spawn (Parkhurst et al. 1950). Some spawning currently takes place in the main stem below the dam and in Cedar Creek, a tributary to the Lewis River below the dam (Howell et al. 1985). Smoker et al. (1951) estimated that prior to construction of the dams the combined summer and winter steelhead escapement was more than 1,000 fish. In the East Fork Lewis River, steelhead historically migrated above Sunset Falls (RKM 51). Modifications to the falls have improved steelhead access to the upper watershed.

Winter steelhead are native to the Clackamas River basin. Although summer steelhead currently are present and spawn naturally in this system, they originated from releases of Skamania Hatchery summer steelhead stock (Appendix A, Table A-3, page 132) (Murtagh et al. 1992, Chilcote 1997). It was determined that of the artificially propagated stocks released into the Clackamas Basin only the Clackamas Hatchery stock (ODFW #122) is part of the Lower Columbia River Steelhead ESU (NMFS 1999b). The Big Creek Hatchery stock of winter steelhead returns to the Clackamas River earlier (October–early March) than the native winter steelhead (February–June) (Murtagh et al. 1992). The peak spawning period for Big

5 Flow conditions and the structure of the falls determine passage at various falls. Some falls (e.g., Willamette) are passable during periods of high flow, when the lower portion of the falls is flooded or nearshore routes become available. Other falls (Kalama, Horseshoe, Duggan, and Shipherd) present a jump or velocity barrier during high flow periods but are passable during low flows.

Creek-derived fish is January to early March, compared with May and June for native Clackamas River winter steelhead. Stone (1878) reported that "steelhead spawning in the Willamette River peaks in May, but may extend as late as August in the Klackamas [sic] River." Barin (1886) observed that "the steel-head [sic] salmon commences its run from the middle of October, and begins spawning about the first of May." Several population configurations have been suggested for the Clackamas River. One alternative includes the Clackamas River main stem and tributaries below North Fork Dam as the lower Clackamas River winter steelhead DIP. Upper tributaries to the Clackamas River may have had the capacity to sustain large populations of steelhead: whether the upper Clackamas River (above North Fork Dam), including the Collawash River, was able to sustain a DIP is unclear.

Johnson and Mount Scott creeks were included as a subpopulation of the Clackamas River winter steelhead historical DIP. Although these creeks are not tributaries to the Clackamas River, their proximity to the mouth of the Clackamas River and the relatively large abundance of Clackamas River steelhead may have resulted historically in a substantial exchange of individuals between these water basins. It also has been suggested that Johnson and Mount Scott creeks historically were part of a DIP that included small tributaries to the Willamette River, below the Clackamas River and along the Columbia River. Steelhead were noted in both creeks during surveys conducted in the 1930s (Bryant 1949) and 1950s (Willis et al. 1960). The Oregon Game Commission collected steelhead broodstock from Crystal Springs Creek, a tributary to Johnson Creek (Willis et al. 1960).

Summer and winter steelhead are native to the Washougal River basin (Bryant 1949). Two falls, Salmon (RKM 28) and Dougan (RKM 34), present barriers to returning adult steelhead during low water periods (Parkhurst et al. 1950, Hymer et al. 1992). The U.S. Bureau of Commercial Fisheries operated an egg-taking station on the Washougal River during the 1920s. From 13 April to 23 May 1923, 834,000 eggs were collected, presumably from winter-run fish (@ 4,000 eggs/female = 209 females) (Howell et al. 1985). Additionally, a large number of immature (most likely summer steelhead) were passed over the weir (Mitchell 1924). In July 1935, a survey counted 539 summer steelhead in resting holes below Salmon Falls (Parkhurst et al. 1950). WDF (1951) provided no escapement estimates, but did estimate that the Washougal River basin contributed 55,000 kg to the fishery (prior to construction of the Skamania Hatchery). The West Fork Washougal (RKM 20.9) is 37 km long, but a 5.5-m waterfall at RKM 8.9 is considered impassable. Bryant (1949) estimated there was suitable spawning habitat for approximately 2,000 fish in the West Fork Washougal River.

Winter and summer steelhead are present in the Sandy River basin, although only winter steelhead are recognized as being native (Kostow 1995). Anecdotal reports exist of a summer steelhead population historically occurring in the Sandy River, however, we know of no documentation to substantiate this. Winter steelhead escapement historically may have been in excess of 20,000 fish (Mattson 1955). Winter steelhead were spawned at the Salmon River Hatchery from 25 February to 28 May 1902, although the vast majority were spawned after 2 April 1902 (ODF 1903). Loss of spawning habitat in the Bull Run River and Little Sandy River basins, in combination with the effects of dams on the mainstem Sandy River, reduced the run to 4,400 in 1954. The Bull Run River alone historically may have produced 5,000 adults (Table 8) (Mattson 1955). More recently the estimated wild escapement of hatchery fish over Marmot Dam (RKM 43) was 851 in 1997, although distinguishing between naturally produced and hatchery-derived winter steelhead has been difficult (Chilcote 1997). ODF (1903) identified a number of tributaries to the upper Sandy River that supported steelhead: “The Salmon River, which is a fork of the Sandy River, I found to be a good stream for artificial work . . . is frequented by the Winter Steelheads.” The ODF (1903) report also stated that Zigzag “Creek” (River) and Still Creek are “very desirable steelhead streams, and could be worked nicely for that variety of fish in connection with a work that may be going on at the eyeing station.” Mattson (1955) estimated that the Salmon River historically produced 2,000 steelhead and simply concluded that the Zigzag River was an “excellent producer of steelhead.”

There are potentially four or five subpopulations of winter steelhead in the Sandy River basin: mainstem Sandy, Bull Run, Little Sandy, Zigzag, and Salmon rivers. It is possible that the geographic separation (Table 1) and physiographic differences (e.g., elevation, temperature, and hydrology) (Figure 1) between the lower tributaries (Bull Run and Little Sandy rivers) and upper tributaries (Zigzag and Salmon rivers) could have resulted in demographic and reproductive isolation between the two areas.

Individual population maps are in Appendix E (pages 199–311), and strata are presented in Figure 15 and Figure 16. Letter designations indicate possible subpopulation designations within the numbered populations. Populations identified in WDF et al. (1993) as a SASSI stock are so indicated. In 1997 WDFW proposed numerous revisions to the SASSI population list. The DIPs listed below that correspond to redefined SASSI populations are identified by “SASSI 1997” (WDFW 1997). The DIPs that correspond to the original SASSI list are identified by “SASSI 1993” (WDF et al. 1993).

1. Cispus River winter run (Figure E-49)
2. Tilton River winter run (Figure E-62)
3. Upper Cowlitz River winter run (Figure E-53)
4. Lower Cowlitz River winter run (SASSI 1993) (Figure E-54)
5. North Fork Toutle River (Green River) winter run (SASSI 1993) (Figure E-63)
   a. North Fork Toutle River winter run (SASSI 1993)
   b. Green River winter run (SASSI 1993)
6. South Fork Toutle River winter run (SASSI 1993) (Figure E-64)
7. Coweeman River winter run (SASSI 1993) (Figure E-51)
8. Kalama River winter run (SASSI 1993) (Figure E-57)
9. Kalama River summer run (SASSI 1993) (Figure E-43)
10. North Fork Lewis River winter (SASSI 1993) (Figure E-59)
11. East Fork Lewis River winter run (SASSI 1993) (Figure E-58)

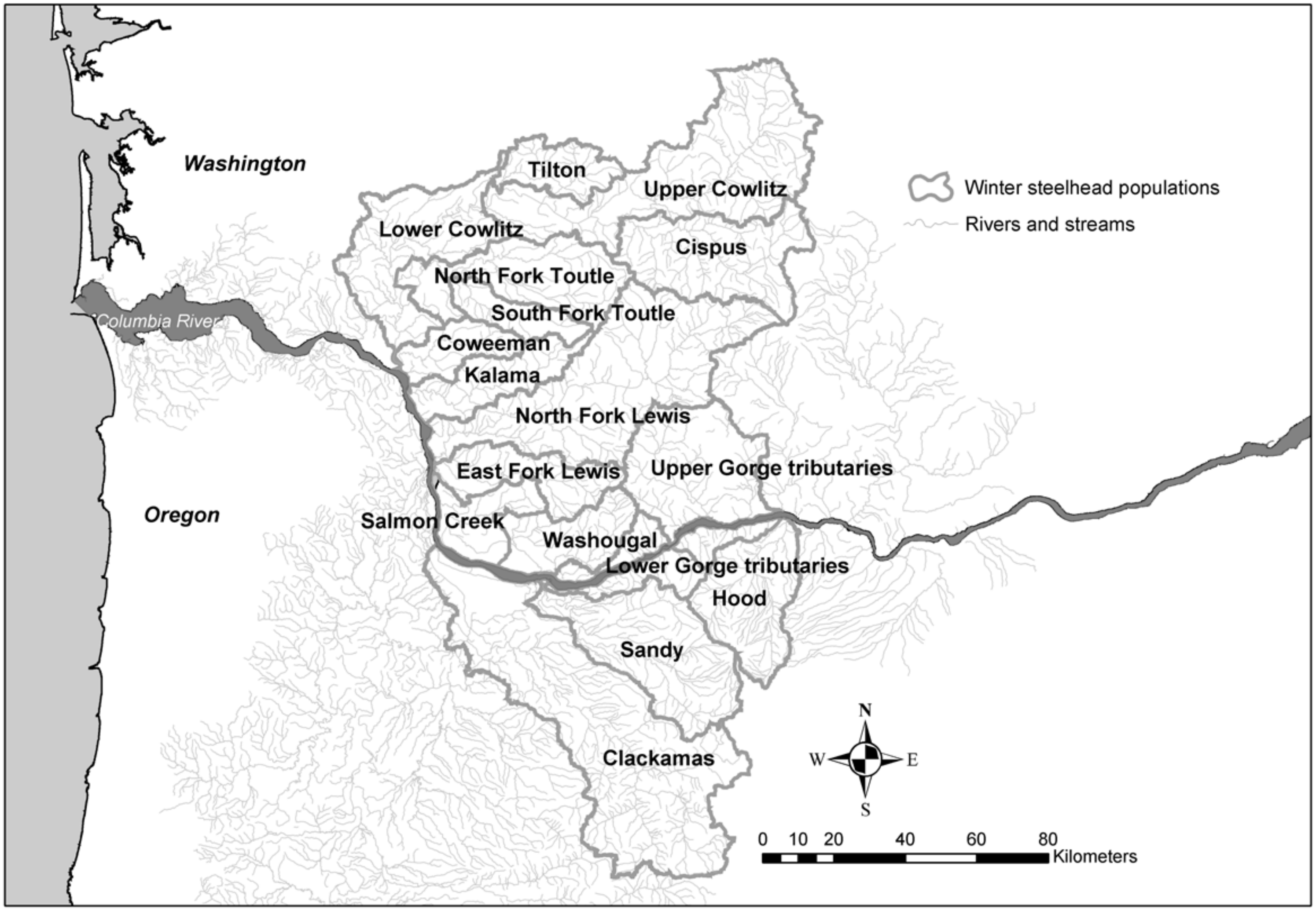


Figure 15. Historical winter DIPs in the Lower Columbia River Steelhead ESU.

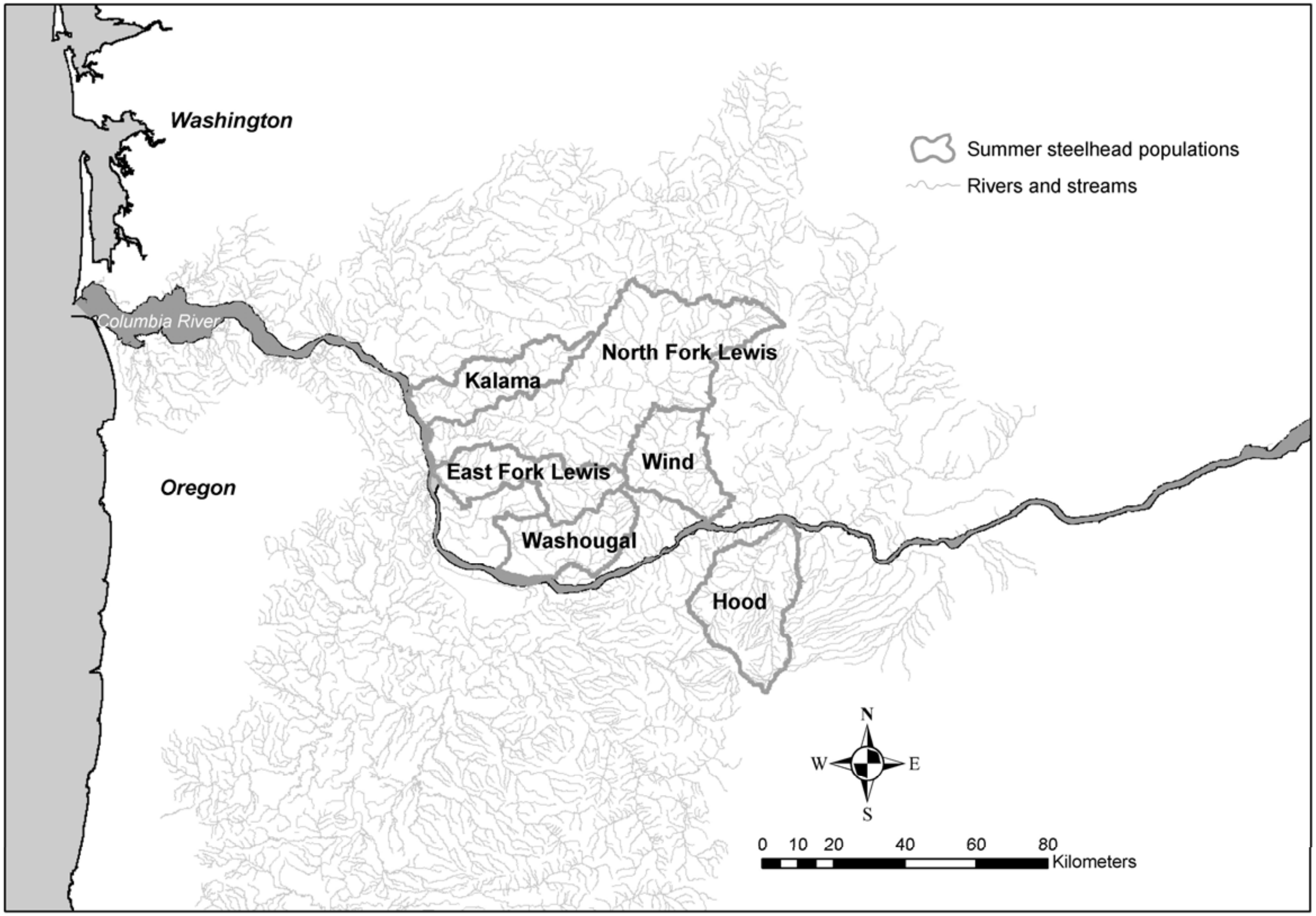


Figure 16. Historical summer DIPs in the Lower Columbia River Steelhead ESU.

12. North Fork Lewis River summer run (SASSI 1993) (Figure E-45)

13. East Fork Lewis River summer run (SASSI 1993) (Figure E-44)

14. Clackamas River winter run (Figure E-50)
    a. Johnson Creek
    b. Eagle Creek
    c. Mainstem and upper Clackamas River winter run
    d. Collawash River

15. Salmon Creek winter run (SASSI 1993) (Figure E-60)

16. Sandy River winter run (Figure E-61)
    a. Bull Run River winter run
    b. Little Sandy winter run
    c. Salmon River winter run
    d. Zigzag River winter run

17. Washougal River winter run (SASSI 1993) (Figure E-65)
    a. Mainstem Washougal River
    b. West (North) Fork Washougal River

18. Washougal River summer run (SASSI 1997) (Figure E-46)
    a. Mainstem Washougal River (SASSI 1993)
    b. West (North) Fork Washougal River (SASSI 1993)

Columbia Gorge Tributaries

The Columbia Gorge tributaries region extends from east of the Washougal River (RKM 195) to the Wind River (RKM 250) on the Washington side and from east of the Sandy River (RKM 194) to the Hood River (RKM 272) on the Oregon side. River basins in this region of the Lower Columbia River Steelhead ESU are influenced by the steeply sloped sides of the Columbia Gorge. Most streams are relatively short. Impassable waterfalls limit accessible habitat to less than a half mile on most small creeks. Larger rivers contain falls or cascades in their lower reaches, which may present migrational barriers during all or most of the year. This region marks a transition between the high rainfall areas of the Cascades and the drier areas to the east. Stream flows can be intermittent, especially during the summer.

Spawning steelhead were observed in several small creeks that line the Columbia Gorge during surveys conducted in the 1930s and 1940s. None provides sufficient habitat for large spawning aggregations of fish, and it is unlikely that any individual creek represented an independent population.

Summer and winter steelhead are native to the Wind River basin. Shipherd Falls (RKM 3) presented a migratory barrier to Chinook salmon but not to steelhead (Hymer et al. 1992). Shipherd Falls historically prevented most winter steelhead from reaching the upper watershed, and there was not sufficient habitat to support a DIP in the lower portion of the Wind River. Winter steelhead spawning in the Wind River were included as part of the Columbia River upper Gorge winter steelhead DIP. WDFW (1997) consolidated winter steelhead in the Wind and Washougal rivers into one population and included the Columbia River lower Gorge tributaries into a separate population centered around Hamilton Creek. At the time of the USFWS surveys (Bryant 1949), summer steelhead abundance already was depressed greatly, but information gathered during interviews indicated that Panther and Cedar creeks historically were "good producers" of summer steelhead. A lumber mill dam at RKM 22.5 on the mainstem Wind River blocked upstream passage until 1947. In 1956 fish passage facilities were constructed at Shipherd Falls, and additional modifications were made to a number of other falls and cascades in order to provide greater access throughout the watershed.

Steelhead escapement for the Wind River in 1951 was estimated at 2,000 fish. Busby et al. (1996) reported summer steelhead escapement to the Wind River averaged 600 fish, half of which were of hatchery origin. Genetic analysis indicates the Wind River summer and winter steelhead resemble fish from the Kalama River (NMFS 1997).

Winter and summer steelhead are native to the Hood River basin (Kostow 1995). The combined escapement for winter and summer steelhead (excluding known hatchery fish) averaged around 1,000 fish during the 1950s and 1960s (Howell et al. 1985). Native summer steelhead escapement was 181 in 1997 and may have been as low as 80 in 1998 (Chilcote 1997). Winter steelhead are not found in the West Fork Hood River. Punchbowl Falls (RKM 0.6) prevents winter-run fish from ascending into the west fork (Olsen et al. 1992).

Some creeks listed may not have sustained steelhead, but the creeks may have occasionally—historically and currently—been utilized by steelhead sometime during their life history, and are included for general inventory purposes. Individual population maps are in Appendix E (pages 199–311), and strata are presented in Figures 15 and 16. Letter designations indicate possible subpopulations within the numbered populations. Populations identified in WDF et al. (1993) as a SASSI stock are so indicated. In 1997 WDFW proposed numerous revisions to the SASSI population list. The DIPs listed below that correspond to redefined SASSI populations are identified by "SASSI 1997" (WDFW 1997). The DIPs that correspond to the original SASSI list are identified by "SASSI 1993" (WDF et al. 1993). (Numbering sequence continued from the population list on page 68.)

19. Columbia River lower Gorge tributaries (winter run) (SASSI 1997) (Figure E-54)
    a. Duncan Creek
    b. Bridal Veil Creek
    c. Wahkeena Creek
    d. Hardy Creek
    e. Hamilton Creek (SASSI 1993)
    f. Multnomah Creek
    g. Moffer Creek
    h. Tanner Creek

20. Columbia River upper Gorge tributaries (winter run) (Figure E-55)

    a. Eagle Creek
    b. Rock Creek
    c. Wind River
    d. Herman Creek
    e. Gorton Creek
    f. Viento Creek
    g. Lindsey Creek
    h. Phelps Creek

21. Wind River summer run (SASSI 1997) (Figure E-47)

    a. Little Wind River
    b. Panther Creek (SASSI 1993)
    c. Trout Creek (SASSI 1993)

22. Hood River winter run (Figure E-56)

23. Hood River summer run (Figure E-42)

Upper Willamette River Steelhead ESU Historical Independent Populations

Of the three temporal runs of steelhead currently found in the Upper Willamette River Steelhead ESU only the late winter steelhead is considered to be native. The same flow conditions at Willamette Falls that only provided access for spring Chinook salmon also provided an isolating mechanism for this unique run time of steelhead. Late winter steelhead enter the Willamette River beginning in January and February, but they do not ascend to their spawning areas until late March or April (Dimick and Merryfield 1945). Spawning takes place from April to 1 June. Redd counts for late winter steelhead in the Willamette River basin are conducted in May (Howell et al. 1985). The ODFW currently uses 15 February to discriminate between native and nonnative (Big Creek) winter steelhead at Willamette Falls (Kostow 1995). It generally is agreed that steelhead did not emigrate historically farther upstream than the Calapooia River (Dimick and Merryfield 1945, Fulton 1970). Historically, the character of the Willamette River at Albany, Oregon, changed from a highly braided, relatively shallow system upstream, to a more centralized channel, deep-river system downstream (Benner and Sedell 1997). Returning winter steelhead may have found upstream passage difficult past the confluence of the Calapooia River, whereas spring Chinook salmon (which delay final maturation until the late summer/early fall) could hold in mainstem or off-channel habitat until passage upstream was possible. Stone (1878) reported that steelhead began arriving at the base of Willamette Falls around Christmas, but were most abundant in April. Spawning peaked in May and was complete by June.

There is limited information with which to estimate the historical abundance of fish in the Upper Willamette River Steelhead ESU. Wilcox (1898) reported that of the fish taken in the Willamette River (below the falls) the catch consisted of 50% Chinook salmon, 40% steelhead, and 10% coho salmon. If the ratio Wilcox (1898) described applies to steelhead passing over

Willamette Falls, then approximately 220,000 steelhead historically would have passed the falls, based on an estimate of 275,000 spring Chinook salmon ascending the falls. Of the four major tributaries that currently, and historically, supported steelhead, the North and South Santiam rivers are thought to have been major producers of steelhead (USFWS 1948). Howell et al. (1985) reported that the relative distribution of steelhead spawning in the upper Willamette River during the 1960s was 8% in the Calapooia River, 57% in the Santiam River, and 35% in the Molalla River. Allocating the estimated escapement using this proportion yields 77,000 in the Molalla River, 125,400 in the Santiam River (with approximately 75,240 and 50,160 in the North and South Santiam rivers, respectively, based on a 60:40 split), and 17,600 in the Calapooia River.

Native steelhead currently are distributed in a few, relatively small, naturally spawning aggregations. In 1982 it was estimated that 15% of the late winter steelhead ascending Willamette Falls were of hatchery origin (Howell et al. 1985). Counts of native late winter steelhead past Willamette Falls had a five-year geometric mean abundance of slightly more than 3,000 fish through 1997 (ODFW 1998).

Surveys in 1940 reported anecdotal information that steelhead spawned in Gales Creek, a tributary to the Tualatin River (Parkhurst et al. 1950). Early winter steelhead (Big Creek stock) and late winter steelhead (North Santiam River stock) have been introduced numerous times into the Tualatin River, but it is unclear whether the existing fish represent native or introduced lineages, or whether steelhead even existed historically in the Tualatin River. Naturally spawning winter steelhead are found currently in several Willamette River west-side tributaries, however, there is considerable debate about the origin of these fish. With the exception of Gales Creek, a tributary to the Tualatin River, Parkhurst et al. (1950) did not report the presence of any salmon or steelhead in these systems. Most of the surveys were conducted during the summer, when adult steelhead would not be present. Hatchery records indicate that large numbers of early winter steelhead were stocked into the Luckiamute and Yamhill rivers. ODFW suggested that, based on spawn timing, late winter steelhead may have recently colonized the Yamhill River (NMFS 1999b). Other than cutthroat trout and the occasional (introduced) coho salmon, surveys conducted during the 1950s did not observe any anadromous salmonids (e.g., Chinook salmon or steelhead), nor were any reported in the North Fork Yamhill River, Marys River, or Long Tom River basins (Willis et al. 1960).

Recent genetic analysis of presumptive steelhead from the west-side tributaries indicated that fish from the Yamhill River and Rickreall Creek were genetically most similar to steelhead populations from the lower Columbia River basin, suggesting the influence of Big Creek winter steelhead or Skamania summer steelhead (Appendix C, pages 161–192, and Figure E-71, page 269) (NMFS 1999a). The sample from the Luckiamute River had no clear affinity with any other steelhead population, and may be descended from native resident rainbow trout. Because of the ecological similarities among the Willamette River west-side tributaries, fish occurring in these basins were grouped together. With the exception of the Tualatin River, little evidence suggests that sustained spawning aggregations of steelhead may have existed historically in the Willamette River basin west-side tributaries. Dimick and Merryfield (1945) concluded that, "Oddly, the cutthroat trout is the only salmonid, except for an occasional stray salmon and the presumably artificial establishment of silver salmon in the Tualatin River and of the steelhead trout in Rickreall Creek, inhabiting the west-side tributaries having their sources in the Coast

Range. These streams include the Tualatin River, Yamhill River, Rickreall Creek, Luckiamute River, Marys River, Long Tom River, and the Coast Fork above Cottage Grove." The recent occurrence of steelhead in many of these tributaries may be related to changes in stream hydrology caused by the construction of numerous dams in these basins. In general, the dams tend to alter stream hydrographs, increasing summer flows and moderating winter floods. It is unlikely that historically these tributaries, individually or collectively, were large enough to constitute a DIP. While not supporting a sustainable population, the west-side tributaries were included in the population maps as a population sink area. This designation recognizes that winter steelhead may intermittently utilize some of these basins for spawning or rearing and underscores the influence of these tributaries on water conditions in the mainstem Willamette River.

The Molalla River currently contains three distinct steelhead runs: native late winter, introduced early winter (from Lower Columbia River Steelhead ESU populations), and introduced Skamania summer steelhead (Chilcote 1997). In 1957 a spawning ground survey observed 370 adult steelhead and 623 redds in the 94.1 km of the Molalla River basin surveyed (Willis et al. 1960). Willis et al. (1960) also noted that several hundred steelhead entered Abiqua Creek annually. Small tributaries above Willamette Falls (e.g., Abernethy Creek) most likely would have been part of the Molalla River winter steelhead population historically.

Native late winter and introduced Skamania summer steelhead are present in the North Santiam River (Chilcote 1997). In 1940 surveys estimated the steelhead run was at least 2,000 fish (Parkhurst et al. 1950). Parkhurst et al. (1950) also reported that larger steelhead runs existed in the Breitenbush, Little North Santiam, and Marion Fork rivers. Native steelhead were artificially propagated at the North Santiam Hatchery beginning in 1930, when a record 2,860,500 eggs (686 females @ 4,170 eggs/female) were taken (Wallis 1963c). The release of hatchery-propagated late winter steelhead in the North Santiam River was discontinued in 1998 (NMFS 1999b). Escapements to the North Santiam River through 1994 averaged 1,800 fish of mixed hatchery and natural origin (Busby et al. 1996).

Native late winter and introduced Skamania summer steelhead are present in the South Santiam River. Hatchery operations began in 1926, and in 1940 a record 3,335,000 eggs were taken (800 females @ 4,170 eggs/female). However, river conditions did not allow the weir to be set in place until after a portion of the steelhead run already had passed (Wallis 1961). The ODFW considers the late winter steelhead in the South Santiam River to be one population of native origin. However, the abundance trends for populations above and below Foster Dam are very different. The number of redds below Foster Dam has remained relatively stable (albeit at a low level), while the redd count above Foster Dam declined dramatically in recent years. Live counts of naturally produced (unmarked) fish passing Foster Dam (1996–2000) have averaged 296 fish, with 728 passing above Foster Dam in 2001 (Nigro unpubl. data).

Genetic analysis indicates a close affinity between winter steelhead populations in the Santiam, Molalla, and Calapooia rivers. Steelhead descended from summer- (Skamania) and early winter-run (Big Creek) hatchery populations are distinct from the native steelhead (Appendix C, pages 161–192) (NMFS 1997). Late winter steelhead are native to the Calapooia River. Parkhurst et al. (1950) reported that steelhead ascended the Calapooia as far as 87 km upstream, although passage at the Finley Mill Dam (RKM 42) may not have been possible during low flow periods. A survey conducted in 1958 from the town of Holley, Oregon, to the mouth of Potts Creek (31.7 km) recorded 73 steelhead adults (live and dead) and 427 redds (Willis et al. 1960). There is no hatchery program on the Calapooia River. Chilcote (1997) estimated that contribution of hatchery fish to escapement (strays from other upper Willamette River releases) is less than 5%. This population has declined to very low levels since the late 1980s.

Individual population maps of upper Willamette River winter steelhead are in Appendix E (pages 199–311), and strata are presented in Figure 17. Letter designations for the following populations indicate possible subpopulation designations within the numbered populations.

1. Molalla River (Figure E-68)
   a. Pudding River
   b. Molalla River

2. North Fork Santiam River (Figure E-69)
   a. Breitenbush River
   b. Marion Fork River
   c. Little North Santiam River

3. South Fork Santiam River (Figure E-70)
   a. South Fork Santiam River
   b. Thomas and Crabtree creeks
   c. Middle Santiam River
   d. Quartzville Creek

4. Calapooia River (Figure E-67)

5. West-side tributaries[6] (Figure E-71)
   a. Tualatin River and Gales Creek
   b. South Fork Yamhill River
   c. Rickreall Creek
   d. Luckiamute River

[6] Spawning winter steelhead have been reported in the west-side tributaries; however the west-side tributaries are not considered to have historically constituted a DIP.

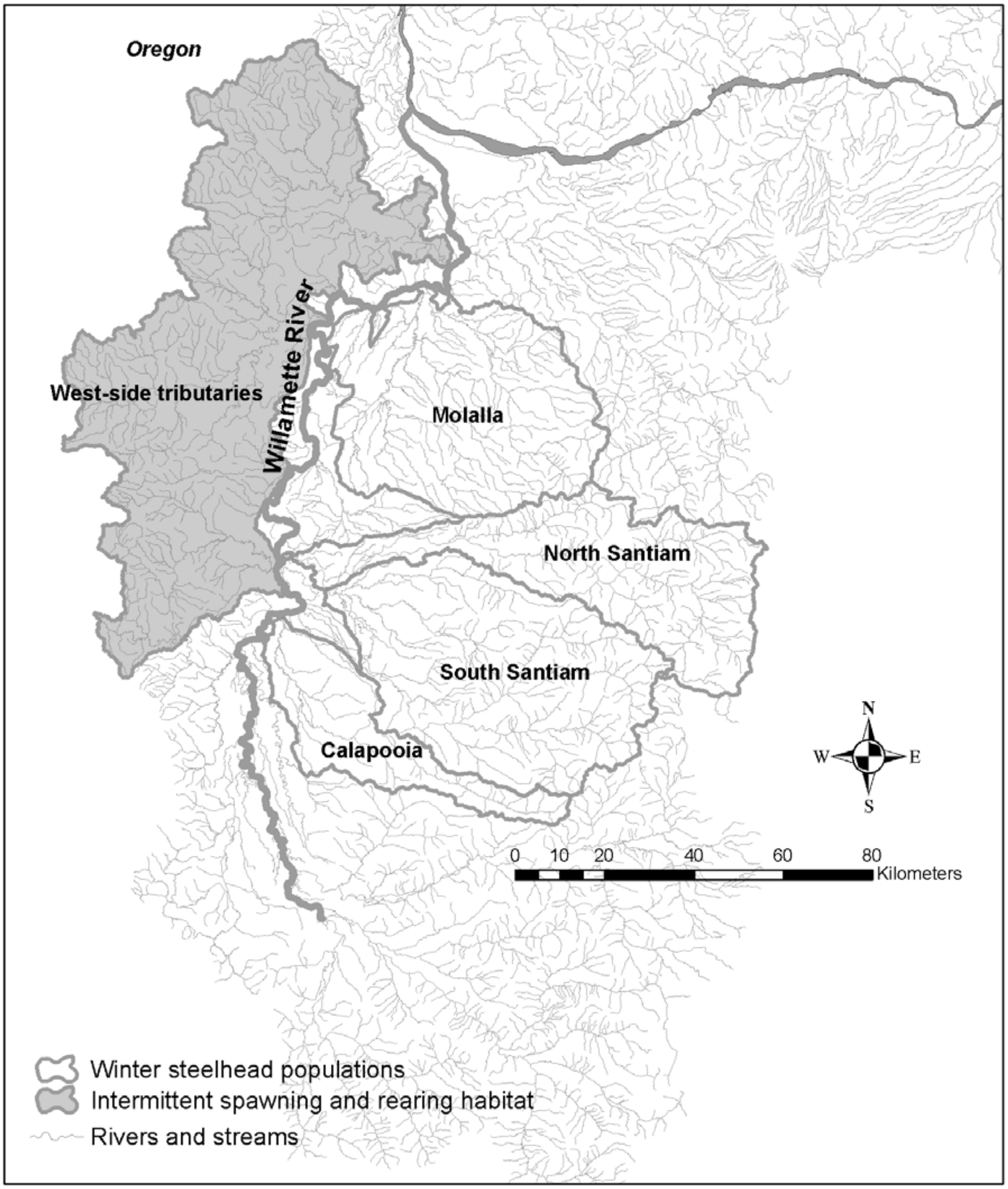


Figure 17. Historical winter DIPs in the Upper Willamette River Steelhead ESU. The west-side tributaries were not designated as an independent population but are included because of their importance to the ESU as a whole.

Coho Salmon

Coho salmon populations in the lower Columbia River have undergone a number of dramatic changes during the past 200 years. Natural production has diminished greatly, and hatchery activities, which account for the majority of escapement, probably have altered the genetic structure of populations within the ESU. Only the Clackamas and Sandy rivers currently support self-sustaining populations of more than 1,000 fish. Numerous other smaller spawning aggregations probably exist, but difficulties in observing spawning adults or recovering carcasses during the late fall spawning season limit the utility of survey-based abundance measures.

Life History

Populations in the Lower Columbia River Coho Salmon ESU display one of two major life history types, early or late adult return time to fresh water (Table 12). Early returning coho salmon (Type S) return to freshwater from August to October and spawn from October to November. The Type S designation is based on the recovery of CWT hatchery fish to the south of the Columbia River (approximately 40% of ocean recoveries, Figure 18) (Weitkamp et al. 1995 and 2001). The other major life history type, late returning or Type N coho salmon, returns to freshwater from October through November or December and spawns primarily from November through January, with some fish spawning to March (WDF et al. 1951). Type N coho salmon generally travel to the north of the Columbia River during their ocean migration. It generally is thought that early returning coho salmon migrate to headwater areas and late returning fish migrate to the lower reaches of larger rivers or into smaller streams and creeks along the Columbia River. Where possible we provided historical information about the spawn timing of coho salmon populations, however, this information generally is limited to whether survey parties observed fish holding or spawning. Most of the recent information also is influenced strongly by the presence of hatchery fish, which may have been introduced from another basin or may have undergone significant changes in spawn timing through continued hatchery propagation (WDF et al. 1993, Fuss et al. 1998).

The two coho salmon life history types in the lower Columbia River could be considered analogous to distinct run times of Chinook salmon and steelhead in that there is some level of reproductive isolation and ecological specialization. In contrast to Chinook salmon and steelhead, however, coho salmon run timing does not appear to be related to migration barriers. There is some uncertainty regarding the level of importance to place on the early and late coho salmon diversity. Some tributaries historically supported spawning by both run types. In contrast to Chinook salmon and steelhead, run timing was not used to establish different life history strata within ecological stratum. Anthropogenic effects may have influenced the distribution of coho salmon run types throughout the Columbia River, so it is difficult to establish whether early and late coho salmon within the same basin constituted different DIPs.

Table 12. Lower Columbia River coho salmon population overview.

Strata	Population	Run types
Coast Range	Youngs Bay	Type N
	Grays River	Type N
	Big Creek	Type N
	Elochoman Creek	Type N
	Clatskanie River	Type N
	Mill, Germany, and Abernathy creeks	Type N
	Scappoose Creek	Type N
Western Cascade Range	Cispus River	Type N and S
	Upper Cowlitz River	Type N and S
	Tilton River	Type N and S
	Lower Cowlitz River	Type N
	North Fork Toutle River	Type N and S
	South Fork Toutle River	Type N and S
	Coweeman River	Type N
	Kalama River	Type N and S*
	North Fork Lewis River	Type N and S
	East Fork Lewis River	Type N and S
	Salmon Creek	Type N
	Clackamas River	Type N and S
	Washougal River	Type N and S*
	Sandy River	Type N and S
Columbia Gorge	Lower Gorge tributaries	Type N
	Upper Gorge tributaries	Type S
	Big White Salmon River	Type S
	Hood River	Type S

* It is unlikely that Type S coho salmon were present in these basins. Source: WDF 1951.

Regardless of whether run timing is an element of diversity on a subpopulation or population level, it should be considered in recovery planning.

There does not appear to be much variation in age at emigration to the ocean or age at maturation. In general, Columbia River coho salmon smolt during their second spring and return to freshwater after one or two years in the ocean. Zero-age outmigrants have been observed, but they do not appear to contribute to adult escapement (Sandercock 1991). One-year ocean fish are predominantly males (jacks). Analysis of coho salmon scales from adults captured in the Columbia River fishery in 1914 (Figure 19) also revealed the presence of 2-year-old smolts (Marr 1943), although they were thought to have originated from rivers in the upper Columbia River and Snake River basins. Two-, 3-, and 4-year-old migrants have been observed in colder, less productive environs such as northern and interior British Columbia and Alaska.

In general, Coast Range rivers historically are thought to have contained only late returning, Type N, coho salmon. Within the Cascade Range stratum, information from a variety of sources indicates that several river basins probably contained early and late returning coho

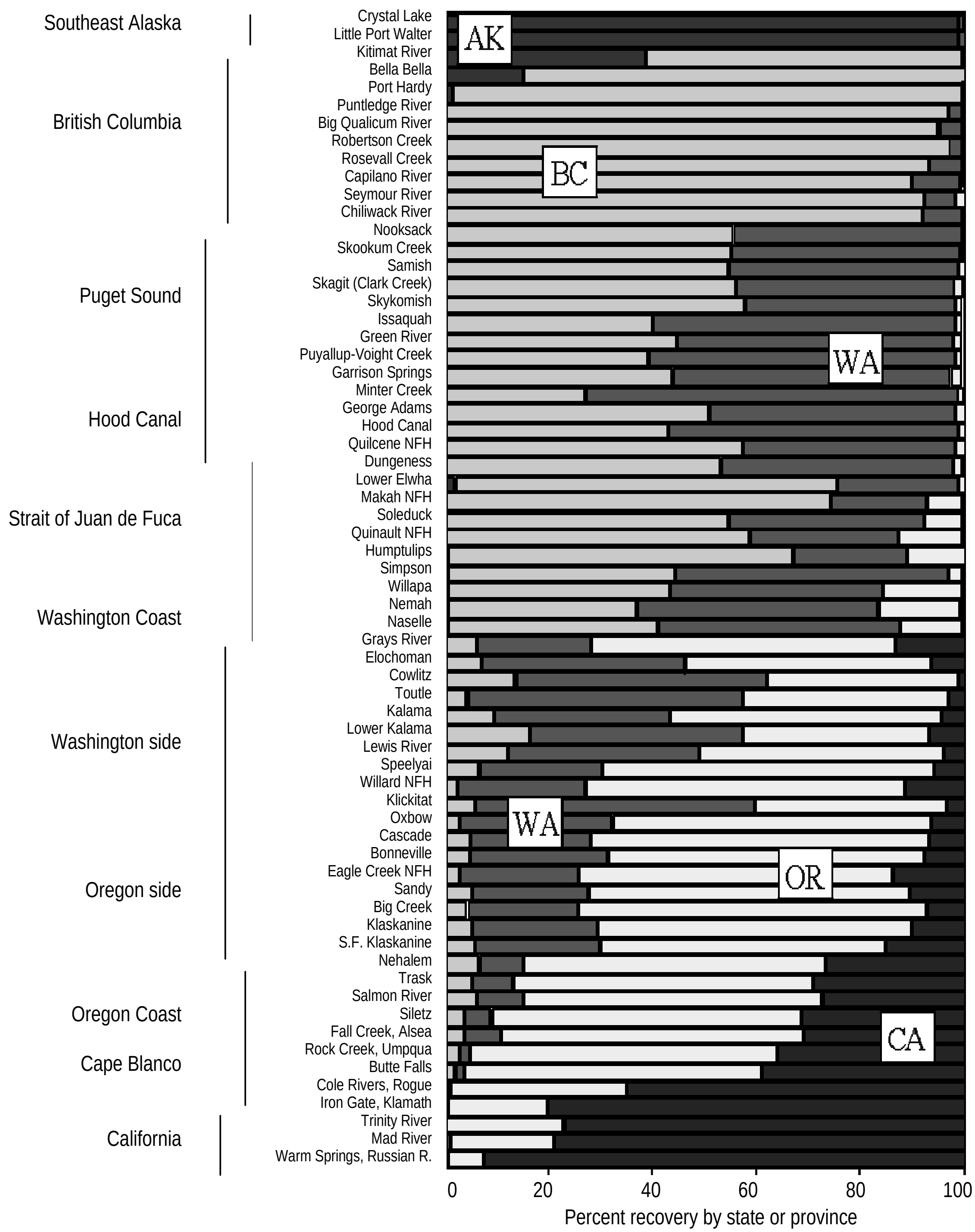


Figure 18. Distribution of ocean recoveries of CWT coho salmon released from locations in Alaska (medium dark gray), British Columbia (light gray), Washington (medium gray), Oregon (white), and California (dark gray). Source: Reprinted from Weitkamp et al. 1995.

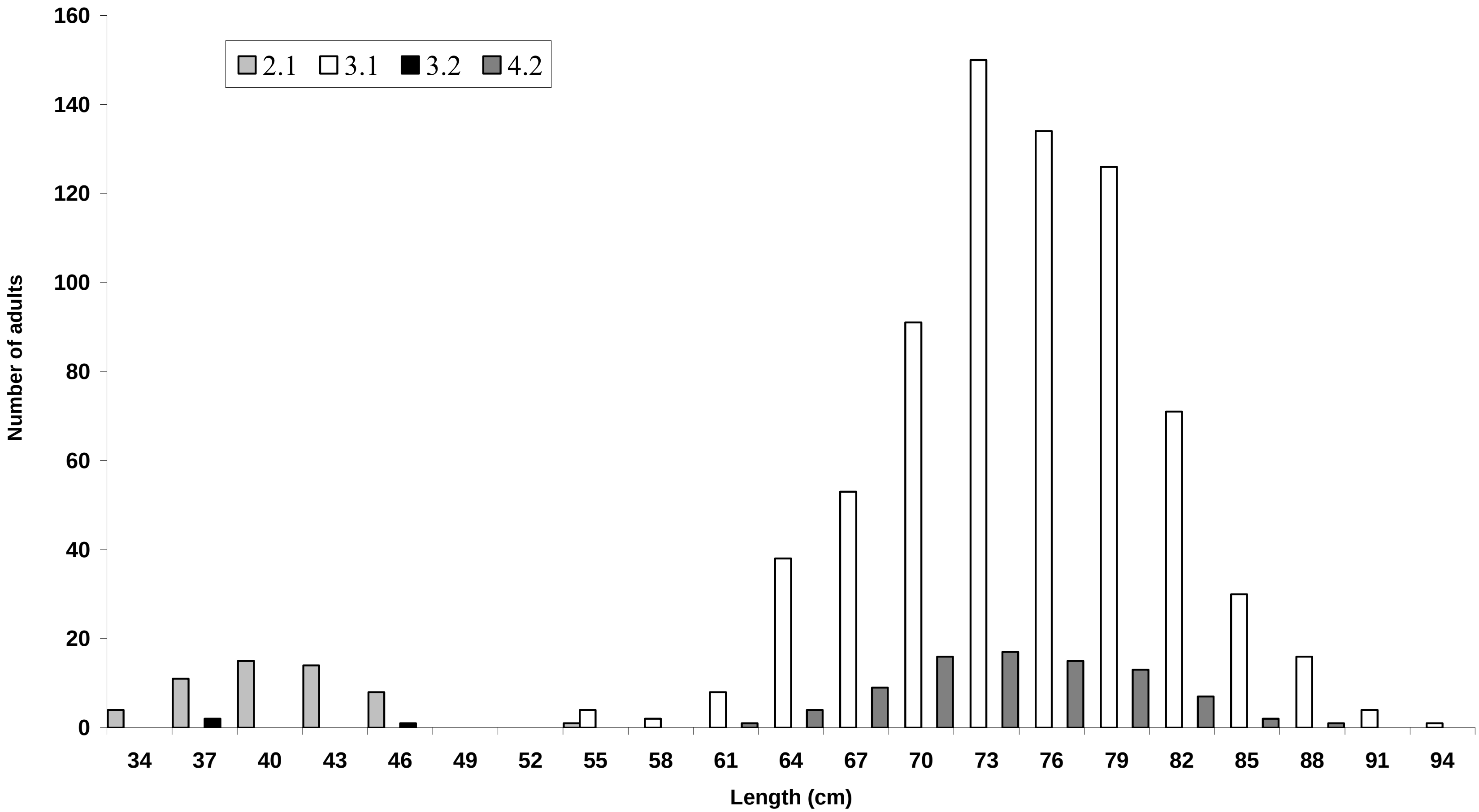


Figure 19. Length distribution of different age-classes of coho salmon adults sampled near the mouth of the Columbia River in 1914. Age structure is denoted as total age in years and years in freshwater (i.e., 3.2 indicates 3-year-old fish that spent 2 years in freshwater). Source: Data from Marr 1943.

salmon: the upper Cowlitz, Cispus, Tilton, North Fork Toutle, South Fork Toutle, North Fork Lewis, East Fork Lewis, Clackamas, Sandy, and Washougal DIPs.

Genetic analysis of coho salmon populations provides only limited information about population distinctiveness. In the absence of historical baselines for populations, and in light of the extensive nature of hatchery transfers, it is difficult to distinguish natural from anthropogenic genetic patterns. While the genetic variability patterns within the Lower Columbia River Coho Salmon ESU have been disrupted, substantial differences still exist between the Lower Columbia River and Coastal Coho Salmon ESUs stocks (Weitkamp et al. 2001). Kostow (1995) indicated that coastal coho salmon are susceptible to *Ceratomyxia shasta*, a parasite common to the Columbia River, while native Columbia River coho are resistant. This parasite may have limited the success of coho salmon transfers and reduced the amount of genetic introgression.

Coho salmon generally spawn in smaller tributaries and side channels and are thought to exhibit a higher homing fidelity relative to fall Chinook salmon. Sandercock (1991) indicated that, on average, straying rates for coho salmon to another basin were on the order of 0.1%. A summary of spawner surveys in the lower Columbia River (Ruggerone 1999) found that 81.8% of the hatchery-origin coho salmon carcasses recovered in streams were recovered within 8 km of a hatchery. Marking techniques did not distinguish between hatcheries, in general, the recovery of coho salmon carcasses in the wild is poor. Analysis of 23 CWT groups released from lower Columbia River hatcheries in Washington and Oregon indicated that 93.7% of all terminal freshwater recoveries occurred at the release site (Figure 20). Given the low intensity of spawner surveys on both sides of the Columbia River, it is likely that more fish may have returned to sites other than the hatcheries, nevertheless it is apparent that homing fidelity is at least as strong in coho salmon as in Chinook salmon.

Much of the historical population structure was based on methods utilized for Chinook salmon and steelhead. The authors generally believe that the homing fidelity of coho salmon was more similar to steelhead than to Chinook salmon or chum salmon. The preference of coho salmon to spawn in smaller side-channel habitats may result in a higher degree of local adaptation.

Introduced Populations above Willamette Falls

A number of contemporary references document the presence of coho salmon in tributaries to the Willamette River above Willamette Falls. Parkhurst et al. (1950) noted the presence of coho salmon in the Tualatin Basin in 1940, specifically Gales and Scoggins creeks. Willis et al. (1960) indicated that spawning adult coho salmon and juveniles were observed in the Tualatin, Molalla, Yamhill, and Luckiamute rivers. In all cases the first recorded occurrence of coho salmon followed introductions of lower Columbia River fish into those basins. Parkhurst et. al. (1950) noted some uncertainty, however, about the origin of coho salmon in the Tualatin River, stating “the origin of silver salmon in the Tualatin River system remains obscure. Some old-time residents claim that silver salmon were not present in the stream prior to about 1920, when they were introduced with plants from Bonneville Hatchery.” Dimick and Merryfield (1945) also asserted that coho salmon above Willamette Falls were an “artificial establishment from hatchery-reared fish.” In general, it is unlikely that coho salmon historically could have ascended Willamette Falls before it was laddered.

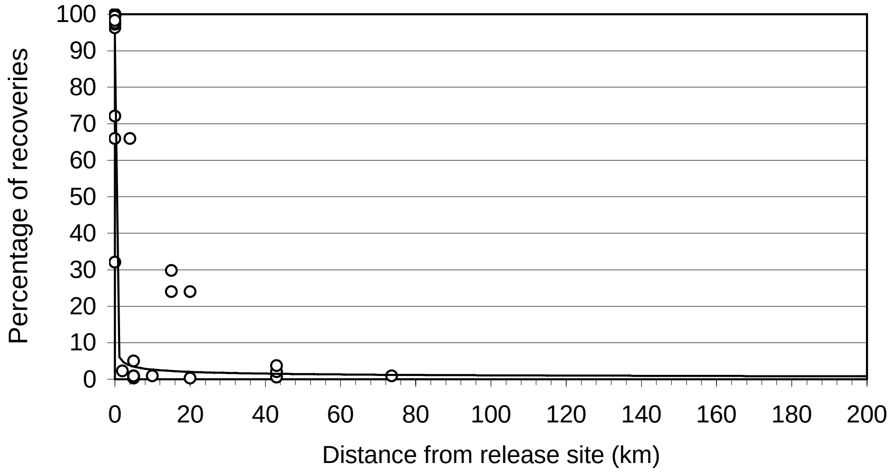


Figure 20. Relative proportion (percent) of recoveries and distance from the release site for 23 CWT coho salmon groups released from lower Columbia River hatcheries. Not shown are three fish recovered more than 200 km from their release sites in the lower Columbia River (two were recovered in Puget Sound and one in the Snake River). Source: PSMFC 2000.

Historical Populations above The Dalles

There were a number of coho salmon populations historically above the existing boundaries of the lower Columbia River TRT domain. Coho salmon appear to have been present in most of the Columbia River tributaries as far upstream as the Spokane River, and up the Snake River as far as the Grande Ronde and Clearwater rivers (Fulton 1970). Girard (1858) does not describe coho salmon among the type of fish captured at Kettle Falls. Gilbert and Evermann (1895) reported the catch of a silverside salmon (coho) at the mouth of the Yakima River on 20 August; it was apparently the "first of the season" for the fisherman involved. Evermann and Meek (1898) reported that the catch of coho salmon at a single fish wheel at Celilo Falls for 4 days between 17 and 23 September totaled only 55 fish (averaging 3.2 kg [7 lb]). About half the fish examined were at an advanced state of maturity. The catch increased: from 25 September to 13 October, 1,911 coho salmon were caught in the fish wheel. Some of these fish contained loose (ripe) eggs (Evermann and Meek 1898).

The OFC operated a weir and hatchery on the Grande Ronde River. During the 1901 spawning season, 7.5 million coho salmon eggs were collected from 2,511 females from 14 October to 8 December (ODF 1902). The distribution of females spawned appeared bimodal: the numbers peaked in late October and late November. A survey of Oregon rivers during the early 1900s indicated that coho salmon were very abundant in the John Day River (ODF 1903). A rack also was installed across the Umatilla River to collect Chinook salmon "but succeeded in stopping nothing but the 'Silverside' variety" (ODF 1903). The WDF collected coho salmon eggs at a number of hatcheries above Celilo Falls. During the early 1900s coho eggs were collected on the Methow and Wenatchee rivers (Mayhall 1925).

Lower Columbia River Coho Salmon Historical Populations

Coast Range Tributaries

The coastal region extends from the mouth of the Columbia River to Coal Creek (RKM 99.8) on the Washington side and to Scappoose Creek (RKM 140) on the Oregon side (Figure 21). Coho salmon spawning in this region were placed in seven population clusters, based on historical population abundance estimates and watershed size.

All Coast Range tributaries are relatively short, less than 40 km. The lower reaches tend to be low gradient, slow-moving systems that are under tidal influence. Many of the tributaries enter the Columbia River through a series of sloughs that offer little usable spawning habitat. The rivers and creeks drain low elevation hills, with peaks less than 1,000 m. Rainfall averages 200–240 cm per year. In the absence of substantial snowpack or groundwater sources, the river flows are correlated strongly with rainfall (peak flows occurring in December and January), and summer flows can be very low (low flows occur in August). It is unlikely that distinctive run times or geographically isolated populations could have developed in one of these systems. It is possible that many of the smaller systems experience short-term extirpations during extended periods of poor ocean conditions or extremes in climate (floods or droughts).

Fulton (1970) indicated that coho salmon historically were present in all major tributaries to the Columbia River in the coastal stratum. There is little historical record of most populations' size or characteristics because of the relatively small size of the coho salmon runs in each tributary and the difficulty of observing or enumerating returning adult coho. Coho salmon also were not the species of choice for fisheries or hatchery activities during the late 1800s and early 1900s, which limited the information collected.

The Youngs Bay coho salmon DIP includes fish spawning in the Lewis and Clark, Youngs, and Klaskanine rivers. Parkhurst et al. (1950) indicated that fair-sized runs of coho salmon existed in the Youngs and Klaskanine rivers. Beginning in 1925, the Klaskanine Hatchery began collecting coho salmon eggs (Wallis 1963b). In addition to local broodstock, large numbers of coho salmon eggs were transferred from the Oregon coast. During the 1950s coho salmon were spawned from mid-October to mid-December (Wallis 1963b), although natural spawning reportedly continued into the winter. Recent spawner surveys reported unmarked (naturally produced) coho salmon spawning from December through February. Available information suggests that the existing native coho salmon population was more similar to Type N. Coho salmon from the Youngs Bay DIP (Lewis and Clark River) are most similar genetically to coho salmon from the Big Creek and Klaskanine hatcheries (Weitkamp et al. 2001). In light of the substantial number of fish transferred between basins, it is unclear whether this similarity is indicative of the historical pattern or simply reflects hatchery transfers (Weitkamp et al. 1995). There are no estimates for total spawner abundance in this DIP, but surveys of index areas since the 1970s indicate that abundance levels have been critically low, failing to observe any adults in some years (Weitkamp et al. 2001). During recent surveys (2000–2002) a number of unmarked (naturally produced) fish were observed spawning in late November through December (van der Naald 2001, Brown et al. unpubl. data).

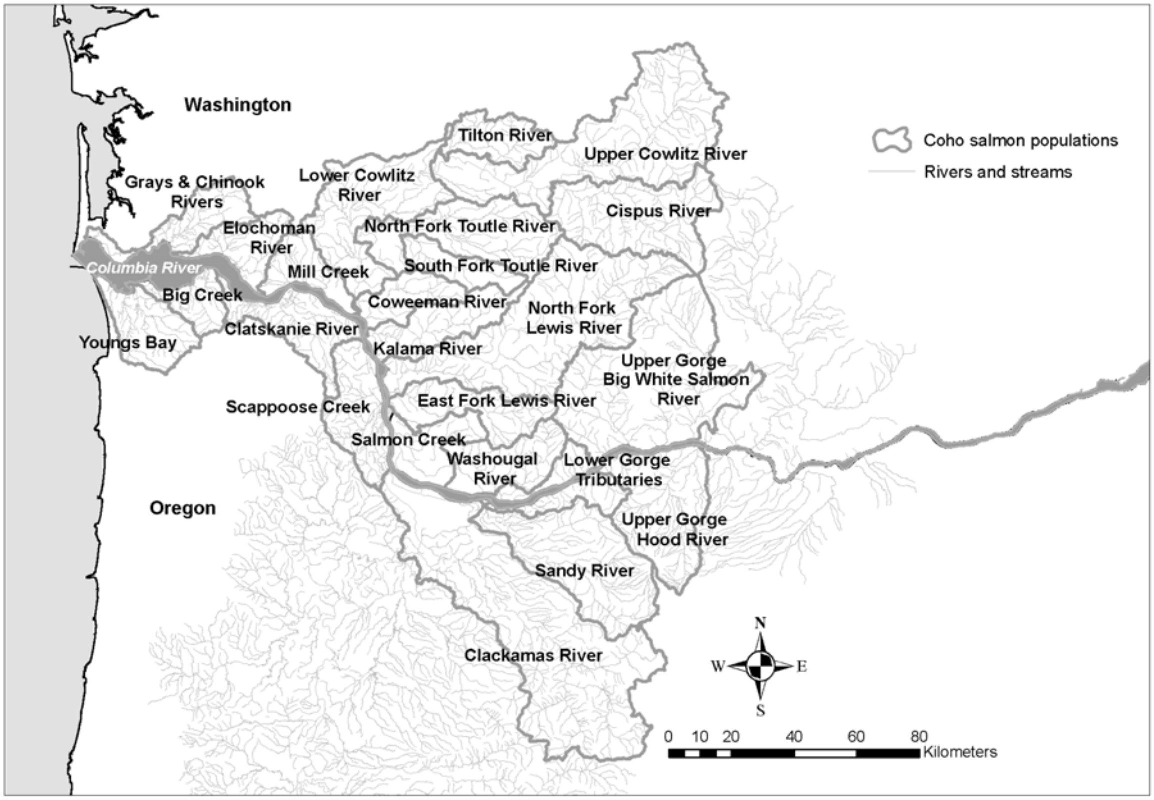


Figure 21. Proposed historical DIPs in the Lower Columbia River Coho Salmon ESU.

Coho salmon are native to the Grays River basin, although the current population is considered to be of mixed origin (WDF et al. 1993). Jordan (1904) quoted H. S. Davis, who described the Chinook River as "a small sluggish stream [that has] never been frequented by Chinook salmon, although considerable numbers of silver and dog salmon enter it late in the fall." Surveys conducted in 1946 indicated that silver salmon spawned throughout much of the Chinook River basin. Large numbers of Type S (Toutle River Hatchery) have been released from the Grays River Hatchery. The Grays River Hatchery broodstock is considered to be an early run, which is apparently similar to the original wild coho in the Toutle River. A small run of coho salmon was reported spawning below water falls 21 km above the mouth of the Grays River in October 1944 (Bryant 1949). USFWS surveys during mid-November 1936 observed several hundred coho spawning in tributaries to the Grays River (Bryant 1949). Current broodstock collection occurs in September and October. The spawn timing for the current population is distinct from the native population, a late returning Type N, described by the WDF (1951). Escapement in 1951 was estimated to be 2,500. Spawn timing still reflects some influence from native or introduced Type N fish, although the ocean distribution of CWTs from Grays River Hatchery fish is similar to Type S populations (WDF et al. 1993). Grays River coho salmon are similar genetically to other lower Columbia River coho salmon. There is some affinity to other geographically proximate populations, specifically the Clatskanie and Cowlitz rivers and Big Creek (Weitkamp et al. 2001). Nonnative introductions most likely altered the present genetic and life history characteristics of Grays River coho salmon, especially run timing, with the influx of Type S coho salmon.

Coho salmon historically were present in the numerous small Columbia River tributaries in this area. Coho were cultured and released from the Big Creek Hatchery beginning in 1938. Transfers into this broodstock occurred in 1944 and 1951 from the Klaskanine Hatchery, in 1970 from Sandy River Hatchery, and in 1984 from the Bonneville Hatchery. Otherwise all broodstock were collected at Big Creek. Coho salmon in Gnat Creek spawn from November through February (Willis 1962). From 1954 to 1959 the peak juvenile outmigration occurred during the first 3 weeks in May (Willis 1962). The population of naturally spawning coho in the lower Columbia River declined sharply in the 1970s and has remained at low levels. Recent examination of returning adults revealed that very few wild coho return to the Big Creek weir (fewer than 20 in the best years). During surveys (2000–2002) a number of unmarked (naturally produced) coho were observed spawning in late November through December (van der Naald 2001, Brown et al. unpubl. data).

Big Creek coho salmon are similar genetically to other lower Columbia River coho populations (Weitkamp et al. 2001). Coho salmon from Grays Creek and the Lewis and Clark River most closely resemble coho salmon from Big Creek. Given the relatively low level of out-of-basin introductions, recent genetic analysis may be helpful in describing historical population characteristics.

Coho salmon are native to the Elochoman River DIP. USFWS surveys in December 1935 observed several hundred coho salmon spawning in the "Alochomin" (Elochoman) River. Bryant (1949) commented that the spawners observed in December represented the later portion of the run. WDF (1951) reported the presence of late returning coho salmon in the Elochoman River and Skamokawa Creek, with fish spawning from October to March. The current spawning aggregations in Skamokawa Creek and the Elochoman River are considered to be of mixed origin (WDF et al. 1993). Large numbers of early returning Type S and late returning Type N coho salmon have been released from the Elochoman Hatchery. Late returning coho salmon are present currently in the basin, however, they are believed to be progeny of Cowlitz River late returning coho salmon released from the hatchery (Hymer et al. 1992) and may not be instructive in describing the historical population. The Elochoman Hatchery broodstock is collected between September and February, but it is considered to be a late run hatchery stock (Type N). Present ocean CWT recoveries from Elochoman Hatchery releases are indicative of a Type N population (WDF et al. 1993).

Merrell (1951) reported coho salmon spawning in the Clatskanie River above Clatskanie Falls and in Carcus Creek, a Clatskanie River tributary. Peak spawning activity was observed during December. Carcus and Page creeks were used as index streams for lower Columbia River coho salmon surveys. The numbers of spawning adults were relatively stable until the early 1970s, after which no spawning adults were observed for several years (Howell et al. 1985). Parkhurst et al. (1950) observed numerous juvenile coho salmon in Beaver Creek during 1946 surveys. While spawner surveys found few or no adult fish in recent years, recent juvenile surveys consistently have found small numbers of coho salmon in the Clatskanie River (Weitkamp et al. 2001). Coho salmon in the Clatskanie River are considered a late run Type N population. During recent surveys (2000–2002) a number of unmarked (naturally produced) coho salmon were observed spawning in late November through December (van der Naald 2001, Brown et al. unpubl. data).

Clatskanie River coho salmon are most similar genetically to Grays River coho salmon (Weitkamp et al. 2001). It is not known to what extent coho salmon in the Clatskanie River are representative of the historical population, but recent low abundance levels make this population susceptible to genetic introgression by hatchery strays and genetic drift.

Coho salmon were observed in Germany Creek during November 1936 surveys, however, none was observed in either Abernathy or Mill creeks during the same period (anecdotal information indicated that coho were present in these basins, but presumably at low levels) (Bryant 1949). According to WDF (1951), late returning coho salmon were native to Abernathy, Mill, and Germany creeks. Monitoring at instream weirs indicated that from 1952 to 1955 coho salmon entered Abernathy Creek from October to February, with the majority of the run passing during November and December (Birtchet and LeMier 1955). Although current run timing is similar to historical (1951), existing late returning coho salmon are thought to have been influenced by transfers of Type N hatchery stocks into the basin or straying by hatchery fish. WDF et al. (1993) considered coho salmon in Mill, Abernathy, and Germany creeks to be of mixed origin because of introgression by hatchery populations. The relatively low productivity of the streams in this system makes them highly prone to introgression from nonnative sources.

Coho salmon are native to Scappoose Creek and surrounding creeks draining to the mainstem Columbia River, with the earliest survey records indicating the presence of coho salmon in 1945 (Parkhurst et al. 1950). Coho salmon were reported as the predominant salmon in this area (Willis et al. 1960). Siercks and Raymond creeks (Scappoose Creek basin) and Milton and Salmon creeks (Milton Creek tributary) have been surveyed annually in December since 1949 as part of a lower Columbia River index (Willis et al. 1960, Weitkamp et al. 2001). Surveys reported returns in the tens and hundreds of fish until the 1970s, when abundance dropped considerably. Low abundance levels may have resulted in the loss of genetic variability. Based on spawner survey timing, coho salmon in this DIP were probably Type N (Howell et al. 1985).

The Scappoose Creek coho salmon DIP (based on 1991 samples from Scappoose and Milton creeks) relatively is distinct genetically from other lower Columbia River populations (Weitkamp et al. 2001). This distinctiveness may reflect natural patterns of variability or could be the result of genetic drift because of the very small size of the breeding population in recent years. The Scappoose Creek basin is relatively isolated geographically and may be less prone to receiving strays from other basins.

Individual population maps are in Appendix E (pages 199–311), and strata are presented in Figure 21. Letter designations for the following populations indicate possible subpopulation designations within the numbered populations. Populations identified in WDF et al. (1993) as a SASSI stock are so indicated.

1. Youngs Bay late run (Type N) (Figure E-96)
    a. Lewis and Clark River
    b. Youngs River
    c. Wallooskee River
    d. Klaskanine River

2. Grays River late run (Type N) (SASSI) (Figure E-83)
    a. Deep River
    b. Grays River

3. Big Creek late run (Type N) (Figure E-73)
    a. John Day River
    b. Mill Creek (Oregon)
    c. Big Creek
    d. Bear Creek

4. Elochoman River late run (Type N) (Figure E-81)
    a. Skamokawa Creek (SASSI)
    b. Elochoman River (SASSI)

5. Clatskanie River late run (Type N) (Figure E-77)
    a. Plympton Creek
    b. Clatskanie River
    c. Beaver Creek

6. Mill Creek (Washington) late run (Type N) (Figure E-88)
    a. Mill Creek (SASSI)
    b. Abernathy Creek (SASSI)
    c. Germany Creek (SASSI)
    d. Coal Creek

7. Scappoose Creek late run (Type N) (Figure E-91)
    a. Tide Creek
    b. Goble Creek
    c. Milton Creek
    d. McNulty Creek
    e. Scappoose Creek

Western Cascade Range Tributaries

The western Cascade Range tributaries region extends from the Cowlitz River (RKM 106.2) to the Washougal River (RKM 194.9) on the Washington side and from the Willamette River (RKM 162.5) to the Sandy River (RKM 193.6) on the Oregon side. There appears to have been several major spawning aggregations in this region, based on historical population abundance information and watershed size.

Rivers in this region are larger than those in the coastal region, with headwaters high in the Cascade Mountains. Many rivers are more than 100 km long, with basins covering 1,000 km^2 or more (Table 1). Snowmelt and groundwater sources are substantial and maintain good year-round flows and cool water temperatures. River flows peak in December or January and are sustained at least 50% of the peak flow for six months or more. The lower reaches of rivers are relatively low gradient, but high gradient sections are common in the middle and upper reaches. Elevation plays a relatively important role in delineating the boundaries of EPA ecological regions (Figure 1).

Upper Cowlitz River tributaries

Much of the historical information available for the upper Cowlitz River basin coho salmon population is not specific to any one of the three historical populations, rather, it describes coho salmon moving upstream into one of the many larger tributaries with higher elevation headwaters. Gilbert and Evermann (1895) listed coho salmon and Chinook salmon as being present in the Cowlitz River basin. Moore and Clarke (1946) estimated that the total coho salmon run size in the Cowlitz River was 77,000, and they indicated that two coho salmon runs entered the Cowlitz River, an early run in late August and September and a later, larger run from October through winter. The early run was thought to spawn in headwater reaches, while the later run spawned throughout the basin (Moore and Clarke 1946). Bryant (1949) described the Cowlitz River as the "greatest silver salmon producing area in the entire Columbia River watershed." Coho salmon escapement to the entire Cowlitz River basin was estimated at 32,500 in 1956 (Smith 1956). Upstream monitoring of coho salmon beyond the Mayfield Dam site (below the Cispus, Tilton, and upper Cowlitz rivers) indicated the run peaked during September (30% of the run) but extended from August to January (Smith 1956).

Juvenile emigration was monitored during the 1950s, before Mayfield Dam was built. Stockley (1961) observed that subyearling coho salmon moved downstream in relatively small numbers throughout their first spring. Yearling coho salmon moved downstream in two pulses, one in December and a second, larger pulse in May. Scale data from returning adults indicate that coho salmon reach the ocean during their second spring, so it is thought that the subyearling migration may be to rearing habitat in the lower Cowlitz River or mainstem Columbia River, or that the subyearling smolts do not successfully transition to the ocean.

Early and late coho salmon historically were found in the upper Cowlitz River basin, above the Mayfield Dam site. Spawner surveys conducted in 1961 (on fish passed around Mayfield Dam) identified early and late coho salmon in Cispus River tributaries (Birtchet and Meekin 1962). Bryant (1949) conducted the majority of surveys during the spring and summer, so for most basins the only information available is the presence of coho juveniles in the streams surveyed. Surveys conducted on 22 October and 23 October 1936 observed 85 coho in Yellowjacket Creek. These fish were not yet spawning, the majority was resting in a pool. Live and dead coho salmon were observed in the North Fork Cispus River during surveys on 30 October and 1 November 1945 (Bryant 1949).

WDF hatchery records (1930–1942) indicate that coho salmon eggs were collected throughout October at a station on the upper Cowlitz River (this timing conforms to early returning, Type S, coho salmon populations). Kiona Creek appears to have been a major producer of coho salmon historically. Bryant (1949) reported that in July 1937 "silver salmon fingerlings were so abundant in this section that the stream resembled a hatchery rearing pond." Early and late coho salmon were surveyed in Kiona Creek from 1956 to 1961 (Birtchet and Meekin 1962). Numerous juvenile coho salmon also were reported by Bryant (1949) in Silver, Lake, Butter, Skate, and Burton creeks during surveys in the late 1930s. WDF (1951) reported that early returning coho salmon moved into the upper basin tributaries, while late returning coho salmon spawned in the lower tributaries.

Recent attempts have been made to reintroduce coho salmon above Mayfield and Mossyrock dams on the Cowlitz River. Since 1996 several thousand predominantly late coho salmon have been transported to the upper Cowlitz basin each year (Dammers et al. unpubl. data). During the 2001–2002 spawning season, 16,654 adult female coho salmon were transferred to the upper Cowlitz and Cispus rivers (Serl and Morrill 2002). Juveniles produced from transported adults and introduced hatchery juveniles are collected at the Cowlitz Falls collection facility. Adults have been transferred into the Tilton River basin along with juveniles collected at Mayfield Dam. Although naturally produced juveniles have been collected from the Tilton, Cispus, and upper Cowlitz rivers, there has been very little opportunity for these populations to adapt to local conditions and more than 96% of the adults transported in 2001–2002 were of hatchery origin (Serl and Morrill 2002). Natural production from these transported adults in the upper Cowlitz and Cispus rivers for 2000 and 2001 was estimated at 106,869 and 334,740 smolts, respectively (Serl and Morrill 2002).

Much of the available information concerning Tilton River coho salmon comes from hatchery records. The WDF operated a hatchery on the Tilton River from 1915 to 1921. During the 1917 season (a broodyear that did not include returning hatchery-reared returning adults), 689 females were spawned.[7] Bryant (1949) reported that survey parties counted 407 adult coho salmon in the Tilton River from 16 October to 20 October 1936. Coho fingerlings also were reported throughout the Tilton River basin during surveys conducted during July 1937.

Lower Cowlitz River tributaries

Lower Cowlitz River tributaries historically contained considerable coho salmon runs. Bryant (1949) identified Arkansas, Ostrander, and Lacamas creeks as primary producers of coho salmon. Birtchet and LeMier (1955) reported that 329 coho salmon were counted entering Arkansas Creek from October through December 1954, until high flood waters washed out the weir in December. WDF et al. (1993) considered current coho salmon to be of mixed origin. Hatchery introductions or the amalgamation of native populations following construction of Mayfield and Mossyrock dams likely are causes for this mixture. Analyses of coho salmon returns to the Cowlitz, Washougal, Lewis, and Elochoman hatcheries indicated a significant delay in return timing, at a rate of approximately 1.7 days per year of propagation (Fuss et al. 1998). Although this may be because of selection in the hatchery, the authors also suggested that timing of in-river harvest could have caused this effect. Run and spawn timing observed in current Cowlitz River coho salmon may reflect the hybridization of early and late returning populations. There appears to be minimal influence from out-of-basin hatchery introductions. Ocean CWT recoveries suggest a Type N migration pattern (WDF et al. 1993). Habitat degradation and loss (because of migration barriers) also limit natural production (WDF et al. 1993), and life history diversity may be further constrained by these factors.

[7] Records only indicate the number of females spawned and the number of eggs obtained. How many coho salmon were intercepted at the hatchery weir is not known.

Coho salmon were listed as one of the species that comprised a considerable fall run into the Toutle River basin (Gilbert and Evermann 1895, Evermann and Meek 1898). There were "extensive" runs in the North Fork Toutle River basin (Bryant 1949), but by 1941 they had diminished considerably. During surveys in the late 1930s and early 1940s juvenile coho salmon were observed in a number of tributaries. Early and late returning coho salmon were found in the North Fork Toutle River (WDF 1951). Birtchet and Meekin (1962) identified 899 early coho salmon in Spirit Lake tributaries. The North Fork Toutle River basin was affected substantially by the 1980 Mount St. Helens eruption. Following the eruption, a number of hatchery introductions reestablished coho salmon in devastated areas. Type S coho salmon from other lower Columbia River hatcheries were used, because they were believed to be the dominant type in the Toutle River basin. Ocean CWT recoveries suggested a Type S migration pattern, with a substantial proportion of recoveries off the Oregon coast (WDF et al. 1993). WDF et al. (1993) considered this population to be of mixed origin and sustained through hatchery and natural production.

Bryant (1949) conducted limited surveys in the South Fork Toutle River during May 1941. The survey parties did not observe any juvenile coho salmon but did report that runs existed in the basin. There is little historical information concerning coho salmon in this basin. WDF et al. (1993) considered this population to be of mixed origin. Type S coho salmon from the Green River (North Fork Toutle River) were introduced throughout the North and South Fork Toutle rivers, and are thought to have influenced populations in the south fork (WDF et al. 1993). The 1980 Mount St. Helens eruptions influenced the South Fork Toutle River less than the north fork.

A few coho salmon were observed in the Coweeman River (Bryant 1949) during surveys conducted in late September 1936, although this would be somewhat early for late coho salmon. WDF (1951) reported that the Coweeman River contained predominantly late returning fish. The existing population of coho salmon is considered to be of mixed origin (WDF et al. 1993) as a result of widespread transfers between basins, although hatchery transfers largely were eliminated by the early 1990s.

Cascade tributaries other than the Cowlitz River

Coho salmon are native to the Kalama River basin, although little is known about their historical distribution. Crawford (1911) described how trout and yearling salmon readily preyed on Chinook salmon released from the Kalama Hatchery in 1897. Yearling salmon most likely would have been coho salmon. Hatchery records indicated that during the 1920s and 1930s coho salmon eggs were collected from late December through February, a spawn timing typical of Type N populations. Although incomplete, WDF records indicate that more than 10 million coho eggs of unidentified origin were introduced into the Kalama River in the early to mid-1920s. Production records suggest that these eggs may have come from the Washington coast or Puget Sound (the success of these transplants is unknown). WDF (1951) reported that early and late coho salmon were present in the Kalama River. Bar spacing at a hatchery weir installed at RKM 3 to collect fall Chinook salmon from 1 August to 15 October currently allows coho salmon to swim past the weir.

Kalama Falls (RKM 16) was not thought to be passable historically for coho salmon, thus coho salmon would not have had access to the headwater regions that were more suitable to Type S fish. A fish ladder was built in the early 1900s, although current access to the upper river is still limited with only a few coho salmon able to jump Kalama Falls. Since historical use of this area was limited, coho salmon that currently reach Kalama Falls Hatchery are returned to the lower river. WDF (1951) indicated that the early run often is prevented from ascending Kalama Falls by the placement of the hatchery weir, which normally is removed by the time the late run arrives. In 1951, the WDF estimated that 3,000 coho salmon returned annually (1,500 fish in each of the two run timings). Birtchet and LeMier (1955) observed coho salmon entering the Little Kalama River from October through December, with 60% of the run entering in October (Figure 22). Ocean CWT recoveries from the Kalama Falls Hatchery indicate a pattern that is an intermediate of Type N and Type S populations (WDF et al. 1993). The Kalama Falls Hatchery historically reared Type N, and the Lower Kalama Hatchery reared Type S (Hymer et al. 1992). Current run and spawn timing for Kalama River coho salmon exhibit characteristics of both types.

Coho salmon are native to the North Fork Lewis River basin although little is known about their historical distribution. Evermann and Meek (1898) noted that a “good many” silver salmon enter the North Fork Lewis River. John Crawford, Washington State superintendent of hatcheries, stated: “Every species of the Pacific Coast salmon, except the blueback (or sockeye) spawned in Salmon Creek and the Lewis River (Crawford 1911).” Type N and Type S may have been present historically, with Type S fish exploiting upper river and headwaters areas and Type N fish spawning in the lower river. Smith (1940) stated that coho salmon were decidedly the most widely distributed of the three salmon species normally spawning in the Lewis River. WDF (1951) reported that early and late coho salmon spawned throughout the Lewis River basin, although the majority of the late run fish appeared to migrate to the East Fork Lewis River, while the early run fish were found in the mainstem North Fork Lewis River. Hatchery records (North Fork Lewis River) indicate that during the 1920s and 1930s coho salmon eggs were collected from early October to early December. Smith (1940) reported that during the 1930s coho salmon enter the hatchery trap from September through December. During its first year of operation the Ariel Dam trap collected nearly 30,000 coho salmon. Peak spawning (1933–1937) for coho salmon collected at the Ariel Dam trap was during the last week in October and the first week in November (Smith 1940). Ocean distribution of Lewis River Hatchery coho salmon (based on CWT recovery) is typical of Type S populations (WDF et al. 1993).

Much of the coho salmon spawning and rearing habitat in the North Fork Lewis River currently is inaccessible behind Merwin Dam, with Cedar Creek providing the majority of the remaining habitat. The overwhelming majority of coho salmon in the north fork presently are hatchery produced. Genetic analysis of Type N and Type S coho salmon broodstocks from the Lewis River Hatchery indicate substantial differences exist (Weitkamp et al. 2001). This is mostly likely because the hatchery established broodstocks from different rivers (in most cases, under natural conditions temporal runs within a river have evolved from a single source). Of the two Lewis River runs, the late returning Type N is most similar to proximate geographic populations in the Cowlitz and Clackamas rivers. The early returning Type S hatchery broodstock is somewhat distinct but most similar to Willard NFH (Columbia River upper Gorge tributaries) and Southwestern Washington Coho Salmon ESU stocks (Weitkamp et al. 2001).

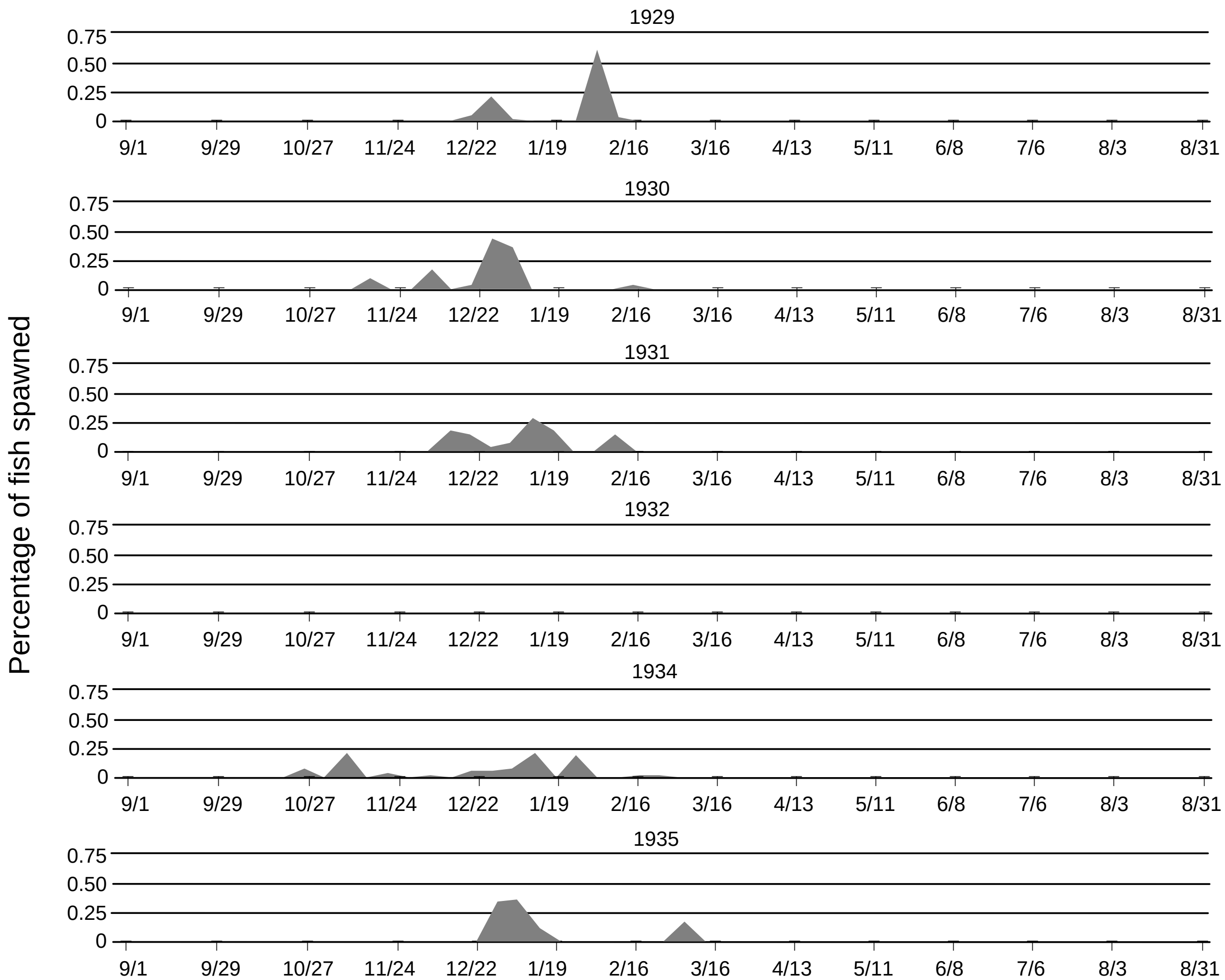


Figure 22. Distribution of eggs taken from coho salmon spawned at the Kalama Hatchery, 1929–1935. The presence of an early spawning component in 1930 and 1934 is thought to be the result of early fish introduced from out of basin. Source: WDFW unpubl. data.

Coho salmon historically were present in the East Fork Lewis River. Little is known about this population's characteristics. Evermann and Meek (1898) reported no salmon spawning below La Center, Washington, because of the muddy condition of the river channel, but that in general a "good many" coho salmon entered the Lewis River basin. In 1936 a USFWS survey team counted 1,166 coho salmon below Lucia Falls (RKM 33.8). WDF et al. (1993) considered East Fork Lewis River coho salmon to be of mixed origin because of a variety of hatchery introductions. WDF (1951) estimated that the majority of fish entering the East Fork Lewis River were late returning coho salmon. Hatchery transfers from outside the basin were terminated in the 1990s.

The Salmon Creek basin historically supported coho salmon as noted by John Crawford, Washington State superintendent of hatcheries (Crawford 1911). Salmon Creek differs from many other basins in the western Cascades stratum, in that it is a low gradient system (0.24%) throughout much of its course. The headwaters are at a relatively low elevation and provide little spring runoff. Sixteen coho salmon were observed on 27 October 1936 during USFWS surveys

(Bryant 1949). At the time of the 1951 WDF survey, habitat in the Salmon Creek basin already was degraded severely (WDF 1951), although spawning coho salmon were reported in Burntbridge and Mill creeks.

The Clackamas River currently contains early and late coho salmon. Barin (1886) observed that coho salmon entered the river in mid-September and began spawning about mid-January. Abernethy (1886) observed that the coho salmon run in the Clackamas River lasted from mid-September to mid-December and that it was equal in quantity to the Chinook salmon run. Coho salmon passage at North Fork Dam historically was unimodal (mid-November peak), but the distribution currently is bimodal, with peak passage in September and January (Cramer and Cramer 1994). Of the two runs, the late run is thought to be native, while the early run is believed to be the result of hatchery introductions (Olsen et al. 1992). Survey teams observed 30 spawning adult coho on 10 December 1957 in Clear Creek, below River Mill Dam (Willis et al. 1960). In Deep Creek, another lower Clackamas River tributary, 64 spawning coho salmon were observed on 11 December 1951 (Willis et al. 1960). Coho salmon passage at River Mill Dam was estimated at several hundred to more than a thousand fish during the 1950s (Willis 1960). Late coho salmon in the Clackamas River are larger at spawning than other lower Columbia River populations (Weitkamp et al. 1995). The Clackamas River coho salmon DIP includes Johnson and Mount Scott creeks. Willis et al. (1960) indicated that small runs utilized both creeks. Juvenile coho salmon and nine adults were observed in Johnson Creek during surveys in 1959, and a few adult salmon were observed consistently in Mount Scott Creek during surveys in the 1950s (Willis et al. 1960).

Early and late coho salmon in the Clackamas River are relatively distinct from one another, although both cluster with other lower Columbia River populations. Early Clackamas River coho salmon are related closely to stocks from the Eagle Creek NFH on Eagle Creek, a Clackamas River tributary (Weitkamp et al. 2001).

Coho salmon historically were present in the Washougal River basin, however, early records are scarce primarily because of the low abundances following fires in 1902 that devastated the basin (there were additional burns in 1912, 1927, and 1929). In November 1934, the first good coho salmon run in many years was reported (Bryant 1949). The existing coho salmon population in the Washougal River basin is thought to be of mixed origin, the result of extensive hatchery introductions (WDF et al. 1993). The late returning coho salmon appear to have been the dominant run in the Washougal River (WDF 1951). Most of the spawning took place in tributaries below Salmon Falls (Little Washougal River, Winkler Creek, and the West Fork Washougal River), although it was thought that some coho salmon were able to ascend Salmon Falls. Alternatively, coho salmon were not able to ascend Duggan Falls (approximately 3 km above the Washougal Salmon Hatchery). Run timing for late returning coho salmon generally extended from October through December, with spawning extending from late November to March.

Coho salmon are native to the Sandy River basin. Mattson (1955) estimated that the Sandy River historically produced spawning runs of 10,000–15,000. We know little about their historical characteristics, although OFC spawning operations at the Sandy River Hatchery (Figure 23) took eggs from 95 coho salmon females from 1 to 22 November (ODF 1903).

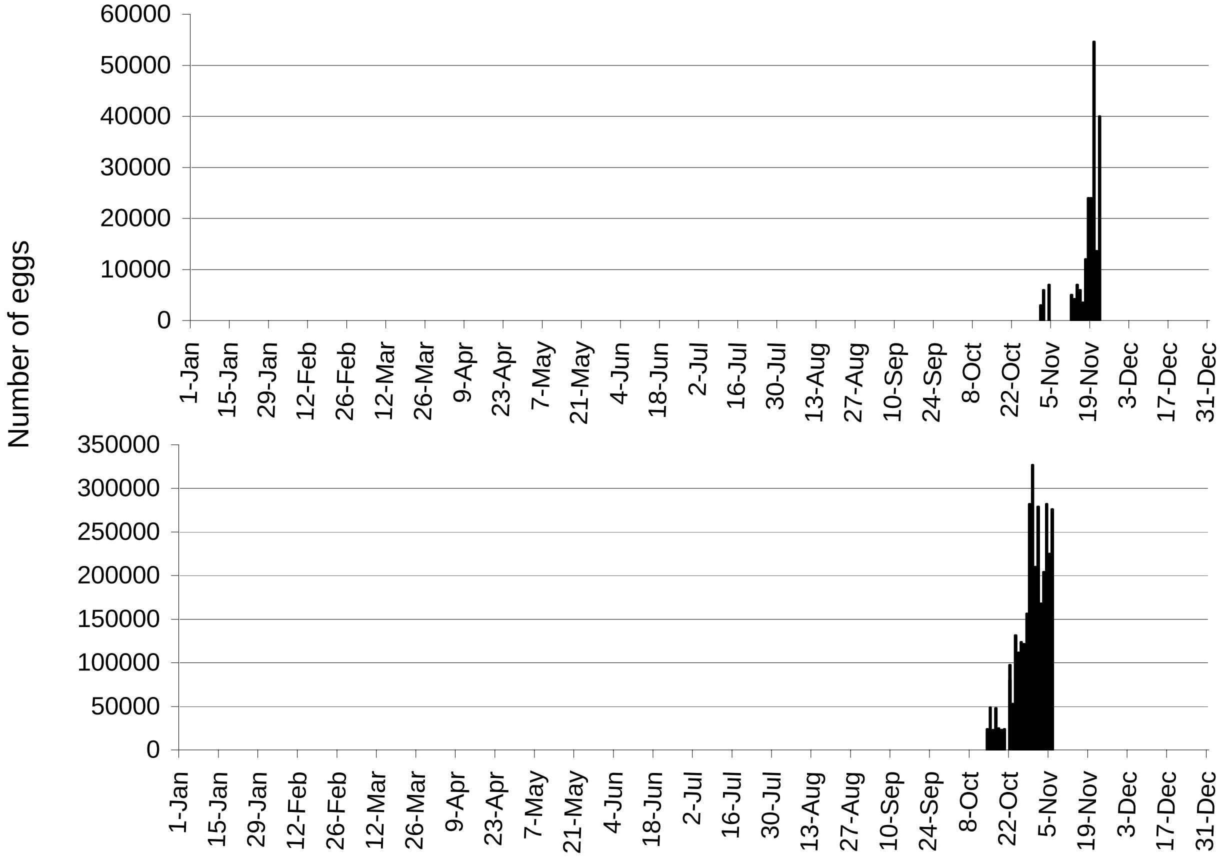


Figure 23. Distribution of eggs taken from coho salmon spawned at ODF hatcheries in the Sandy River (top) and Grande Ronde River (bottom) basins in 1901. Source: ODF 1903.

Returning adults pass Marmot Dam (RKM 43) from September through December, with peak passage during October and November (Howell et al. 1985). Below Marmot Dam, coho salmon historically maintained a large run in the Bull Run River basin (Craig and Suomela 1940). Craig and Suomela (1940) also estimated that the Salmon River supported the largest run in the Sandy River. Sandy River coho salmon mainly have been unaffected by out-of-basin introductions (Weitkamp et al. 2001). The Sandy River Hatchery broodstock is considered to consist primarily of local-origin fish (Kostow 1995). Sandy River coho salmon somewhat are distinct genetically from other Lower Columbia River Coho Salmon ESU stocks, but they are distinct from coastal (out of ESU) populations (Weitkamp et al. 2001).

Individual population maps are in Appendix E (pages 199–311), and strata are presented in Figure 21. Letter designations indicate possible subpopulations within the numbered populations. Populations identified in WDF et al. (1993) as a SASSI stock are so indicated. (Numbering sequence is continued from the list of populations on page 85.)

8. Upper Cowlitz River early and late runs (Type S and Type N) (SASSI) (Figure E-80)

9. Cispus River early and late runs (Type S and Type N) (SASSI) (Figure E-75)

10. Tilton River early and late runs (Type S and Type N) (SASSI) (Figure E-92)

11. North Fork Toutle (Green) River early and late runs (Type S and Type N) (Figure E-93)
    a. North Fork Toutle River early and late runs (Type S and Type N) (SASSI)
    b. Green River early and late runs (Type S and Type N) (SASSI)

12. South Fork Toutle River early and late runs (Type S and Type N) (SASSI) (Figure E-94)

13. Lower Cowlitz River late run (Type N) (SASSI) (Figure E-79)

14. Coweeman River late run (Type N) (SASSI) (Figure E-78)

15. Kalama River late run (Type N) and possibly early run (Type S) (SASSI) (Figure E-85)

16. North Fork Lewis River early and late runs (Type S and Type N) (SASSI) (Figure E-87)

17. East Fork Lewis River early and late runs (Type S and Type N) (SASSI) (Figure E-86)

18. Salmon Creek late run (Type N) (SASSI) (Figure E-89)

19. Clackamas River early and late runs (Type S and Type N) (Figure E-76)
    a. Eagle Creek
    b. Upper Clackamas River

20. Washougal River early and late runs (Type S and Type N) (SASSI) (Figure E-95)

21. Sandy River early and late runs (Type S and Type N) (Figure 90)
    a. Bull Run River
    b. Salmon River
    c. Mainstem Sandy River

Columbia Gorge Tributaries

The Columbia Gorge tributaries region extends from east of the Washougal River (RKM 194.9) to the White Salmon River (RKM 270) on the Washington side and from east of the Sandy River (RKM 193.6) to the Hood River (RKM 272) on the Oregon side. Rivers in this region are influenced heavily by the steeply sloped sides of the Columbia Gorge. Most streams are relatively short. Impassable falls limit accessible habitat to less than a half mile on most small creeks. Larger rivers contain falls or a series of cascades in their lower reaches, which may present migrational barriers during all or most of the year. Physiographically, this region marks a transition between the high-rainfall areas of the Cascades and the drier areas to the east. Stream flows can be intermittent, especially during the summer.

In its lower Columbia River coho salmon management plan, ODFW recognized three DIPs: Columbia Gorge tributaries, Big White Salmon River, and Hood River (Chilcote 2001b). This is based in part on the limited current spawning and rearing habitat available to coho salmon on the Oregon side of the Columbia Gorge area. Initially the TRT had identified four DIPs in this ecological region: Columbia River lower Gorge tributaries, Columbia River upper Gorge tributaries, Big White Salmon River, and Hood River. Based on available information, the TRT and ODFW have identified the following interim DIPs.

Columbia River lower Gorge tributaries

The Columbia River lower Gorge tributaries DIP extends upstream of the Sandy and Washougal rivers to the historical location of the Cascade Rapids (approximately at the current location of Bonneville Dam). There are very few natural-origin coho salmon populations in this area, and there is very little habitat available for them. Hatchery fish may stray into these areas. Tanner and Eagle creeks, two of the larger creeks, are blocked by hatchery weirs. WDF et al. (1993) identified a number of small tributaries on the Washington side where coho salmon are known to spawn: Gibbons, Duncan, Hardy, and Hamilton creeks. Coho salmon spawning in these creeks were considered to be late (Type N) coho salmon. WDF (1951) estimated that escapement to these minor tributaries near the Washougal River accounted for 2,050 adults. The USFWS has monitored naturally spawning coho salmon in Gibbons Creek for a number of years and although abundances have been low (less than 100), they have been consistently present (Brandt et al. 2003). Spawn surveys conducted in 1998 and 1999 observed peak spawner and redd abundances in mid-November (Brandt et al. 2003).

Washington upper Gorge tributaries and Big White Salmon River

The Columbia River upper Gorge tributary DIP extends from the historical location of the Bonneville Rapids (Cascades) to the ESU’s eastern boundary. Larger rivers contain falls or cascades in their lower reaches that may present migration barriers during all or most of the year. Spawning coho salmon were observed in several small creeks that line the Columbia Gorge during the surveys conducted during the 1930s and 1940s (Bryant 1949). None of these streams provides sufficient habitat for large spawning aggregations of fish, and it is unlikely that there were any independent populations. WDF (1951) estimated the spawning run in Rock Creek at 200 adults. Fulton (1970) identified coho salmon as being present in most of this area’s small tributaries. Escapement in Eagle, Herman, and Lindsey creeks was estimated at 3,000, 250, and 300, respectively (Howell et al. 1985), however, estimates for Eagle Creek include hatchery-origin fish returning to the Cascade Hatchery.

There is little historical information on coho salmon in the Big White Salmon River (RKM 270). The construction of Condit Dam (RKM 4) in 1913 eliminated anadromous access to the majority of the basin (Fulton 1968). Anadromous fish historically may have been able to ascend the Big White Salmon River as far as Trout Lake (RKM 45.4) (WDF 1951). Stream surveys conducted in the 1950s suggested that suitable coho salmon spawning habitat existed in Rattlesnake, Buck, and Trout Lake creeks, but because of low summer and early autumn flows only late run (Type N) coho salmon would be suitable (LeMeir and Smith 1955). LeMeir and Smith (1955) also estimated that the existing habitat could support about 200 coho salmon.

Oregon upper Gorge tributaries and Hood River

Coho salmon are indigenous to the Hood River basin and are found throughout the basin except for the West Fork Hood River above Punchbowl Falls. Fulton (1970) indicated that Neal

Creek supported much of the run. Run-timing data suggests that the Hood River coho salmon are an early returning Type S population, with peak passage past Powerdale Dam in September and October (Howell et al. 1985, Olsen et al. 1992). Spawning begins in October and goes into November (OSGC 1963 cited in Howell et al. 1985). Counts at Powerdale Dam were in the hundreds of fish during the 1960s (Howell et al. 1985), but there have been fewer than a hundred fish during the past few years (ODFW 2004).

Recent coho spawner surveys estimated that on the Oregon side of the Gorge tributaries there were only 11 miles of coho spawning habitat (Suring et al. 2005). This estimate does not include habitat above weirs on Eagle and Tanner creeks, nor does it include habitat that was lost because of the filling of the Bonneville Pool. Culverts along Interstate 84 also may limit current accessible habitat. Geographically, the majority of the tributaries in this area, with the exception of the Hood River, are very short and may have historically only contained a few hundred meters of usable habitat. Estimates by Maher et al. (2005) indicate that the Oregon tributaries to the upper Gorge (excluding the Hood River) historically contained 11 km of coho salmon spawning and rearing habitat. Based on the opinion of ODFW biologists and the absence of historical information on the abundance of coho salmon in this area, the TRT determined that (at a minimum) a combination of upper Gorge tributaries in addition the Hood River provided sufficient habitat and geographical structure to support a DIP.

Individual population maps are in Appendix E (pages 199–311), and strata are presented in Figure 21. Letter designations indicate possible subpopulation designations within the numbered populations. No populations were identified in WDF et al. (1993) as a SASSI stock. Please note that with the redelineation of the Gorge tributaries, the former upper Gorge tributaries (Figure E-83) now are divided into Washington and Oregon tributaries associated with the Big White Salmon River (E-74) and Hood River (E-85). (Numbering sequence is continued from the list of populations on page 93.)

22. Columbia River lower Gorge tributaries early run (Type S) (Figure E-82)
    a. Bridal Veil Creek
    b. Wahkeena Creek
    c. Hardy Creek
    d. Hamilton Creek
    e. Multnomah Creek
    f. Moffer Creek
    g. Tanner Creek
    h. Eagle Creek
    i. Rock Creek

23. Washington upper Gorge tributaries and Big White Salmon River early run (Type S) (Figure E-74)
    a. Wind River
    b. Spring Creek
    c. Little White Salmon River

24. Oregon upper Gorge tributaries and Hood River early run (Type S) (Figure E-84)

   a. Herman Creek
   b. Gorton Creek
   c. Viento Creek
   d. Lindsey Creek
   e. Phelps Creek

Chum Salmon

Life History

Chum salmon have the widest natural geographic and spawning distribution of any Pacific salmonid, primarily because their range extends farther along the shores of the Arctic Ocean than other salmonids (Groot and Margolis 1991). Chum salmon have been documented spawning from Korea and the island of Honshu, Japan, east around the rim of the North Pacific Ocean to Monterey Bay, California. Chum salmon also grow to be among the largest of Pacific salmon, second only to Chinook salmon in adult size, with individuals reported up to 108.9 cm in length and 20.8 kg in weight (Pacific Fisherman 1928). Average size for the species is around 3.6–6.8 kg (Salo 1991).

Chum salmon usually spawn in coastal areas and juveniles emigrate almost immediately after emerging from the gravel (Salo 1991). This ocean-rearing migratory behavior contrasts with the stream-rearing behavior of some other species of *Oncorhynchus* (e.g., coastal cutthroat trout, steelhead, coho salmon, and most types of Chinook salmon and sockeye salmon), which usually migrate to sea at a larger size after months or years of freshwater rearing. This means that survival and growth of chum salmon in the first year depend less on freshwater conditions than on favorable estuarine conditions, unlike the behavior of other salmonids (coho salmon, steelhead, and stream-type Chinook salmon) that depend heavily on freshwater habitats. Another behavioral difference between chum salmon and species that rear extensively in freshwater is that chum salmon juveniles form schools, presumably to reduce predation (Pitcher 1986).

In Asia and North America, chum salmon spawn commonly in the lower reaches of rivers, with redds usually dug in the main stem or side channels of rivers from just above tidal influence to nearly 100 km from the sea. In some areas they typically spawn where groundwater percolates through the redds (Bakkala 1970, Salo 1991). Some chum salmon even spawn in intertidal zones of streams, especially in Alaska, where tidal fluctuation is extensive and upwelling of groundwater in intertidal areas may provide preferred spawning sites.[8] Bailey (1964) reported that chum salmon eggs in Olsen Creek in Alaska could survive exposure to tidewater up to 55% of the time during embryonic development. Chum salmon were observed spawning in the intertidal zone of Walcott Slough in Hood Canal, Washington (O'Malley 1922). It also was noted that chum salmon spawn where springwater seepage occurs, and the developing embryos may be exposed to relatively low concentrations of salt water in these areas of freshwater upwelling.

[8] J. Helle, Alaska Fisheries Science Center, Auke Bay Laboratory, Juneau, AK. Pers. commun., April 1995.

Chum salmon spawn primarily in the lower reaches of rivers, because they usually show little persistence in surmounting river blockages and falls. However, in some Pacific Northwest streams, such as the Skagit River in Washington, chum salmon routinely migrate over long distances, at least 170 km.[9] In the Yukon River in Alaska and the Amur River in Russia chum salmon migrate more than 2,500 km inland. Although these distances are impressive, both rivers have low gradients and no extensive falls or other blockages to migration. In the Columbia River basin, reports indicate that chum salmon may historically have spawned in the Umatilla and Walla Walla rivers, more than 500 km from the sea (Nehlsen et al. 1991). However, these fish would have had to pass the Cascades and Celilo Falls, a web of rapids and cascades that once existed in the Columbia River, which would have presented a considerable migration obstacle. In the Columbia River, adults typically enter freshwater in October with spawning activity extending from early November through December (Johnson et al. 1997). Chum salmon returning to the Grays River (and the Columbia River in general) mature at 3 or 4 years of age.

The Columbia River historically contained large runs of chum salmon, which supported a substantial commercial fishery in the first half of the twentieth century (Figure 24). These landings represented a harvest of more than 500,000 chum salmon in some years. There are presently neither recreational nor directed commercial fisheries for chum salmon in the Columbia River, although some chum salmon are taken incidentally in the gill-net fisheries for coho salmon and Chinook salmon, and there has been minor recreational harvest in some tributaries (WDF et al. 1993). Hymer (1993 and 1994) and WDF et al. (1993) monitored returns of chum salmon to three streams in the Columbia River basin and suggested a few thousand, perhaps up to 10,000, chum salmon may spawn annually in the basin. Kostow (1995) identified 23 spawning populations on the Oregon side but provided no estimates of the spawner numbers in these populations. Spawner surveys conducted by ODFW during the autumn and winter of 2000–2001 only found a single chum salmon in the 29 streams surveyed (van der Naald 2001), although a number of chum salmon apparently were observed at hatchery weirs on the Oregon side during the 2000–2001 return year.

An estimate of the minimum run size for chum salmon returning to the Oregon and Washington sides was calculated by summing harvest, spawner surveys, Bonneville Dam counts, and returns to the Sea Resources Hatchery on the Chinook River in Washington (ODFW and WDFW 1995). This estimate suggests that the chum salmon run size in the Columbia River has been relatively stable (albeit at a very low level) since the run collapsed in the mid-1950s (Figure 24). The minimum estimate for the Columbia River run size in 1999 was 2,400 adult fish (Keller 2001).

[9] D. Hendrick, Washington Dept. Fish and Wildlife, Mount Vernon, WA. Per. commun., January 1996.

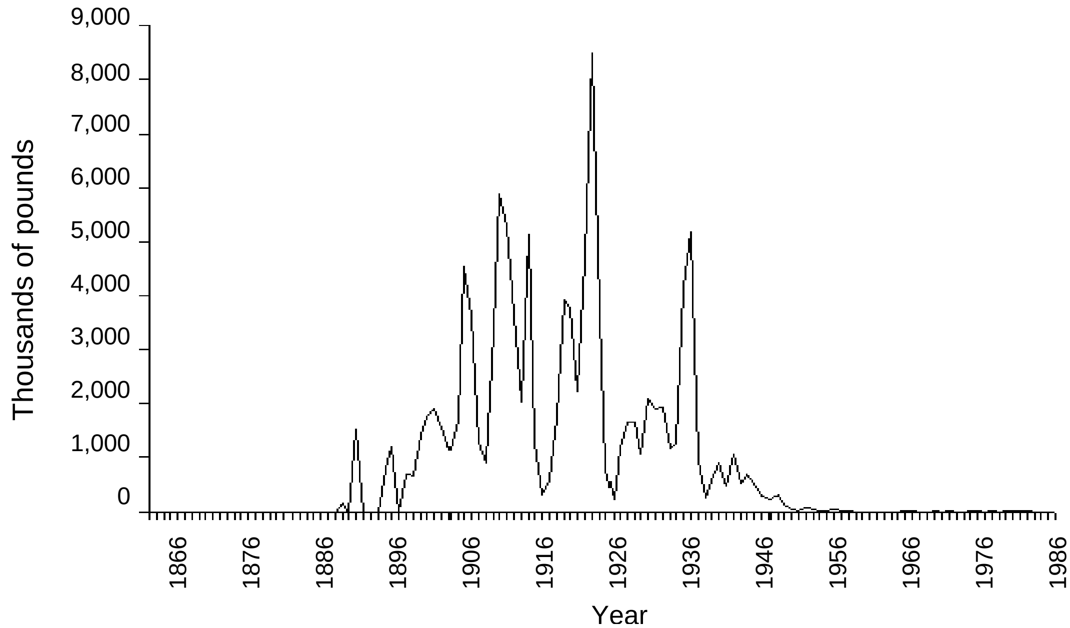


Figure 24. Commercial landings of chum salmon in the Columbia River, 1886–1993. Source: Johnson et al. 1997.

Columbia River Chum Salmon ESU Historical Independent Populations

Coast Range Tributaries

Chum salmon are native to rivers and creeks near the mouth of the Columbia River. There is little information about the size or distribution of chum salmon populations in specific river basins prior to the 1930s, and by that time chum abundance already was severely in decline.

From 1936 to 1945, chum salmon were observed in the Chinook, Deep, Elochoman, and Grays rivers, and Mill, Abernathy, and Germany creeks (Table 2) (Parkhurst et al. 1950). The Chinook River is small relatively and may have represented an important transition between the Washington coast and Columbia River populations, but there is no historical information to establish its relationship with the other populations. Jordan (1904) quoted H. S. Davis, who described the Chinook River as "a small sluggish stream . . . [that has] never been frequented by Chinook salmon, although considerable numbers of silver and dog [chum] salmon enter it late in the fall." It tentatively is clustered with the Grays River, the most important tributary remaining for chum salmon in this area. In 1936 survey crews observed more than 6,200 chum salmon adults in the Grays River (Parkhurst et al. 1950). The WDF (1951) estimated that average chum salmon escapement to the Grays River was 7,500, with an additional 1,200 fish spawning in nearby tributaries to the Columbia River. Spawning chum salmon also were observed in the Elochoman River and Abernathy Creek during the 1936 survey. In general, spawning chum salmon were reported in most rivers and creeks in this area. WDF (1951) estimated average escapement for the Elochoman River and Abernathy Creek basins at 4,000 and 2,700 adults, respectively. Birtchet and LeMier (1955) observed chum salmon returning to Abernathy Creek in 1954 with all fish arriving at the weir between 2 November and 12 November. Recent genetic analysis of samples from the Grays River were similar to samples from the Columbia River (Hardy and Hamilton creeks), but distinct from coastal and Puget Sound populations (Phelps et al. 1994b).

Parkhurst et al. (1950) reported that chum salmon were present in almost every watershed from the Lewis and Clark River to Scappoose Creek (Table 2), but no abundance estimates were presented and most information was anecdotal. Records show that between 1950 and 1960 an average of 607 chum salmon were intercepted at the Big Creek Hatchery rack annually, with a maximum of 2,430 chum salmon encountered in 1958 (Wallis 1963a). Chum salmon also were captured at the Klaskanine Hatchery rack. Although no adult numbers were recorded, a maximum of 1,481,294 eggs was obtained in 1940 (@ 2,800 eggs/female = 530 females) (Wallis 1963b). Wallis (1963a) also noted that chum salmon utilized the South Fork Klaskanine River, but not the north fork. Willis et al. (1960) reported that Milton Creek was the greatest producer of chum salmon (about 200 per year) in the area surrounding Scappoose Creek. The ODFW identified 23 populations on the Oregon side of the Lower Columbia River Chum Salmon ESU, although this inventory apparently was based on incidental observations rather than set criteria for populations (Kostow 1995).

Western Cascade Range and Columbia Gorge Tributaries

Chum salmon historically were distributed widely in tributaries below Celilo Falls. Barin (1886) observed that dog salmon (chum salmon) appeared in the Clackamas River by November and spawned soon afterward. By 1944 chum salmon were not found during biological surveys of the Clackamas River (Dimick and Merryfield 1945). Probably the same water-quality problems that had extirpated the early fall Chinook salmon eliminated chum salmon. Chum salmon also were present historically in the Sandy River basin (Mattson 1955). At the time of his review, Mattson estimated that approximately 200 chum salmon returned annually to the Sandy River. Although there are no current estimates, chum salmon have been reported in recent surveys of this river.[10]

Chum salmon are native to tributaries in this area, although their current abundance is a fraction of historical levels. Hatcheries in the lower Columbia River basin made little effort to collect chum salmon, primarily because of their low market value in the commercial fishery. Most eggs were collected at the Lewis River Hatchery (up to 750 females spawned in any one year). Transfers of chum salmon from outside the Columbia River basin, however, were substantial. Between 1913 and 1918 some 30 million chum fry (predominantly from the Chehalis River) were released throughout the Columbia River (including a number of sites above Celilo Falls and in the Methow and Walla Walla rivers) (WDFG 1916, 1918). Hatchery practices at the time emphasized releasing unfed fry, and the success of many of these transfers, especially those far upriver, is doubtful.

---

[10] O. Johnson, Northwest Fisheries Science Center, Seattle, WA. Per. commun., January 2000.

The WDF (1951) annual escapement estimates were 1,000 in the Cowlitz River, 600 in the Kalama River, 3,000 in the Lewis River, and 1,000 in the Washougal River in 1951 (when chum salmon populations already were well in decline). Within the Cowlitz River basin, chum salmon migrated beyond the Mayfield Dam site and spawned in the lower tributaries of the Cowlitz River: Coweeman River, Ostrander Creek, Arkansas Creek, Toutle River, Salmon Creek, Olequa Creek, and Lacamas Creek (WDF 1951). Adult chum salmon were observed migrating past a weir on Arkansas Creek (lower Cowlitz River) from 1 November to 13 December 1954, when the trap was rendered inoperable by high waters (Birtchet and LeMier 1955). Emigrating chum salmon fry were sampled at the Mayfield Dam site in 1955 and 1956 (Stockley 1961). Chum salmon recently were recovered in the mainstem Cowlitz River below the Cowlitz Salmon Hatchery and at the hatchery rack. The Cowlitz River chum salmon that are recovered near the Cowlitz Salmon Hatchery have an early "summer" run timing and spawn considerably earlier than downstream populations of fall chum salmon. It is unclear how the construction of Mayfield Dam may have altered conditions in the lower Cowlitz River and affected the expression of this trait. Unpublished genetic analysis of Cowlitz River chum salmon indicates that this spawning aggregation is distinct from fall chum salmon in the Cowlitz River and nearby tributaries. Whether summer chum salmon constitute a DIP or are perhaps the sole representative of a summer-run stratum needs to be studied further, but this run timing represents an important component of ESU diversity.

Naturally spawning populations of chum salmon currently exist in Hardy (RKM 228) and Hamilton creeks (RKM 229), and in man-made spawning channels associated with these creeks. These small Columbia River tributaries are located just downstream of Bonneville Dam. Returning chum salmon adults were spawned incidentally at the Bonneville and Oxbow hatcheries (Tanner and Herman creeks) from the 1930s to the 1950s. Chum salmon also were spawned incidentally at the USBF's Little White Salmon Hatchery, especially when Chinook salmon egg collections did not fill incubation capacity. In 1917 the Little White Salmon Hatchery collected 1,447,500 chum salmon eggs (Smith 1919) (@ 2,250 eggs/female = approximately 643 females [Howell et al. 1985]). There is no indication what proportion of the run was collected.

There are few current estimates of chum salmon abundance in tributaries to the lower Columbia River. Aside from the Grays River and Hamilton and Hardy creeks, chum salmon have been observed in a number of rivers (Cowlitz, Lewis, and mainstem Columbia) on the Washington side (Keller 2001). It is probable that chum salmon exist at low abundance levels in many of their historical watersheds. In 1998 and 1999 only 195 and 135 chum salmon, respectively, were observed ascending the fish ladder at Bonneville Dam (Keller 2001, NMFS 2000).

Little genetic or life history information for chum salmon is available for reconstructing the historical population structure in the lower Columbia River (Small et al. 2004). Genetic information currently exists only for the Grays River and Hamilton and Hardy creeks populations. Similarities between fish from Hamilton and Hardy creeks relative to Grays River samples would be expected given the proximity of these watersheds and the relatively small size of the populations. No differences in age structure of the three spawning aggregations are apparent, 3-year-old fish predominate (Keller 2001). Analysis of scales taken from chum salmon returning to the Columbia River in 1914 also indicated that 3-year-old fish constituted 70.4% of the run (Marr 1943), however, the 1914 sample was obtained from the net fishery, which may have provided a biased sample. Peak spawning activity for chum salmon in the Grays River and Hamilton and Hardy creeks differs by about a month (8 November and 8 or 10 December each year, respectively, providing considerable geographic and temporal isolation (Keller 2001). Differences in spawning times may be related to differences in water sources between Grays River and Hamilton and Hardy creeks (rainfall vs. groundwater). The preference of chum salmon to spawn in the lower river reaches and mainstem Columbia River increases the likelihood of migration between local populations, especially given the large historical populations that existed in the Columbia River. It also is possible, however, that if salmon were returning to a specific site, such as a mainstem groundwater seep, they would need a high degree of homing fidelity. Tributaries to the Columbia River in the coastal region also are under tidal influence and salmon would have to move some distance upstream to find adequate spawning areas, providing some degree of geographic isolation between basins.

Analysis of the correlation between allozyme allelic frequencies for fall chum salmon populations in British Columbia and the distance between populations suggested that populations farther apart than 250 km do not genetically influence one another through migration (Tallman and Healey 1994, Johnson et al. 1997). This distance should be considered an upper bound, since genetic independence is much more sensitive to migration than demographic independence. The British Columbia data may not be applicable to the current situation in the lower Columbia River because of the proximity of neighboring populations in British Columbia relative to the lower Columbia River.

It is clear from the historical record that chum salmon were present in most tributaries to the lower Columbia River and to an unknown extent present in the main stem. Without an understanding of the dynamics of migration between populations, however, it is difficult to identify discrete populations. Life history similarities between fall Chinook salmon and chum salmon were used to establish the population boundaries in the Lower Columbia River Chum Salmon ESU. Additionally, since chum salmon prefer lower mainstem and off-channel spawning areas, no attempt was made to establish multiple population boundaries within a single basin. Further study is needed to establish the relationship of chum salmon spawning in the mainstem Columbia River to tributary spawners. It currently is assumed that there is a close association between mainstem spawners and geographically proximate basins. In the case of chum salmon that spawn near the Interstate-205 bridge, for example, we decided to associate this spawning aggregation with the Washougal River, the nearest major river terminus, rather than the Salmon Creek population boundary to which it is adjacent.

Individual population maps are in Appendix E (pages 199–311), and strata are presented in Figure 25. Letter designations in the following list of populations indicate possible subpopulation designations within the numbered populations. Populations identified in WDF et al. (1993) as a SASSI stock are so indicated.

1. Youngs Bay fall run (Figure E-113)
    a. Lewis and Clark River
    b. Youngs River
    c. Wallooskee River
    d. Klaskanine River

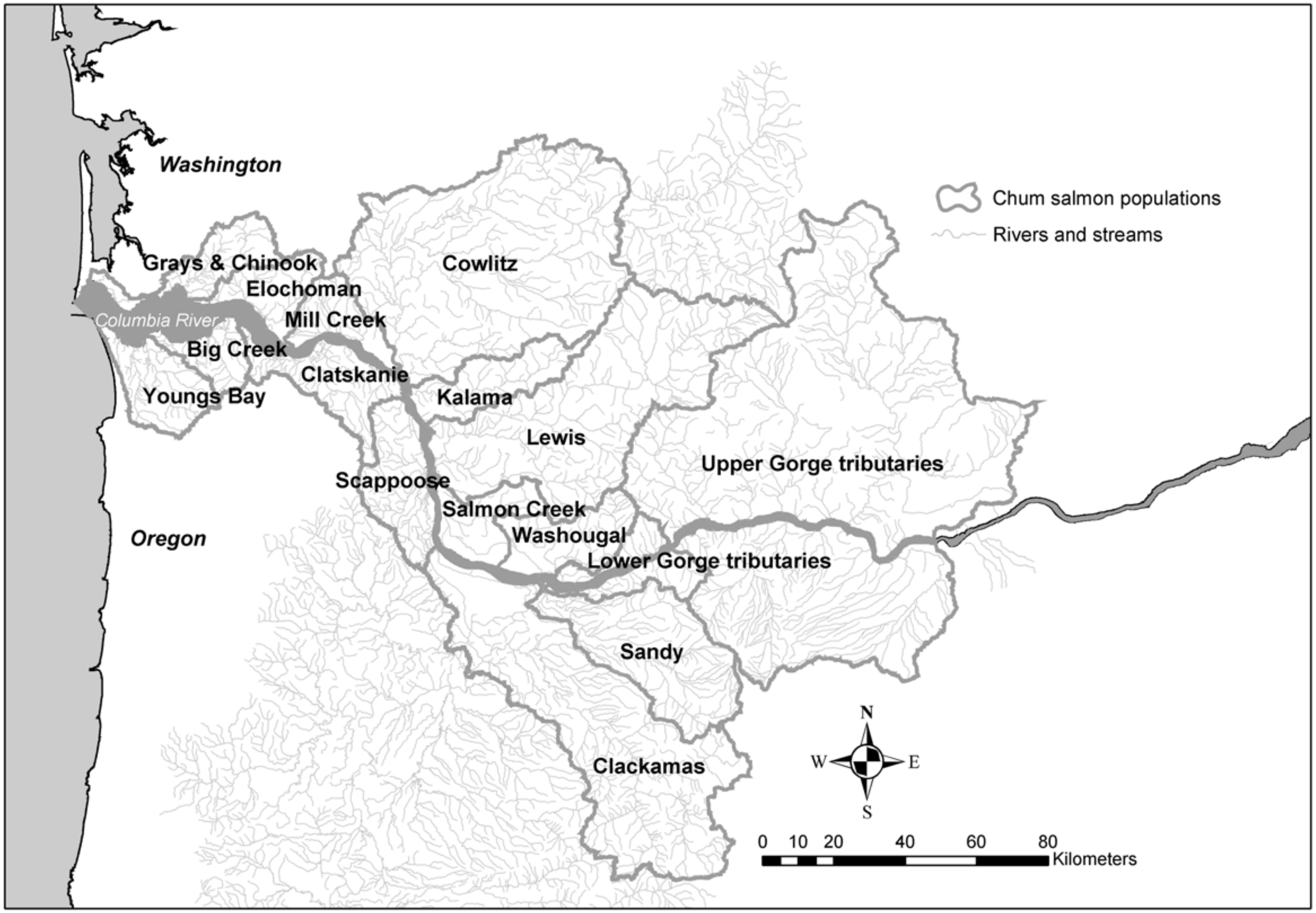


Figure 25. Historical DIPs in the Lower Columbia River Chum Salmon ESU.

2. Grays River fall run (SASSI) (Figure E-105)
    a. Chinook River
    b. Deep River
    c. Grays River

3. Big Creek (Figure E-98)
    a. Big Creek
    b. Bear Creek

4. Elochoman River fall run (Figure E-102)
    a. Skamokawa Creek
    b. Elochoman River

5. Clatskanie River fall run (Figure E-100)
    a. Plympton Creek
    b. Clatskanie River
    c. Beaver Creek

6. Mill Creek fall run (Figure E-108)
    a. Mill Creek
    b. Abernathy Creek
    c. Germany Creek
    d. Coal Creek

7. Scappoose Creek fall run (Figure E-111)
    a. Tide Creek
    b. Goble Creek
    c. Milton Creek
    d. McNulty Creek
    e. Scappoose Creek

8. Cowlitz River summer run (Figure E-101)

9. Cowlitz River fall run (Figure E-101)

10. Kalama River fall run (Figure E-106)

11. Salmon Creek fall run (Figure E-109)

12. Lewis River fall run (Figure E-107)

13. Clackamas River fall run (Figure E-99)

14 Washougal River fall run (Figure E-112)

15. Sandy River fall run (Figure E-110)

16. Columbia River lower Gorge tributaries fall run (Figure E-103)
    a. Mainstem Columbia River
    b. Bridal Veil Creek
    c. Wahkeena Creek
    d. Hardy Creek (SASSI)
    e. Hamilton Creek (SASSI)
    f. Multnomah Creek
    g. Moffer Creek
    h. Tanner Creek
17. Columbia River upper Gorge tributaries fall run (Figure E-104)
    a. Eagle Creek
    b. Rock Creek
    c. Herman Creek
    d. Wind River
    e. Gorton Creek
    f. Little White Salmon River
    g. Viento Creek
    h. Lindsey Creek
    i. Phelps Creek
    j. Big White Salmon River
    k. Hood River

References

Abernethy, A. S. 1886. Salmon in the Clackamas River. Bull. U.S. Fish Comm. 8:332.

Aebersold, P. B., G. A. Winans, D. J. Teel, G. B. Miller, and F. M. Utter. 1987. Manual for starch gel electrophoresis: A method for the detection of genetic variation. U.S. Dept. Commer., NOAA Tech. Rep. NMFS 61.

Bailey, J. E. 1964. Intertidal spawning of pink and chum salmon at Olsen Bay, Prince William Sound, Alaska. Manuscr. Rep. MR 64–6, U.S. Fish and Wildlife Service Biology Laboratory, Auke Bay, AK.

Bakkala, R. G. 1970. Synopsis of biological data on the chum salmon, (*Oncorhynchus keta*) (Walbaum) 1792. FAO Fish. Synop. 41, U.S. Fish and Wildlife Service, Circ. 315.

Barin, L. T. 1886. Salmon in the Clackamas River. Bull. U.S. Fish Comm. 8:111–112.

Benner, P. A., and J. R. Sedell. 1997. Upper Willamette River landscape: A historic perspective. *In* D. Dunnette and A. Laenen (eds.), River quality: Dynamics and restoration. Lewis Publishers/CRC Press, Inc., Boca Raton, FL.

Bennett, D. E. 1987. Willamette River spring Chinook salmon run. Oregon Dept. Fish and Wildlife. (Available from ODFW, P. O. Box 59, Portland, OR 97207.)

Bennett, D. E. 1988. Willamette River spring Chinook run. Oregon Dept. Fish and Wildlife, 88-031. (Available from ODFW, P. O. Box 59, Portland, OR 97207.)

Bentzen, P., J. Olsen, and J. Britt. 1998. Microsatellite DNA polymorphism in spring Chinook salmon (*Oncorhynchus tshawytscha*) from Clackamas Hatchery, the upper Sandy River and Bull Run River and its implication for population structure. Final rep. to City of Portland, Bureau of Water Works, Portland, OR. (Available from Marine Molecular Biotechnology Laboratory, Univ. Washington, Seattle.)

Berman, C. H., and T. P. Quinn. 1991. Behavioral thermoregulation and homing by spring Chinook salmon *Oncorhynchus tshawytscha* in the Yakima River. J. Fish Biol. 39:301–312.

Birtchet, R., and E. LeMier. 1955. Summary of weir and trap observations on several lower Columbia streams January through April, 1955. Washington Dept. Fisheries rep. (Available from WDF, 115 General Administration Building, Olympia, WA 98504.)

Birtchet, R., and T. Meekin. 1962. Spawning ground surveys, Cowlitz and North Fork Lewis Rivers, 1961. Washington Dept. Fisheries memo. (Available from WDF, 115 General Administration Building, Olympia, WA 98504.)

Bishop, S. M. 1995. Distribution of West Coast Chinook stocks or hatchery groups. Report submitted to the ESA Administrative Record for West Coast Chinook salmon. August 1995. (Available from NMFS, Environmental and Technical Services Division, 525 NE Oregon St., Suite 500, Portland, OR 97232.)

Bouck, G. R., A. V. Nebeker, and D. G. Stevens. 1975. Effects of holding temperatures on reproductive development in adult sockeye salmon (*Oncorhynchus nerka*). *In* J.R. Donaldson (ed.), 26th Annual Northwest Fish Culture Conference, Otter Rock, OR, p. 24–40.

Bowers, G. M. 1902. Little White Salmon Station, Washington. Report of the Commissioner, U.S. Commission of Fish and Fisheries, Washington D.C.

Brandt, S., J. Taylor, T. Coley, B. Ensign, J. Stone, and M. Yoshinaka. 2003. Determinates of Gibbons Creek watershed condition and health: Results of the Gibbons Creek watershed analysis, 1997–1999. U.S. Fish and Wildlife Service. Online at http://www.fws.gov/pacific/columbiariver/pdfdocs/habitat/gibbons99.pdf [accessed June 2005].

Brown, E. T., S. E. Jacobs, and D. A. Kreager. Unpubl. data. Assessment of the status of Oregon populations of natural coho salmon spawners in the Lower Columbia River, 2002. Sept. 2003 draft. (Available from ODFW, 3406 Cherry Drive NE, Salem, OR 97303.)

Bryant, F. G. 1949. A survey of the Columbia River and its tributaries with special references to management of its fishery resources. 2. Washington streams from the mouth of the Columbia River to and including the Klickitat River (Area I). U.S. Fish and Wildlife Service Special Sci. Rep. No. 62.

Busack, C. Unpubl. data. Letter. (Available from WDFW, 600 Capital Way N., Olympia, WA 98501.)

Busack, C., and A. R. Marshall. 1995. Defining units of genetic diversity in Washington salmonids. *In* C. Busack and J. B. Shaklee (eds.), Genetic diversity units and major ancestral lineages of salmonid fishes in Washington. Washington Dept. Fish and Wildlife Tech. Rep. No. RAD 95–02. (Available from WDFW, 600 Capital Way N., Olympia, WA 98501.)

Busby, P. J., T. C. Wainwright, G. J. Bryant, L. J. Lierheimer, R. S. Waples, F. W. Waknitz, and I. V. Lagomarsino. 1996. Status review of West Coast steelhead from Washington, Idaho, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-27.

Cavalli-Sforza, L. L., and A. W. F. Edwards. 1967. Phylogenetic analysis: Models and estimation procedures. Evolution 21:550–570.

CBIC (Columbia Basin Interagency Committee). 1967. River mile index. Cowlitz, Lewis, Klickitat, and minor right bank Columbia River tributaries. Columbia Basin Interagency Committee. (Available from NMFS, Environmental and Technical Services Division, 525 NE Oregon St., Portland, OR 97232.)

Chilcote, M. W. 1997. Conservation status of steelhead in Oregon. Draft rep., Aug. 1997. (Available from ODFW, P.O. Box 59, Portland, OR 97207.)

Chilcote, M. W. 2001a. Conservation assessment of steelhead populations in Oregon. (Available from ODFW, P.O. Box 59, Portland, OR 97207.)

Chilcote, M. W. 2001b. Oregon Dept. Wildlife's endangered species management plan for lower Columbia Gorge coho salmon conservation assessment of steelhead populations in Oregon. (Available from ODFW, P.O. Box 59, Portland, OR 97207.)

Chilcote, M. W., S. A. Leider, and J. J. Loch. 1986. Differential reproductive success of hatchery and wild summer-run steelhead under natural conditions. Trans. Am. Fish. Soc. 115:726–735.

Clanton, R. E. 1911. Annual report of the Oregon Master Fish Warden. Pacific Fisherman, April 1911, p. 33–37.

Collins, J. W. 1892. Report on the fisheries of the Pacific coast of the United States. *In* Report of the Commissioner for 1888, p. 3–269. U.S. Commission Fish and Fisheries, Washington, DC.

Collins, M. D. 1980. The 1979 Willamette River spring Chinook salmon run. (Available from ODFW, P.O. Box 59, Portland, OR 97207.)

Connolly, P. J., M. G. Wade, J. M. Hutchinson, and J. S. Ziller. 1992. Middle Fork Willamette subbasin fish management plan. (Available from ODFW, P.O. Box 59, Portland, OR 97207.)

Craig, J. A., and L. D. Townsend. 1946. An investigation of fish-maintenance problems in relation to the Willamette Valley Project. U.S. Fish and Wildlife Service, Special Sci. Rep. 33:74.

Craig, J. A., and A. J. Suomela. 1940. A survey of the Sandy River and its tributaries, 1940, with reference to fish management. U.S. Fish and Wildlife Service, Special Sci. rep. No. 14.

Cramer, D. P., and S. P. Cramer. 1994. Status and population dynamics of coho salmon in the Clackamas River. Tech. rep. Portland General Electric Co., Portland, OR.

Cramer, S. P., C. F. Willis, D. P. Cramer, M. Smith, T. Downey, and R. Montagne. 1996. Status of Willamette River spring Chinook salmon in regards to the federal Endangered Species Act (Part II). S.P. Cramer & Associates, Inc., Gresham, OR. (Available from S. P. Cramer & Associates, Inc., 300 SE Arrow Creek Lane, Gresham, OR 97080.)

Crawford, J. M. 1911. Destruction of salmon fry in non-hatchery streams. Pacific Fisherman., p. 27–31.

Dammers, W., P. Foster, M. Kohn, C. Morrill, J. Serl, and G. Wade. Unpubl. data. Cowlitz River subbasin summary. 2002 draft. (Available from Northwest Power Planning Council, 851 S.W. Sixth Ave., Suite 1100, Portland, OR 97204.)

Dimick, R. E., and F. Merryfield. 1945. The fishes of the Willamette River system in relation to pollution. Oregon State College, Engineering Experiment Station, Corvallis.

Evermann, B. W., and S. E. Meek. 1898. A report upon salmon investigations in the Columbia River basin and elsewhere on the Pacific Coast in 1896. Bull. U.S. Fish Comm. 17:15–84.

Fulop, J. Unpubl. data. Age structure of Sandy River Chinook salmon. Information faxed to NWFSC in 2000. (Available from J. Myers, NWFSC, 2725 Montlake Blvd. E., Seattle, WA 98112.)

Fulton, L. A. 1968. Spawning areas and abundance of Chinook salmon (*Oncorhynchus tshawytscha*) in the Columbia River basin—past and present. U.S. Dept. Commer., NMFS, Special Sci. Rep. No. 571.

Fulton, L. A. 1970. Spawning areas and abundance of steelhead trout and coho, sockeye, and chum salmon in the Columbia River basin—past and present. U.S. Dept. Commer., NMFS, Special Sci. Rep. No. 618.

Fuss, H., J. Byrne, and C. Ashbrook. 1998. Stock characteristics of hatchery-reared salmonids at Washington Dept. of Fish and Wildlife Columbia River hatcheries. Annual rep. H98-03. Washington Dept. Fish Wildlife, Hatcheries Program, Olympia.

Fuss, H. J., R. Fuller, M. A. Kimbel, A. E. Appleby, S. A. Hammer. 1994. Annual Coded Wire Tag Program (Washington) Missing Production Groups. Washington Dept. Fisheries annual report 1994, Report to Bonneville Power Administration, Contract No. 1989BI01873, Project No. 198906600 (BPA report DOE/BP-01873-2). Online at http://www.efw.bpa.gov/Publications/A01873-2.pdf [accessed June 2005]. (Available from BPA, Environment, Fish and Wildlife Division, P.O. Box 3621, 905 NE 11th Ave., Portland, OR 97208.)

Gharrett, A. J., and W. W. Smoker. 1993. Genetic components in life history traits contribute to population structure. *In* J. G. Cloud and G. H. Thorgaard (eds.), Genetic conservation of salmonid fishes, p. 197–201. Plenum, London.

Gilbert, C. H. 1912. Age at maturity of Pacific coast salmon of the genus *Oncorhynchus*. Bull. U.S. Fish Comm. 32:57–70.

Gilbert, C. H., and B. W. Evermann. 1895. A report upon investigations in the Columbia River basin, with descriptions of four new species of fishes. Bull. U.S. Fish Comm.. 14:169–205.

Girard, C. 1858. Fishes. Explorations and surveys for a railroad route from the Mississippi River to the Pacific Ocean. U.S. War Dept., Washington, DC.

Gleeson, G. W. 1972. The return of a river, the Willamette River, Oregon. WRRI-13. Oregon State Univ., Water Resources Research Institute, Corvallis.

Good, T. P., R. S. Waples, and P. Adams (eds.). 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-66.

Gower, J. C. 1966. Some distance properties of latent root and vector methods used in multivariate analysis. Biometrika 53:325–338.

Groot, C., and L. Margolis (eds.). 1991. Pacific salmon life histories. University of British Columbia Press, Vancouver, Canada.

Harlan, K. 1999. Washington Columbia River and tributary stream survey sampling results, 1997. Columbia River Progress Rep., 99-09. (Available from WDFW, 600 Capital Way N., Olympia, WA 98501.)

Hastings, A. 1993. Complex interactions between dispersal and dynamics: Lessons from coupled logistic equations. Ecology 74:1362–1372.

Healey, M. C. 1983. Coastwide distribution and ocean migration patterns of stream- and ocean-type Chinook salmon, *Oncorhynchus tshawytscha*. Can. Field-Nat. 97:427–433.

Healey, M. C. 1986. Optimum size and age at maturity in Pacific salmon and effects of size selective fisheries. Can. Spec. Publ. Fish. Aquat. Sci. 89:39–52.

Healey, M. C. 1991. The life history of Chinook salmon (*Oncorhynchus tshawytscha*). *In* C. Groot and L. Margolis (eds.), Life history of Pacific salmon, p. 397–405. University of British Columbia Press, Vancouver, Canada.

Hockersmith, E., J. Vella, L. Stuehrenberg, R. N. Iwamoto, and G. Swan. 1994. Yakima River radio-telemetry study: Spring Chinook salmon, 1991–1992. U.S. Dept. Energy, Bonneville Power Administration project no. 89-089, Portland, OR. (Available from BPA, P.O. Box 3621, Portland, OR 97208.)

Howell, P., J. Hutchinson, and R. Hooton. 1988. McKenzie subbasin fish management plan. (Available from ODFW, P. O. Box 59, Portland, OR 97207.)

Howell, P., K. Jones, D. Scarnecchia, L. Lavoy, W. Kendra, and D. Ortmann. 1985. Stock assessment of Columbia River anadromous salmonids. Volume II: Steelhead stock summaries, stock transfer guidelines—Information needs. Final rep., Project no. 83-355. U.S. Dept. Energy, Bonneville Power Administration, Portland, OR. (Available from BPA, P.O. Box 3621, Portland, OR 97208.)

Hughes, R. M., E. Rexstad, and C. E. Bond. 1987. The relationship of aquatic ecoregions, river basins, and physiographic provinces to the icthyogeographic regions of Oregon. Copeia 1987:423–432.

Hulett, P. L., R. H. Bradford, C. W. Wagemann, and S. A. Leider. 1993. Studies of hatchery and wild steelhead in the lower Columbia region. Washington Dept. Fish and Wildlife Management Division 93–12. (Available from WDFW, 600 Capital Way N., Olympia, WA 98501.)

Hydrosphere Products, Inc. 1993. Hydrodata regional CD-ROMs: USGS daily values, Vols. West 1, West 2. (Available from Hydrosphere Products, Inc., 1002 Walnut St., Suite 200, Boulder, CO 80302.)

Hymer, J. 1993. Estimating the natural spawning chum population in the Grays River basin, 1944–1991. Columbia River Research Laboratory progress rep. 93-17. (Available from WDFW, Columbia River Research Laboratory, P. O. Box 999, Battle Ground, WA 98604.)

Hymer, J. 1994. Estimating chum salmon population in Hardy Creek, 1957–1993. Columbia River Research Laboratory progress rep. 94-11. (Available from WDFW, Columbia River Research Laboratory, P. O. Box 999, Battle Ground, WA 98604.)

Hymer, J., R. Pettit, M. Wastel, P. Hahn, and K. Hatch. 1992. Stock summary reports for Columbia River anadromous salmonids. Volume III: Washington subbasins below McNary Dam. Project no. 88-108. U.S. Dept. Energy, Bonneville Power Administration, Portland, OR. (Available from BPA, P.O. Box 3621, Portland, OR 97208.)

Johnson, O. W., W. S. Grant, R. G. Kope, K. Neely, F. W. Waknitz, and R. S. Waples. 1997. Status review of chum salmon from Washington, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-32.

Jordan, D. S. 1904. Salmon of the Pacific. Pacific Fisherman II(1):13–16.

Keller, K. 2001. 1999 Columbia River chum return. Columbia River Research Laboratory progress rep. 2000-6. (Available from WDFW, 600 Capital Way N., Olympia, WA 98501.

Kostow, K. 1995. Biennial report on the status of wild fish in Oregon. (Available from ODFW, P.O. Box 59, Portland, OR 97207.)

Kostow, K. 2003. Evolutionarily significant unit boundaries and status assessment in a highly polymorphic species, *Oncorhynchus mykiss*, in the Columbia Basin. 18 August 2003 draft rep. NOAA Fisheries Service and Oregon Dept. Fish and Wildlife. (Available from ODFW, P.O. Box 59, Portland, OR 97207.)

Kostow, K. E., A. R. Marshall, and S. R. Phelps. 2003. Naturally spawning hatchery steelhead contribute to smolt production, but experience low reproductive success. Trans. Am. Fish. Soc. 132:780–790.

Kruskal, J. B. 1964. Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis. Psychrometricka 29:1–27.

Leider, S. A., P. L. Hulett, J. J. Loch, and M. W. Chilcote. 1990. Electrophoretic comparison of the reproductive success of naturally spawning transplanted and wild steelhead trout through the returning adult stage. Aquaculture 88:239–252.

Leider, S. A., J. J. Loch, and P. L. Hulett. 1986. Studies of hatchery and wild steelhead in the lower Columbia Region. Washington Dept. Game and Fish Management Division rep. 86-14. (Available from WDFW, 600 Capital Way N., Olympia, WA 98501.)

LeMier, E. H., and W. E. Smith. 1955. Biological appraisal of the Big White Salmon River. Research Division rep., Washington Dept. Fisheries, Olympia.

Lessa, E. P. 1990. Multidimensional analysis of geographic genetic structure. Syst. Zool. 39:242–252.

Lister, D. B., C. E. Walker, and M. A. Giles. 1971. Cowichan River Chinook salmon escapements and juveniles production 1965–1967. Fish. Serv. Pac. Reg. Tech. Rep. 1971-38.

Lindsay, R. B., K. R. Kenaston, R. K. Schroeder, J. T. Grimes, M. G. Wade, K. Homolka, and L. Borgerson. 1997. Spring Chinook salmon in the Willamette and Sandy rivers. Annual progress rep. F-163-R-01, Task 1.2—The proportion of wild fish in natural spawning populations. (Available from ODFW, P. O. Box 59, Portland, OR 97207.)

Lindsay, R. B., R. K. Schroeder, and K. R. Kenaston. 1999. Spring Chinook salmon in the Willamette and Sandy rivers. Annual progress rep. F-163-R-03. (Available from ODFW, P. O. Box 59, Portland, OR 97207.)

Maher, M., M. B. Sheer, E. A. Steel, and P. McElhany. 2005. Atlas of salmon and steelhead habitat in the Oregon lower Columbia and Willamette basins. NOAA Fisheries. Northwest Fisheries Science Center, Seattle, WA. Available online at http://www.nwfsc.noaa.gov/trt/atlas_salmon.htm [accessed 6 December 2005].

Marr, J. C. 1943. Age, length, and weight studies of three species of Columbia River salmon (*Oncorhynchus keta, O. gorbuscha,* and *O. kisutch*). Stanford Ichthyol. Bull. 2:157–197.

Marshall, A. 1998. Genetic analysis of mainstem Columbia River, below Bonneville Dam, Chinook spawners. Memo. to K. Harlan, 9 Feb. 1998. (Available from WDFW, 600 Capital Way N., Olympia, WA 98501.)

Marshall, A. R., M. Miller, C. Busack, and S. R. Phelps. 1991. Genetic stock identification analysis of three 1990 Washington ocean and Strait of Juan de Fuca Chinook salmon fisheries. GSI summary rep. 91-1. Washington Dept. Fisheries, Olympia.

Marshall, A. R., C. Smith, R. Brix, W. Dammers, J. Hymer, and L. LaVoy. 1995. Genetic diversity units and major ancestral lineages for Chinook salmon in Washington. *In* C. Busack and J. B. Shaklee (eds.), Genetic diversity units and major ancestral lineages of salmonid fishes in Washington. Tech. rep. RAD 95-02. (Available from WDFW, 600 Capital Way N., Olympia, WA 98501.)

Mattson, C. R. 1948. Spawning ground studies of Willamette River spring Chinook salmon. Fish Commission Research Briefs, Oregon Fish Commission, Clackamas 1(2):21–32. (Available from ODFW, P.O. Box 59, Portland, OR 97207.)

Mattson, C. R. 1955. Sandy River and its anadromous salmonid populations. Unpubl. manuscr. Oregon Fish Commission, Clackamas. (Available from ODFW, P.O. Box 59, Portland, OR 97207.)

Mattson, C. R. 1962. Early life history of Willamette River spring Chinook salmon. Oregon Fish Commission, Clackamas. (Available from ODFW, P.O. Box 59, Portland, OR 97207.)

Mattson, C. R. 1963. An investigation of adult spring Chinook salmon of the Willamette River system. Oregon Fish Commission, Clackamas. (Available from ODFW, P.O. Box 59, Portland, OR 97207.)

Mayhall, L. E. 1925. Review of hatchery operations in Washington. Thirty-fourth and thirty-fifth annual reports of the Washington Dept. Fisheries, p. 17–30. (Available from WDFW, 600 Capital Way N., Olympia, WA 98501.)

McElhany, P., M. H. Ruckelshaus, M. J. Ford, T. C. Wainwright, and E. P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-42.

McIsaac, D. O., and T. P. Quinn. 1988. Evidence for a hereditary component in homing behavior of Chinook salmon (*Oncorhynchus tshawytscha*). Can. J. Fish. Aquat. Sci. 45:2201–2205.

McKernan, D. L., and C. R. Mattson. 1950. Observations on pulp and paper effluents and the probable effects of this pollutant on the fisheries resources of the Willamette River in Oregon. Fish Commission Research Briefs. Oregon Fish Commission, Clackamas, 3(1):14–21.

McPhail, J. D., and C. C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Bull. Fish. Res. Board Can. 173:381.

Merrell, T. R. 1951. Stream improvement as conducted in Oregon on the Clatskanie River and its tributaries. Fish Commission Research Briefs. Oregon Fish Comm. 3:41–47.

Miller, R. J., and E. L. Brannon. 1982. The origin and development of life history patterns in Pacific salmon. *In* E. L. Brannon and E. O. Salo (eds.), Proceedings of the Salmon and Trout Migratory Behavior Symposium, p. 296–309. University of Washington Press, Seattle.

Mitchell, H. C. 1924. Clackamas (Ore.) Station and substations. *In* Report of the United States Commissioner of Fisheries for the Fiscal Year 1923, p. 33–37. Washington, DC.

Moore, M., and D. Clarke. 1946. A report on the fisheries problems in connection with the proposed hydro-electric development of the Cowlitz River, Lewis County, Washington. Washington Dept. Fisheries and Washington Dept. Game, Olympia.

Murtagh, T., R. Rohrer, M. Gray, E. Olsen, R. Rien, and J. Massey. 1992. Clackamas subbasin fish management plan. Oregon Dept. Fish and Wildlife, Portland. (Available from ODFW, P. O. Box 59, Portland, OR 97207.)

Myers, J. M., R. G. Kope, B. J. Bryant, D. Teel, L. J. Lierheimer, T. C. Wainwright, W. S. Grant, F. W. Waknitz, K. Neely, S. T. Lindley, and R. S. Waples. 1998. Status review of Chinook salmon from Washington, Idaho, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-35.

Myers, K. W., D. E. Rogers, C. K. Harris, C. M. Knudsen, R. V. Walker, and N. D. Davis. 1984. Origins of Chinook salmon in the area of the Japanese mothership and land-based driftnet salmon fisheries in 1975–1981. Univ. Washington, Fisheries Research Institute, Seattle.

Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington. Fisheries (Bethesda, Maryland) 16(2):4–21.

Nei, M. 1978. Estimation of average heterozygosity and genetic distance from a small number of individuals. Genetics 89:583–590.

Netboy, A. 1958. Salmon of the Pacific Northwest: Fish vs. dams. Binfords & Mort, Portland, OR.

Nicholas, J. 1995. Status of Willamette spring-run Chinook salmon relative to the federal Endangered Species Act. Rep. to the National Marine Fisheries Service. Oregon Dept. Fish and Wildlife, Portland. (Available from ODFW, P.O. Box 59, Portland, OR 97207.)

Nigro, T. 2001. Unpubl. data. Letter to J. Myers regarding historical population document comments from the Oregon Dept. Fish and Wildlife, 20 July 2001. (Available from ODFW, P.O. Box 59, Portland, OR 97207.)

NMFS (National Marine Fisheries Service). 1997. Status review update for deferred and candidate ESUs of West Coast steelhead. Memo from West Coast Steelhead Biological Review Team. (Available from NMFS, 525 NE Oregon St., Suite 500, Portland, OR 97232.)

NMFS (National Marine Fisheries Service). 1998a. Conclusions regarding the status of hatchery populations in deferred ESUs of West Coast steelhead. Memo to W. Stelle (Northwest Region, NMFS) and W. Hogarth (Southwest Region, NMFS) from M. Schiewe (Northwest Fisheries Science Center), 13 January 1998. (Available from NMFS, 525 NE Oregon St., Suite 500, Portland, OR 97232.)

NMFS (National Marine Fisheries Service). 1998b. Washington, Idaho, Oregon, and California: Hatchery populations. (Lower Columbia River, Klamath Mountains Province, Northern California, and Central Valley). Memo from the West Coast Steelhead Biological Review Team, 5 January 1998. (Available from NMFS, 525 NE Oregon St., Suite 500, Portland, OR 97232.)

NMFS (National Marine Fisheries Service). 1999a. BRT conclusions regarding the updated status steelhead (*Oncorhynchus mykiss*) of the upper Willamette River and middle Columbia River ESUs. Memo to W. Stelle (Northwest Region, NMFS) and W. Hogarth (Southwest Region, NMFS) from M. Schiewe (Northwest Fisheries Science Center), 12 January 1999. (Available from NMFS, 525 NE Oregon St., Suite 500, Portland, OR 97232.)

NMFS (National Marine Fisheries Service). 1999b. Evaluation of the status of Chinook and chum salmon and steelhead hatchery populations for ESUs identified in final listing determinations. Memo from the Conservation Biology Division, Northwest Fisheries Science Center, 4 March 1999. (Available from NMFS, 525 NE Oregon St., Suite 500, Portland, OR 97232.)

NMFS (National Marine Fisheries Service). 2000. Biological opinion. Reinitiation of consultation on operation of the Federal Columbia River Power System, including the Juvenile Fish Transportation Program, and 19 Bureau of Reclamation projects in the Columbia Basin. Endangered Species Act—Section 7 consultation. (Available from NMFS, 525 NE Oregon St., Suite 500, Portland, OR 97232.)

NRC (Natural Resource Consultants). 1996. Artificial propagation of anadromous Pacific salmonids, 1950 to present. Chinook salmon. Contract rep. to U.S. Dept. Commer., NOAA, NMFS, February 1996. (Available from NMFS, Environmental and Technical Services Division, 525 N.E. Oregon St., Portland, OR 97232.)

ODF (Oregon Dept. Fisheries). 1900. Report of fish commissioner. Annual reports of the Dept. of Fisheries of the State of Oregon 1901. State of Oregon, Salem.

ODF (Oregon Dept. Fisheries). 1902. Report of the master fish warden. Annual reports of the Dept. Fisheries of the State of Oregon to the Legislative Assembly, Twenty-First Regular Session. State of Oregon, Salem.

ODF (Oregon Dept. Fisheries). 1903. Report of master fish warden. Annual reports of the Dept. Fisheries of the State of Oregon. State of Oregon, Salem.

ODF (Oregon Dept. Fisheries). 1904. Report of master fish warden. Annual reports of the Dept. Fisheries of the State of Oregon. State of Oregon, Salem.

ODFW (Oregon Dept. Fish and Wildlife). 1990. McKenzie River, Willamette River subbasin. Salmon and steelhead production plan. Northwest Power Planning Council, Portland, Oregon. (Available from Northwest Power and Conservation Council, 851 SW Sixth Ave. Suite 1100, Portland, OR 97204.)

ODFW (Oregon Dept. Fish and Wildlife). 1998. Documents submitted to the ESA Administrative Record for West Coast Chinook salmon by J. W. Greer, 13 October 1998. Salem, Oregon. (Available from ODFW, P.O. Box 59, Portland, OR 97207.)

ODFW (Oregon Dept. Fish and Wildlife). 2004. Implementation of the lower Columbia River coho endangered species management plan. April 2004. Salem, OR. (Available from ODFW, P.O. Box 59, Portland, OR 97207.)

ODFW and WDFW (Oregon Dept. Fish and Wildlife and Washington Dept. Fish and Wildlife). 1995. Status report: Columbia River fish runs and fisheries, 1938–94. (Available from ODFW, P. O. Box 59, Portland, OR 97207.)

Olsen, E. A., R. A. French, and J. A. Newton. 1994. Hood River and Pelton Ladder evaluation studies. Annual report 1993. U.S. Dept. Energy, Bonneville Power Administration, Portland, OR. (Available from BPA, P.O. Box 3621, Portland, OR 97208.)

Olsen, E., P. Pierce, M. McLean, and K. Hatch. 1992. Stock summary reports for Columbia River anadromous salmonids. Volume I: Oregon. Project no. 88-108. U.S. Dept. Energy, Bonneville Power Administration, Portland, OR. (Available from BPA, P.O. Box 3621, Portland, OR 97208.)

O'Malley, H. 1922. Investigations and experiments, fertilization of salmon eggs in natural spawning, p. 27–29. Rep. United States Commissioner of Fisheries for the fiscal year 1921. U.S. Dept. Commer., U.S. Bureau of Fisheries, Washington, DC.

Omernik, J. M. 1987. Ecoregions of the conterminous United States. Ann. Assoc. Am. Geogr. 77:118–125.

Orsi, J. A., and H. W. Jaenicke. 1996. Marine distribution and origin of prerecruit Chinook salmon *Oncorhynchus tshawytscha* in southeastern Alaska. Fish. Bull. 94(3):482–497.

Pacific Fisherman. 1928. Record chum caught off Quadra. Pacific Fisherman 1928(Oct.):13.

Parkhurst, Z. E., F. G. Bryant, and R. S. Nielson. 1950. Survey of the Columbia River and its tributaries. Part 3. USFWS Special Sci. Rep.-Fish., No. 36. Online at http://www.fishlib.org/ Subbasins/ssrfsurvey.html [accessed 24 January 2006].

Parkinson, E. A. 1984. Genetic variation in populations of steelhead trout (*Salmo gairdneri*). Trans. Am. Fish. Soc. 70:209–220.

PFMC (Pacific Fishery Management Council). 2000. Review of 1999 Ocean Fisheries Salmon Fisheries. (Available from PFMC, 2130 SW Fifth Ave., Suite 224, Portland, OR 97201.)

Phelps, S. R., B. M. Baker, P. L. Hulett, and S. A. Leider. 1994a. Genetic analysis of Washington steelhead: Initial electrophoretic analysis of wild and hatchery steelhead and rainbow trout. WDFW rep. 94-9. (Available from WDFW, 600 Capital Way N., Olympia WA 98501.)

Phelps, S. R., L. L. LeClair, S. Young, and H. L. Blankenship. 1994b. Genetic diversity patterns of chum salmon in the Pacific Northwest. Can. J. Fish. Aquat. Sci. 51(Suppl. 1):65–83.

Phelps, S. R., S. A. Leider, P. L. Hulett, B. M. Baker, and T. Johnson. 1997. Genetic analyses of Washington steelhead: Preliminary results incorporating 36 new collections from 1995 and 1996. Progress rep. (Available from WDFW, 600 Capital Way N., Olympia, WA 98501.)

Phelps, S., J. Uehara, D. Hendrick, A. Blakley and R. Brix. 1995. Genetic diversity units and major ancestral lineages for chum salmon in Washington. *In* C. Busack and J. B. Shaklee (eds.), Genetic diversity units and major ancestral lineages of salmonid fishes in Washington. WDFW rep. 95-02. (Available from WDFW, 600 Capital Way N., Olympia, WA 98501.)

Pitcher, T. J. 1986. Functions of shoaling in teleosts. *In* T. J. Fisher (ed.), The behavior of teleost fishes, p. 294–337. Johns Hopkins University Press, Baltimore, MD.

PNRBC (Pacific Northwest River Basins Commission). 1969. Columbia-North Pacific region comprehensive framework study of water and related lands. Appendix II. The Region. Pacific Northwest River Basins Commission, Vancouver, WA.

PSMFC. 2000. Regional mark information. Online at http://www.rmis.org [accessed June 2005].

PSTRT (Puget Sound Technical Recovery Team). 2001. Independent populations of Chinook salmon in Puget Sound. Puget Sound TRT public review draft, 11 April 2001. (Available from NWFSC, 2725 Montlake Blvd. E., Seattle, WA 98112.)

Ravenel, W. 1898. Report on the propagation and distribution of food-fishes. U.S. Fish commissioner's annual rep. for year ending June 30, 1897, Part XXIII, p. vii–xxix. U.S. Interior Dept., Washington, DC.

Reimers, P. E., and R. E. Loeffel. 1967. The length of residence of juvenile fall Chinook salmon in selected Columbia River tributaries. Oregon Fish Commission, Res. Briefs 13(1):5–19, Clackamas.

Rice, W. R. 1989. Analyzing tables of statistical tables. Evolution 43:223–225.

Rich, W. H., and H. B. Holmes. 1928. Experiments in marking young Chinook salmon on the Columbia River, 1916 to 1927. U.S. Bur. Fish. Bull. 44:215–264.

Ricker, W. E. 1972. Hereditary and environmental factors affecting certain salmonid populations. *In* R. C. Simon and P. A. Larkin (eds.), The stock concept in Pacific salmon, p. 27–160. University of British Columbia Press, Vancouver, Canada.

Rohlf, F. J. 1994. NTSYSpc: Numerical taxonomy and multivariate system. Exeter Software, Setauket, NY.

Ruggerone, G. T. 1999. Abundance and stock origin of coho salmon on spawning grounds of lower Columbia River tributaries. Natural Resources Consultants, Inc. Contract no. 97-2, Pacific States Marine Fisheries Commission (PSMFC). (Available from PSMFC, 205 SE Spokane St., Portland, OR 97202.)

Salo, E. O. 1991. Life history of chum salmon (*Oncorhynchus keta)*. *In* C. Groot and L. Margolis (eds.), Pacific salmon life histories, p. 233–309. University of British Columbia Press, Vancouver, Canada.

Sandercock, F. K. 1991. Life history of coho salmon (*Oncorhynchus kisutch)*. *In* C. Groot and L. Margolis (eds.), Pacific salmon life histories, p. 397–445. University of British Columbia Press, Vancouver, Canada.

Schreck, C. B., H. W. Li, C. S. Sharpe, K. P. Currens, P. L. Hulett, S. L. Stone, and S. B. Yamada. 1986. Stock identification of Columbia River Chinook salmon and steelhead trout. Project No. 83-45. U.S. Dept. Energy, Bonneville Power Administration, Portland, OR. (Available from BPA, P.O. Box 3621, Portland, OR 97208.)

Schroeder, R. K., K. R. Kenaston, and R. B. Lindsay. 2000. Spring Chinook salmon in the Willamette and Sandy rivers. Oregon Dept. Fish and Wildlife annual progress rep. F-163-R-04. (Available from ODFW, P.O. Box 59, Portland, OR 97207.)

Serl, J., and C. Morrill. 2002. Draft annual report for the Cowlitz Falls project. Bonneville Power Administration contract no. 96BI92557. (Available from BPA, P.O. Box 3621, Portland, OR 97208.)

Shaklee, J. B., F. W. Allendorf, D. C. Morizot, and G. S. White. 1990. Gene nomenclature for protein-coding loci in fish. Trans. Am. Fish. Soc. 188:218–227.

Shaklee, J. B., T. D. Beacham, L. Seeb, and B. A. White. 1999. Managing fisheries using genetic data: Case studies from four species of Pacific Salmon. Fish. Res. 43:45–78.

Sharpe, C., P. Hulett, and C. Wagerman. 2000. Studies of hatchery and wild steelhead in the lower Columbia region. Washington Dept. Fish and Wildlife rep. no. FPA 00-10. (Available from WDFW, 600 Capital Way N., Olympia, WA 98501.)

Small, M., A. Frye, J. Von Bargen, and S. Young. In press. Genetic structure of chum salmon (*Oncorhynchus keta*) populations in the lower Columbia River: Are chum salmon in Cascade tributaries remnant populations? Conserv. Genetics.

Small, M., J. Von Bargen, A. Frye, S. Young. 2004. Population genetic structure in lower Columbia River chum salmon (*Oncorhynchus keta*) inferred from microsatellite DNA. Lower Columbia chum Rep. Washington Dept. Fish and Wildlife, Olympia. (Available from WDFW, 600 Capital Way N., Olympia, WA 98501.)

Smith, H. M. 1895. Notes on a reconnoissance [sic] of the fisheries of the Pacific coast of the United States in 1894. Bull. U.S. Fish Comm. XIV(1894):223–288.

Smith, H. M. 1919. Report of the United States Commissioner of Fisheries for the Fiscal Year 1917. U.S. Bureau of Fisheries, Washington, DC.

Smith, T. 1940. Report on the Lewis River Salmon Conservation Program. Washington Dept. Fisheries rep., Olympia.

Smith, W. 1956. Cowlitz River salmon escapements. Washington Dept. Fisheries rep., Olympia.

Smoker, W. A., J. M. Hurley, and R. C. Meigs. 1951. Compilation of observations on the effect of Ariel Dam on the production of salmon and trout in the Lewis River. Washington Dept. Fisheries rep, Olympia.

Sneath, P. H. A., and R. R. Sokal. 1973. Numerical taxonomy. W. H. Freeman, San Francisco.

Sokal, R. R., and F. J. Rohlf. 1981. Biometry, the principles and practice of statistics in biological research (2nd ed.). W. H. Freeman, San Francisco.

Stockley, C. E. 1961. The migration of juvenile salmon past the Mayfield Dam site, Cowlitz River, 1955 and 1956. Washington Dept. Fisheries rep., Olympia.

Stone, L. 1878. The salmon fisheries of the Columbia River. *In* Report of the Commissioner, U.S. Commission of Fish and Fisheries, p. 801–823. U.S. Dept. Interior, Washington, DC.

Suckley, G. 1858. Fishes. Report upon the fishes collected on the survey. Explorations and surveys for a railroad route from the Mississippi River to the Pacific Ocean. U.S. War Dept., Washington, DC.

Suring, E. J., E. T. Brown, and K. M. S. Moore. Lower Columbia River coho status report 2002–2004, Population abundance, distribution, run timing, and hatchery influence. Rep. no. OPSW-ODFW-2005-1. Oregon Dept. Fish and Wildlife, Salem. (Available from ODFW, P.O. Box 59, Portland, OR 97207.)

Swofford, D. L., and R. B. Selander. 1981. BIOSYS-1: A FORTRAN program for the comprehensive analysis of electrophoretic data in population genetics and systematics. J. Hered. 72:281–283.

Tallman, R. F., and M. C. Healey. 1994. Homing, straying, and gene flow among seasonally separated populations of chum salmon (*Oncorhynchus keta*). Can. J. Fish. Aquat. Sci. 51(3):577–588.

Teel, D. J., D. M. Van Doornik, D. R. Kuligowski, and W. S. Grant. 2003. Genetic analysis of juvenile coho salmon (*Oncorhynchus kisutch*) off Oregon and Washington reveals few Columbia River wild fish. Fish. Bull. 101:640–652.

Titcomb, J. W. 1904. Report on the propagation and distribution of food-fishes. *In* Report of the Commissioner, U.S. Commission of Fish and Fisheries, p. 22–47. U.S. Interior Dept. Washington, DC.

USDOC (U.S. Dept. Commer.) 1968. Climate atlas of the United States. Natl. Climatic Data Center (NOAA reprint 1983), Asheville, NC.

USFWS (U.S. Fish and Wildlife Service). 1948. Willamette Valley Project Oregon. Preliminary evaluation report on fish and wildlife resources. U.S. Dept. Interior. (Available from USFWS, 911 NE 11th Ave., Portland, OR 97232.)

USGS (U.S. Geological Survey). 1993. National water summary 1990–91. Hydrologic events and stream water quality. U.S. Dept. Interior, USGS paper 2400. (Available from USGS Store, online at http://store.usgs.gov/ [accessed 24 January 2006].)

van der Haegen, G., and D. Doty. 1995. Homing of coho and fall Chinook salmon in Washington. Washington Dept. Fish and Wildlife rep. H95-08. (Available from WDFW, 600 Capital Way N., Olympia WA 98501.)

van der Naald, W. D., 2001. Chum survey data. Unpubl. data. (Available from ODFW, P.O. Box 59, Portland, OR 97207.)

van der Naald, W. D., B. Spellman, and R. Clark. 2001. 1998–1999 Evaluation of fall Chinook and chum salmon spawning below Bonneville, The Dalles, John Day, and McNary dams. Report DOE/BP-15007-1. U.S. Dept. Energy, Bonneville Power Administration, Portland, OR. (Available from BPA, P.O. Box 3621, Portland, OR 97208.)

Wallis, J. 1961. An evaluation of the McKenzie River Salmon Hatchery. Oregon Fish Commission. Research Laboratory rep. Clackamas.

Wallis, J. 1962. An evaluation of the Willamette River Salmon Hatchery. Oregon Fish Commission. Research Laboratory rep. Clackamas.

Wallis, J. 1963a. An evaluation of the Big Creek Salmon Hatchery. Oregon Fish Commission. Research Laboratory rep. Clackamas.

Wallis, J. 1963b. An evaluation of the Klaskanine Salmon Hatchery. Oregon Fish Commission. Research Laboratory rep. Clackamas.

Wallis, J. 1963c. An evaluation of the North Santiam River Salmon Hatcheries. Oregon Fish Commission. Research Laboratory rep. Clackamas.

Waples, R. S. 1990. Conservation genetics of Pacific salmon. I. Temporal changes in allele frequency. Conserv. Biol. 4:144–156.

WDF (Washington Dept. Fisheries). 1951. Planning reports. Lower Columbia River Fisheries Development Program. Washington. Unpubl. manuscr. Washington Dept. Fisheries, Olympia.

WDF and WDG (Washington Dept. Fisheries and Washington Dept. Game). 1946. A report on the fisheries problems in connection with the proposed hydro-electric development of the Cowlitz River, Lewis County, Washington. Washington Dept. Fisheries, Olympia.

WDF, WDG, and WWTIT (Washington Dept. Fisheries, Washington Dept. Game, and Western Washington Treaty Indian Tribes). 1993. 1992 Washington salmon and steelhead stock inventory (SASSI). Washington Dept. Fisheries, Olympia.

WDFG (Washington Dept. Fish and Game). 1902. Thirteenth annual report of the State Fish Commissioner to the Governor of the State of Washington, Seattle.

WDFG (Washington Dept. Fish and Game). 1907. Sixteenth and seventeenth annual reports of the State Fish Commission to the Governor of the State of Washington. 1905–1906. Washington Dept. Fish and Game, Olympia.

WDFG (Washington Dept. Fish and Game). 1913. Twenty-second and twenty-third annual reports of the State Fish Commission to the Governor of the State of Washington. 1911–1912. Washington Dept. Fish and Game, Olympia.

WDFG (Washington Dept. Fish and Game). 1916. Twenty-fourth and twenty-fifth annual reports of the State Fish Commission to the Governor of the State of Washington from April 1, 1913 to March 31, 1915. Washington Dept. Fish and Game, Olympia.

WDFG (Washington Dept. Fish and Game). 1918. Twenty-sixth and twenty-seventh annual reports of the State Fish Commission to the Governor of the State of Washington from April 1, 1914 to March 31, 1917. Washington Dept. Fish and Game, Olympia.

WDFG (Washington Dept. Fish and Game). 1928. Thirty-sixth and thirty-seventh annual reports of the State Dept. of Fisheries and Game, Division of Fisheries from April 1, 1925 to March 31, 1927. Washington Dept. Fish and Game, Olympia.

WDFW (Washington Dept. Fish and Wildlife). 1997. Preliminary stock status update for steelhead in the lower Columbia River, Washington. Unpubl. manuscr. (Available from WDFW, 600 Capital Way N., Olympia, WA 98501.)

WDFW (Washington Dept. Fish and Wildlife). 2000. Fish passage barrier and surface water diversion screening assessment and prioritization manual. Washington Dept. Fish and Wildlife Habitat Program, Environmental Restoration Division, Salmonid Screening, Habitat Enhancement, and Restoration (SSHEAR) Section, Olympia.

WDFW (Washington Dept. Fish and Wildlife). 2003. Washington salmonid stock inventory (SaSI). Washington Dept. Fish and Wildlife, Olympia.

Weitkamp, L., P. Busby, B. Iwamoto, O. Johnson, R. Kope, P. Lawson, G. Matthews, P. McElhany, R. Reisenbichler, M. Schiewe, D. Teel, T. Wainwright, B. Waknitz, R. Waples, J. Williams. 2001. Status review update for Lower Columbia River coho salmon. Unpubl. manuscr. (Available from L. Weitkamp, NWFSC, Conservation Biology Division, Hatfield Marine Science Center, 2032 SE OSU Dr., Newport, OR 97303.)

Weitkamp, L. A., T. C. Wainright, G. J. Bryant, G. B. Milner, D. J. Teel, T. G. Kope, and R. S. Waples. 1995. Status review of coho salmon from Washington, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-24.

Whisler, J., B. Morgan, and K. Melcher. 1998. Oregon lower Columbia River fall and winter Chinook spawning ground surveys, 1948–1997. (Available from ODFW, 2501 SW First Ave., P.O. Box 59, Portland, OR 97207.)

Wilcox, W. A. 1898. Notes of the fisheries of the Pacific Coast in 1895. Report of the commissioner for the year ending June 30, 1896. U.S. Bureau of Fisheries, Washington, DC.

Wilkes, C. E. 1845. Narrative of the United States exploring expedition. During the years 1838, 1839, 1840, 1841, 1842. Volume 4. Lea and Blanchard, Philadelphia.

Willis, R. A. 1962. Gnat Creek weir studies. Final rep., Oregon Fish Commission, Research Division, Clackamas.

Willis, C. F., S. P. Cramer, D. Cramer, M. Smith, T. Downey, and R. Montagne. 1995. Status of Willamette River spring Chinook salmon in regards to the federal Endangered Species Act. Part 1. Portland General Electric Company and Eugene Water and Electric Board. (Available from S. P. Cramer & Associates, Inc. 300 SE Arrow Creek Lane, Gresham, OR 97080.)

Willis, R. A., M. D. Collins, and R. E. Sams. 1960. Environmental survey report pertaining to salmon and steelhead in certain rivers of eastern Oregon and the Willamette River and its tributaries. Part II. Survey reports of the Willamette River and its tributaries. Oregon Fish Commission, Research Division, Clackamas.

Appendix A: Salmonid Hatchery Releases for the Lower Columbia River and Upper Willamette River ESUs

The sources for Tables A-1 through A-5 are NRC (1996) and Good et al. (2005).

Chinook Salmon

Table A-1. Hatchery releases for the Lower Columbia River Chinook Salmon ESU fall runs.

				Total ESU releases	
Watershed	Duration[a]	Year	Broodstock origination	Inside	Outside
Chinook River	1964, 1971		Big Creek Hatchery	1,150,865	
	1981–1993		Chinook Hatchery	8,403,778	
	1989	1	Elochoman Hatchery	124,700	
	1970	1	Issaquah Creek Hatchery		97,511
	1982	1	Lower Columbia River Hatchery (WA)	830,589	
	1953, 1988–1989		Lower Kalama Hatchery and Kalama Falls Hatchery[c]	1,105,550	
	1965–1983	4	Spring Creek NFH	3,146,137	
	1970–1980	3	Toutle River Hatchery	1,177,853	
	1972–1979	4	Unknown[d]	2,473,102	
	1987, 1990	3	Washougal River Hatchery	1,584,500	
	Totals			19,997,074	97,511
Deep River	1980, 1993	2	Cowlitz Hatchery/ Kalama River[c]	960,456	
	Totals			960,456	
Grays River	1968–1983	9	Abernathy NFH	8,795,726	
	1977–1984	2	Big Creek Hatchery	1,406,632	
	1981–1984	3	Bonneville Dam Hatchery	4,970,683	
	1980, 1986	2	Cowlitz Hatchery	4,018,755	
	1967–1989	5	Elochoman Hatchery	3,434,258	
	1966–1993	26	Grays River Hatchery	22,542,491	
	1986	1	Grays River Hatchery/ Elochoman Hatchery[c]	102,000	
	1981, 1993	2	Kalama River/ Grays River Hatchery[c]	190,073	
	1981	1	Klickitat Hatchery	225,134	
	1981, 1982	2	Lower Columbia River (WA)	5,768,516	
	1957, 1966	2	Lewis River Hatchery	1,400,329	
	1953, 1954	2	Lower Kalama Hatchery	399,997	
	1968–1993	8	Lower Kalama Hatchery	9,578,125	

Table A-1 continued. Hatchery releases for the Lower Columbia River Chinook Salmon ESU fall runs.

				Total ESU releases	
Watershed	**Duration[a]**	**Years[b]**	**Broodstock origination**	Inside	Outside
Grays River continued	1987	1	Skamokawa Creek	107,000	
	1953–1992	15	Spring Creek NFH	17,437,295	
	1980	1	Toutle Hatchery	1,951,871	
	1984–1987	4	Washougal Hatchery	1,572,395	
	Totals	1		83,901,280	
Skamokawa Creek	1958	3	Klickitat Hatchery	237,380	
	Totals			237,380	
Elochoman River	1966–1978		Abernathy NFH	709,546	
			Basin Stocks	2,928,957	
	1964	1	Big Creek Hatchery	2,049,806	
	1980	1	Cowlitz Hatchery	2,310,420	
	1974	1	Elk River Hatchery		30,070
	1956–1993	26	Elochoman Hatchery	78,855,922	
	1986	1	Elochoman Hatchery/ Kalama River[c]	1,194,177	
	1980	1	Elochoman Hatchery/ Toutle Hatchery[c]	2,411,131	
	1956	1	Green River Hatchery	67,484	
	1975–1993	5	Kalama Falls Hatchery	5,392,994	
	1958, 1982	2	Klickitat Hatchery	1,759,005	
	1982	1	Lower Columbia River (WA)	1,300,072	
	1956–1966	3	Lewis River Hatchery	3,007,696	
	1953–1954	2	Lower Kalama Hatchery	400,080	
	1971	1	Nemah Hatchery	132,750	
	1987	1	Skamokawa Creek	511,300	
	1953–1967	12	Spring Creek NFH	14,699,029	
	1975, 1980	2	Toutle Hatchery	2,337,931	
	1974	1	Trask Hatchery		38,974
	1955	1	Unknown[d]	3,758	
	1988	1	Washougal Hatchery	418,000	
	Totals			120,490,058	69,044
Abernathy Creek	1974–1994	21	Abernathy NFH	29,120,068	
	1977	1	Spring Creek NFH	5,090	
	1960–77	18	Unknown[d]	15,273,548	
	Totals			44,398,706	
Columbia River RM 29	1971, 1977, 1979	3	Abernathy NFH	3,481,359	
	1979	1	Carson NFH	966,240	
	1979	1	Cascade Hatchery	25,617	
	1980	1	Cowlitz Hatchery	7,565,885	
	1957, 1958	2	Klickitat Hatchery	731,595	
	1980	1	Lower Columbia River (WA)[c]	50,414	
	1968	1	Lower Kalama Hatchery	77,693	
	1971	1	Priest Rapids Hatchery		1,804,000
	1957–1969	4	Spring Creek NFH	5,183,331	
	1969	1	Toutle Hatchery	500,396	
	1990, 1991	2	Tule stocks[c]	1,000	

Table A-1 continued. Hatchery releases for the Lower Columbia River Chinook Salmon ESU fall runs.

Watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases Inside	Total ESU releases Outside
Columbia River RM 29 continued	1960–1985	10	Unknown[d]	471,660,276	
	1971	1	Wells Hatchery		1,784,000
	1979	1	Willard NFH	148,575	
	Totals			490,392,381	3,588,000
Cowlitz River	1981	1	Big Creek Hatchery (OR)	807,000	
	1981	1	Bonneville Hatchery	4,217,937	
	1961–1993	27	Cowlitz Hatchery	152,192,405	
	1953–1981	3	Lower Kalama Hatchery	2,830,087	
	1953, 1955	2	Spring Creek NFH	586,673	
	1968, 1979	2	Toutle Hatchery	1,008,357	
	1978, 1990	2	Washougal Hatchery	2,606,330	
	1952	1	Carson NFH	24,506	
	Totals			164,273,295	
Toutle River	1967	1	Big Creek Hatchery (OR)	463,459	
	1952	1	Carson NFH	1,164,070	
	1991, 1993	2	Cowlitz Hatchery	641,382	
	1989	1	Elochoman Hatchery	868,700	
	1988	1	Grays River Hatchery	3,937,000	
	1966–1975	4	Green River Hatchery	8,024,234	
	1957	1	Lewis River Hatchery	348,799	
	1953–1993	5	Lower Kalama Hatchery/ Kalama Falls Hatchery[c]	6,880,135	
	1953–1960, 1993	8	Spring Creek NFH	9,400,907	
	1953–1993	28	Toutle Hatchery	55,647,988	
	1964, 1965	2	Unknown[d]	6,479,628	
	1987, 1993	2	Washougal Hatchery	987,600	
	1960	1	Willard NFH	795,932	
	Totals			95,639,834	
Kalama River	1978	1	Big Creek Hatchery (OR)	88,568	
	1977, 1982	2	Bonneville Hatchery	734,074	
	1958–1993	31	Kalama Falls Hatchery	169,592,860	
	1956	1	Lewis River Hatchery	661,447	
	1952–1984	28	Lower Kalama Hatchery	51,969,100	
	1976–1981	3	Priest Rapids Hatchery		280,209
	1972	1	Ringold Hatchery		190,316
	1978–1984	6	Snake River		2,194,002
	1959, 1960	2	Spring Creek NFH	5,168,368	
	1978, 1979	2	Toutle Hatchery	4,286,684	
	1980	1	Tucannon River		183,034
	Totals			232,684,135	2,847,561
Lewis River	1979	1	Grays River Hatchery	23,567	
	1952–1993	30	Lewis River Hatchery	15,283,070	
	1954	1	Lower Kalama Hatchery	41,128	
	1954, 1974	2	Lower Kalama Hatchery	274,978	
	1961–1979	3	Speelyai Hatchery	1,315,749	
	1959–1981	3	Spring Creek NFH	3,121,717	
	1948–1951	4	Unknown[d]	510,252	
	1984, 1985	2	Upriver brights[c]		1,187,029

Table A-1 continued. Hatchery releases for the Lower Columbia River Chinook Salmon ESU fall runs.

Watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases Inside	Total ESU releases Outside
Lewis River continued	1980	1	Washougal Hatchery	28,267	
	Totals			20,598,728	1,187,029
Salmon Creek	1969	1	Lower Kalama Hatchery	3,000	
	1969	1	Toutle Hatchery	3,000	
	Totals			6,000	
Washougal River	1967, 1986	2	Abernathy NFH	2,239,237	
	1971	1	Big Creek Hatchery (OR)	856,650	
	1977–1983	3	Bonneville Hatchery	4,437,019	
	1980, 1986	2	Cowlitz Hatchery	7,489,190	
	1986	1	Elochoman Hatchery	75,600	
	1985	1	Grays River Hatchery	79,750	
	1966–1985	7	Kalama Falls Hatchery	8,996,220	
	1981	1	Lower Columbia River (OR/WA)[c]	5,509,822	
	1955–1966	4	Lewis River Hatchery	2,449,402	
	1953	1	Lower Kalama Hatchery	175,000	
	1989	1	Priest Rapids Hatchery		1,216,800
	1958–1965	8	Spring Creek NFH	21,186,454	
	1992	1	Spring Creek/Toutle Hatchery[c]	5,522,700	
	1969–1980	5	Toutle Hatchery	7,451,494	
	1979	1	Toutle Hatchery/Washougal Hatchery[c]	5,342,147	
	1964, 1967	2	Unknown[d]	4,776,903	
	1959–1993	24	Washougal Hatchery	83,605,011	
	Totals			160,192,599	1,216,800
Columbia River RM 141	1992, 1993	2	Bonneville Hatchery	857,601	
	1978–1988	9	Lower Columbia River (WA)	653,305	
	1992	1	Little White Salmon NFH (URB)		1,628,987
	1977	1	Priest Rapids Hatchery		241,000
	1977	1	Snake River (WA)		3,326
	1955–1979	4	Unknown[d]	1,510,096	
	1982	1	Washougal Hatchery	49,034	
	Totals			3,070,036	1,873,313
Hamilton Creek	1977	1	Spring Creek NFH	50,160	
	Totals			50,160	
Wind River	1952–1968	11	Unknown[d]	54,803,553	
	1976	1	Carson NFH	668,692	
	Totals			55,472,245	
Spring Creek NFH	1979–1984	5	Abernathy NFH	29,113,699	
	1985–1991	7	Bonneville Hatchery	44,276,578	
	1991	1	Clackamas River (early)	3,292,304	
	1987, 1988	2	Lower Columbia River (WA)[c]	10,771,008	
	1987	1	Little White Salmon NFH	973,610	
	1987	1	Priest Rapids Hatchery		1,100,000
	1973–1994	18	Spring Creek NFH	228,514,095	
	1988	1	Tule stock[c]	1,084,816	
	1988	1	Unknown[d]	217,350	
	Totals			318,243,460	1,100,000

Table A-1 continued. Hatchery releases for the Lower Columbia River Chinook Salmon ESU fall runs.

Watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases Inside	Total ESU releases Outside
Little White Salmon River	1985		Bonneville Hatchery	203,996	
	1994		Carson NFH	1,797,922	
	1976–1985	9	Little White Salmon NFH		
	1978, 1994	2	Spring Creek NFH	5,937,253	
	1983	1	Tule stock[c]	8,430,082	
	1951–1979	16	Unknown[d]	152,096,514	
	1983–1993	11	Upriver brights[c]		20,708,020
	Totals			255,114,904	20,708,020
Columbia River RM 164	1994	1	Carson NFH	325	
	1981	1	Little White Salmon NFH	37,400	
	1979	1	Unknown[d]	265,472	
	Totals			303,197	
Big White Salmon River	1976–1984	4	Abernathy NFH	8,231,545	
	1979	1	Lower Columbia River (WA)	101,896	
	1981	1	Little White Salmon NFH	1,084,839	
	1954, 1979	2	Spring Creek NFH	3,082,047	
	1950–1979	18	Unknown[d]	74,351,025	
	1979	1	Willard NFH	98,597	
	Totals			86,949,949	
Skipanon River	1987	1	Klaskanine Hatchery	15,500	
	Totals			15,500	
Lewis and Clark River	1951, 1952	2	Lower Columbia River (OR)	146,230	
	1950	1	Unknown[d]	61,600	
	Totals			207,830	
Youngs River	1988, 1991	2	Big Creek Hatchery	621,005	
	1986	1	Bonneville Hatchery	26,397	
	1989–1992	3	Cole Rivers Hatchery		475,352
	1961, 1989	2	Klaskanine Hatchery	122,625	
	Totals			770,027	475,352
Klaskanine River	1979	1	Abernathy NFH	56,260	
	1950–1989	10	Big Creek Hatchery	33,173,221	
	1931	1	Big White Salmon River	737,702	
	1929, 1936	2	Bonneville Hatchery	5,955,830	
	1978–1986	9	Bonneville Hatchery	32,704,826	
	1975	1	Chetco River		41,079
	1983–1988	6	Cole Rivers Hatchery		572,601
	1925–1978	13	Klaskanine Hatchery	16,042,881	
	1927, 1928	2	Klaskanine Hatchery/USBF[c]	2,145,108	
	1960, 1962	1	Klaskanine Hatchery/ Willard NFH[c]	1,993,540	
	1932–1966	8	Lower Columbia River (OR)[c]	11,302,002	
	1933, 1942	2	Lower Columbia River (OR)/ Willamette Hatchery[c]		7,371,078
	1931–1939	4	Lower Columbia River (WA)/ Willamette Hatchery[c]	9,209,991	
	1946, 1958	2	Oxbow Hatchery	860,537	
	1959	1	Spring Creek NFH	965,428	

Table A-1 continued. Hatchery releases for the Lower Columbia River Chinook Salmon ESU fall runs.

Watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases	
				Inside	Outside
Klaskanine River continued	1975	1	Trask Hatchery		39,369
	1923–1977	5	Unknown[d]	13,334,263	
	Totals			119,271,598	17,234,118
Big Creek	1944–1993	31	Big Creek Hatchery	123,924,819	
	1946, 1948	2	Big Creek Hatchery/ Bonneville Hatchery[c]	1,573,622	
	1959, 1960	2	Big Creek Hatchery/ Willard NFH[c]	3,171,214	
	1943	1	Bonneville Hatchery	338,500	
	1981–1987	3	Bonneville Hatchery	14,313,343	
	1984–1994	11	Cole Rivers Hatchery		3,519,553
	1941	1	McKenzie River Hatchery		1,290,875
	1950, 1968–1976	9	Unknown[d]	54,142,951	
	1942	1	Willamette Hatchery		568,500
	Totals			197,464,449	5,378,928
Gnat Creek	1952	1	Big Creek Hatchery	29,520	
	1954–1957	4	Bonneville Hatchery	150,769	
	1957, 1958	2	Trask Hatchery		52,220
	Totals			180,289	52,220
Clatskanie River	1951–1953	3	Big Creek Hatchery	208,200	
	Totals			208,200	
Mid-Columbia River (OR)	1979–1984	5	Abernathy NFH	965,896	
	1964, 1987	2	Big Creek Hatchery	1,949,466	
	1978–1983	4	Bonneville Hatchery	5,806,919	
	1939, 1954	2	Bonneville Hatchery/ Oxbow Hatchery[c]	2,714,025	
	1965	1	Carson NFH	411,965	
	1978, 1981	2	Cascade Hatchery	5,625,444	
	1978	1	Deschutes River (OR)		73,092
	1910	1	Lower Columbia River (OR)	15,170,324	
	1981	1	Little White Salmon NFH	25,933	
	1940, 1941, 1963	3	Oxbow Hatchery	5,246,079	
	1977–1980	3	Spring Creek NFH	3,359,797	
	1966	1	Tule stock	377,520	
	1940, 1969, 1970		Unknown[d]	1,119,151	
	1987–1991	5	Upriver brights[c]		1,804,107
	1966	1	Willamette Hatchery		11,025
	Totals			42,772,519	1,888,224
Scappoose Creek	1952, 1953	2	Big Creek Hatchery	69,450	
	Totals			69,450	
Clackamas River	1952–1954	3	Bonneville Hatchery	2,160,060	
	1981	1	Bonneville Hatchery	4,080	
	1965	1	Lower Columbia River (OR)	921,545	
	1955, 1965	2	Oxbow Hatchery	1,214,851	

Table A-1 continued. Hatchery releases for the Lower Columbia River Chinook Salmon ESU fall runs.

Watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases Inside	Total ESU releases Outside
Clackamas River continued	1960	1	Spring Creek NFH	1,012,607	
	1960–1972	7	Unknown[d]	16,585,148	
	Totals			21,898,291	
Eagle Creek	1938, 1953	2	Bonneville Hatchery	630,000	
	1961, 1967	2	Cascade Hatchery	10,923,441	
	1949, 1960–1965	4	Lower Columbia River (OR)[c]	20,420,776	
	1962	1	Lower Columbia River (OR)/ Mount Shasta Hatchery[e]		4,853,922
	1929	1	Lower Columbia River (OR)/ Willamette Hatchery[e]		347,000
	1934–1965	7	Unknown[d]	978,056	
	Totals			32,952,273	5,200,922
Sandy River	1938–1954	3	Bonneville Hatchery	4,057,279	
	1966	1	Cascade Hatchery	174,648	
	1945–1965	8	Lower Columbia River (OR)[c]	18,696,769	
	1960	1	Lower Columbia River (OR/WA)[c]	2,919,481	
	1955–1964	5	Sandy Hatchery	2,207,995	
	1934–1977	12	Unknown[d]	4,758,926	
	Totals			32,815,098	
Multnomah Creek	1951	1	Lower Columbia River (OR)[c]	50,400	
	1953	1	Oxbow Hatchery	152,064	
	Totals			65,832,660	
Tanner Creek	1990–1992	3	Big Creek Hatchery	14,585,543	
	1928–1966	14	Bonneville Hatchery	106,965,953	
	1977–1993	14	Bonneville Hatchery	130,296,696	
	1912–1961	14	Bonneville Hatchery mix[c]	80,763,654	
	1945	1	Bonneville Hatchery and Rock Creek Hatchery[e]		4,601,000
	1958	1	Bonneville Hatchery/ Trask Hatchery[e]		4,225,234
	1965	1	Bonneville Hatchery/unknown[c,d]	9,601,000	
	1940–1967	6	Lower Columbia River (OR)	34,203,415	
	1955–1962	3	Lower Columbia River (OR/WA)[c]	27,961,223	
	1979–1981	3	Snake River (OR)[c]		512,440
	1957	1	Trask Hatchery		3,756,712
	1986–1991	3	Tule stock[c]	2,894,909	
	1918–1977	21	Unknown[d]	206,351,204	
	1978–1993	16	Priest Rapids Hatchery		46,736,964
	Totals			613,623,597	59,832,350
Herman Creek	1918	1	Bonneville Hatchery	3,937,598	
	1928–1954	4	Lower Columbia River (OR)[c]	4,402,471	
	1958	1	Lower Columbia River (OR/WA)[c]	2,348,962	
	1951–1967	12	Oxbow Hatchery	39,619,232	
	1925–1968	3	Unknown[d]	8,998,412	
	Totals			59,306,675	

Table A-1 continued. Hatchery releases for the Lower Columbia River Chinook Salmon ESU fall runs.

				Total ESU releases	
Watershed	**Duration**[a]	**Years**[b]	**Broodstock origination**	Inside	Outside
Hood River	1938–1954	7	Bonneville Hatchery	1,473,180	
	1951	1	Lower Columbia River (OR)[c]	503,200	
	1934–1937	4	Unknown[d]	680,000	
	Totals			2,656,380	
Fifteenmile Creek	1949	1	Lower Columbia River (OR)[c]	80,500	
	Totals			80,500	

[a] Duration is the time frame of the releases.

[b] Years is the total number of years that fish actually were released within the time frame. The majority of ocean-type, fall and summer Chinook salmon were released as subyearlings. No releases of eggs or fry (<5 g) are included. Data before 1950 are not necessarily complete (NRC 1996).

[c] A mix of two or more stocks from the same area.

[d] Stocks of unknown origin are assumed to be from within the ESU. Fish releases derived from adults returning to that river also are assumed to be native regardless of past introductions, unless the hatchery broodstock is known to be from outside the ESU.

[e] A mix of stocks from different areas.

Table A-2. Hatchery releases for the Lower Columbia River Chinook Salmon ESU spring runs.

				Total ESU releases	
Watershed	**Duration**[a]	**Years**[b]	**Broodstock origination**	Inside	Outside
Grays River	1977	1	Kalama Falls Hatchery	116,800	
	Totals			116,800	
Abernathy Creek	1975	1	Abernathy NFH	91,744	
	1969, 1975		Unknown[d]	90,050	
	Totals			181,794	
Cowlitz River	1968–1993	26	Cowlitz Hatchery	68,063,606	
	1979	1	Little White Salmon NFH	224,590	
	1948–1970	4	Unknown[d]	1,716,588	
	1968, 1969	2	Willamette Hatchery		999,295
	Totals			70,004,784	999,295
Toutle River	1974–1984	7	Cowlitz Hatchery	2,661,471	
	1953	1	Unknown[d]	11,184	
	Totals			2,672,655	
Kalama River	1964	1	Ancient wild stocks	46,657	
	1964, 1966	2	Bitter Creek	147,074	
	1967, 1981	2	Cowlitz Hatchery	525,909	
	1969–1993	25	Kalama Falls Hatchery	9,084,007	
	1965	1	Klaskanine Hatchery	195,800	
	1972, 1973	2	Lower Columbia River mix[c]	99,175	
	1978	1	Little White Salmon NFH	136,989	
	1964	1	Sherwood Creek	132,054	
	Totals			10,367,665	
Lewis River	1973–1981	4	Carson NFH		702,708
	1972–1987	9	Cowlitz Hatchery	2,476,235	
	1981–1993	5	Kalama Falls Hatchery	2,415,550	
	1975, 1976	2	Klickitat Hatchery		203,660
	1977–1993	11	Lewis River Hatchery	6,999,862	
	1980	1	Lewis River Hatchery/ Kalama River[c]	807,408	
	1977–1982	4	Speelyai Hatchery	2,011,325	
	1948–1951	4	Unknown[d]	192,943	
	Totals			14,903,323	906,368
Columbia River (Beacon Rock)	1978–1988	8	Lower Columbia River (WA)[c]	959,953	
	1973–1990	14	Snake River (WA)[c]		1,412,152
	Totals			959,953	1,412,152
North Hatchery Bonneville Dam (bypass system tests)	1978	1	Carson NFH		76,060
	1980	1	Kooskia Hatchery		62,300
	1978, 1980	2	Rapid River Hatchery		35,000
	1973–1977	4	Snake River (WA)		425,801
	Totals				599,161
Columbia River RM 164	1974, 1994	2	Carson NFH		5,350
	Totals				5,350
Wind River	1976	1	Abernathy NFH	82,697	
	1979	1	Lower Columbia River (WA)[c]	45,014	
	1956–1975	19	Unknown[d]	27,098,613	
	Totals			27,226,324	
Spring Creek NFH	1993	1	Kalama Falls Hatchery/ Ringold Hatchery/ Carson NFH[e]		669,400
	Totals				669,400

Table A-2 continued. Hatchery releases for the Lower Columbia River Chinook Salmon ESU spring runs.

				Total ESU releases	
Watershed	**Duration[a]**	**Years[b]**	**Broodstock origination**	Inside	Outside
Little White Salmon River	1985	1	Abernathy NFH	946,959	
	1986–1994	7	Carson NFH		9,819,820
	1976–1989	13	Little White Salmon NFH		13,759,232
	1966–1975	8	Unknown[d]	4,807,330	
	Totals			5,754,289	23,579,052
Big White Salmon River	1986–1994	8	Carson NFH		4,880,790
	1982	1	Cowlitz Hatchery	149,071	
	1991	1	Little White Salmon NFH		942,804
	Totals			149,071	5,823,594
Youngs River	1991, 1992	2	Clackamas River early		242,534
	1994	1	Marion Forks Hatchery		301,361
	1989–92	4	Willamette Hatchery		1,048,266
	Totals				1,592,161
Klaskanine River	1931	1	Big White Salmon River		158,643
	1991	1	Clackamas River (early)		119,627
	1994	1	Marion Forks Hatchery		109,974
	1928–1934	3	McKenzie River Hatchery		4,404,514
	1994	1	Santiam River		100,000
	1930	1	Trask Hatchery		953,400
	1920–1924	3	Unknown[d]	14,548,862	
	1989–1992	3	Willamette Hatchery		577,944
	1927	1	Willamette Hatchery mixed[c]		2,101,000
	Totals			14,548,862	8,525,102
Big Creek	1985	1	Clackamas River (early)		20,449
	Totals				20,449
Mid-Columbia River (OR)	1980	1	Carson NFH		44,344
	1991	1	Lookingglass Hatchery		8,398
	1946	1	Unknown[d]	605,750	
	Totals			605,750	70,651
Scappoose Creek	1930		Marion Forks Hatchery/ Trask Hatchery[e]		60,000
	Totals				60,000
Clackamas River	1975	1	Carson NFH		289,710
	1977, 1978	2	Cascade Hatchery	195,203	
	1985, 1992	2	Clackamas River		232,947
	1978–1994	14	Clackamas River (early)		11,595,754
	1979	1	Clackamas River (late)		98,461
	1975–1987	5	Eagle Creek NFH		1,294,822
	1978	1	Marion Forks Hatchery		188,261
	1979–1988	4	Santiam River		1,653,231
	1939–1989	30	Unknown[d]	25,649,266	
	1982–1989	6	Willamette Hatchery		4,319,098
	Totals			25,844,469	19,672,284
Sandy River	1990	1	Bonneville Hatchery	258,629	
	1978	1	Carson NFH		57,861
	1979–1993	11	Clackamas River (early)		3,067,038

Table A-2 continued. Hatchery releases for the Lower Columbia River Chinook Salmon ESU spring runs.

Watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases Inside	Total ESU releases Outside
Sandy River continued	1948, 1949	2	Lower Columbia River (OR)[c]	441,169	
	1942, 1959	2	McKenzie River Hatchery		1,066,949
	1952–1960	7	Sandy Hatchery	2,192,294	
	1939–1947	4	Sandy Hatchery/ McKenzie River Hatchery[e]		3,903,646
	1957	1	Sandy Hatchery/ Willamette Hatchery[e]		40,475
	1979, 1981, 1986	3	Santiam River		305,729
	1920–1984	8	Unknown[d]	2,007,960	
	1973, 1974	2	USFWS-unspecified	37,483	
	1982–1988	4	Willamette Hatchery		1,153,877
	Totals			4,937,535	9,595,575
Tanner Creek	1925–1945	8	Bonneville Hatchery/ Willamette Hatchery[e]		27,815,501
	1930	1	Marion Forks Hatchery/ Trask Hatchery[e]		1,710,240
	1920–1922	3	Unknown[d]	15,861,909	
	Totals			15,861,909	29,525,741
Herman Creek	1920–1935	3	Bonneville Hatchery	7,119,680	
	1924	1	Oxbow Hatchery	3,963,540	
	1921–1972	19	Unknown[d]	50,327,069	
	Totals			61,410,289	
Hood River	1919	1	Bonneville Hatchery	291,860	
	1946–1947	2	Oxbow Hatchery	680,750	
	1984–1985	2	Clackamas Hatchery		53,920
	1985–1992	6	Carson Hatchery		871,406
	1993–1994	2	Deschutes River		69,127
	Totals			972,610	994,453
	Totals for ESU #9			3,607,547,163	226,965,239

[a] Duration is the time frame of the releases.

[b] Years is the total number of years that fish actually were released within the time frame. The majority of spring Chinook salmon were released as yearling smolts. No releases of eggs or fry (<5 g) are included. Data before 1950 are not necessarily complete (NRC 1996).

[c] A mix of two or more stocks from the same area.

[d] Stocks of unknown origin are assumed to be from within the ESU. Fish releases derived from adults returning to that river also are assumed to be native regardless of past introductions, unless the hatchery broodstock is known to be from outside the ESU.

[e] A mix of stocks from different areas.

Table A-3. Hatchery releases for the Upper Willamette River Chinook Salmon ESU.

				Total ESU releases	
Watershed	**Duration**[a]	**Years**[b]	**Broodstock origination**	Inside	Outside
Clackamas River	1975	1	Carson NFH	289,710	
	1977, 1978	2	Cascade Hatchery		195,203
	1985, 1992	2	Clackamas River	232,947	
	1978–1994	14	Clackamas River (early)	11,595,754	
	1979	1	Clackamas River (late)	98,461	
	1975–1987	5	Eagle Creek NFH	1,294,822	
	1978	1	Marion Forks Hatchery	188,261	
	1979–1988	4	Santiam River	1,653,231	
	1939–1989	30	Unknown[c]	25,649,266	
	1982–1989	6	Willamette Hatchery	4,319,098	
	Totals			45,321,550	195,203
Molalla River	1991	1	Clackamas River (early)	469,890	
	1964	1	McKenzie River Hatchery	72,975	
	1981–1992	3	Santiam River	2,032,335	
	1964–1965	2	Unknown[c]	375,209	
	1982–1992	10	Willamette Hatchery	7,520,897	
	Totals			10,471,306	
Pudding River	1964	1	McKenzie River Hatchery	62,550	
	1983–1985	3	Willamette Hatchery	453,479	
	Totals			516,029	
Luckiamute River	1968	1	Unknown[c]	88,128	
	Totals			88,128	
Santiam River	1965–1982	7	Carson NFH		1,416,271
	1980, 1981	2	Clackamas River (early)	752,939	
	1967–1975	4	Hagerman NFH	645,175	645,175
	1923–1994	53	Marion Forks Hatchery	87,932,370	
	1936, 1937	2	Marion Forks Hatchery/ McKenzie River Hatchery[d]	8,441,800	
	1961–1978	7	McKenzie River Hatchery	1,009,442	
	1941, 1948	2	McKenzie River Hatchery/ Santiam River[d]	1,663,717	
	1932–1994	46	Santiam River	61,605,990	
	1963, 1964	2	Santiam River/ Willamette Hatchery[d]	1,989,604	
	1962	1	Spring Creek NFH		191,298
	1918–1981	26	Unknown[c]	16,976,462	
	1981–86	6	Willamette Hatchery	10,566,693	
	Totals			191,584,192	2,252,744
Willamette River	1952, 1962–1967	4	Marion Forks Hatchery	343,676	
	1949, 1978	2	McKenzie Hatchery	50,003	
	1955	1	McKenzie Hatchery/ Willamette Hatchery[d]	1,173,991	
	1953, 1987	2	Santiam River	420,240	
	1916–1977	14	Unknown[c]	12,567,419	
	1955–1967	7	Willamette Hatchery	9,457,376	

Table A-3 continued. Hatchery releases for the Upper Willamette River Chinook Salmon ESU.

Watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases Inside	Total ESU releases Outside
Willamette River continued	1979–1992	11	Willamette Hatchery	10,089,414	
	Totals			34,102,119	
Calapooia River	1981, 1985	2	Santiam River	46,188	
	1982–1985	4	Willamette Hatchery	500,522	
	Totals			546,710	
McKenzie River	1969–1975	7	Hagerman NFH		1,424,563
	1966	1	Marion Forks Hatchery	47,418	
	1952	1	Marion Forks Hatchery/ McKenzie Hatchery	1,125,897	
	1966	1	Marion Forks Hatchery/ Willamette Hatchery[d]	3,030	
	1902–1969	62	McKenzie Hatchery	192,671,426	
	1978–1994	17	McKenzie Hatchery	15,997,516	
	1951–1965	4	McKenzie Hatchery/ Willamette Hatchery[d]	1,309,620	
	1972–1991	4	Santiam River	288,820	
	1918–1977	17	Unknown[c]	4,144,703	
	1966–1984	4	Willamette Hatchery	1,318,574	
	Totals			216,907,004	1,424,563
Middle Fork Willamette River	1974	1	Hagerman NFH		41,379
	1920–1976	4	Lower Columbia River (OR)/ Willamette Hatchery[d]		1,885,217
	1983, 1990	1	Marion Forks Hatchery	290,174	
	1979–1990	4	McKenzie Hatchery	1,038,153	
	1928, 1952	2	McKenzie Hatchery/ Willamette Hatchery	8,310,778	
	1958	1	Nehalem River/ Willamette Hatchery[d]		19,962
	1978–1991	7	Santiam River	3,439,419	
	1952–1966	6	Santiam River/ Willamette Hatchery	6,984,701	
	1950–1977	9	Unknown[c]	17,681,493	
	1958	1	Wenatchee River/ Willamette Hatchery[d]		67,827
	1921–1994	59	Willamette Hatchery	17,934,084	
	Totals			55,678,802	2,014,385
Molalla River	1965, 1967	2	Big Creek Hatchery[e]		1,397,158
	1958	1	Bonneville Hatchery/ Trask Hatchery[d, e]		100,000
	1978	1	Cascade Hatchery[e]		2,111,600
	1959, 1960	2	Lower Columbia River (OR)/ Willamette Hatchery[d, e]		401,858
	1967	1	Oxbow Hatchery[e]		500,132
	1957	1	Trask River (Bonneville Hatchery)[e]		75,000
	1964–76	11	Unknown[c, e]		9,310,823
	Totals				13,896,571

Table A-3 continued. Hatchery releases for the Upper Willamette River Chinook Salmon ESU.

Watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases Inside	Total ESU releases Outside
Luckiamute River	1974, 1976	2	Unknown[c, e]		1,945,098
	Totals				1,945,098
Marys River	1970	1	Oregon coast[e]		176,400
	Totals				176,400
Santiam River	1966	1	Big Creek Hatchery[e]		1,000,848
	1921, 1951	2	Bonneville Hatchery/ Oxbow Hatchery[d, e]		1,669,444
	1966	1	Cascade Hatchery[e]		350,000
	1956, 1957	2	Klickitat Hatchery[e]		175,974
	1958, 1966	2	Oxbow Hatchery[e]		599,911
	1964–1976	11	Unknown[c, e]		54,236,434
	Totals				58,032,611
Willamette River	1953–1956	4	Bonneville Hatchery[e]		2,922,337
	1977–1993	16	Bonneville Hatchery[e]		88,960,581
	1949	1	Bonneville Hatchery/ Trask Hatchery[d, e]		8,776
	1970	1	Oregon coast[e]		14,560
	1965–1985	13	Willamette Hatchery[e]		34,294,598
	Totals				126,200,852
McKenzie River	1966	1	Bonneville Hatchery[e]		510,150
	1966	1	Cascade Hatchery[e]		650,454
	1964–1968	3	Unknown[c, e]		3,399,591
	Totals				4,560,195
	Totals for ESU #10:			555,215,840	210,698,622

[a] Duration is the time frame of the releases.

[b] Years is the total number of years that fish actually were released within the time frame. The majority of spring Chinook salmon were released as yearling smolts. The majority of ocean-type, fall and summer Chinook salmon were released as subyearlings. No releases of eggs or fry (<5 g) are included. Data before 1950 are not necessarily complete (NRC 1996).

[c] Stocks of unknown origin are assumed to be from within the ESU. Fish releases derived from adults returning to that river also are assumed to be native regardless of past introductions, unless the hatchery broodstock is known to be from outside the ESU.

[d] A mix of stocks from different areas.

[e] Nonnative fall Chinook salmon.

Steelhead

Table A-4. Hatchery steelhead releases, listed by ESU.

Watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases Inside	Outside	Run[c]
Southwest Washington ESU						
Beaver Creek (WA)	1959–1973	12	Unknown[d]	834,116		na
	1986–2000	3	Elochoman River		86,673	s
	1983	1	Kalama River		10,750	s
	1993	1	North Fork Lewis River		33,840	s
	1968–1981	4	Unknown[d]		90,601	s
	1984–1997	7	Washougal River		1,143,957	s
	1984–1994	8	Skamania Hatchery		1,115,780	s
	1986–1997	6	Beaver Creek (WA, Elochoman)	829,057		w
	1982–1983	2	Bogachiel River	157,038		w
	1982–2000	15	Elochoman Hatchery	1,374,575		w
	1985	1	Green River (WDFW)		19,976	w
	1993	1	Kalama River		19,040	w
	1994–1996	1	Lewis River Hatchery		57,270	w
	1959–1981	19	Unknown[d]	1,232,901		w
	1990	1	Washougal River	4,950		w
	Totals			4,432,637	2,577,887	
Grays River	1993–2000	3	Elochoman Hatchery	125,748		w
	1995–1997	3	Beaver Creek Hatchery	115,975		w
	1995–1999	3	Lewis River Hatchery	78,947		w
	Totals			320,670		
Skamokawa Creek	1996-1997	2	Beaver Creek Hatchery	12,107		w
	1995	1	Lewis River Hatchery	5,100		w
	Totals			17,207		
Big Creek	1968–1975	5	Unknown[d]	312,493		na
	1976–2002	27	Big Creek	2,073,024		w
	1972–1977	4	Unknown[d]	262,244		w
	Totals			3,323,515		
Gnat Creek (OR)	1965, 1966	2	Alsea River and tributaries		405,905	na
	1961	1	Carson NFH		75,273	na
	1961–1964	4	Columbia River (OR, early)		481,114	na
	1971	1	Deschutes River		27,375	na
	1961–1971	9	Cedar Creek Hatchery (OR)		825,522	na
	1961–1966	6	Hood River		375,461	na
	1968	1	Nestucca River		1,498	na
	1971–1973	4	Deschutes River		138,545	s
	1974–1976	3	Foster Reservoir		365,720	s
	1978–1992	15	South Santiam Hatchery		3,311,941	s
	1977	1	Unknown[d]		204,949	s
	1966	1	Alsea River and tributaries		10,268	w
	1976–1992	15	Big Creek	7,077,693		w

Table A-4 continued. Hatchery steelhead releases, listed by ESU.

Watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases Inside	Outside	Run[c]
Southwest Washington ESU continued						
Gnat Creek (OR) continued	1967–1975	9	Cedar Creek Hatchery (OR)		2,509,075	w
	1991–2000	10	Gnat Creek Hatchery	408,360		w
	1982	1	Marion Forks Hatchery		23,492	w
	1777	1	Unknown	354,942		w
	Totals			7,840,995	8,756,138	
Elochoman River	1999	1	Elochoman Hatchery		4,690	s
	1998	1	Skamania Hatchery		24,314	s
	1996	1	Beaver Creek Hatchery	7,100		w
	1999–2001	3	Elochoman Hatchery	322,913		w
	Totals			330,013	25,004	
Klaskanine River	1978–1996	15	Big Creek	875,134		w
	1991–2002	12	Klaskanine Hatchery	651,189		w
	1972–1977	5	Unknown[d]	228,231		w
	1991–1993	2	West Fork Washougal River		42,000	s
	Totals			1,103,365	42,000	
Germany Creek	1995	1	Lewis River Hatchery		5,000	w
	1996–1997	2	Beaver Creek Hatchery	17,498		w
	1998	1	Elochoman Hatchery	6,998		w
	Totals			24,496	5,000	
Coal Creek	1996–1997	2	Beaver Creek Hatchery	9.677		w
	1999	1	Cowlitz Hatchery		1,326	w
	Totals			9,677	1,326	
Trojan Pond	1987–1990	4	Big Creek	240,137		w
	Totals			240,137		
Scappoose Creek	1991–1996	6	Gnat Creek Hatchery	60,353		w
	Totals			60,353		
Lower Columbia River ESU						
Cowlitz River basin						
Coweeman River Pond	1984–2001	15	Elochoman Hatchery		1,077,354	w
	1999	1	Kalama Hatchery	12,240		w
	1995, 1999	2	Lewis River Hatchery	33,650		w
	1995	1	Skamania Hatchery		4,645	w
	1986	1	Mixed coastal	8,927		w
	Totals			54,817	1,081,999	
South Fork Toutle River	1984–1990	4	Washougal River	359,850		s
	1986–1994	5	West Fork Washougal River	379,940		s
	1971–1981	11	Unknown[d]	286,160		s
	1968–1985	2	Beaver Creek	58,079		w
	Totals			1,084,029		

Table A-4 continued. Hatchery steelhead releases, listed by ESU.

Watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases Inside	Total ESU releases Outside	Run[c]
Lower Columbia River ESU continued						
Cowlitz River (Trout)	1976–2001	23	Cowlitz River (WDFW)		6,382,923	s
	1971–1981	11	Unknown[d]		1,311,165	s
	Totals			11,150,732	1,889,558	
North Fork Toutle River	1985	1	Elochoman River		6,345	w
	1980–1996	3	Beaver Creek Hatchery		32,991	w
	1980	1	Cowlitz Hatchery	27,436		w
	1988–1997	6	Washougal Hatchery		208,707	s
	1972–2001	10	Skamania Hatchery		403,446	s
	Totals			27,436	651,489	
Kalama River basin						
Gobar Pond	1985	1	Cowlitz River (WDFW)		50,726	s
	1975–1981	7	Unknown[d]		447,285	s
	2000–2001	2	Kalama River	114,357		s
	1982–2001	17	Skamania Hatchery		2,684,402	s
	1982	1	Chambers Creek Hatchery		219,746	w
	1984–2001	15	Elochoman River		2,357,158	w
	1985	1	Green River (Cowlitz River tributary)	169,395		w
	1995	1	Cowlitz River Hatchery	61,776		w
	1993–2001	4	Kalama River	299,075		w
	1995–1998	3	Skamania Hatchery		48,525	w
	Totals			644,603	5,807,842	
Lewis River basin						
Lewis River	1953–2001	12	Lewis River (WDFW)	1,748,523		w
	1948–1951	4	Unknown[d]	95,434		na
	1979–1981	3	Unknown[d]	93,944		s
	1984–2001	17	Skamania Hatchery		1,578,269	s
	1997	1	Beaver Creek Hatchery		50,600	w
	1983	1	Chambers Creek Hatchery		41,000	w
	1998–2001	3	Cowlitz River Hatchery	24,534		w
	1988–1991	3	Elochoman River		114,325	w
	1979–1981	3	Unknown[d]	104,100		w
	1984–1993	4	Skamania Hatchery		324,564	w
	Totals			2,066,535	2,108,758	
East Fork Lewis River	1996–2001	3	Beaver Creek Hatchery		313,895	w
	1995–2001	4	Skamania Hatchery		279,999	w
	1996–1999	2	Lewis River Hatchery	204,856		w
	1995–2001	7	Skamania Hatchery		293,306	s
	Totals			204,856	887,200	
Salmon Creek basin						
Salmon Creek	1979	1	Big Creek Hatchery		12,323	w
	1996–2001	4	Beaver Creek Hatchery		50,777	w

Table A-4 continued. Hatchery steelhead releases, listed by ESU.

Watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases Inside	Outside	Run[c]
Lower Columbia River ESU continued						
Salmon Creek basin continued						
Salmon Creek continued	1996–1999	3	Lewis River Hatchery	35,040		w
	1995–2000	3	Skamania Hatchery		56,052	w
	Totals			35,040	119,152	
Washougal River basin						
Skamania Hatchery	1953–1966	12	Unknown[d]	145,158		na
	1985	1	Chambers Creek Hatchery		56,169	s
	1983	1	Columbia River (WA, upper)		39,492	s
	1985	1	Cowlitz River (WDFW)		2,660	s
	1980–2001	21	Skamania Hatchery		9,097,157	s
	1985	1	Skykomish River (WDFW)		75,053	s
	1957–1981	25	Unknown[d]	3,564,653		s
	1985	1	Willamette River (ODFW)		4,988	s
	1983	1	Wind River		115,605	s
	1983	1	Bogachiel River		1,745,308	w
	1982, 1986	2	Chambers Creek		214,731	w
	1985, 1986	2	Cowlitz River (WDFW)		622,435	w
	1984–2001	6	Beaver Creek Hatchery		2,417,319	w
	1957–1981	13	Unknown[d]		1,908,187	w
	1996–1997	2	Lewis River Hatchery	191,979		
	1985	1	Washougal River	1,697		w
	1984–1994	11	West Fork Washougal River	4,506,909		w
	Totals			4,700,585	7,023,585	
Vancouver Hatchery	1950–1965	12	Unknown[d]	751,528		na
	1951–1980	7	Unknown[d]	1,033,052		s
	1982–1993	11	Washougal River	5,427,645		s
	1985, 1986	2	Skamania Hatchery		1,064,254	s
	1994	1	Skamania Hatchery		60,667	w
	1964–1979	8	Unknown[d]	618,829		w
	Totals			7,831,054	1,124,921	
Wallace Pond	1989–1994	5	Cowlitz River (WDFW)	677,570		w
	Totals			677,570		
Bonneville Hatchery	1979	1	Big Creek		12,323	w
	Totals				12,323	
Clackamas River basin						
Clackamas River	1992	1	South Santiam Hatchery		38,756	s
	1981–1999	8	Big Creek Hatchery		358,686	w
	1992–2002	11	Clackamas Hatchery		1,718,722	s
	1986–2002	7	Clackamas River late	860,567		w
	1991–1996	6	Gnat Creek Hatchery		833,735	s
	1991–1996	6	Gnat Creek Hatchery		782,748	w
	1997–1999	3	Bonneville Hatchery	89,288		
	Totals			949,855	3,732,647	

Table A-4 continued. Hatchery steelhead releases, listed by ESU.

Watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases Inside	Outside	Run[c]
Lower Columbia River ESU continued						
Clackamas River basin continued						
Eagle Creek NFH	1977	1	Big Creek Hatchery		84,103	na
	1979	1	Clackamas River late run	162,067		na
	1959	1	Unknown[d]	34,267		na
	1978	1	Big Creek Hatchery		51,714	w
	1989–2001	11	Clackamas River early run		2,678,134	w
	1960–1988	27	Unknown[d]	6,448,482		w
	Totals			6,644,816	2,813,951	
Collawash River	1991–1994	3	Gnat Creek Hatchery		45,851	w
	1997–2002	2	Bonneville Hatchery	248,979		w
	Totals			248,979	45,851	
Rock Creek basin						
Rock Creek	1989–1994	3	West Fork Washougal	23,020		w
	1991	1	Elochoman Hatchery		10,000	w
	Totals			23,020	10,000	
Sandy River basin						
Sandy River	1939–1946	7	Marmot Dam	4,254,606		na
	1900–1909	9	Salmon River fry	2,644,018		na
	1955–1958	4	Sandy + unknown[d]			na
	1976	1	Marion Forks Hatchery		9,758	w
	1977	1	Unknown[d]	7,980		w
	1993–1994	2	Gnat Creek Hatchery		65,647	s
	1991–1996	6	Gnat Creek Hatchery		997,554	w
	1998–2000	3	Oak Springs Hatchery		111,985	s
	1997–2000	4	Bonneville Hatchery		443,769	w
	1991–1997	7	Clackamas Hatchery	214,123		
	Totals			7,120,727	1,628,713	
Cedar Creek	1998–2002	4	Sandy Hatchery		274,533	s
	1988–2000	2	STEP Project[e]		99,119	s
	1997–2002	6	Sandy Hatchery	472,450		w
	1998–2000	3	STEP Project[e]	48,107		w
	Totals			520,557	373,652	
Zig Zag River	1991–1997	7	Oak Spring Hatchery		71,281	s
	Totals				71,281	
Salmon River	1992–1994	3	Gnat Creek Hatchery		116,786	s
	1991–1997	7	Oak Springs Hatchery		293,023	s
	Totals				409,809	
Wind River basin						
Wind River	1964–1969	4	Goldendale Hatchery	241,080		s
	1965	1	Wild stock[f]	27,770		s
	1963–1997	23	Skamania Hatchery		1,596,987	s
	1985–1993	8	Vancouver Hatchery (Washougal)	297,715		s
	1956–1970	5	Carson NFH	145,731		na

Table A-4 continued. Hatchery steelhead releases, listed by ESU.

Watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases Inside	Outside	Run[c]
Lower Columbia River ESU continued						
Wind River basin continued						
	1959–1962	3	Skamania Hatchery	101,245		na
	1951	1	Vancouver Hatchery (unknown[d])	7,520		na
	1961,1963	2	Skamania Hatchery	35,740		w
	Totals			856,801	1,510,536	
Lower Gorge tributaries						
Hamilton Creek	1995	1	Beaver Creek Hatchery		5,440	w
	1995–1997	2	Skamania Hatchery		14,006	w
	Totals				19,446	
Tanner Creek	2000–2001	2	Bonneville Hatchery		44,003	s
	2002	1	Bonneville Hatchery	3,580		w
	2002	1	Irrigon Hatchery	23,968		w
	Totals			27,548	44,003	
Big White Salmon River basin						
Big White Salmon River	1983	1	Upper Columbia River		21,001	s
	1982–1987	2	Washougal River	30,144		s
	1984–1993	5	West Fork Washougal River	224,935		s
	1985	1	Willamette River		10,006	s
	1991–1992	2	Beaver Creek Hatchery		79,260	w
	1982	1	Chambers Creek Hatchery		32,901	w
	1985–1986	2	Cowlitz River Hatchery	123,841		w
	1984	1	Elochoman Hatchery		10,047	w
	1994	1	North Fork Washougal River	10,047		w
	1990–1994	4	Washougal River	129,838		w
	Totals			518,805	153,215	
Hood River basin						
Hood River Hatchery	1958–1966	8	Hood River	147,375		s
	1991–2002	12	Skamania Hatchery		1,760.699	s
	1999–2002	4	Blackberry Hatchery	136,726		s
	2000	1	Oak Springs Hatchery	4,762		s
	1984–1991	8	Big Creek Hatchery		233,467	w
	1992–2001	9	Hood River	426,133		
	Totals			714,996	235,228	
Upper Willamette River ESU						
Molalla River	1984–1997	7	Skamania Hatchery		909,134	s
	1970–1996	10	Gnat Creek Hatchery		497,922	w
	1976–1993	17	Big Creek Hatchery		908,516	w
	1979–1974	4	Alsea River		156,683	w
	1957–1977	6	Marion Forks/S. Santiam	270,912		w
	1982	1	Marion Forks Hatchery	23,492		w
	Totals			294,404	2,472,255	

Table A-4 continued. Hatchery steelhead releases, listed by ESU.

Watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases Inside	Outside	Run[c]
Upper Willamette River ESU continued						
North Santiam River Leaburg	1970–1976	3	Foster Reservoir		107,650	s
	1980–1994	15	McKenzie River		1,257,715	s
	1978–1985	8	South Santiam Hatchery		677,723	s
	1991–1997	7	Roaring River Hatchery		799,121	s
	1998–2001	2	Marion Forks Hatchery		324,346	s
	Totals				3,166,555	
North Santiam River Marion Forks	1931–1985	18	Marion Forks Hatchery 11,528,482			na
	1968–1975	4	Unknown[d]	394,191		na
	1998–2001	3	South Santiam Hatchery		324,346	s
	1976–1998	16	Marion Forks Hatchery			w
	1984	1	South Santiam Hatchery			w
	1969–1977	5	Unknown[d]			w
	Totals			14,565,857	324,346	
Roaring River	1971	1	Foster Reservoir	84		na
	1975	1	Hagerman	8,022		na
	1960	1	Roaring River	9,620		na
	1965	1	Wickiup Reservoir	16,592		na
	1971	1	Foster Reservoir	84		na
	1973–1976	4	Foster Reservoir		388,568	s
	1978–1992	15	South Santiam Hatchery		1,867,166	s
	1977	1	Unknown[d]		2,750	s
	1959	1	Wickiup Reservoir		16,133	s
	1968, 1969	2	Wickiup Reservoir		54	s
	1972, 1976	2	Alsea River and tributaries		114,976	w
	1976–1992	12	Big Creek Hatchery		1,630,062	w
	1985–1988	3	Klaskanine River		222,317	w
	1972, 1977	2	Unknown[d]	149,024		w
	Totals			183,342	4,242,026	
South Santiam River	1929	1	Rogue River		411,056	na
	1928–1944	13	South Santiam Hatchery	13,697,599		na
	1969–1975	3	Unknown[d]	350,192		na
	1976–2002	26	South Santiam Hatchery		4,348,730	s
	1972–1977	4	Unknown[d]		641,043	s
	1981	1	Marion Forks Hatchery	26,489		w
	Totals			14,074,280	5,400,829	
McKenzie River	1913	1	Trask Hatchery fingerlings		90,551	na
	1911	1	Unknown[d]	35,000		na
	1991–2002	12	Leaburg Hatchery		1,386,686	s
	1983–1996	11	McKenzie River		1,652,584	s
	1982–1992	10	South Santiam Hatchery		811,307	s
	Totals			35,000	3,941,128	

Table A-4 continued. Hatchery steelhead releases, listed by ESU.

Watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases Inside	Total ESU releases Outside	Run[c]
Upper Willamette River ESU continued						
Middle Fork Willamette River	1957–1959	3	Alsea River and tributaries		182,218	na
	1956	1	Oak Springs	1,069		na
	1972	1	Unknown[d]	20,936		na
	1955, 1957	2	Willamette River	102,271		na
	1994–1998	5	Willamette Hatchery		719,811	s
	1984–2002	4	South Santiam Hatchery		266,152	s
	1987	1	Big Creek	82,211		w
	Totals			412,953	182,218	
Fall Creek	1992–2000	8	Dexter Ponds		155,750	s
	1995–1997	2	North Santiam	42,608		w
	Totals			662,048	1,506,149	
West-side tributaries						
Tulatin River	1991–1996	6	Gnat Creek Hatchery		117,543	w
	1991–1996	6	Big Creek Hatchery		60,055	w
	1975–1990	16	Big Creek/Gnat Creek Hatcheries		554,666	w
Yamhill River	1958–1991	18	Big Creek Hatchery		429,497	w
	1968	1	Marion Forks Hatchery	9,976		w
Luckiamute River	1979	1	Big Creek Hatchery		55,211	w
	1957	1	Sandy River Hatchery		119,211	w
	Totals			9,976	1,336,183	

[a] Duration is the time frame of the releases.

[b] Years is the total number of years that fish actually were released within the time frame. No releases of eggs or fry (<5 g) are included. Data before 1950 are incomplete (NRC 1996).

[c] W is for winter run, s is for summer run.

[d] Stocks of unknown origin are assumed to be from within the ESU. Fish releases derived from adults returning to that river also are assumed to be native regardless of past introductions, unless the river historically never contained a run.

[e] STEP stands for Salmon and Trout Enhancement Program.

[f] "Wild stock" — WDG broodstock nomenclature, source unknown, but likely collected from naturally produced steelhead returning to the Wind River.

Coho Salmon

Table A-5. Hatchery releases for the Lower Columbia River Coho Salmon ESU, listed by DIP.

DIP/ watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases Inside	Total ESU releases Outside	Stage[c]
Youngs Bay DIP						
Lewis and Clark River	1981, 1987	2	Bonneville Hatchery	110,280		F
	1948–1952	4	Klaskanine Hatchery	391,504		F, Y
	1978	2	Big Creek Hatchery	156,632		Y
	1961	1	Gnat Creek	44,695		F
	1980–1983	4	Sandy River	406,757		F, Y
Youngs River	1953, 1959, 1987, 1991–1992	5	Big Creek Hatchery	783,122		F, Y
	1988–1993	6	Clackamas River (early)	5,561,484		F, Y
	1984	1	Cowlitz Hatchery	110,176		F
	1992	1	Kalama Falls	405,976		Y
	1983, 1989, 1992, 1996–1999	6	Sandy River	2,433,337		Y
	1987, 1993–1999	8	Bonneville Hatchery	9,430,860		F, Y
	1951, 1955, 1958, 1991–1994	7	Klaskanine Hatchery	808,463		Y
	1991–1994	4	Eagle Creek NFH	5,828,402		Y
Klaskanine River	1953–2002	7	Big Creek Hatchery	2,448,532		F, Y
	1981–1989	5	Bonneville Hatchery	4,857,320		F, Y
	1925–2002	54	Klaskanine Hatchery	91,222,392		F, Y
	1988–1989	2	Clackamas River (early)	671,922		Y
	1984	1	Cowlitz (WA)	61,651		F
	1981–1984	3	Eagle Creek NFH	1,914,816		Y
	1981–1983, 1987, 1989–1991	7	Sandy River	2,839,393		F, Y
	1990	1	Siletz River		37,603	Y
	1957	1	Trask River		56,586	Y
	1985–1986	2	Tanner Creek	2,230,033		Y
	1921–1988	11	Unknown[d]	15,739,186		F, Y
	Totals			148, 456,933	94,189	
Grays River DIP						
Grays River	1951	1	Ancient wild stock	16,800		F
	1956–1957	2	Big Creek Hatchery (OR)	138,072		F, Y

Table A-5 continued. Hatchery releases for the Lower Columbia River Coho Salmon ESU, listed by DIP.

DIP/ watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases Inside	Total ESU releases Outside	Stage[c]
Grays River DIP continued						
Grays River continued	1973–1993	13	Columbia River	7,042,419		F, Y
	1958, 1981	2	Elochoman Hatchery	119,526		F
	1954	1	Green River	140,037		F
	1963–1964	2	Klaskanine Hatchery (OR)	1,374,284		Y
	1957	1	Lewis River	42,986		F
	1955–1976	5	Toutle River	543,552		F, Y
	1973–1978, 1980–1981	8	Cowlitz (Type N)	4,573,325		F, Y
	1956–2000	20	Toutle (Type S)	8,768,501		F, Y
	1957–1981	19	Grays River (Type[d])	18,675,358		F, Y
	1977	1	Washougal	446,031		Y
	1997	1	Chehalis River (Type N)		4,005	F
	1996–2001	5	Grays Hatchery (Type S)	587,311		Y
Chinook River	1996	1	Grays Hatchery (Type N)	6,400		F
	1997–1998	2	Grays Hatchery (Type S)	97,600		F
	1968–1973	5	Grays Hatchery (Type[d])	151,378		F, Y
	1980–1992	8	Chinook River	429,412		F, Y
	1986–1993		Columbia River (general)	1,036,880		F, Y
	1995	1	Toutle River (Type S)	500,000		F
Deep River	1995–2001	4	Grays Hatchery (Type S)	799,239		Y
	1995–2001	4	Toutle River (Type S)	1,050,999		Y
	Totals			46,540,110	4,005	
Big Creek DIP						
Big Creek	1938–2002	58	Big Creek Hatchery	60,137,909		F, Y
	1986	1	Bonneville Hatchery	844,434		Y
	1950–1977	9	Unknown[d]	7,602,148		F, Y
	1981	1	Umpqua		65,292	Y
Gnat Creek	1952, 1956	2	Big Creek Hatchery	37,914		F
	1963–1964	2	Unknown[d]	123,500		Y
Tongue Point	2000–2002	2	Big Creek/ Bonneville Hatchery[e]	2,077,553		F,Y
Blind Slough	2001–2002	2	Sandy River Hatchery	643,253		F,Y
	2000		Bonneville Hatchery	299,411		
	Totals			71,766,122	65,292	

Table A-5 continued. Hatchery releases for the Lower Columbia River Coho Salmon ESU, listed by DIP.

DIP/ watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases Inside	Outside	Stage[c]
Elochoman River DIP						
Elochoman River	1963	1	Ancient wild stock	97,696		Y
	1956		Big Creek (OR)	51,327		F
	1981–1993		Columbia River[e]	3,035,832		Y
	1961		Eagle Creek NFH (OR)	896,668		Y
	1955–1988	26	Elochoman River	26,487,577		F, Y
	1954, 1957, 1961	3	Green River	289,803		F
	1962–1965	4	Klaskanine Hatchery (OR)	2,706,042		F, Y
	1957	1	Lewis River	100,701		F
	1955, 1958, 1961	3	Toutle River	162,213		F
	1972, 1974–1987, 1989–1992	19	Cowlitz Hatchery (Type N)	30,135,913		F, Y
	1966, 1968–1981, 1986, 1990–1992	19	Toutle River (Type S)	25,558,411		F, Y
	1959, 1960	2	Washougal River	100,061		F, Y
	1995–2000	4	Elochoman River (Type N)	1,138,363		F, Y
	1998–2000	3	Lewis River Hatchery (Type N)	1,409,482		F, Y
	1995–2001	6	Elochoman Hatchery (Type S)	1,769,461		F, Y
	1998	1	Grays Hatchery (Type S)	313,125		Y
	2000–2001	2	Kalama Hatchery (Type S)	308,300		Y
	1999, 2001	2	Toutle River (Type S)	51,675		Y
Skamokawa Creek	1957–1965	3	Big Creek Hatchery	83,664		F
	1955	1	Green River	29,965		F
	1975	1	Cowlitz Hatchery	363,343		F
	1965–1966	2	Elochoman Hatchery	458,998		F, Y
	1954–1957	3	Toutle (Type N)	61,404		F
	1964–1965	2	Klaskanine Hatchery	338,772		F
	Totals			95,948,796		
Clatskanine River DIP						
Clatskanine River	1949, 1951–1953, 1955–1959	9	Big Creek Hatchery	695,324		F

Table A-5 continued. Hatchery releases for the Lower Columbia River Coho Salmon ESU, listed by DIP.

DIP/ watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases Inside	Total ESU releases Outside	Stage[c]
Clatskanine River DIP continued						
Clatskanine River continued	1984	1	Cowlitz Hatchery (WA)	109,037		F
	1986	1	Klaskanine River	230,300		
	1980, 1982–1983, 1988	4	Sandy River	969,774		F, Y
	1981, 1987	2	Bonneville Hatchery	992,337		F
	Totals			2,996,772		
Mill Creek DIP						
Abernathy Creek	1955	1	Lewis River Hatchery	80,000		Y
	1955–1988	7	Elochoman River	899,549		Y
	1957–1958	2	Big Creek Hatchery	96,665		F
	1969–1974	7	Unknown[d]	464,962		F, Y
Germany Creek	1955–1988	10	Elochoman River	993,682		Y
	1963	1	Kalama River	100,172		Y
	1957	1	Big Creek Hatchery	30,030		Y
	1955	1	Green River (Puget Sound)		30,008	Y
	1958	1	Lewis River	50,511		Y
	1956	1	Toutle River (Type N)	20,000		Y
Mill Creek	1955–1988	9	Elochoman River	819,366		Y
	1972	1	Cowlitz River	301,600		Y
	1974–1976		Grays River	154,477		Y
	1955	1	Green River (Puget Sound)		35,212	
	1957	1	Big Creek	40,040		F
	1958	1	Lewis River	59,055		F
	1965	1	Klaskanine River	25,956		F
	Totals			4,136,065	65,220	
Lower Columbia River DIP						
Cowlitz River	1956–1957, 1964	3	Big Creek Hatchery (OR)	98,952		F, Y
	1969–1993	24	Cowlitz River Hatchery	120,965,049		F, Y
	1956–1969	3	Toutle (Type N)	404,785		F
	1974	1	Elochoman Hatchery	31,838		Y
	1954–1966	5	Green River (Puget Sound)		569,724	F, Y
	1965–1971	3	Kalama Hatchery	1,246,024		Y
	1962, 1965	2	Klaskanine Hatchery (OR)	669,756		F, Y

Table A-5 continued. Hatchery releases for the Lower Columbia River Coho Salmon ESU, listed by DIP.

DIP/ watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases		Stage[c]
				Inside	Outside	
Lower Columbia River DIP						
Cowlitz River continued	1954, 1958, 1990	3	Lewis River Hatchery	249,246		F, Y
	1995–1999	5	Cowlitz Hatchery (Type N)	28,129,260		F, Y
Riffe Lake	1995–1999	5	Cowlitz Hatchery (Type N)	3,110,589		Y
	1982–1992	11	Cowlitz Hatchery	3,035,832		F, Y
	Totals			157,941,331	569,724	
Upper Cowlitz River DIP						
Upper Cowlitz River	1972–1989	17	Cowlitz Hatchery	17,776,163		F, Y
Ohanapecosh River	1972–1993	23	Cowlitz Hatchery	3,909,445		F, Y
	Totals			21,685,608		
Tilton River DIP						
Tilton River	1954–1984	12	Cowlitz Hatchery (Type N)	2,618,815		F, Y
	Totals			2,618,815		
Cispus River Dip						
North Fork Cispus River	1972–1986	7	Cowlitz Hatchery	1,088,985		F
Iron Creel	1976–1986	9	Cowlitz Hatchery	685,252		F
	1972–1992	20	Cowlitz Hatchery	4,945,686		F, Y
	1954		Toutle River (Type N)	24,050		Y
	Totals			6,743,973		
North Fork Toutle River DIP						
North Fork Toutle River	1960–1965	2	Green River (Puget Sound)		113,884	F, Y
	1993	1	Columbia River[e]	174,801		Y
	1954–1991	14	Toutle River	2,952,917		F, Y
	2001	1	Toutle River (Type S)	242,060		Y
Hoffstadt Creek	1954–1966	8	Toutle River (Type N)	238,165		Y
	1965	1	Green River (Puget Sound)		42,924	Y
Green River	1966	1	Green River (Puget Sound)		122,991	Y
	1986–1993	4	Columbia River[e]	3,288,700		F, Y
	1972–1977	5	Cowlitz Hatchery	1,130,173		Y
	1967	1	Grays River	90,100		F
	1974–2001	12	Toutle River(Type S)	9,307,798		F, Y
	1954–1980	16	Toutle River (Type N)	14,494,434		F, Y
	1967–1979	11	Toutle River	12,891,750		Y
	Totals			44,810, 898	279,799	

Table A-5 continued. Hatchery releases for the Lower Columbia River Coho Salmon ESU, listed by DIP.

DIP/ watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases Inside	Outside	Stage[c]
South Fork Toutle River DIP						
South Fork Toutle River	1960	1	Green River (Puget Sound)	22,440		F
	1963	1	Klaskanine Hatchery	96,228		Y
	1954–1975	16	Toutle (Type N)	1,786,192		F, Y
	Totals			1,904,860		
Coweeman River DIP						
Coweeman River	1981–1989	4	Cowlitz Hatchery	638,000		F
	1965–1971	3	Kalama River	447,416		F, Y
	1963–1965	2	Klaskanine Hatchery	390,261		Y
	1957–1972	4	Toutle River(Type N)	129,307		Y
	1955	1	Green River (Puget Sound)		45,560	F
	Totals			1,604,984	45,560	
Kalama River DIP						
Kalama River	1962, 1965	2	Klaskanine Hatchery (OR)	139,024		F, Y
	1981–1989	4	Columbia River[e]	1,786,440		F, Y
	1957–1980		Kalama River	18,352,325		F, Y
	1954–1966	7	Lewis River Hatchery	1,711,962		F, Y
	1956–1966	9	Toutle River (Type N, Type S)	2,681,290		F, Y
	1973–1992	19	Type N (Cowlitz)	20,173,931		F, Y
	1967–1992	24	Type S (Toutle)	37,655,135		F, Y
	1960–1961	2	Washougal River	1,635,134		F, Y
	1995–2001		Kalama Hatchery (Type N)	4,915,605		Y
	1995–2001		Fallert Creek Hatchery (Type S)	3,339,720		Y
	2001		Elochoman Hatchery (Type N)	258,500		Y
Gobar Creek	1966–1974	4	Kalama River	503,608		F, Y
	1986–1993	3	Columbia River[e]	2,875,000		F, Y
Fallert Creek	1958–1980	7	Kalama River	5,272,938		F, Y
	1984–1992	5	Columbia River[e]	2,337,700		Y
	1990–1991	2	Toutle River (Type S)	1,086,986		Y
	1969–1977	3	Washougal River	2,183,728		Y
	Totals			106,909,026		
North Fork Lewis River DIP						
Lewis River	1963	1	Abernathy NFH	518,056		F
	1965	1	Big Creek Hatchery (OR)	163,548		Y
	1963	1	Eagle Creek NFH (OR)	2,624,122		F

Table A-5 continued. Hatchery releases for the Lower Columbia River Coho Salmon ESU, listed by DIP.

DIP/ watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases Inside	Total ESU releases Outside	Stage[c]
North Fork Lewis River DIP continued						
Lewis River continued	1963, 1966	2	Kalama Falls Hatchery	167,152		F, Y
	1962, 1965	2	Klaskanine Hatchery (OR)	272,148		F, Y
	1952–1980	28	Lewis/Speelyai Hatchery[e]	33,148,667		F, Y
	1958	1	Toutle River	15,878		Y
	1975–1992	18	Cowlitz Hatchery (Type N)	65,681,281		F, Y
	1967–1992	26	Toutle River (Type S)	58,287,123		F, Y
	1981–1993	10	Unknown[d]	9,461,447		F, Y
	1963	1	Washougal River	96,110		F
Cedar Creek	1965	1	Big Creek Hatchery	83,349		Y
	1986	1	Columbia River[e]	88,200		F
	1986–1993	3	Cowlitz River Hatchery	454,000		F
	1952–1973	8	Lewis River Hatchery	676,960		F, Y
Speelyai Creek	1986–1993	7	Columbia River[e]	2,771,722		F, Y
	1976–1993	3	Cowlitz River Hatchery	124,280		Y
	1959–1979	9	Speelyai Hatchery	1,990,244		F, Y
North Fork Lewis River	1997, 2001	2	Cowlitz River Hatchery (Type N)	1,282,287		Y
	1995–2001	7	Lewis River Hatchery (Type N)	15,029,281		F, Y
	1995–2001	7	Lewis River Hatchery (Type S)	7,294,310		F, Y
	Totals			200,230, 165		
East Fork Lewis DIP						
East Fork Lewis	1952–1975	7	Lewis River Hatchery	454,230		F, Y
Copper Creek	1974–1979	3	Lewis River Hatchery	482,184		F
	1985	1	Cowlitz River Hatchery	49,900		F
Green Fork	1974–1979	3	Lewis River Hatchery	953,697		F
	1985	1	Cowlitz River Hatchery	33,200		F
	Totals			1,973,211		
Scappoose Creek DIP						
Goble Creek	1950–1959	5	Big Creek Hatchery	107,214		F, Y
	1980–1983	3	Sandy River Hatchery	135,116		F
Scappoose Creek	1950–1959		Big Creek	430,862		F, Y
	1952		Bonneville/Cascade Hatchery[e]	75,000		F
	1980–1983		Sandy Hatchery	465,125		F
	Totals			1,213,317		

Table A-5 continued. Hatchery releases for the Lower Columbia River Coho Salmon ESU, listed by DIP.

DIP/ watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases Inside	Total ESU releases Outside	Stage[c]
Clackamas River DIP						
Clackamas River	1936–1987	8	Bonneville Hatchery	2,603,675		F
	1983	1	Cascade Hatchery	402,447		F
	1988–1989	2	Clackamas River (late)	40,107		Y
	1984	1	Cowlitz River Hatchery (WA)	140,429		F
	1983	1	Gnat Creek Hatchery	395,776		F
	1981–1987	4	Oxbow Hatchery	1,541,870		F
	1965–1991	17	Sandy River	5,448,809		F, Y
	1936	1	Ten Mile Lakes		25,000	
	1967	1	Trask River		165,000	F
	1967–1980	8	Unknown[d]	1,451,031	190,000	F, Y
	2001	1	Eagle Creek NFH	53,720		Y
	1998–2001	4	Sandy Hatchery	274,437		Y
Eagle Creek	1976–1999	18	Clackamas (early)	15,593,378		Y
	1959–1980	10	Cascade (Bonneville/ Cascade Hatchery)[e]	12,287,935		F, Y
	1960–1988	28	Eagle Creek NFH (unknown[d])	30,814,193		Y
	1991	1	Big Creek Hatchery	26,440		F, Y
	2001	1	Eagle Creek NFH	711,927		Y
	1992	1	Sandy River	292,041		Y
	1995	1	Toutle River (Type S)	71,749		Y
	1960–1985	6	Unknown[d]	581,346		F, Y
	Totals			72,731,310		
Salmon Creek DIP						
Salmon Creek	1959	1	Green River (Puget Sound)		79,107	F
	1962	1	Big Creek Hatchery	150,782		F
	1965–1975	2	Kalama River Hatchery	83,400		F, Y
	1958–1965	5	Toutle River (Type N)	359,713		F, Y
	1960–1992	5	Washougal River	307,733		F, Y
	Totals			901,628	79,107	
Sandy River	1950–2003	42	Sandy River Hatchery	35,703,130		F, Y
	1918–1952	5	Bonneville Hatchery	518,725		F
	1939–1945	6	Marmot Dam	1,581,626		
	Totals			37,803,481		
Washougal River DIP						
Washougal River	1962	1	Big Creek Hatchery (OR)	565,553		F
	1961	1	Eagle Creek NFH (OR)	60,000		Y

Table A-5 continued. Hatchery releases for the Lower Columbia River Coho Salmon ESU, listed by DIP.

DIP/ watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases Inside	Total ESU releases Outside	Stage[c]
Washougal River DIP						
Washougal River continued	1954	1	Green River (Puget Sound)		70,022	F
	1954	1	Lewis River Hatchery	100,000		F
	1955–1965	4	Toutle River	1,942,243		F, Y
	1974–1992	18	Cowlitz River Hatchery (Type N)	30,046,629		F, Y
	1967–1989	22	Toutle River (Type S)	41,062,608		F, Y
	1995–1999	4	Lewis River Hatchery (Type N)	1,063,525		Y
	1960–2001	27	Washougal River (Type N)	34,574,152		F, Y
	1998	1	Big Creek Hatchery (Type S)	1,090		Y
	2000	1	Lewis River Hatchery (Type S)	93,193		Y
	1998	1	Toutle River (Type S)	1,048		Y
West Fork Washougal River	1981–1985	2	Columbia River[e]	207,000		F
	1982–1993	6	Cowlitz River Hatchery	470,000		F, Y
	1966–1975	6	Washougal Hatchery	690,423		F, Y
	Totals			110,877,464	70,022	
Lower Gorge tributaries DIP						
Hamilton Creek	1962–1963	4	Big Creek Hatchery	150,450		Y
	1965	1	Toutle River (Type N)	19,200		Y
	1964–1965	2	Washougal River	87,500		Y
Duncan Creek	1962	1	Big Creek Hatchery	75,360		Y
	1983–1993	4	Cowlitz River Hatchery	529,000		F, Y
	1965	1	Toutle River Hatchery (Type N)	44,226		Y
	1964–1965	2	Washougal River	65,000		Y
Gibbons Creek	1985–1992	2	Cowlitz River Hatchery	92,100		F
Tanner Creek	1934–2002	26	Bonneville Hatchery	25,950,267		F, Y
	1965–1984	9	Cascade Hatchery	4,172,087		Y
	1978–1993	17	Tanner Creek	30,616,462		F, Y
	1935–1945	6	Ten Mile Lakes		6,685,948	F
	1944–1990	11	Coast and Columbia Mixture		12,959,488	F, Y
	1918–1977	14	Unknown[d]	26,929,536		F, Y
	Totals			88,731,188	19,645,436	
Washington upper Gorge tributaries and Big White Salmon River DIP						
Wind River	1977, 1979	2	Unknown[d]	416,890		F
	1961–1969	5	Unknown[d]	5,418,784		Y
	1973	1	Carson NFH	1,540,600		Y

Table A-5 continued. Hatchery releases for the Lower Columbia River Coho Salmon ESU, listed by DIP.

DIP/ watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases		Stage[c]
				Inside	Outside	
Washington upper Gorge tributaries and Big White Salmon River DIP						
Wind River continued	1951, 1953–1954	3	Lewis River Hatchery	407,598		F
	1982	1	Cowlitz River Hatchery (Type N)	59,064		F
	1967–1968, 1971, 1973, 1980	5	Toutle River (Type S)	4,212,293		F
	1987–1988	2	Willard WFH	2,930,46		F, Y
Klickitat River	1995–1999	4	Lewis River (Type N)	6,687,347		Y
	1995–2001	7	Washougal River (Type N)	5,935,923		Y
	2001	1	Elochoman River (Type N)	6,044		Y
	1998	1	Big Creek Hatchery (S Type)	544,415		Y
	2001	1	Cascade Hatchery (Type S)	220,000		Y
	1997	1	Eagle Creek NFH	790,000		Y
	1997–2001	2	Elochoman Hatchery	343,718		Y
	2001		Kalama Hatchery	140,722		Y
	2000	1	Lewis River Hatchery (Type S)	93,193		Y
	1998	1	Toutle River (Type S)	1,048		Y
Little White Salmon River	2000	1	Lewis River Hatchery (Type N)	547,398		Y
	1977	1	Abernathy NFH	600,000		F
	1981–1987	2	Toutle River (Type N)	2,384,439		Y
	1981–1987	3	Toutle River (Type S)	5,966,788		Y
	1998	1	Bonneville Hatchery	1,294,749		Y
	1996	1	Kalama Hatchery	256,083		Y
	1997	1	Klaskanine Hatchery	948,562		Y
	1976–1999	10	Little White Salmon NFH	46,332,868		Y
	1994–1997	4	Carson NFH	3,803,485		Y
	1951–1975	17	Unknown[d]	31,991,783		F, Y
	1984–2001	5	Willard NFH	8,946,021		Y
	Totals			134,973,834	5,289,920	
Big White Salmon River	1985, 1987	2	Cowlitz River Hatchery	629,880		F
	1981–1987	7	Cowlitz River Hatchery (Type N)	2,630,650		F, Y
	1971, 1980	2	Toutle River (Type S)	1,047,841		F, Y
	1973	1	Unknown[d]	336,704		F
	Totals			4,645,075		

Table A-5 continued. Hatchery releases for the Lower Columbia River Coho Salmon ESU, listed by DIP.

DIP/ watershed	Duration[a]	Years[b]	Broodstock origination	Total ESU releases		Stage[c]
				Inside	Outside	
Oregon upper Gorge tributaries and Hood River DIP						
Herman Creek	1940–1965	8	Oxbow Hatchery	1,815,639		Y
	1938	1	Bonneville Hatchery/ Ten Mile Lakes[e]		5,289,920	
	1954–1961	1	Bonneville Hatchery	337,912		Y
Hood River	1963	1	Oxbow Hatchery	546,858		
	1960	1	Big Creek/ Bonneville Hatchery[e]	54,721		Y
	Totals			601,579		
Columbia River (main stem)[f]						
	1984–1993	8	Tanner Creek	13,545,394		Y
	1967–1993	8	Sandy River Hatchery	4,406,725		Y
	1977–1980	2	Little White Salmon NFH	211,034		Y
	1984	1	Cowlitz River Hatchery	714,186		F
	1983–1987	3	Big Creek	1,468,064		F
	1978–1983	3	Cascade River Hatchery	3,284,531		Y
	1937–1977	3	Unknown[d]	3,778,887		Y
RKM 227	1978–1980	3	Columbia River[e]	125,711		
	Totals			27,534,532		

[a] Duration is the time frame of the releases. No releases of eggs or fry (<5 g) are included. Data before 1950 are incomplete (NRC 1996).

[b] Years is the total number of years that fish actually were released within the time frame.

[c] Stage of fish at time of release. F is for fingerling, Y is for yearling.

[d] Stocks of unknown origin are assumed to be from within the ESU. Fish releases derived from adults returning to that river also are assumed to be native regardless of past introductions, unless the river historically never contained a run.

[e] A mix of stocks from different areas.

[f] These are fish released in the main stem. They are not associated with any DIP.

Appendix B: Summary of Information Used to Determine Historical Salmonid DIPs in Listed Lower Columbia River and Upper Willamette River ESUs

Tables B-1 through B-8 summarize the information utilized to determine historical DIPs. Information categories address these fundamental questions about the population:

- Historical presence: Is there documentation that the population in question occupied or utilized the river basin?
- Historical abundance: Is there evidence that the population in question historically was large enough to be demographically independent?
- Life history characteristics: Is there evidence that the population in question exhibited life history characteristics that would indicate local adaptation or would provide reproductive isolation from other populations?
- Genetics: Is there genetic evidence that the population in question was or is genetically distinct from other populations (e.g., isolated reproductively to some degree)?
- Geography: Are there any aspects of river morphology that would promote population isolation, or is the basin large enough to produce a sustainable population, or is the population sufficiently distant from other populations to reduce the rate of migration between populations?

Each population was given a distinct code, which was used to identify watershed or population boundaries on maps in the document. Within each data category, information quantity and quality was scored on a scale from 0 to 3.

Information scale:

0 no information available,

1 some information but of limited quality or quantity,

2 information available but of limited use because of quality issues (i.e., hatchery, nonnative stock influences, environmental degradation, etc.), and

3 good information directly pertaining to historical populations or to present populations that are representative of historical populations.

Chinook Salmon

Table B-1. Historical fall populations in the Lower Columbia River Chinook Salmon ESU.

Population	Map code	Historical presence	Historical abundance	Life history characteristics	Genetics	Geography
Youngs Bay	YOUN-KF	2	2	1	0	2
Grays River	GRAY-KF	3	2	1	1	3
Big Creek	BIGC-KF	2	1	1	1	2
Elochoman River	ELOC-KF	2	1	1	1	2
Clatskanie River	CLAT-KF	2	1	1	0	2
Mill Creek	MILL-KF	2	1	1	2	2
Scappoose Creek	SCAP-KF	2	1	0	0	2
Upper Cowlitz River	UCWL-KF	3	1	2	1	3
Lower Cowlitz River	LCWL-KF	3	2	2	2	3
Coweeman River	COWE-KF	3	2	3	3	3
Toutle River	TOUT-KF	3	2	1	0	3
Kalama River	KALA-KF	3	2	2	2	3
Lewis River early	LEWE-KF	2	1	1	3	3
Salmon Creek	SALM-KF	2	1	0	1	2
Lewis River late	LEWL-KF	3	2	3	3	3
Clackamas River	CLCK-KF	2	1	1	2	3
Washougal River	WASH-KF	2	2	2	2	3
Sandy River early	SNDE-KF	1	0	0	0	2
Sandy River late	SNDL-KF	2	2	2	3	3
Columbia River lower Gorge tributaries	LGRG-KF	2	2	1	0	2
Columbia River upper Gorge tributaries	UGRG-KF	2	2	1	0	2
Big White Salmon River	BWSR-KF	2	1	1	2	3
Hood River	HOOD-KF	2	1	1	0	3

Table B-2. Historical spring populations in the Lower Columbia River Chinook Salmon ESU.

Population	Map code	Historical presence	Historical abundance	Life history characteristics	Genetics	Geography
Upper Cowlitz River	UCWL-KS	3	2	1	2	3
Cispus River	CISP-KS	3	2	1	0	3
Tilton River	TILT-KS	3	2	1	0	3
Toutle River	TOUT-KS	3	2	1	0	3
Kalama River	KALA-KS	2	1	0	2	3
Lewis River	LEWS-KS	3	2	1	1	3
Sandy River	SAND-KS	3	2	2	0	3
Big White Salmon River	BWSR-KS	2	0	0	0	3
Hood River	HOOD-KS	3	2	1	0	3

Table B-3. Historical spring populations in the Upper Willamette River Chinook Salmon ESU.

Population	Map code	Historical presence	Historical abundance	Life history characteristics	Genetics	Geography
Clackamas River	CLCK-KS	3	2	2	1	3
Molalla River	MOLA-KS	3	1	1	0	3
North Santiam River	NSNT-KS	3	2	2	1	3
South Santiam River	SSNT-KS	2	2	1	1	3
Calapooia River	CALA-KS	3	1	1	0	3
McKenzie River	MCKZ-KS	3	2	2	2	3
Middle Fork Willamette River	MFWL-KS	3	2	2	0	3

Steelhead

Table B-4. Historical winter populations in the Lower Columbia River Steelhead ESU.

Population	Map code	Historical presence	Historical abundance	Life history characteristics	Genetics	Geography
Cispus River	CISP-SW	3	1	0	0	3
Tilton River	TILT-SW	3	1	0	0	3
Upper Cowlitz River	UCWL-SW	3	2	0	0	2
Lower Cowlitz River	LCWL-SW	3	1	1	1	2
North Fork Toutle River (Green River)	NTOU-SW	3	1	0	1	2
South Fork Toutle River	STOU-SW	3	1	0	0	2
Coweeman River	COWE-SW	3	1	0	0	2
Kalama River	KALA-SW	3	2	2	1	3
North Fork Lewis River	NLEW-SW	3	2	1	1	3
East Fork Lewis River	ELEW-SW	3	2	1	1	3
Clackamas River	CLCK-SW	3	2	2	2	3
Salmon Creek	SALM-SW	2	0	0	0	2
Sandy River	SAND-SW	3	2	1	0	3
Washougal River	WASH-SW	3	1	1	0	3
Columbia River lower Gorge tributaries	LRG-SW	2	0	0	0	3
Columbia River upper Gorge tributaries	UGRG-SW	2	0	0	0	2
Hood River	HOOD-SW	3	2	1	0	3

Table B-5. Historical provisional summer populations in the Lower Columbia River Steelhead ESU.

Population	Map code	Historical presence	Historical abundance	Life history characteristics	Genetics	Geography
Kalama River	KALA-SS	3	2	2	2	3
North Fork Lewis River	NLEW-SS	3	1	1	1	3
East Fork Lewis River	ELEW-SS	2	1	2	1	3
Washougal River	WASH-SS	3	2	1	1	3
Wind River	WIND-SS	3	1	1	1	3
Hood River	HOOD-SS	3	1	1	0	3

Table B-6. Historical provisional winter populations in the Upper Willamette River Steelhead ESU.

Population	Map code	Historical presence	Historical abundance	Life history characteristics	Genetics	Geography
West-side tributaries	WEST-SW	1	1	0	1	2
Molalla River	MOLA-SW	3	1	1	2	3
North Santiam River	NSNT-SW	3	2	2	2	3
South Santiam River	SSNT-SW	3	2	2	2	3
Calapooia River	CALA-SW	3	1	1	2	3

Coho Salmon

Table B-7. Historical winter populations in the Lower Columbia River Coho ESU.

Population	Map code	Historical presence	Historical abundance	Life history characteristics	Genetics	Geography
Youngs Bay	YOUN-CS	3	2	1	2	2
Grays River	GRAY-CS	3	2	1	2	3
Big Creek	BIGC-CS	2	2	2	2	2
Elochoman River	ELOC-CS	2	1	1	0	2
Clatskanie River	CLAT-CS	2	1	1	2	2
Mill Creek	MILL-CS	2	1	1	0	2
Scappoose Creek	SCAP-CS	2	1	1	2	2
Cispus River	CISP-CS	3	1	1	0	3
Tilton River	TILT-CS	3	1	1	0	3
Upper Cowlitz River	UCWL-CS	3	2	1	2	3
Lower Cowlitz River	LCWL-CS	3	2	1	2	3
North Fork Toutle River (Green River)	NTOU-CS	3	1	1	0	3
South Fork Toutle River	STOU-CS	3	1	0	0	3
Coweeman River	COWE-CS	3	1	0	0	3
Kalama River	KALA-CS	3	2	2	0	3
North Fork Lewis River	NLEW-CS	3	2	1	2	3
East Fork Lewis River	ELEW-CS	3	2	1	2	3
Clackamas River	CLCK-CS	3	2	2	3	3
Salmon Creek	SALM-CS	3	1	1	0	2
Sandy River	SAND-CS	3	2	2	3	3
Washougal River	WASH-CS	2	2	1	0	3
Columbia River lower Gorge tributaries	LCRG-CS	2	1	1	0	2
Columbia River upper Gorge tributaries	UCRG-CS	2	1	1	0	2
Hood River	HOOD-CS	2	1	1	0	3

Chum Salmon

Table B-8. Historical populations in the Lower Columbia River Chum Salmon ESU.

Population	Map code	Historical presence	Historical abundance	Life history characteristics	Genetics	Geography
Chinook River	CHIN-CM	2	1	0	0	1
Youngs Bay	YOUN-CM	3	1	0	0	2
Grays River	GRAY-CM	3	1	2	3	3
Big Creek	BIGC-CM	3	1	0	0	2
Elochoman River	ELOC-CM	3	1	0	0	2
Clatskanie River	CLAT-CM	3	1	0	0	2
Mill Creek	MILL-CM	3	1	0	0	2
Scappoose Creek	SCAP-CM	2	1	0	0	2
Cowlitz River fall	COWF-CM	3	2	2	0	3
Cowlitz River summer	COWS-CM	1	1	1	2	2
Kalama River	KALA-CM	3	1	0	0	3
Salmon Creek	SALM-CM	2	0	0	0	3
Lewis River	LEWS-CM	3	2	1	0	3
Clackamas River	CLCK-CM	3	1	1	0	3
Washougal River	WASH-CM	3	1		0	3
Sandy River	SAND-CM	3	1	1	0	3
Columbia River lower Gorge tributaries	LGRG-CM	3	1	2	2(?)	2
Columbia River upper Gorge tributaries	UGRG-CM	3	1	1	0	2

Appendix C: Genetic Data Available on Salmonid Populations in the Lower Columbia River and Upper Willamette River ESUs

Introduction

This document describes and summarizes the genetic data currently available on the following salmonids ESUs:

- lower Columbia River Chinook salmon,
- upper Willamette River Chinook salmon,
- lower Columbia River steelhead,
- upper Willamette River steelhead, and
- lower Columbia River chum salmon.

Although DNA data likely will become available on at least some of these populations in the next few years, all the currently available data are from electrophoretic analysis of soluble enzymes (e.g., Aebersold et al. 1987), often called allozyme data. All data described herein were produced by the genetics labs of either the WDFW in Olympia and the Northwest Fisheries Science Center in Seattle or its research station in Manchester, Washington.

Standards for data consistency and quality (informally called the coastwide process) between these three laboratories and others in the region were developed during the past 15 years (Shaklee and Phelps 1990), ensuring that data from the two groups can be combined. The only exception is for steelhead, for which some standardization work remains to be done.[11] Data from a number of laboratories throughout the region were combined to produce the NMFS status reviews on chum salmon, Chinook salmon, and steelhead. The databases are described in the tables in this appendix. Most of the data already have appeared in the status reviews, but there is a considerable amount of new data for some species and ESU combinations.

The collections available may seem to be a reasonably comprehensive sampling of the populations for the regions in the lower Columbia and upper Willamette rivers, but a subtle bias to sampling can be potentially important in the TRT's review of these data. Genetic sampling has been done largely to characterize differences between groups that already were viewed as distinct stocks, not as a means of delineating populations. The reason for this distinction is that the initial impetus for genetic work on these fish, especially Chinook salmon, was analysis of mixed-stock fisheries (e.g., Marshall et al. 1991). The bias results from the fact that the smaller the stock, the less important it would be to the fishery, and thus the less likely it was to be

[11] D. Teel, Northwest Fisheries Science Center, Seattle, WA. Pers. commun., May 2000.

sampled. Thus there is circularity: we have data because we thought groups of fish were different, and now we use that data to determine that these groups are different. Since ESA listings began, there has been a sampling strategy change in terms of small populations that, if not for ESA significance, would get little attention from fish management agencies, however, it is important to consider how our view of populations may have been shaped by this sampling strategy.

The states of Washington and Oregon formally have described populations (not necessarily genetically distinct) of Chinook salmon, steelhead, and chum salmon and genetic groupings of these populations. These population designations and genetic groupings may be of some use in TRT population identification work. WDF, WDG, and tribal biologists (WDF et al. 1993) have defined stocks for salmon and steelhead in the Salmon and Steelhead Stock Inventory (SASSI, now known as the Salmonid Stock Inventory [SaSI]). WDFW genetic groupings, called major ancestral lineages (MALs) and genetic diversity units (GDUs), are described for Chinook salmon in Marshall et al. (1995), for chum salmon in Phelps et al. (1995), and for steelhead in Phelps et al. (1994a and 1997). Population designations and genetic management groups for salmon and steelhead in Oregon are described in Kostow (1995).

Genetic population structure usually is a continuum rather than a set of discrete steps. Therefore there are no established, widely accepted criteria for describing genetic groupings, just guidelines that can differ from place to place and can involve a fair degree of subjectivity. In Washington, biologists were asked to develop groupings that captured the “basic genetic essence” of the species (Busack and Marshall 1995), the idea being that if only one population per GDU survived, the basic genetic structure of the species still would be preserved. In the absence of distinctive life history differences, population groups often were described based on cluster analysis of allozyme data. A similar process was followed in Oregon (Kostow 1995). To date, no attempt has been made below the ESU level to describe genetic groupings that include Washington and Oregon populations.

An important feature to be aware of in reviewing the genetic data is that more data are available on Washington populations of all three species than on Oregon populations.

Analyses

There are two ways of examining the data in this technical memorandum:

- ordination of populations or collections, and
- testing for genetic differences between populations or collections.

Both methods are based on allele frequency differences among populations, so to this extent they are not independent.

Ordination

Allele-frequency differences among collections or groups of collections are summarized as genetic distances. Two genetic distance statistics are presented in tables: Nei’s unbiased genetic distance (Nei 1978) and Cavalli-Sforza and Edwards chord distance (Cavalli-Sforza and Edwards 1967), hereafter called CSE chord distance. The genetic distances are then presented graphically as dendrograms, using unweighted pair-group method cluster analysis (Sneath and

Sokal 1973) or in nonmetric multidimensional scaling (MDS) diagrams (Kruskal 1964). Genetic distances were calculated using the BIOSYS-1 program (Swofford and Selander 1981). Dendrograms were created using BIOSYS-1 or NTSYS (Rohlf 1994). MDS diagrams were created using NTSYS. Principal coordinate analysis (Gower 1966) was used to provide an initial ordination for generation of MDS diagrams.

The two types of genetic distance statistics assume two different modes of population differentiation. Nei's assumes differences arise primarily through mutation, while the CSE method assumes differences arise primarily through genetic drift. Nei distances have a long history in the literature, and Nei's is unbiased. The CSE chord distance does have some bias problems (Busack unpubl. data), but the drift mechanism it incorporates probably is a more accurate model for genetic differentiation in salmon and steelhead than mutation. CSE distances have been used extensively in the NMFS status reviews. In this technical memorandum, we present Nei's unbiased distances and CSE chord distances, but we use the latter exclusively for ordination.

The two ordination methods used in this technical memorandum, dendrograms and MDS diagrams, distort relationships between populations to some extent. Dendrograms are created by the stepwise addition of populations to clusters and then by recomputing distances between clusters and unclustered populations. Thus distances change as the clustering proceeds. The technique also forces populations into clusters. Gradual allele frequencies over a geographical area cannot be depicted accurately in dendrograms (Lessa 1990). MDS is simpler conceptually. Given all the pairwise distances, MDS attempts to draw a "map" of relationships in two- or three-dimensional space. MDS diagrams may be more challenging to interpret than dendrograms, but they have the advantages of being able to depict allele-frequency clines, and they do not generate artifactual clusters. However, the scaling of distances in dendrograms does not appear in MDS diagrams.

Tests of Allele-frequency Heterogeneity

All pairwise combinations of populations and collections were tested for allele-frequency differences by log-likelihood tests using the G statistic (Sokal and Rohlf 1981). The distribution of the G approximates the X^2 distribution. Williams's correction (Sokal and Rohlf 1981) is included in the tests to make the approximation closer. Tests are done for each locus and then summed for the final G value. Test results are presented as p values, that is, the probability of the null hypothesis of both samples representing random draws from the same gene population. Thus we leave determining levels of statistical significance, including Bonferroni corrections (e.g., Rice 1989) for multiple tests, to the reader.

Two caveats need to be considered in evaluating these test results:

- Power is strongly influenced by sample size. Small samples may yield large p values despite biologically meaningful allele-frequency differences. Conversely, very large samples may yield small p values that are not biologically meaningful. We have attempted in these analyses to avoid tests involving sample-size extremes.
- Low p values indicate only that the null hypothesis of random draws from the same gene pool probably is violated, and there are a variety of reasons the null hypothesis can be untrue. There may be significant levels of gene flow between populations that show sizable allele-frequency differences. Different year classes from the same population also

may differ in allele frequency. This is to be expected actually (Waples 1990) and thus is not necessarily a reflection of the population being ill-defined genetically. This phenomenon makes comparisons of populations sampled in different years problematic. With enough information about the age structure of the populations being compared, test statistics can be adjusted for the temporal scale of allele-frequency comparisons (Waples 1990). We have not attempted that in this technical memorandum.

Results

Lower Columbia River Chinook Salmon ESU

Two databases were available for evaluation of the Lower Columbia River Chinook Salmon ESU genetic structure: one from WDFW and one from NMFS (Table C-1). The overlap between the databases is large, with a substantial portion of the data in the NMFS database contributed by WDFW. There is a major geographical difference in coverage, however, with the NMFS database also including data on populations in the Upper Willamette River Chinook Salmon ESU. The WDFW database contains more recent data on Washington populations that are not included in the NMFS database. The two databases differ in locus and allele coverage (Table C-2). The WDFW database was developed specifically for TRT use, to provide the most complete set of genetic data for the Lower Columbia River Chinook Salmon ESU currently possible. The WDFW database includes fewer loci than the NMFS database (29 vs. 37), but the reduction resulted from excluding loci that were not variable in the Lower Columbia River Chinook Salmon ESU. The WDFW database also includes alleles scored confidently but not yet included in the coastwide NMFS database.

Table C-3 presents matrices of genetic distances among all pairwise combinations of populations in the WDFW database. The genetic distance relationship among these populations is summarized by a dendrogram (Figure C-1) and by multidimensional scaling (Figure C-2). The most conspicuous group on the dendrogram is the lower cluster consisting of hatchery stocks from Abernathy, Big, and Spring creeks. The hatcheries at Big and Spring creeks are large with a rich history of stock mixing, whereas Abernathy is a small research station that has received fish from several stocks. That this is a genetically distinct group (see also the group's position on the MDS in Figure C-2) is obvious, but exactly what it represents is unclear. It is possible that it represents an historical lineage, possibly reflecting the genetic composition of the Big White Salmon fall Chinook founders of the Spring Creek Hatchery population, but it is more likely that it is just a genetically distinct amalgam of several populations. The ancestry of this group needs additional study through examination of hatchery records. This group is considered a GDU (mid-Columbia River tule fall) by Marshall et al. (1995).

Excluding that cluster, there are two other major groups apparent in both figures: spring Chinook salmon and all other fall Chinook salmon populations. In the spring Chinook cluster, Cowlitz probably represents a blend of the pre-dam, Cowlitz spring Chinook salmon populations. This population has been large since the dams were constructed and has received very few hatchery introductions (Appendix A, Table A-1). However, because of incomplete separation by

Table C-1. Collections from the Lower Columbia River (LC) and Upper Willamette River (UW) Chinook Salmon ESUs included in the WDFW and NMFS databases.

Population sampled	ESU	State	Collection code[a]	Collection year	Life stage[b]	Sample size	Database
Cowlitz Hatchery spring	LC	WA	S0053	1982	A	50	NMFS
			W87QA	1987	A	102	Both
Cowlitz Hatchery fall	LC	WA	W88QZ	1988	A	99	Both
			S0045	1982	A	50	NMFS
			S0049	1981	A	49	NMFS
North Fork Lewis River spring	LC	WA	W88XF	1988	A	135	Both
North Fork Lewis River fall (bright)	LC	WA	W90CZ	1990	A	120	Both
Kalama Hatchery spring	LC	WA	W90BK	1990	A	109	Both
			S0113	1982	A	50	NMFS
Big Creek Hatchery	LC	OR	W90CM	1990	A	100	Both
			S0012	1982	J	50	NMFS
Elochoman River fall	LC	WA	W95EP	1995	A	35	WDFW
			W97EY	1997	A	84	WDFW
Abernathy Creek fall	LC	WA	W95EO	1995	A	43	WDFW
			W97EX	1997	A	41	WDFW
			W98DY	1998	A	30	WDFW
Abernathy Hatchery fall	LC	WA	W95EK	1995	A	100	WDFW
Coweeman River fall	LC	WA	W96CF	1996	A	76	WDFW
			W97FE	1997	A	14	WDFW
Kalama Hatchery fall	LC	WA	W88AB	1988	A	49	WDFW
			W89BG	1989	A	100	WDFW
			S0116	1982	J	50	Both
East Fork Lewis River fall (early)	LC	WA	W95EQ	1995	A	12	WDFW
			W96DV	1996	A	63	WDFW
			W97FC	1997	A	33	WDFW
Washougal River fall	LC	WA	W95ER	1995	A	65	WDFW
			W96EA	1996	A	39	WDFW
Sandy River fall (bright)	LC	OR	W90DA	1990	A	54	Both
			W91FN	1991	A	36	Both
			W92FA	1992	A	50	Both
			W93ET	1993	A	14	WDFW
Spring Creek NFH fall	LC	WA	W87AL	1987	A	104	Both
			W90CL	1990	A	150	Both
			S0012	1982	J	50	NMFS
			S0261	1982	J	50	NMFS
Sandy River spring	LC	OR	S1099	1997	J	—[c]	NMFS
Dexter Hatchery spring	UW	OR	W87AJ	1987	A	100	NMFS
McKenzie Hatchery spring	UW	OR	S0157	1982	A	38	NMFS
			W88QP	1988	A	110	NMFS
McKenzie River spring	UW	OR	S1098	unknown	—[d]	100	NMFS
North Santiam River spring	UW	OR	S1135	1998	J	99	NMFS
Clackamas Hatchery spring	UW	OR	W88AD	1988	A	100	NMFS

Table C-1 continued. Collections from the Lower Columbia River (LC) and Upper Willamette River (UW) Chinook Salmon ESUs included in the WDFW and NMFS databases.

Population sampled	**ESU**	**State**	**Collection code**[a]	**Collection year**	**Life stage**[b]	**Sample size**	**Database**
North Fork Clackamas River spring	UW	OR	S1091	1997	J	80	NMFS
Marion Forks Hatchery spring	UW	OR	W90CK	1990	A	100[c]	NMFS

[a] Codes beginning with S signify collections analyzed by NMFS, collection codes beginning with W signify collections analyzed by WDFW.

[b] A stands for adult, J stands for juvenile.

[c] Number of fish sampled is either unknown or approximated.

[d] Life stage is unknown.

Table C-2. Chinook salmon loci included in the NMFS and WDFW databases. Loci nomenclature follows conventions of Shaklee et al. (1990).

Locus	**Database**	**Locus**	**Database**	**Locus**	**Database**
mAAT-1	Both	GPI-B2	Both	sMEP-2	NMFS
mAAT-2	WDFW	GPIB-2a	NMFS	MPI	Both
sAAT-1,2	NMFS	GPIr	NMFS	PEPA	Both
sAAT-3	Both	GR	Both	PEPB-1	Both
sAAT-4	Both	bHEX	NMFS	PEPD-2	Both
ADA-1	Both	IDDH1	NMFS	PEP-LT	Both
ADA-2	NMFS	mIDHP-2	Both	PGDH	NMFS
ADH	NMFS	sIDHP-1	Both	PGK-2	Both
mAH-1	NMFS	sIDHP-2	Both	PGM-1	Both
mAH-3	NMFS	LDHB-1	NMFS	PGM-2	Both
mAH-4	Both	LDHB-2	NMFS	mSOD	NMFS
sAH	Both	LDH-C	Both	sSOD-1	Both
ALAT	NMFS	mMDH-2	Both	sSOD-2	WDFW
FDHG	Both	sMDHA-1,2	NMFS	TPI-3	NMFS
GAPDH-2	NMFS	sMDH-B1,2	Both	TPI-4	Both
GPI-A	Both	sMEP-1	Both		

run timing, Cowlitz spring and fall Chinook have been crossed at the hatchery. The similarity of the other two populations to Cowlitz may be natural. The case is easiest to make for the Kalama River, which has used 88% native fish (Table 3 and Table 4) in the hatchery, and which also has a natural production component. The Lewis River spring stock has received far more out-of-basin introductions, and it has long been thought that the original spring Chinook salmon run either died out or was largely replaced by introduced fish. The cluster of spring Chinook salmon makes geographical sense, however. The three basins are neighbors and all three had spring runs historically.

Table C-3. Genetic distances among 15 Lower Columbia River Chinook Salmon ESU populations, based on the WDFW database. Figures above the dashes are Nei's (1978) unbiased distances, figures below the dashes are CSE (1967) chord distances.

Population	1	2	3	4	5	6	7	8
1. Cowlitz Hatchery spring	—	0.0033	0.0003	0.0083	0.0050	0.0032	0.0103	0.0107
2. North Fork Lewis River spring	0.0614	—	0.0025	0.0115	0.0032	0.0045	0.0134	0.0061
3. Kalama Hatchery spring	0.0505	0.0569	—	0.0088	0.0049	0.0035	0.0099	0.0115
4. Big Creek Hatchery fall	0.0939	0.1018	0.0866	—	0.0051	0.0019	0.0002	0.0169
5. Elochoman River fall	0.0869	0.0765	0.0777	0.0771	—	0.0008	0.0067	0.0040
6. Abernathy Creek fall	0.0774	0.0786	0.0701	0.0550	0.0450	—	0.0032	0.0073
7. Abernathy Hatchery fall	0.1012	0.1075	0.0908	0.0371	0.0800	0.0575	—	0.0206
8. Coweeman River fall	0.1074	0.1023	0.1066	0.1143	0.0740	0.0839	0.1276	—
9. Cowlitz Hatchery fall	0.0644	0.0612	0.0615	0.0827	0.0517	0.0574	0.0874	0.0898
10. Kalama Hatchery fall	0.0771	0.0790	0.0692	0.0529	0.0438	0.0305	0.0619	0.0804
11. East Fork Lewis River early fall	0.0861	0.0745	0.0780	0.1054	0.0642	0.0711	0.1124	0.0613
12. North Fork Lewis River fall LRB	0.0781	0.0696	0.0695	0.0978	0.0543	0.0610	0.1039	0.0646
13. Washougal River fall	0.0762	0.0718	0.0715	0.0877	0.0438	0.0581	0.0945	0.0682
14. Sandy River fall LRB	0.0901	0.0767	0.0822	0.0923	0.0601	0.0666	0.0995	0.0670
15. Spring Creek fall NFH	0.1088	0.1166	0.0999	0.0377	0.0932	0.0685	0.0368	0.1334

Table C-3 continued. Genetic distances among 15 Lower Columbia River Chinook Salmon ESU populations, based on the WDFW database. Figures above the dashes are Nei's (1978) unbiased distances, figures below the dashes are CSE (1967) chord distances.

Population	9	10	11	12	13	14	15
1. Cowlitz Hatchery spring	0.0012	0.0037	0.0061	0.0035	0.0034	0.0052	0.0109
2. North Fork Lewis River spring	0.0027	0.0058	0.0032	0.0028	0.0036	0.0037	0.0145
3. Kalama Hatchery spring	0.0010	0.0040	0.0059	0.0036	0.0039	0.0055	0.0101
4. Big Creek Hatchery fall	0.0060	0.0020	0.0138	0.0106	0.0068	0.0090	0.0007
5. Elochoman River fall	0.0017	0.0013	0.0029	0.0016	0.0008	0.0017	0.0079
6. Abernathy Creek fall	0.0013	0.0000	0.0052	0.0028	0.0015	0.0026	0.0039
7. Abernathy Hatchery fall	0.0072	0.0032	0.0165	0.0127	0.0090	0.0115	0.0003
8. Coweeman River fall	0.0073	0.0084	0.0010	0.0022	0.0033	0.0018	0.0224
9. Cowlitz Hatchery fall	—	0.0013	0.0035	0.0016	0.0010	0.0029	0.0082
10. Kalama Hatchery fall	0.0516	—	0.0057	0.0034	0.0015	0.0033	0.0042
11. East Fork Lewis River early fall	0.0659	0.0695	—	0.0002	0.0016	0.0009	0.0181
12. North Fork Lewis River LRB fall	0.0548	0.0575	0.0423	—	0.0006	0.0006	0.0138
13. Washougal River fall	0.0503	0.0495	0.0496	0.0412	—	0.0007	0.0105
14. Sandy River fall LRB	0.0682	0.0626	0.0550	0.0517	0.0520	—	0.0128
15. Spring Creek fall NFH	0.0987	0.0718	0.1229	0.1141	0.1062	0.1105	—

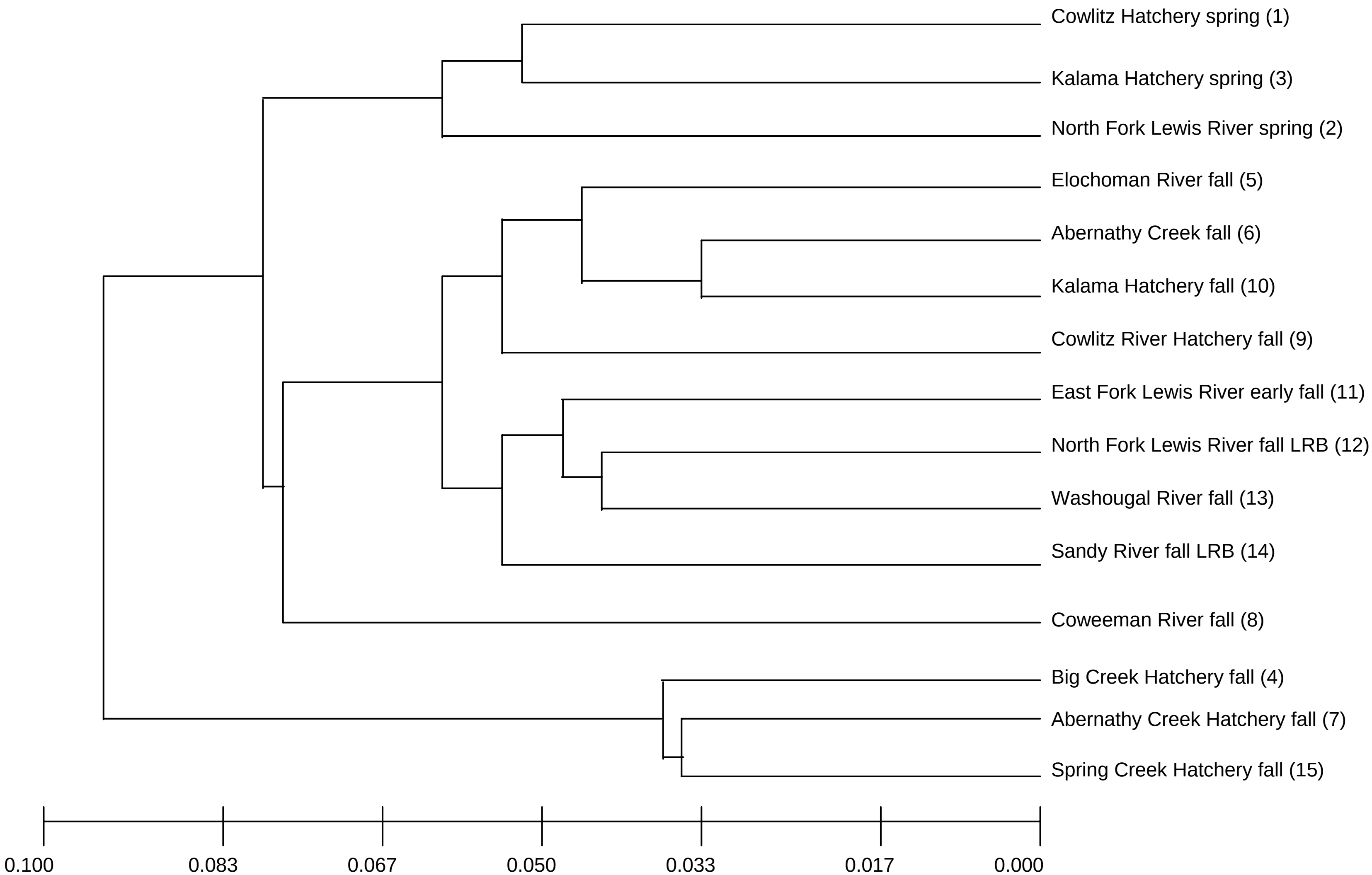
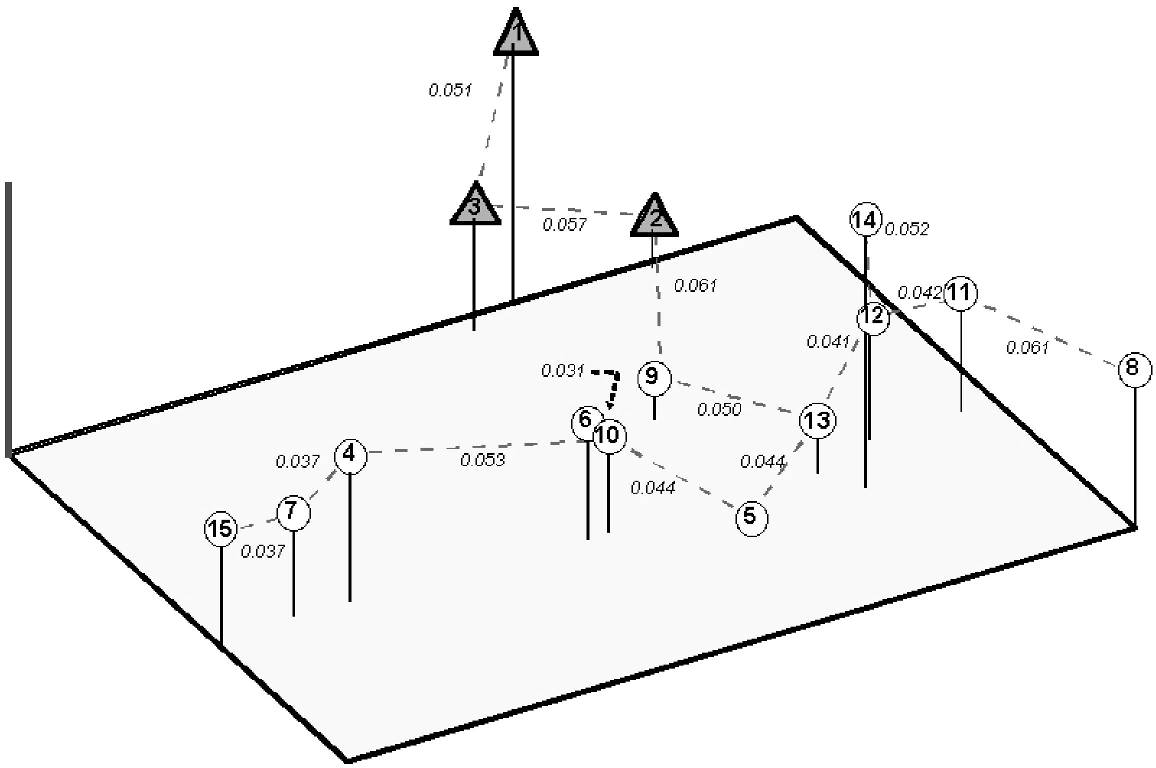


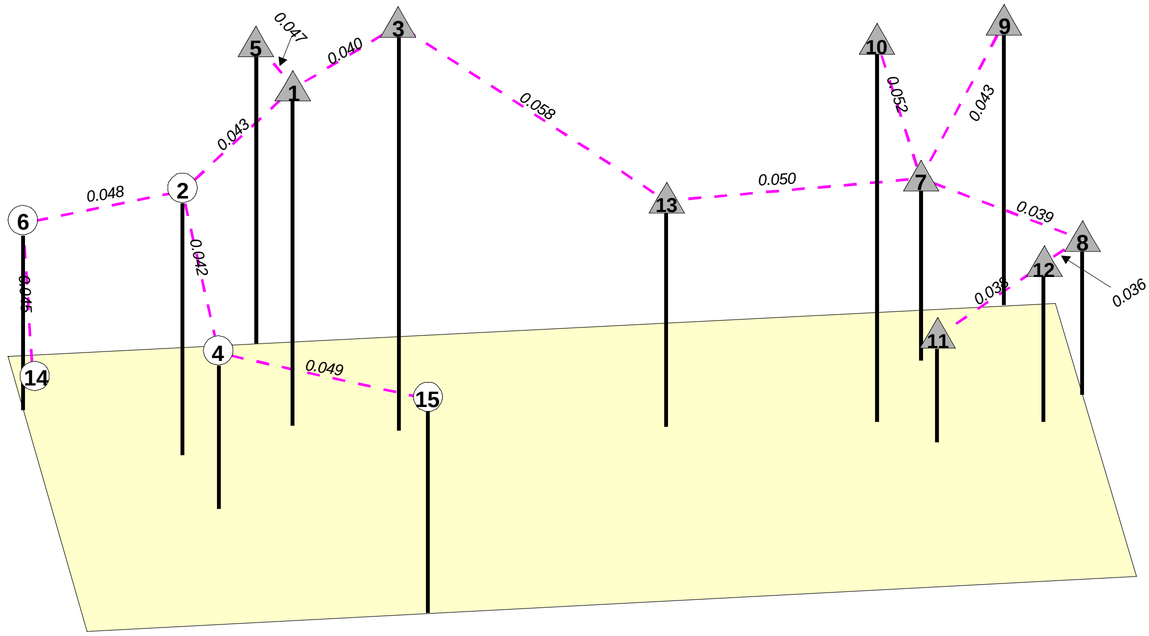
Figure C-1. UPGMA dendogram of CSE (1967) chord distances among 15 Washington populations in the Lower Columbia River Chinook Salmon ESU. The number in parenthesis corresponds to the numbers in Figure C-2.



1. Cowlitz Hatchery spring
2. North Fork Lewis River spring
3. Kalama Hatchery spring
4. Big Creek Hatchery fall
5. Elochoman River fall
6. Abernathy Creek fall
7. Abernathy Creek Hatchery fall
8. Coweeman River fall
9. Cowlitz Hatchery fall
10. Kalama Hatchery fall
11. East Fork Lewis River early fall
12. North Fork Lewis River fall bright
13. Washougal River fall
14. Sandy River Bright fall
15. Spring Creek Hatchery fall

Figure C-2. Multidimensional scaling analysis for the Lower Columbia River Chinook Salmon ESU with minimum spanning tree of CSE (1967) chord distances at 30 allozyme loci. Triangles are spring populations, circles are fall populations.

In the fall Chinook salmon cluster, the most distinct population is Coweeman River. This distinctiveness likely reflects natural genetic variation. This is a wild population, with little or no hatchery influence, and it has remained distinctive from the Cowlitz Hatchery fall Chinook salmon run. This probably means that historically it was a separate population from the mainstem Cowlitz. The remaining fall Chinook salmon are in two clusters that are not so apparent on the MDS diagram: one consisting samples from of the Lewis, Sandy, and Washougal rivers, and the other consisting samples from the Elochoman, Cowlitz, and Kalama rivers, and Abernathy Creek. These patterns may reflect some level of natural differentiation over the geographical area sampled, however, the lack of an obvious cline, coupled with the large amount of genetic exchange known to have occurred among hatcheries in the area, make risky any inferences about the resemblance of these patterns to original patterns. The only possible exception is the relationship between the two LRB populations (Lewis and Sandy rivers) and to tules from the Lewis and Washougal rivers. Either there is some gene flow (in one or both directions) or the bright populations have not diverged from the tule populations.



1. Cowlitz Hatchery spring
2. Cowlitz Hatchery fall
3. Kalama Hatchery spring
4. Kalama Hatchery fall
5. Lewis Hatchery spring
6. Lewis Hatchery fall
7. McKenzie and Dexter hatcheries spring
8. McKenzie River spring
9. North Santiam River spring
10. Clackamas Hatchery spring
11. North Fork Clackamas River spring
12. Marion Forks Hatchery spring
13. Sandy River spring
14. Sandy River fall
15. Spring Creek and Big Creek hatcheries

Figure C-3. Multidimensional scaling analysis for the Lower Columbia River and the Upper Willammette River Chinook salmon ESUs with minimum spanning tree of CSE (1967) chord distances at 37 allozyme loci. Triangles are spring populations, circles are fall populations.

The G-test results (Table C-4) offer additional insight in several respects. First, although most values were very low (less than 0.00005), the few high p values help scale the diagrams. Although significance levels are not denoted explicitly in the table, any p value greater than 0.05 can be taken as insignificant, no matter what level of correction for multiple tests is done. Thus most clusters on the dendrogram created at a genetic distance of less than 0.05 are insignificant. Second, they back up the observation that at least the Lewis River brights are not very different from tules from the Washougal and Lewis rivers: they are, in fact, insignificantly different.

There are other data that could have been included on presumed nonnative fish that have had some genetic impact on fish in the Lower Columbia River Chinook Salmon ESU. These include samples of “upriver brights” (URBs) spawning in the mainstem Columbia River and from the Little White Salmon and Bonneville hatcheries, and also Rogue River bright fall Chinook salmon that have been released from Youngs Bay net pens and from Big Creek Hatchery for several years.

Relationships between some of the same populations are presented in an MDS diagram based on the NMFS database (Figure C-3), along with the addition of Sandy River spring Chinook salmon. The Sandy River population is shown to be quite distinctive from the downstream populations and appears to be a transitional population between the Lower

Table C-4. Results of Williams-corrected G tests (Sokal and Rohlf 1981) for allele-frequency heterogeneity on all pairwise comparisons of 15 collections from the Lower Columbia River Chinook Salmon ESU in the WDFW database. Values shown are p values. Only values greater than 0.00005 are shown.

Comparison	P value
Big Creek Hatchery fall vs. Abernathy Hatchery fall	0.2297
Abernathy Creek fall vs. Kalama Hatchery fall	0.6238
East Fork Lewis River early fall vs. North Fork Lewis River fall LRB	0.0699
North Fork Lewis River late bright fall vs. Washougal River fall	0.0922
Big Creek Hatchery fall vs. Spring Creek NFH fall	0.0190
Elochoman River fall vs. Abernathy Creek fall	0.0075
Elochoman River fall vs. Kalama Hatchery fall	0.0012
Elochoman River fall vs. Washougal River fall	0.0095
Abernathy Hatchery fall vs. Spring Creek NFH fall	0.0096
Cowlitz Hatchery spring vs. Kalama Hatchery spring	0.0004
Elochoman River fall vs. Cowlitz Hatchery fall	0.0001
Cowlitz Hatchery fall vs. Washougal River fall	0.0007
East Fork Lewis River early fall vs. Washougal River fall	0.0001

Columbia River and Upper Willamette River Chinook Salmon ESUs. However, the large number of releases of Willamette River spring Chinook salmon from the Sandy River Hatchery (Table 3 and Table 4) may account for much if not all of the resemblance to the Upper Willamette River populations, making it unclear how different from more downstream populations the Sandy River population originally was.

Figure C-4, a CSE dendrogram of most of the Chinook salmon populations in Washington, puts the genetic diversity observed among Lower Columbia River Chinook Salmon ESU stocks in perspective. Lower Columbia River Chinook Salmon ESU populations are included in the grouping designated by WDFW as MAL II, Puget Sound Chinook Salmon ESU stocks comprise MAL IV. Note that the Puget Sound populations fall in large part into major groupings that have a geographical basis: Nooksack, Skagit and Stillaguamish, Snohomish, and White rivers, and South Sound and Hood Canal. Assuming that the distance at which branch points occur approximates the level of diversity among populations comprising the cluster, it can be seen that the diversity in the Lower Columbia River Chinook Salmon ESU is far less than that in the Puget Sound Chinook salmon ESU. Based only on this diagram, the diversity in the Lower Columbia River Chinook Salmon ESU fall populations appears to be about the same as that among fall populations in the South Puget Sound and Hood Canal Chinook Salmon ESUs, a group notable for extensive impacts of hatchery stocking. However, the Lower Columbia River Chinook Salmon ESU data included in this analysis that this diagram is based on does not include data from the Coweeman River, one of the most distinctive Lower Columbia Chinook Salmon ESU populations, or from any of the Oregon populations. Thus the Lower Columbia River Chinook Salmon ESU populations probably are more differentiated than the southern Puget Sound Chinook Salmon ESU populations.

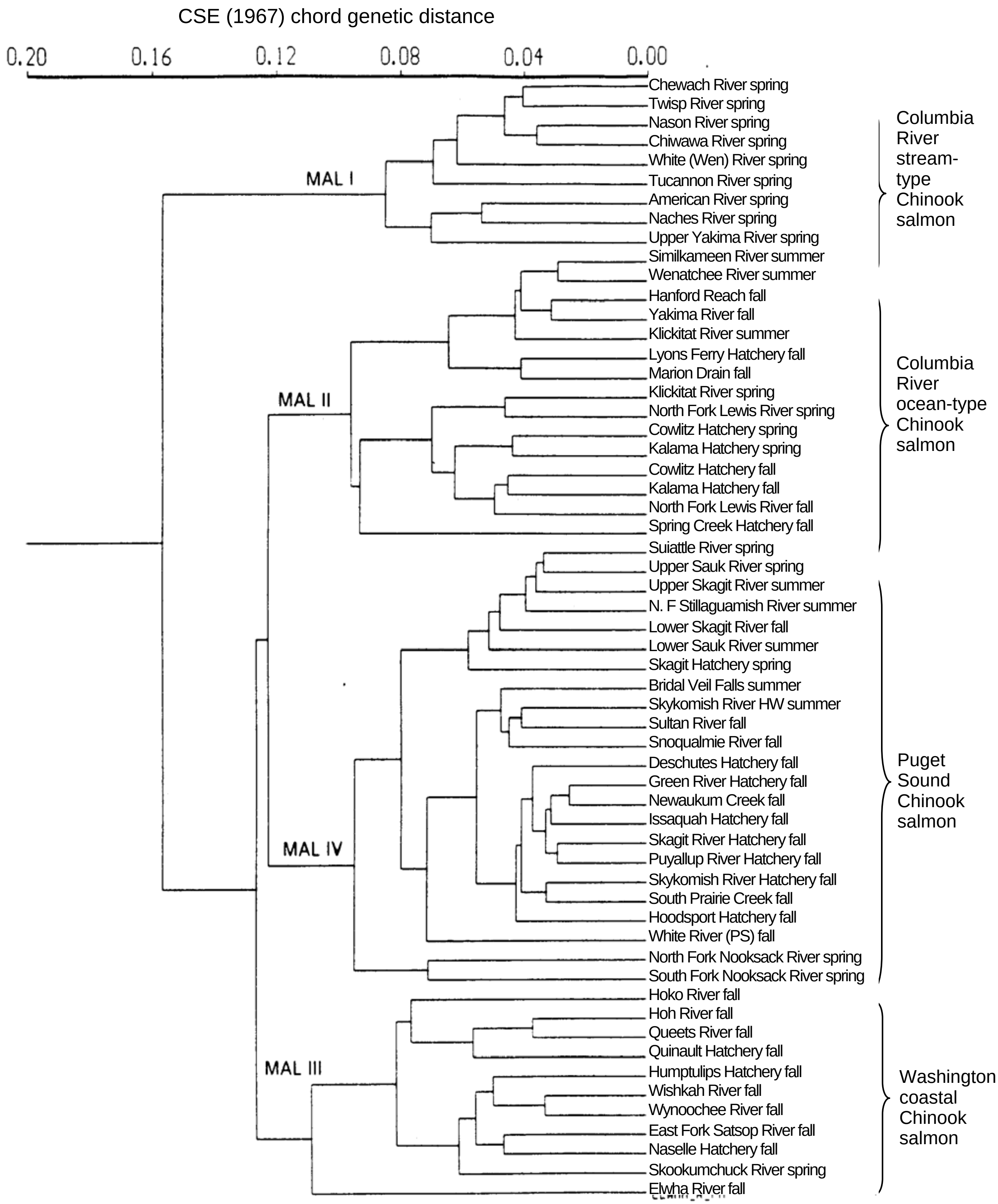


Figure C-4. UPGMA dendrogram of Washington Chinook salmon populations, based on CSE (1967) chord distances. Source: Modified from Marshall et al. 1995.

Upper Willamette River Chinook Salmon ESU

The Upper Willamette River Chinook Salmon ESU has not been sampled genetically nearly as extensively as the Lower Columbia River Chinook Salmon ESU. Distances are shown in Table C-5, an MDS diagram is presented in Figure C-3, and G-test results are presented in Table C-6. All comparisons have fairly low p values, indicating substantial differences, but there is no geographical pattern to the diversity. Moreover, the relationship between wild fish and hatchery fish is surprising. Clackamas River wild fish appear to be very different from Clackamas Hatchery fish. McKenzie River wild appear very similar to fish from Marion Forks Hatchery, a facility on the Santiam River. North Santiam River wild are quite distinct from Marion Forks Hatchery fish. These results indicate either that the wild fish are genetically distinct from the hatchery fish, which seems unlikely given the low levels of wild production and high relative level of hatchery production, or that the wild fish samples have given misleading results. This could be the case if they were the progeny of few spawners, which is quite possible in these Willamette River tributaries. The fact that at least two of these wild collections (Clackamas and North Santiam) were juveniles also may be a contributing factor. As juveniles, they likely represent a single year class. A population's year classes can vary significantly if effective size is low or if the adult age distribution is heavily weighted toward a single age. If the wild collections were excluded from Figure C-3, the remaining collections would show far less diversity, about as much as the spring populations in the Lower Columbia River Chinook Salmon ESU.

The available information on stock transfers suggests there has been enough genetic exchange among hatcheries in the Willamette River basins to justify considering Upper Willamette River Chinook Salmon ESU spring populations at present as a single gene pool (Kostow 1995, Table A-2 and Table C-5). If so, any diversity observed would be solely a reflection of small amounts of drift creating ephemeral genetic differences among the hatchery stocks. The amount of diversity observed, including the low p values, is not inconsistent with this hypothesis. Alternatively, if the hatcheries now are attempting to limit transfers, they would presumably start drifting apart.

Lower Columbia River Steelhead ESU

Two databases were used again to examine genetic relationships among populations in the Lower Columbia River and Upper Willamette River Steelhead ESUs: a WDFW database focusing on the Lower Columbia River Steelhead ESU and a NMFS database covering both ESUs (Table C-7). Also, as in the case of Chinook salmon, overlap between the databases is considerable. Loci used are presented in Table C-8. Genetic distances among the Lower Columbia River Steelhead ESU collections in the WDFW database are shown in Table C-9, and a dendrogram appears in Figure C-5. In cases in which populations were sampled more than once, data from the multiple collections were pooled.

Hatchery fish have been used extensively on the Washington side of the Lower Columbia River Steelhead ESU, but as in the case with steelhead hatchery plants throughout Western Washington, only two stocks have been used: the Chambers Creek winter stock from the Puget Sound Steelhead ESU, based on fish from Chambers Creek, and the Skamania Hatchery summer stock, based on fish from the Washougal River and Klickitat River basins. Samples from Chambers Creek Hatchery and from Beaver Creek Hatchery, a Chambers Creek derivative in the

Table C-5. Genetic distances among 15 Lower Columbia River and Upper Willamette River Chinook Salmon ESUs populations, based on the NMFS database. Figures above the dashes are Nei's (1978) unbiased distances, figures below the dashes are CSE (1967) chord distances.

Population	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1. Cowlitz Hatchery spring	—	0.0005	0.0001	0.0016	0.0026	0.0023	0.0071	0.0087
2. Cowlitz Hatchery fall	0.0432	—	0.0007	0.0006	0.0019	0.0010	0.0067	0.0086
3. Kalama Hatchery spring	0.0395	0.0541	—	0.0022	0.0018	0.0022	0.0052	0.0070
4. Kalama Hatchery fall	0.0510	0.0425	0.0607	—	0.0037	0.0023	0.0089	0.0104
5. Lewis Hatchery spring	0.0474	0.0531	0.0487	0.0656	—	0.0017	0.0081	0.0113
6. Lewis River fall	0.0602	0.0483	0.0621	0.0507	0.0602	—	0.0109	0.0137
7. McKenzie/Dexter hatcheries spring	0.0846	0.0927	0.0760	0.0974	0.0850	0.1098	—	0.0005
8. McKenzie River spring	0.0977	0.1081	0.0901	0.1065	0.1041	0.1229	0.0386	—
9. North Santiam River spring	0.0969	0.1009	0.0894	0.1055	0.1001	0.1176	0.0432	0.0548
10. Clackamas Hatchery spring	0.0781	0.0893	0.0709	0.0898	0.0851	0.1027	0.0524	0.0564
11. North Fork Clackamas River spring	0.0872	0.0941	0.0812	0.0924	0.0893	0.1127	0.0435	0.0409
12. Marion Forks Hatchery spring	0.0947	0.1019	0.0873	0.1016	0.0992	0.1140	0.0454	0.0360
13. Sandy River spring	0.0646	0.0682	0.0585	0.0679	0.0730	0.0807	0.0501	0.0655
14. Sandy River fall	0.0704	0.0631	0.0746	0.0606	0.0644	0.0448	0.1088	0.1212
15. Spring Creek and Big Creek hatcheries fall	0.0665	0.0720	0.0711	0.0491	0.0835	0.0869	0.0947	0.1011

Table C-5 continued. Genetic distances among 15 Lower Columbia River and Upper Willamette River Chinook Salmon ESUs populations, based on the NMFS database. Figures above the dashes are Nei's (1978) unbiased distances, figures below the dashes are CSE (1967) chord distances.

Population	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1. Cowlitz Hatchery spring	0.0094	0.0059	0.0073	0.0089	0.0037	0.0033	0.0035
2. Cowlitz Hatchery fall	0.0084	0.0054	0.0066	0.0083	0.0032	0.0019	0.0030
3. Kalama Hatchery spring	0.0076	0.0045	0.0055	0.0072	0.0025	0.0035	0.0038
4. Kalama Hatchery fall	0.0110	0.0067	0.0076	0.0100	0.0049	0.0029	0.0014
5. Lewis Hatchery spring	0.0110	0.0080	0.0082	0.0109	0.0058	0.0018	0.0063
6. Lewis River fall	0.0128	0.0094	0.0117	0.0127	0.0068	0.0003	0.0069
7. McKenzie/Dexter hatcheries spring	0.0009	0.0023	0.0015	0.0018	0.0011	0.0118	0.0088
8. McKenzie River spring	0.0015	0.0021	0.0009	0.0003	0.0016	0.0150	0.0092
9. North Santiam River spring	—	0.0030	0.0030	0.0024	0.0018	0.0139	0.0112
10. Clackamas Hatchery spring	0.0595	—	0.0018	0.0017	0.0014	0.0108	0.0063
11. North Fork Clackamas River spring	0.0633	0.0564	—	0.0008	0.0015	0.0128	0.0053
12. Marion Forks Hatchery spring	0.0605	0.0553	0.0384	—	0.0019	0.0142	0.0089
13. Sandy River spring	0.0624	0.0542	0.0604	0.0614	—	0.0084	0.0052
14. Sandy River fall	0.1167	0.1051	0.1115	0.1158	0.0890	—	0.0076
15. Spring Creek and Big Creek hatcheries fall	0.1061	0.0861	0.0829	0.0976	0.0718	0.0914	—

Table C-6. Results of Williams-corrected G tests (Sokal and Rohlf 1981) for allele-frequency heterogeneity on all pairwise comparisons for 15 collections from the Lower Columbia River and Upper Willamette River Chinook Salmon ESUs in the NMFS database. Values shown are p values. Only values greater than 0.00005 are shown.

Comparison	P value
Cowlitz Hatchery spring vs. Cowlitz Hatchery fall	0.0001
Cowlitz Hatchery spring vs. Kalama Hatchery spring	0.0004
Lewis River fall vs. Sandy River fall	0.0001
McKenzie/Dexter hatcheries spring vs. McKenzie River spring	0.0005
McKenzie/Dexter hatcheries spring vs. North Fork Clackamas River spring	0.0001
McKenzie River spring vs. Marion Forks Hatchery spring	0.0091
McKenzie River spring vs. North Fork Clackamas River spring	0.0069
North Fork Clackamas River spring vs. Marion Forks Hatchery spring	0.0039

Southwest Washington Steelhead ESU, were included in the analysis to provide insight on hatchery influences, along with two samples of the Skamania Hatchery summer stock, one of them from the Santiam River. Low reproductive success of the Skamania Hatchery stock was demonstrated in the Kalama River (Chilcote et al. 1986, Leider et al. 1990) and Clackamas River basins (Kostow et al. 2003).

Some caveats are in order before discussing the steelhead results. Unlike Chinook salmon, most steelhead collections are of juveniles. Because of this, they tend to be of a single year-class. If effective size is small or the population is dominated by a particular age-class, there may be sizable differences in allele frequency among broodyears, and thus among annual samples of juveniles from a single population. Thus a single year's collection representing a single broodyear, which often is all that is available, may be inadequate for understanding genetic relationships between it and other populations. Also, juvenile steelhead samples may be mixed collections of resident and anadromous fish or of different run times if both occur in the same basin. A final consideration is that the sample sizes tend to be lower than for Chinook salmon, thus the variance of allele-frequency estimates is higher.

Several interesting population clusters are apparent in Figure C-5. The uppermost cluster consists of the two Skamania summer steelhead collections. The next cluster down, containing collections from the Kalama (a juvenile sample probably containing winter and summer fish), the Lewis, and the Toutle, also may reflect Skamania Hatchery influence, as this stock is heavily used in all three basins. The next cluster consists of two summer-run collections from the Wind River and a collection of Cowlitz summers, two more basins in which the Skamania stock has been heavily used. However, the inclusion of the Wind collections also may indicate a natural genetic affinity to the Skamania stock in that the Wind basin neighbors the Washougal and the Klickitat, populations from which the Skamania stock is derived.

The next large cluster is of winter steelhead hatchery stocks, all Chambers Creek derivatives, and Green (Toutle) River and Cedar Creek. The latter two streams have received considerable numbers of hatchery winter steelhead, but the Green River has not been planted

Table C-7. Collections from the Lower Columbia (LC) River and Upper Willamette (UW) River Steelhead ESUs included in the WDFW and NMFS databases.

Population sampled	Run[a]	ESU	State	Collection code[b]	Collection year	Life stage[c]	Sample size	Database
Clackamas at Eagle Creek Hatchery	w	LC	OR	W96ED	1996	J	50	WDFW
Clackamas River	w	LC	OR	C95AM	1995–1997	A	68	WDFW
Clatskanie River	w	LC	OR	CLATS	1996	–	40	NMFS
Cowlitz Hatchery	s	LC	WA	W96EM	1996	J	50	WDFW
Cowlitz Hatchery early	w	LC	WA	W96EN	1996	J	50	WDFW
Cowlitz Hatchery late	w	LC	WA	W96EO	1996	J	70	WDFW
East Fork Lewis River	s	LC	WA	W96DK	1996	J	59	WDFW
East Fork Lewis River	w	LC	WA	W96DL	1996	J	59	WDFW
Green River (Toutle)	w	LC	WA	W96DP	1996	J	50	WDFW
Kalama River	s, w	LC	WA	C94BR	1994	J	95	Both
North Fork Lewis River (Cedar Creek)	w	LC	WA	W96DS	1996	J	59	WDFW
South Fork Toutle River	w	LC	WA	W96DM	1996	J	49	WDFW
Skamania Hatchery	w	LC	WA	W93CA	1993	J	50	Both
Skamania Hatchery	s	LC	WA	C91AA	1991,1994	A	197	Both
Washougal River	s	LC	WA	C93CS	1993	J	110	Both
Wind River (Panther Creek)	s	LC	WA	W94CU	1994	J	55	Both
Wind River (Trout Creek)	s	LC	WA	W93CR	1993	J	50	Both
Wind River	s	LC	WA	W94BU	1994	J	54	Both
Chambers Creek Hatchery	w	PS	WA	W93CD	1993	–[f]	50	WDFW
Beaver Creek Hatchery	w	SWW	WA	W93CB	1993	J	47	WDFW
Calapooia River	w	UW	OR	32445	1997	J	39	NMFS
Luckiamute River	w	UW	OR	32439	1997	J	31	NMFS
Marion Forks Hatchery	w	UW	OR	32548	1998	J	40	NMFS
Middle Fork Willamette River (resident trout)	r	UW	OR	32547	1998	J	31	NMFS
North Fork Molalla River	w	UW	OR	32311	1996	J	50	NMFS
North Santiam River	w	UW	OR	SANTI	1997	J	36	NMFS
Rickreall Creek (Canyon Creek)	w	UW	OR	32440	1997	J	34	NMFS
South Santiam River (Wiley Creek)	w	UW	OR	32444	1997	J	40	NMFS
Skamania Hatchery at South Santiam River	s	UW	OR	W95AN	1995	J	51	WDFW
Upper McKenzie River (Deer Creek) (resident trout)	r	UW	OR	32546	1998	J	33	NMFS
Yamhill River Willamina Creek)	w	UW	OR	32442	1981	J	49	NMFS

[a] W is for winter, s is for summer, r is for resident form.

[b] Entirely alphabetical or entirely numerical codes signify collections analyzed by NMFS, collections codes beginning with W signify collections analyzed by WDFW.

[c] J is for juvenile, A is for adult, – is for unknown.

Table C-8. Loci included in the NMFS and WDFW steelhead databases. Loci nomenclature follows conventions of Shaklee et al. (1990).

Locus	Database	Locus	Database	Locus	Database
mAAT-1	Both	GAPDH-3	Both	sMDH-A12	Both
sAAT-12	Both	bGLUA	Both	sMDH-B12	Both
sAAT-3	NMFS	GPI-A	Both	mMEP-1	Both
ADA-1	Both	GPI-B1	Both	MPI	Both
ADA-2	Both	GPI-B2	Both	NTP	Both
ADH	Both	G3PDH-1	Both	PEPA	Both
mAH-3	WDFW	IDDH-1	Both	PEPB-1	Both
sAH	Both	IDDH-2	Both	PEPD-1	Both
ALAT	Both	mIDHP-1	NMFS	PEP-LT	NMFS
CK-A1	NMFS	mIDHP-2	Both	PGK-2	Both
CK-A2	NMFS	sIDHP-1	Both	PGM-1	Both
CK-C2	WDFW	sIDHP-2	Both	PGM-2	NMFS
FDHG	NMFS	LDH-B1	NMFS	sSOD-1	Both
FH	NMFS	LDH-B2	Both	TPI-3	Both

since 1980.[12] The remaining clusters on the dendrogram include populations that are more genetically distinct from the hatchery stocks than those discussed above. Forming a single-population cluster is Clackamas wild winter steelhead. The next cluster contains Trout Creek, a Wind River tributary where hatchery fish have been largely excluded by a trap, and Washougal River, collected from above partial barriers where hatchery fish are unlikely to stray. The last two collections on the dendrogram probably reflect additional genetic distinctiveness from the complex of hatcheries rearing Skamania Hatchery and Chambers Creek Hatchery stocks, but not necessarily distinctiveness from hatchery stocks in general. The Clackamas River at Eagle Creek Hatchery collection is of Eagle Creek Hatchery/Big Creek Hatchery stock, possibly with some Clackamas River influence (Kostow et al. 2003), but the Cowlitz Hatchery late winter run spawns sufficiently late enough that interbreeding with Chambers Creek Hatchery fish is unlikely.

Overall, this figure is not overly informative, probably showing two genetically distinctive populations—Cowlitz and Clackamas rivers winter steelhead—and some other possible reflections of original genetic relationships. However, it does not show anything close to a good separation of several populations that correlates well with geography. The G tests are not very informative (Table C-10). No inferences can be drawn from them about population groupings. Table C-11 displays genetic distances among collections in the NMFS database, and a dendrogram appears in Figure C-6. Two samples from outside the ESU, the Clatskanie and Grays rivers, are included in this database. The clustering of Lower Columbia River Steelhead ESU collections provides no additional insight over that gleaned from the WDFW database.

[12] D. Rawding, WDFW, Region 5, Vancouver, WA. Pers. commun., May 2000.

Table C-9. Genetic distances among 20 Lower Columbia River Steelhead ESU collections, based on the WDFW database. Figures above the dashes are Nei's (1978) unbiased distances, figures below the dashes are CSE (1967) chord distances. This two-page table is continued horizontally.

Population	1	2	3	4	5	6	7	8	9	10
1. Skamania Hatchery summer	—	0.0081	0.0023	0.0055	0.0049	0.0056	0.005	0.0023	0.0041	0.0012
2. Washougal River summer	0.0906	—	0.0063	0.0051	0.0057	0.0036	0.0047	0.0058	0.0079	0.0071
3. Kalama River summer and winter	0.0797	0.0908	—	0.0029	0.0017	0.0017	0.0029	0.0008	0.0008	0.0031
4. Skamania Hatchery winter	0.0861	0.0906	0.0854	—	0.0019	0.0013	0.0053	0.0037	0.0025	0.0061
5. Beaver Creek Hatchery winter	0.1033	0.0955	0.0832	0.069	—	0.0004	0.0055	0.0029	0.0023	0.0034
6. Chambers Creek Hatchery winter	0.0944	0.0894	0.072	0.0644	0.0644	—	0.0046	0.0018	0.0019	0.0052
7. Trout-Wind summer	0.1012	0.0915	0.0985	0.1142	0.1194	0.1124	—	0.0019	0.0029	0.0064
8. Wind River summer	0.0726	0.0919	0.0782	0.0911	0.1053	0.0935	0.074	—	0.0003	0.0039
9. Panther Creek summer	0.087	0.0976	0.0769	0.09	0.1044	0.0904	0.0863	0.0673	—	0.0058
10. Skamania/Santiam hatcheries summer	0.0663	0.0814	0.0835	0.0864	0.0983	0.0955	0.1084	0.0812	0.0957	—
11. East Fork Lewis River summer	0.0758	0.0965	0.0739	0.0893	0.1042	0.0915	0.1071	0.0825	0.0866	0.0745
12. East Fork Lewis River winter	0.0826	0.0883	0.0625	0.0922	0.094	0.0778	0.0995	0.0827	0.0837	0.0801
13. South Fork Toutle River winter	0.0805	0.0874	0.0691	0.0823	0.0872	0.083	0.1018	0.0893	0.0992	0.0872
14. Green-North Fork Toutle River winter	0.0916	0.0896	0.0765	0.0832	0.0837	0.0894	0.1101	0.0892	0.0836	0.0875
15. Cedar Creek winter	0.0801	0.1012	0.0707	0.0638	0.0707	0.0686	0.1068	0.0885	0.086	0.0915
16. Eagle Creek Hatchery winter	0.1161	0.1071	0.0858	0.1031	0.0998	0.0963	0.1209	0.1132	0.1015	0.1162
17. Cowlitz Hatchery summer	0.0722	0.1051	0.0737	0.0838	0.0952	0.0802	0.11	0.0757	0.0787	0.0863
18. Cowlitz Hatchery early winter	0.087	0.1098	0.0772	0.0719	0.0858	0.0897	0.1177	0.0926	0.0918	0.0907
19. Cowlitz Hatchery late winter	0.1089	0.1179	0.0999	0.0939	0.115	0.1129	0.1304	0.1054	0.102	0.1106
20. Clackamas River winter	0.0987	0.0961	0.0801	0.107	0.1099	0.1019	0.1091	0.0911	0.095	0.0998

Table C-9 continued. Genetic distances among 20 Lower Columbia River Steelhead ESU collections, based on the WDFW database. Figures above the dashes are Nei's (1978) unbiased distances, figures below the dashes are CSE (1967) chord distances. This two-page table is continued horizontally.

Population	11	12	13	14	15	16	17	18	19	20
1. Skamania Hatchery summer	0.0031	0.0041	0.0022	0.004	0.002	0.0069	0.0022	0.0027	0.0053	0.0052
2. Washougal River summer	0.0076	0.0056	0.0033	0.0058	0.0074	0.0064	0.0087	0.0096	0.0109	0.0072
3. Kalama River summer and winter	0.0018	0.0006	0.0015	0.0003	0.0004	0.0014	0.001	0.0006	0.0033	0.0033
4. Skamania Hatchery winter	0.0045	0.0042	0.0031	0.0031	0.002	0.0043	0.0032	0.0025	0.006	0.0065
5. Beaver Creek Hatchery winter	0.0028	0.0018	0.0026	0.0009	0.0018	0.0027	0.0018	0.0017	0.005	0.0069
6. Chambers Creek Hatchery winter	0.003	0.0014	0.0023	0.0011	0.0017	0.0018	0.0028	0.003	0.0061	0.0038
7. Trout-Wind summer	0.0043	0.0038	0.0028	0.0035	0.0041	0.0041	0.0046	0.005	0.0063	0.005
8. Wind River summer	0.002	0.0012	0.0025	0.0008	0.0013	0.0027	0.0014	0.0024	0.0038	0.0023
9. Panther Creek summer	0.0023	0.0016	0.0044	0.0004	0.0013	0.0017	0.0005	0.0011	0.0026	0.0047
10. Skamania/Santiam hatcheries summer	0.0042	0.0044	0.002	0.0045	0.0032	0.0078	0.0033	0.0032	0.0072	0.0078
11. East Fork Lewis River summer	—	0.0016	0.0029	0.0018	0.0022	0.0038	0.0015	0.0023	0.0044	0.0044
12. East Fork Lewis River winter	0.0687	—	0.0025	0.0004	0.0017	0.0017	0.0024	0.0024	0.0051	0.0032
13. South Fork Toutle River winter	0.0841	0.0815	—	0.0025	0.0017	0.0039	0.0037	0.0027	0.0059	0.0042
14. Green-North Fork Toutle River winter	0.0814	0.0783	0.0817	—	0.001	0.0008	0.0016	0.0011	0.0022	0.0039
15. Cedar Creek winter	0.0841	0.0798	0.0751	0.0727	—	0.0027	0.0019	0.0001	0.0033	0.0034
16. Eagle Creek Hatchery winter	0.104	0.098	0.0893	0.0872	0.0955	—	0.0038	0.003	0.0054	0.004
17. Cowlitz Hatchery summer	0.0797	0.0852	0.0949	0.0881	0.0816	0.1147	—	0.0007	0.0026	0.0064
18. Cowlitz Hatchery early winter	0.0874	0.0908	0.0815	0.072	0.0553	0.0968	0.0804	—	0.0024	0.0062
19. Cowlitz Hatchery late winter	0.1013	0.1132	0.1018	0.0899	0.0914	0.1222	0.1025	0.0844	—	0.0092
20. Clackamas River winter	0.1018	0.0867	0.0962	0.0934	0.0946	0.1013	0.1093	0.1051	0.119	—

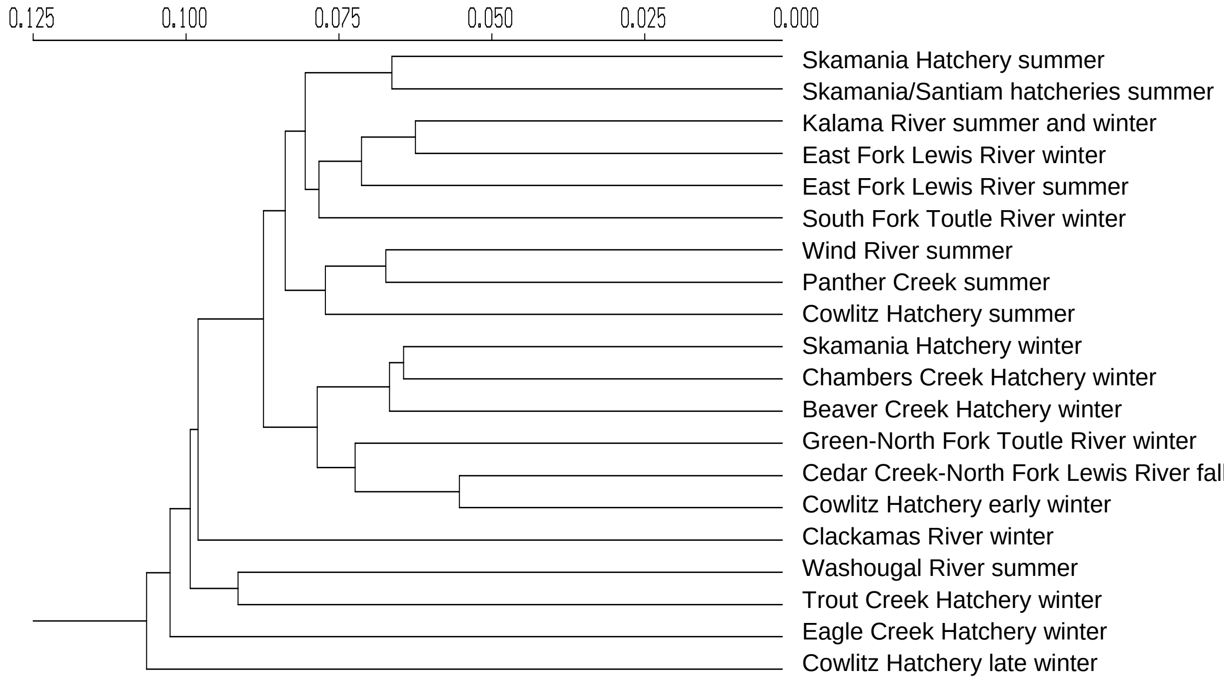


Figure C-5. Cluster analysis UPGMA of genetic distances for WDFW samples from the Lower Columbia River Steelhead ESU.

Upper Willamette River Steelhead ESU

Based on their placement in the dendrogram (Figure C-6), Upper Willamette River Steelhead ESU collections appear more diverse genetically than those from the Lower Columbia River Steelhead ESU. Most distinctive (bottom cluster) are the two samples of resident trout from the upper Mackenzie and Middle Fork Willamette rivers. The Luckiamute River collection is distinctive from most other Willamette River collections, and distinctive from the other west-side collections (Rickreall Creek and Yamhill River), which cluster with the Clatskanie River collection. Possibly this reflects lower-river hatchery influence. The remaining Upper Willamette River Steelhead ESU collections cluster together. It is not clear how much the relationships among them may reflect hatchery activity, but they appear to be more distinct from each other than are the Lower Columbia River Steelhead ESU collections.

As was the case with the collections in the WDFW database, G-test p values (Table C-12) are almost all very low, and thus not informative.

Columbia River Chum Salmon ESU

Chum salmon probably occur in very low numbers in many streams on both sides of the lower Columbia River. Until recently, chum salmon were seen in numbers large enough for meaningful allozyme analysis only in two regions, Grays River and just downstream of

Table C-10. Results of Williams-corrected G tests (Sokal and Rohlf 1981) for allele-frequency heterogeneity on all pairwise comparisons of 20 collections from the Lower Columbia River and Upper Willamette River Steelhead ESUs in the WDFW database.

Comparison	P value*
Cedar Creek winter 1996 vs. Cowlitz Hatchery early winter 1996	0.0465
Skamania Hatchery winter 1993 vs. Chambers Creek Hatchery winter 1993	0.0026
Beaver Creek Hatchery winter 1993 vs. Chambers Creek Hatchery winter 1993	0.0064
Wind River summer 1994 vs. Panther Creek summer 1994	0.0063
Kalama River summer 1994 vs. East Fork Lewis River winter 1996	0.0001
Kalama River summer 1994 vs. South Fork Toutle River winter 1996	0.0002
Skamania Hatchery winter 1993 vs. Beaver Creek Hatchery winter 1993	0.0001
Skamania Hatchery winter 1993 vs. Cedar Creek winter 1996	0.0004
Chambers Creek Hatchery winter 1993 vs. Cedar Creek winter 1996	0.0001
Panther Creek summer 1994 vs. Cowlitz Hatchery summer 1996	0.0001
Green-North Fork Toutle River winter 1996 vs. Cowlitz Hatchery early winter 1996	0.0005
South Fork Toutle River winter 1996 vs. Cedar Creek winter 1996	0.0001
South Fork Toutle River winter 1996 vs. Green-North Fork Toutle River winter	0.0001

* Values shown are p values. Only values greater than 0.00005 are shown.

Bonneville Dam. In the latter area, spawning was observed in Hamilton and Hardy creeks. Several collections of spawning adults, totaling several hundred fish, were made from these sites from 1992 to 2000 (Table C-13). More recently, spawning was observed in the mainstem Columbia River at Ives Island, a spot just off Hamilton and Hardy creeks. Small numbers of Ives Island adults and juveniles were collected in 1998 and 1999, and a large number was collected in 2000. Fish also were observed spawning in seep areas of the Columbia River at Vancouver near the Interstate 205 bridge, and a large collection was made in 2000–2001. Small numbers of chum salmon, also not yet analyzed, were collected in the Elochoman and Cowlitz rivers in 2000.

Loci used in the genetic analysis are presented in Table C-14. Genetic distances among 11 chum salmon collections are presented in Table C-15 and a dendrogram based on the CSE chord distances is presented in Figure C-7. Three small collections from the Ives Island area were not included in the analysis, because small sample sizes might not adequately characterize the populations. Two collections from Hamilton Creek also were pooled to avoid small-sample-size problems. The cluster analysis clearly separates the samples into three groups: Grays River, the below-Bonneville Dam area (Hamilton and Hardy creeks, Ives Island, and the Interstate 205 seeps), and the Sea Resources Hatchery on the Chinook River. At the time it was sampled, this hatchery was propagating a non–Columbia River chum salmon stock from southwestern Washington (it has since switched to a Grays River stock). Thus there appear to be two Columbia River chum salmon groups, in agreement with the GDU designations of Phelps et al. (1995). There is, however, no clear distinction among the below–Bonneville Dam collections.

G-test results (Table C-16) support the cluster analysis. The maximum p value between the Grays River collections and any other collection was 0.0001, showing good separation

Table C-11. Genetic distances among 19 collections from the Lower Columbia River and Upper Willamette River Steelhead ESUs, based on the NMFS database. Figures above the dashes are Nei's (1978) unbiased distances, figures below the dashes are CSE (1967) chord distances. This two-page table is continued horizontally.

Population	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1. Clatskanie River 1996	—	0.0012	0.0015	0.0057	0.0055	0.0035	0.0020	0.0012	0.0045	0.0002
2. Grays River 1994	0.0751	—	0.0017	0.0094	0.0098	0.0062	0.0028	0.0012	0.0057	0.0019
3. Kalama River 1994	0.0850	0.0625	—	0.0044	0.0040	0.0050	0.0010	0.0007	0.0018	0.0023
4. North Fork Molalla River 1993	0.0851	0.1002	0.0833	—	0.0014	0.0099	0.0065	0.0065	0.0055	0.0061
5. North Santiam River 1997	0.0958	0.1138	0.0916	0.0754	—	0.0080	0.0051	0.0067	0.0053	0.0056
6. Washougal River 1993–1994	0.0936	0.0841	0.0816	0.1048	0.0992	—	0.0038	0.0063	0.0066	0.0042
7. Wind River 1993–1994	0.1002	0.0814	0.0717	0.1006	0.0993	0.0750	—	0.0010	0.0024	0.0033
8. Panther Creek 1994	0.0911	0.0766	0.0676	0.0941	0.1029	0.0873	0.0595	—	0.0033	0.0019
9. Skamania Hatchery summer 1991	0.0926	0.0850	0.0708	0.0883	0.0917	0.0816	0.0722	0.0778	—	0.0046
10. Skamania Hatchery winter 1991	0.0722	0.0634	0.0793	0.0940	0.0984	0.0817	0.0899	0.0776	0.0768	—
11. Beaver Creek Hatchery 1993	0.0896	0.0609	0.0761	0.1025	0.1146	0.0841	0.0925	0.0860	0.0863	0.0593
12. Luckiamute River 1997	0.0916	0.1013	0.1095	0.1076	0.1258	0.1300	0.1256	0.1146	0.1221	0.1016
13. Rickreall Creek 1997	0.0777	0.0936	0.1104	0.1196	0.1209	0.1078	0.1134	0.1030	0.1128	0.0892
14. Yamhill River 1997	0.0715	0.0898	0.0931	0.0834	0.0878	0.1074	0.1066	0.1029	0.1029	0.0805
15. South Santiam River 1997	0.1013	0.0975	0.1016	0.0823	0.0896	0.1065	0.1061	0.1104	0.1130	0.0972
16. Marion Forks Hatchery 1998	0.0947	0.1175	0.0925	0.0639	0.0707	0.1095	0.1049	0.1043	0.0975	0.1083
17. Calapooia River 1997	0.1113	0.1238	0.1081	0.0807	0.0857	0.1159	0.1101	0.1098	0.1088	0.1133
18. Upper McKenzie River1998	0.1668	0.1764	0.1635	0.1480	0.1428	0.1772	0.1755	0.1688	0.1791	0.1637
19. Middle Fork Willamette River 1998	0.1604	0.1780	0.1682	0.1402	0.1400	0.1686	0.1726	0.1755	0.1772	0.1634

Table C-11 continued. Genetic distances among 19 collections from the Lower Columbia River and Upper Willamette River Steelhead ESUs, based on the NMFS database. Figures above the dashes are Nei's (1978) unbiased distances, figures below the dashes are CSE (1967) chord distances. This two-page table is continued horizontally.

Population	11	12	13	14	15	16	17	18	19
1. Clatskanie River 1996	0.0015	0.0065	0.0030	0.0019	0.0075	0.0057	0.0083	0.0368	0.0330
2. Grays River 1994	0.0012	0.0061	0.0038	0.0047	0.0091	0.0098	0.0130	0.0449	0.0443
3. Kalama River 1994	0.0013	0.0076	0.0066	0.0032	0.0067	0.0045	0.0077	0.0370	0.0352
4. North Fork Molalla River 1993	0.0067	0.0117	0.0147	0.0035	0.0024	0.0000	0.0014	0.0230	0.0177
5. North Santiam River 1997	0.0079	0.0134	0.0146	0.0026	0.0035	0.0003	0.0011	0.0246	0.0203
6. Washougal River 1993–1994	0.0049	0.0165	0.0089	0.0070	0.0114	0.0095	0.0107	0.0423	0.0332
7. Wind River 1993–1994	0.0032	0.0111	0.0061	0.0048	0.0079	0.0057	0.0076	0.0391	0.0356
8. Panther Creek 1994	0.0018	0.0059	0.0041	0.0037	0.0086	0.0067	0.0097	0.0385	0.0397
9. Skamania Hatchery summer 1991	0.0042	0.0132	0.0115	0.0061	0.0097	0.0057	0.0081	0.0426	0.0376
10. Skamania Hatchery winter 1991	0.0016	0.0064	0.0061	0.0014	0.0078	0.0064	0.0088	0.0358	0.0349
11. Beaver Creek Hatchery 1993	—	0.0069	0.0064	0.0049	0.0086	0.0080	0.0117	0.0398	0.0380
12. Luckiamute River 1997	0.1088	—	0.0097	0.0057	0.0149	0.0132	0.0186	0.0379	0.0469
13. Rickreall Creek 1997	0.1075	0.1088	—	0.0075	0.0144	0.0138	0.0178	0.0473	0.0438
14. Yamhill River 1997	0.1031	0.0927	0.0921	—	0.0046	0.0036	0.0055	0.0272	0.0267
15. South Santiam River 1997	0.1049	0.1214	0.1184	0.0867	—	0.0029	0.0034	0.0246	0.0176
16. Marion Forks Hatchery 1998	0.1167	0.1187	0.1263	0.0933	0.0999	—	0.0003	0.0243	0.0184
17. Calapooia River 1997	0.1269	0.1451	0.1367	0.1130	0.0948	0.0003	—	0.0229	0.0172
18. Upper McKenzie River1998	0.1732	0.1741	0.1806	0.1536	0.1432	0.0243	0.0229	—	0.0162
19. Middle Fork Willamette River 1998	0.1733	0.1844	0.1741	0.1546	0.1315	0.0184	0.0172	0.0162	—

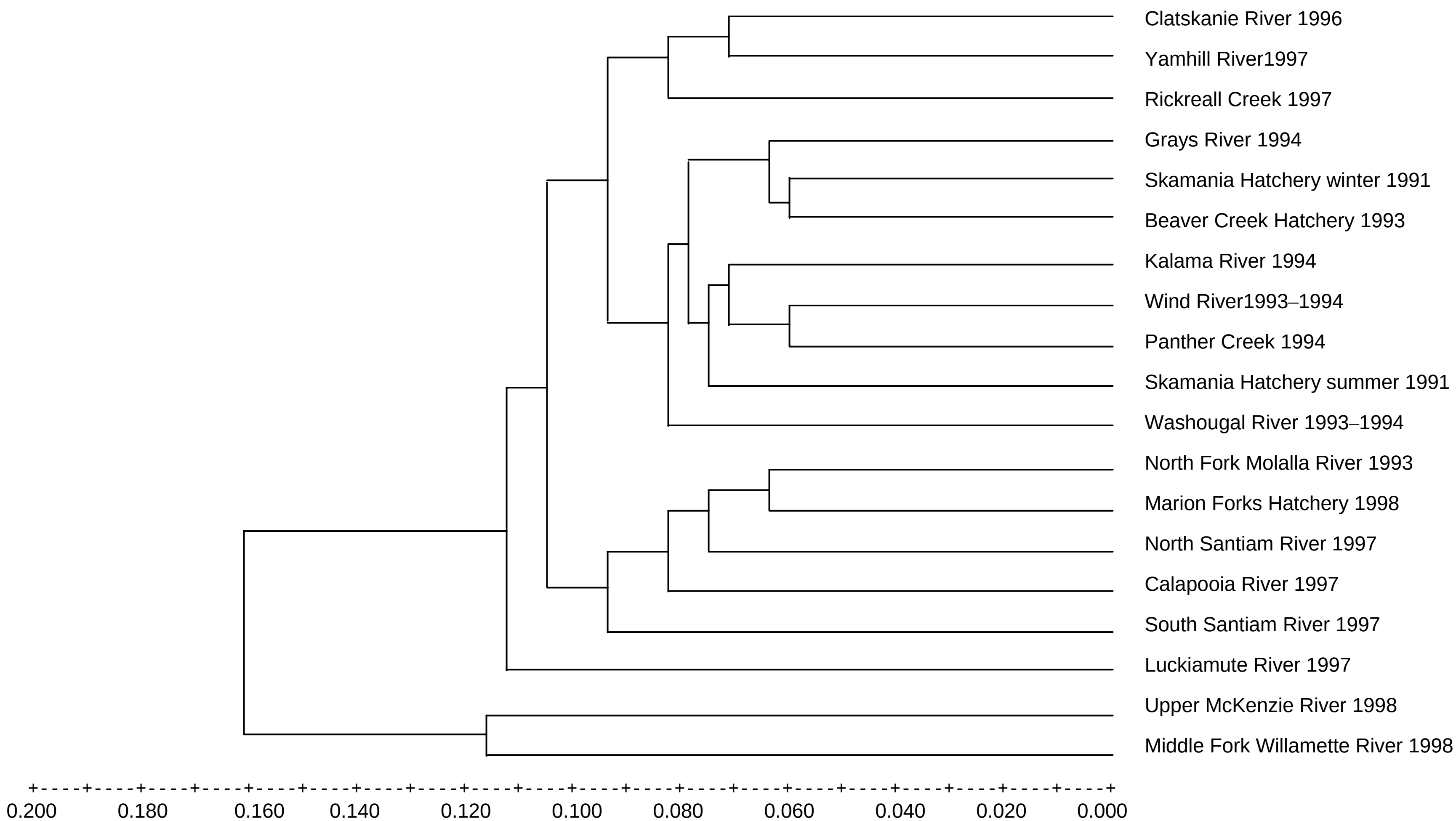


Figure C-6. UPGMA dendogram of CSE (1967) chord distances among 19 collections from the Lower Columbia River and Upper Willamette River Steelhead ESUs.

Table C-12. Results of Williams-corrected G tests (Sokal and Rohlf 1981) for allele-frequency heterogeneity on all pairwise comparisons of 19 collections from the Lower Columbia River and Upper Willamette River ESUs in the NMFS database.

Comparison	P value*
North Fork Molalla River 1993 vs. Marion Forks Hatchery 1998	0.0152
Clatskanie River 1996 vs. Grays River 1994	0.0011
Clatskanie River 1996 vs. Skamania Hatchery winter 1991	0.0035
Grays River 1994 vs. Beaver Creek Hatchery 1993	0.0086
North Santiam River 1997 vs. Marion Forks Hatchery 1998	0.0042
Clatskanie River 1996 vs. Yamhill River 1997	0.0002
Grays River 1994 vs. Kalama River 1994	0.0004
Grays River 1994 vs. Panther Creek 1994	0.0001
Grays River 1994 vs. Skamania Hatchery winter 1991	0.0010
North Fork Molalla River 1993 vs. North Santiam River 1997	0.0008
Wind River 1993 and 1994 vs. Panther Creek 1994	0.0006
Skamania Hatchery 1991 winter vs. Beaver Creek Hatchery 1993	0.0003

* Values shown are p values. Only values greater than 0.00005 are shown.

Table C-13. Collections from the Lower Columbia River Chum Salmon ESU included in the WDFW database.

Population sampled	State	Collection codes	Collection year	Life stage	Sample size
Grays River	WA	W92HA	1992	Adult	100
Grays River	WA	W97FT	1997	Adult	136
Grays River	WA	W98KG	1998	Adult	79
Hamilton Creek	WA	W92HB	1992	Adult	100
Hamilton Creek	WA	W96FS	1996	Adult	38
Hamilton Creek	WA	W97FR	1997	Adult	65
Hamilton Creek	WA	W98LF	1998	Adult	100
Hardy Creek	WA	W96FR	1996	Adult	97
Hardy Creek	WA	W97FS	1997	Adult	100
I-205 seeps	WA	W00KY W00PT	2000	Adult	86
Ives Island area	WA	W00LC	2000	Adult	94
Sea Resources Hatchery	WA	W96EC	1996	Adult	100

Table C-14. Loci included in the WDFW chum salmon database. Loci nomenclature follows conventions of Shaklee et al. (1990).

mAAT-1	ALAT	G3PDH-2	LDH-B1	sMEP-1	SSOD1
sAAT-1,2	CKA-1	mIDHP-1	mMDH-3	MPI	TPI-1
sAAT-3	ESTD-2	sIDHP-1	sMDHA-1	PEPA	TPI-3
mAH-1	GAPDH-2	sIDHP-20	sMDHB-1,2	PEPB-1	TPI-4
mAH-2	GPI-A	LDH-A1	mMEP-2	PGDH	ESTD-1
mAH-3	G3PDH-1	LDH-A2			

between this population and all others. Several comparisons within the below–Bonneville Dam collections undoubtedly are not significant. Especially important are comparisons of collections made the same year. Similarly there are several high p value comparisons among the Hardy and Hamilton creeks collections. At this point, there is good evidence that the Grays River and below–Bonneville Dam populations are isolated reproductively to a large degree, but there is no such evidence for isolation among the below–Bonneville Dam areas. Therefore there appears to be at least two genetically distinct populations, Grays River and below–Bonneville Dam mainstem and tributary spawners. The similarity between the collections from the Interstate 205 seeps and the more upstream collections seem to indicate opportunistic colonization of a new area.

Table C-15. Genetic distances among 10 collections from the Lower Columbia River Chum Salmon ESU included in the WDFW database. Figures above the dashes are Nei's (1978) unbiased distances, figures below the dashes are CSE (1967) chord distances.

Population	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1. Columbia I-205 seeps	—	0.0000	0.0029	0.0003	0.0070	0.0007	0.0007	0.0036	0.0010	0.0000
2. Columbia Ives Island	0.0349	—	0.0028	0.0006	0.0070	0.0000	0.0008	0.0035	0.0012	0.0000
3. Grays River 1992	0.0706	0.0692	—	0.0025	0.0023	0.0020	0.0011	0.0000	0.0011	0.0018
4. Hamilton Creek 1992	0.0408	0.0420	0.0596	—	0.0077	0.0011	0.0008	0.0026	0.0016	0.0003
5. Sea Resources 1996	0.0755	0.0820	0.0701	0.0821	—	0.0057	0.0039	0.0023	0.0036	0.0062
6. Hardy Creek 1996	0.0382	0.0304	0.0615	0.0391	0.0727	—	0.0007	0.0023	0.0013	0.0000
7. Hardy Creek 1997	0.0431	0.0447	0.0510	0.0433	0.0691	0.0383	—	0.0015	0.0000	0.0004
8. Grays River1997	0.0685	0.0681	0.0293	0.0583	0.0664	0.0602	0.0515	—	0.0019	0.0024
9. Hamilton Creek 1998	0.0447	0.0466	0.0578	0.0451	0.0708	0.0441	0.0272	0.0579	—	0.0008
10. Hamilton Creek 1996/1997	0.0351	0.0356	0.0601	0.0364	0.0764	0.0277	0.0400	0.0614	0.0374	—

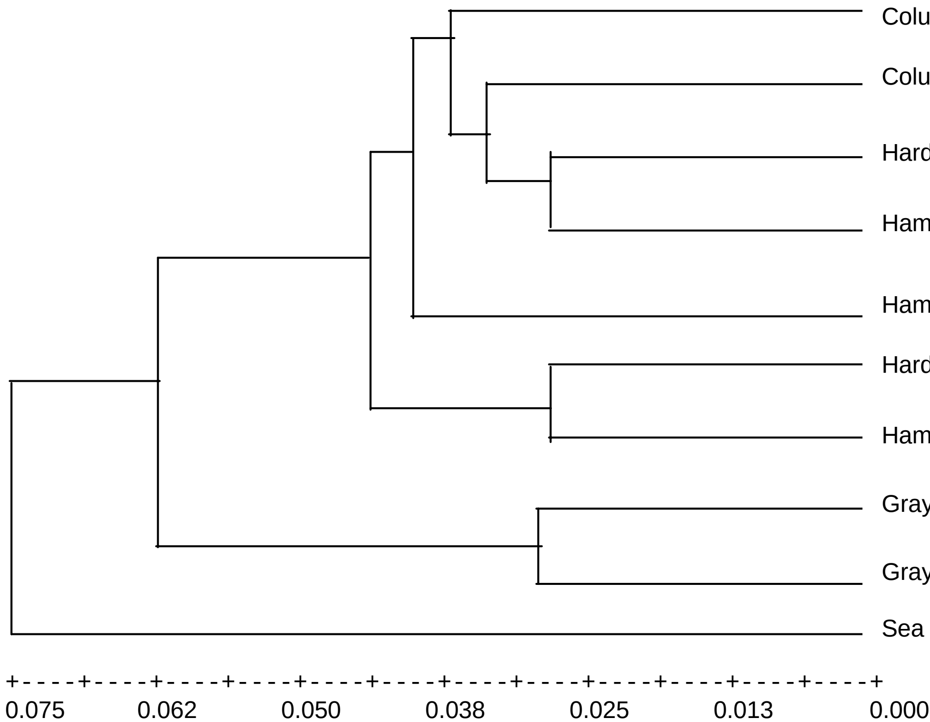


Figure C-7. UPGMA dendrogram of CSE (1967) chord distances (scale) among 10 collections from the Lower Columbia River Chum Salmon ESU.

Table C-16. Pairwise G-test results for the Lower Columbia River Chum Salmon ESU. Only comparisons with p values greater than 0.00005 are shown.

Comparisons for Columbia River Interstate 205 seeps 2000	
Pair	**p value**
Columbia River I-205 seeps vs. Columbia River Ives Island	0.2292
Columbia River I-205 seeps vs. Hamilton Creek 1996/1997	0.0652
Columbia River I-205 seeps vs. Hamilton Creek 1992	0.0031
Columbia River I-205 seeps vs. Hardy Creek 1996	0.0098
Columbia River I-205 seeps vs. Hardy Creek 1997	0.0003
Columbia River I-205 seeps vs. Hamilton Creek 1998	0.0001

Comparisons for Columbia River Ives Island 2000	
Pair	**p value**
Columbia River Ives Island vs. Hardy Creek 1996	0.4493
Columbia River Ives Island vs. Hamilton Creek 1996/1997	0.1709
Columbia River Ives Island vs. Hamilton Creek 1992	0.0045
Columbia River Ives Island vs. Hardy Creek 1997	0.0005
Columbia River Ives Island vs. Hamilton Creek 1998	0.0001

Comparisons for Hardy and Hamilton creeks	
Pair	**p value**
Hardy Creek 1996 vs. Hamilton Creek 1996/1997	0.5684
Hardy Creek 1997 vs. Hamilton Creek 1998	0.7875
Hamilton Creek 1992 vs. Hardy Creek 1996	0.0131
Hamilton Creek 1992 vs. Hamilton Creek 1996/1997	0.0423
Hardy Creek 1996 vs. Hardy Creek 1997	0.0277
Hardy Creek 1997 vs. Hamilton Creek 1996/1997	0.0144
Hamilton Creek 1998 vs. Hamilton Creek 1996/1997	0.0262
Hamilton Creek 1992 vs. Hardy Creek 1997	0.0014
Hardy Creek 1996 vs. Hamilton Creek 1998	0.0011
Hamilton Creek 1992 vs. Hamilton Creek 1998	0.0001

Other comparisons	
Pair	**p value**
Grays River 1992 vs. Grays River 1997	0.4458
Grays River 1992 vs. Hardy Creek 1997	0.0001

Appendix D: Lower Columbia River Coho Salmon Genetics

In this updated review,[13] we examined the genetic relationships of coho salmon populations from the lower Columbia River and southwest Washington coast by analyzing an allozyme data set consisting of 84 samples from populations in Oregon, Washington, and British Columbia (Table D-1). The data set includes samples from the 1994 status review (Weitkamp et al. 1995), and 28 more recent samples collected by NMFS, ODFW, and WDFW.

In this analysis, we used the following 61 polymorphic gene loci to compute CSE (1967) chord distances between all pairs of samples (locus nomenclature follows Shaklee et al. 1990):

sAAT-1,2*	CK-A1*	bGALA*	mIDHP-1*	sMDH-A1,2*	PGK-2*
sAAT-3*	CK-A2*	GAPDH-2	mIDHP-2*	sMDH-B1,2*	PGM-1*
sAAT-4*	CK-B*	GAPDH-3*	sIDHP-1*	MPI*	PGM-2*
ADA-1*	CK-C1*	GAPDH-4*	sIDHP-2*	PEPA*	PK2*
ADA-2*	CK-C2*	GAPDH-5*	LDH-A1*	PEPB-1*	PNP-1*
mAH-1*	EST-1*	bGLUA*	LDH-A2*	PEPC*	sSOD-1*
mAH-2*	FBALD-3*	GPI-A*	LDH-B1*	PEPD-2*	TPI-1*
mAH-3*	FBALD-4*	GPI-B1*	LDH-B2*	PEPLT*	TPI-2*
sAH*	FDHG*	GPI-B2*	LDH-C*	PGDH*	TPI-3*
AK*	FH*	GR*	aMAN*	PGK-1*	TPI-4*
ALAT*					

The electrophoretic procedures and method of genetic distance computation were as described in the status review.

We constructed a dendrogram based on the pairwise genetic distance values to depict genetic relationships (Figure D-1), using UPGMA. Five major clusters, which separated at chord genetic distances ranging from 0.058 to 0.067, were identified that are largely distinct geographically. A cluster of samples from southwest Washington coastal populations is differentiated from a cluster of samples mostly from lower Columbia River sources at a distance of 0.058. Samples from Bear River (number 42) and Chehalis River Oakville Fishery (47) of southwest Washington coastal populations and one Sol Duc Hatchery (57) from the Olympic Peninsula are included in this cluster of lower Columbia River samples. A large cluster of samples from middle Oregon coastal populations diverges at a distance of 0.059 from a large cluster of samples from Georgia Basin populations that includes sources in the Olympic Peninsula, Strait of Juan de Fuca, Hood Canal, Puget Sound, and southern British Columbia. Six

[13] This section is reproduced from Weitkamp et al. 2001. Further information and analysis can be found in Teel et al. 2003.

Table D-1. Samples of coho salmon from Oregon and Washington. Samples numbers correspond to sample numbers used in Figures D-1 and D-2.

Sample no.	Name	Location	Year collected	N[a]
Oregon coast				
1	Sixes	Crystal and Edson creeks	1993	44
2	New	Bether and Morton creeks	1993	62
3	Coquille	Butte Falls Hatchery, stock #44	1993	100
4	Coos	Cole River Hatchery, stock #37, South Fork Coos River	1993	129
5	Coos	Millicoma River[a], Marlow Creek	1993, 1997[b]	50
6	Umpqua	Rock Creek Hatchery, stock #55	1993	100
7	Umpqua	North Umpqua River[a], Williams Creek	1993, 1997[b]	67
8	Umpqua	Butte Falls Hatchery, stock #18	1993	100
9	Eel	Butte Falls Hatchery, stock #63	1993	100
10	Ten Mile	Big Creek, Noble Creek, Ten Mile Lake	1992	56
11	Smith	Smith River, Halfway Creek	1993	40
12	Tahkenitch	Fall Creek Hatchery, stock #113	1993	100
13	Siuslaw	Siuslaw River	1996	51
14	Alsea	Fall Creek Hatchery, stock #31	1993	100
15	Alsea	Fall Creek Hatchery, stock #43	1993	95
16	Alsea	Alsea River[a]	1996[b]	62
17	Beaver	Beaver Creek	1993	62
18	Yaquina	Yaquina River[a]	1996[b]	54
19	Siletz	Salmon River Hatchery, stock #33	1993	100
20	Siletz	Forth of July, Sunshine, and Buck creeks	1993	50
21	Salmon	Salmon River Hatchery, stock #36	1993	100
22	Trask	Trask River Hatchery, stock #34	1992, 1993	220
23	Nehalem	Nehalem River Hatchery, stock #99	1992	80
24	Nehalem	Nehalem River Hatchery, stock #32	1993	100
Columbia River				
25	Lewis and Clark	Lewis and Clark River	1991, 1993	36
26	Klaskanine	Klaskanine Hatchery	1992	100
27	Big	Big Creek Hatchery	1991	80
28	Grays	Grays River Hatchery	1987, 1991	200
29	Clatskanie	Clatskanie River, Carcus Creek	1991, 1992, 1996	113
30	Cowlitz early	Cowlitz Hatchery	1991	80
31	Cowlitz late	Cowlitz Hatchery	1991	180
32	Scappoose	Siercks, Raymond, and Milton creeks	1991	44
33	Lewis early	Lewis River Hatchery	1991	80
34	Lewis late	Lewis River Hatchery	1991	80
35	Eagle	Eagle Creek Hatchery	1991, 1992	180
36	Clackamas early	North Fork Clackamas River	1998[b]	48
37	Clackamas late	North Fork Clackamas River	1999[b]	45
38	Sandy	Sandy River Hatchery	1991, 1992	180
39	Sandy	Sandy River, Still Creek	1991, 1992, 1996	124
40	Bonneville	Bonneville Hatchery	1991, 1992	180
41	Willard	Willard Hatchery	1991	80

Table D-1 continued. Samples of coho salmon from Oregon and Washington. Samples numbers correspond to sample numbers used in Figures D-1 and D-2.

Sample no.	Name	Location	Year collected	N[a]
Southwest Washington coast				
42	Bear	Bear River	1995	37
43	Naselle	Naselle River Hatchery	1991	100
44	Nemah	Nemah River Hatchery	1991	100
45	Willapa	Willapa River Hatchery	1991	100
46	Chehalis	Stillman Creek	1995	71
47	Chehalis	Oakville Fishery	1995[b]	79
48	Chehalis	Satsop River, Bingham Creek	1995	98
49	Chehalis	Bingham Creek Hatchery	1991,[c] 1992,[c] 1995	180
50	Chehalis	Upper Chehalis River	1995	91
51	Chehalis	Hope Creek	1994, 1995, 1996	171
Olympic Peninsula				
52	Queets	Queets River	1995	99
53	Clearwater	Clearwater River	1995	100
54	Quillayute	Bogachiel River	1987	80
55	Sol Duc	Sol Duc Hatchery summer	1994[c]	80
56	Sol Duc	Sol Duc River summer	1995	120
57	Sol Duc	Sol Duc Hatchery fall	1995[b]	80
58	Hoko	Hoko River	1987	96
Puget Sound				
59	Dungeness	Dungeness Hatchery	1987	80
60	Quilcene	Quilcene Hatchery	1994[b]	100
61	Skokomish	North Fork Skokomish River	1994,[c] 1995[c]	126
62	Dewatto	Dewatto River	1994,[c] 1995,[c] 1996[c]	169
63	Minter	Minter Creek Hatchery	1992, 1995[c]	80
64	Soos	Soos Creek Hatchery	1994, 1995,[c] 1996	680
65	Snohomish	Pilchuck River, Little Pilchuck Creek	1987	120
66	Snohomish	Snoqualmie River, Harris Creek	1987	120
67	Snohomish	Snoqualmie River, Grizzly Creek	1994,[c] 1995,[c] 1996[c]	215
68	Snohomish	North Fork Skykomish River, Lewis Creek	1995[c]	102
69	Stillaguamish	North Fork Stillaguamish River, Fortson Creek	1987, 1989	200
70	Stillaguamish	North Fork Stillaguamish River, McGovern Creek	1987	40
71	Skagit	Upper Skagit River	1993	127
72	Skagit	Carpenter Creek	1993	139
73	Skagit	West Fork Nookachamps Creek	1987, 1993	220
74	Skagit	Baker River	1992[c]	303
75	Skagit	Suiattle River, All Creek	1987, 1993	200
76	Skagit	Upper Sauk River	1992, 1993	200
77	Skagit	Upper Cascade River	1992, 1993	224
78	Samish	Samish River, Ennis Creek	1994,[c] 1995,[c] 1996[c]	167

Table D-1 continued. Samples of coho salmon from Oregon and Washington. Samples numbers correspond to the sample numbers used in Figures D-1 and D-2.

Sample no.	Name	Source	Year collected	N[a]
South British Columbia				
79	Chilliwack	Chilliwack River Hatchery	1984	100
80	Cowichan	Cowichan River Hatchery	1984	80
81	Big Qualicum	Big Qualicum Hatchery	1989, 1991	180
82	Robertson	Robertson Creek Hatchery	1984	100
83	Capilano	Capilano Hatchery	1989, 1991	200
84	Squamish	Squamish River Hatchery	1988[b]	98

[a] N is the number of samples.
[b] Samples collected subsequent to the Status Review of Coho Salmon from Washington, Oregon, and California (Weitkamp et al. 1995).
[c] Samples taken from adult fish, others are from juvenile coho salmon genetic distance matrix.

samples from northern Oregon coastal populations form a genetically diverse cluster and are differentiated from all other samples in the analysis at a distance of 0.067.

We also performed a MDS analysis of the genetic distances (Rohlf 1994). MDS provides a means of representing genetic relationships in two or three dimensions, in contrast, a dendrogram provides a one-dimensional view of the data. Additionally, we computed a minimum spanning tree (MST) of Table D-1. When superimposed on an MDS plot, an MST can be useful to detect distortions—pairs of points that look close together in the plot but actually are not.

Results of the MDS and MST for samples from southwest Washington coastal and lower Columbia River populations are shown in Figures 3, 4, and 5 of this technical memorandum. Samples from the southwest Washington coast, including those from Bear River (42) and Chehalis River Oakville Fishery (47), cluster separately from samples from the lower Columbia River. Within the southwest Washington coastal group, samples from Naselle, Nemah, and Willapa hatcheries (43, 44, and 45) are genetically similar to each other and distinct from samples from the Chehalis River (46–51). Two clusters are apparent within the group of lower Columbia River samples. One cluster contains samples from several populations in Washington (28, 30, 31, 33, 34, and 41) and also the samples from the Clatskanie River (29) and the late run in the Clackamas River (37). A second cluster contains all other samples from lower Columbia River populations in Oregon (25–27, 32, 35, 36, and 38–40).

A study conducted by Dr. Terry Beacham of the Department of Fisheries and Oceans Canada (Shaklee et al. 1999) provided additional information on the genetic relationships of coho salmon populations in the lower Columbia River and southwest Washington coast. The authors used four microsatellite DNA loci and one major histocompatibility locus and presented a neighbor-joining dendrogram based on CSE (1967) chord distances for 53 coho salmon populations from southern British Columbia and Washington. Their analyses included two samples from the lower Columbia River (Cowlitz and Lewis rivers), and two samples from the

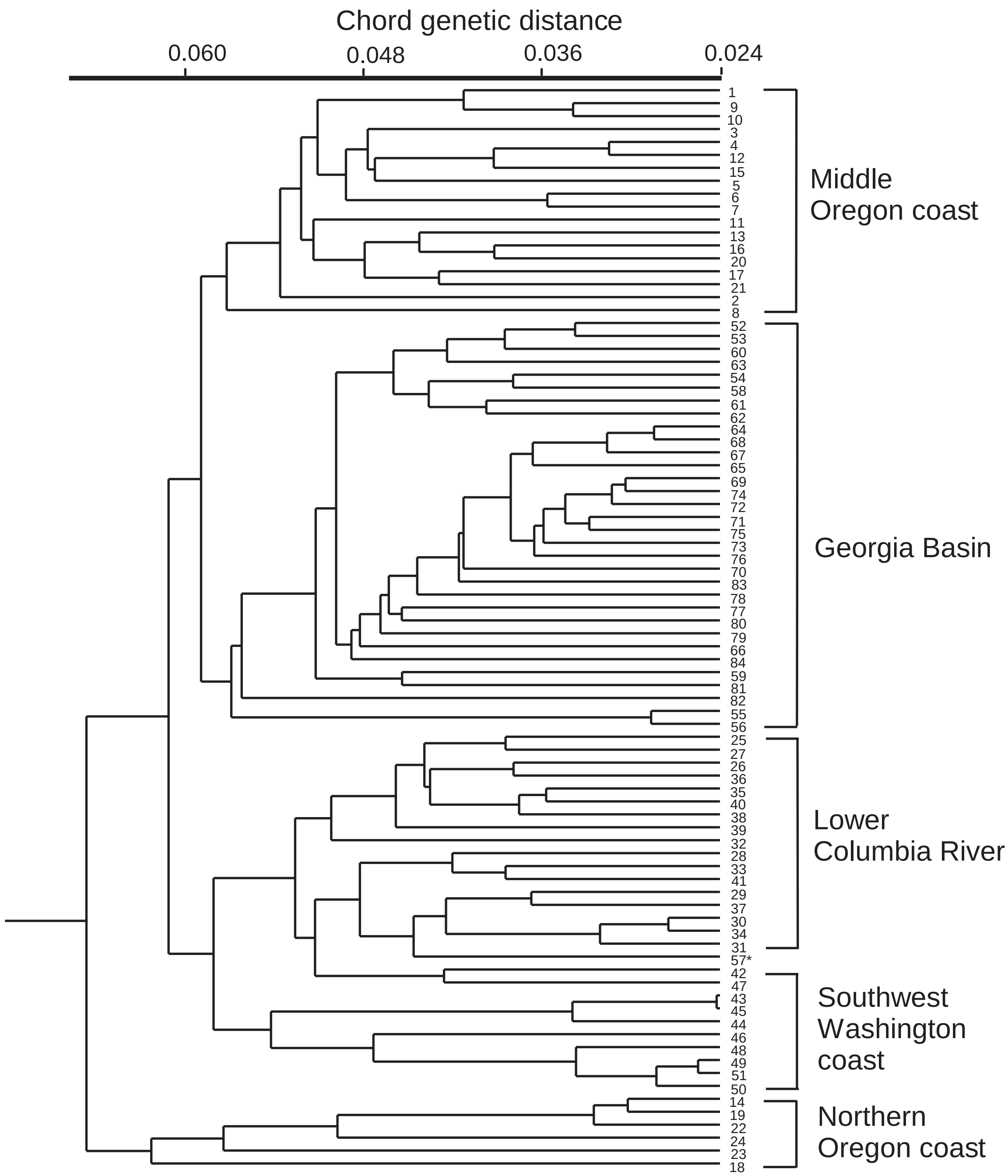


Figure D-1. UPGMA tree of CSE (1967) chord distances based on 61 allozyme loci between 84 composite samples of coho salmon from populations extending from Oregon to British Columbia. Sample numbers correspond to those in Table D-1.

southwest Washington coast clustered closely with several samples from the Olympic Peninsula and were distinct from the lower Columbia River samples.

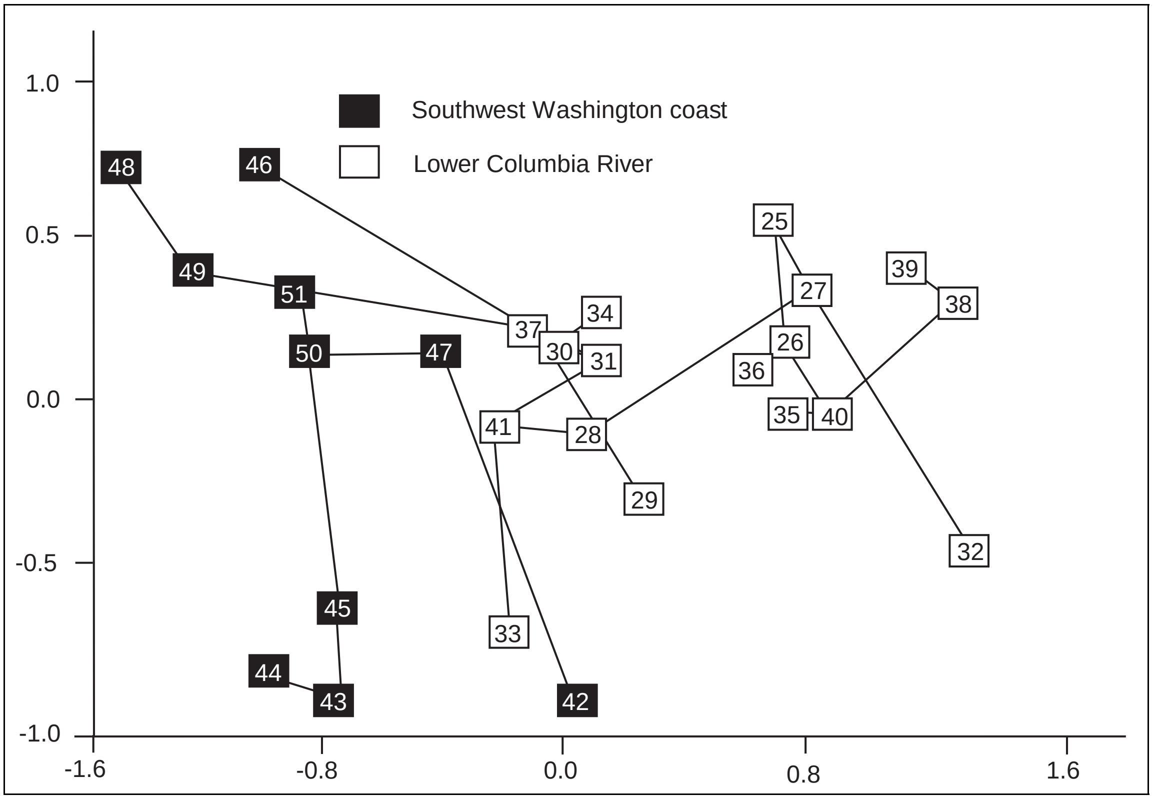


Figure D-2. Multidimensional scaling and minimum spanning tree of pairwise chord distance values (CSE 1967) among 27 samples of coho salmon from the lower Columbia River and southwest Washington coast. Analysis was based on data for 61 gene loci. Numeric codes correspond to those in Table D-1. Samples from lower Columbia River populations are identified by white squares, those from southwest Washington are identified by black squares.

Appendix E: Historical Accessibility Maps

This appendix contains historical accessibility maps for the following populations:

- lower Columbia River fall Chinook salmon, Figure E-1 through Figure E-22
- lower Columbia River spring Chinook salmon, Figure E-23 through Figure E-32
- upper Willamette River spring Chinook salmon, Figure E-33 through Figure E-40
- lower Columbia River summer steelhead, Figure E-41 through Figure E-47
- lower Columbia River winter steelhead, Figure E-48 through Figure E-65
- upper Willamette River winter steelhead, Figure E-66 through Figure E-71
- lower Columbia River coho salmon, Figure E-72 through Figure E-96
- lower Columbia River chum salmon, Figure E-97 through Figure E-113

Lower Columbia River Fall Chinook Salmon Historical Accessibility

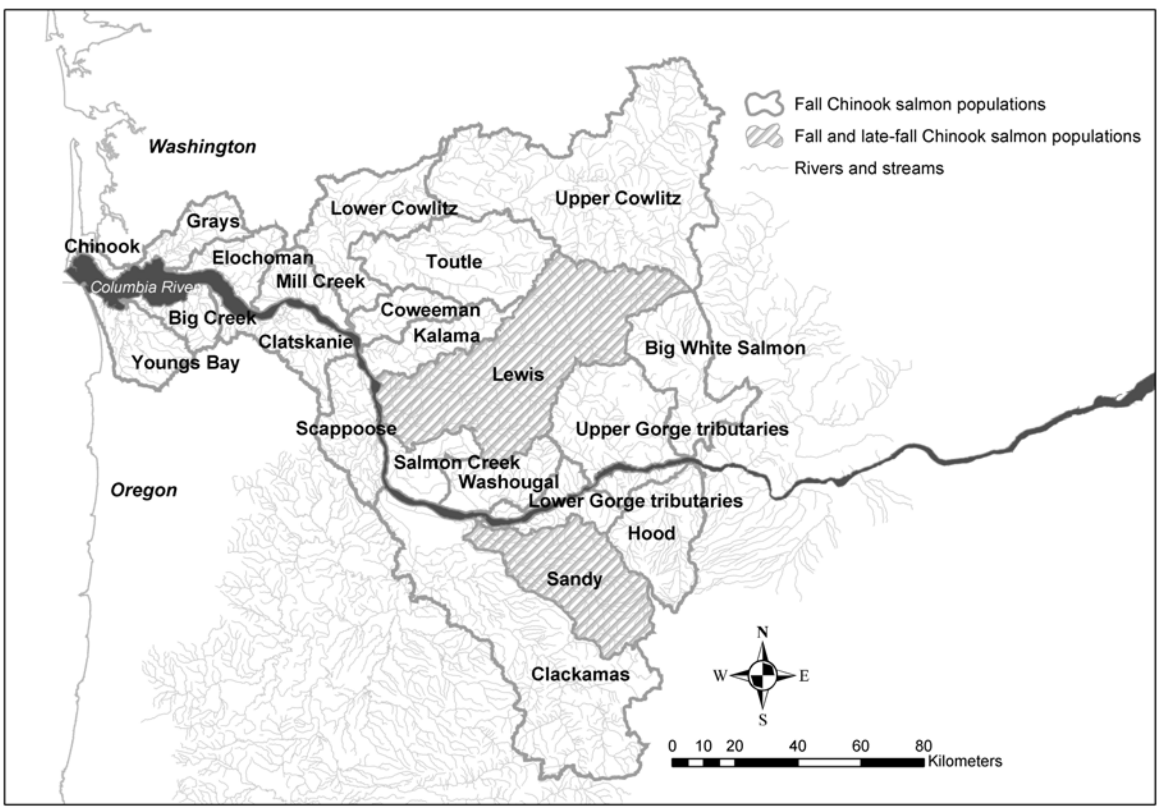


Figure E-1. Lower Columbia River fall Chinook salmon population areas.

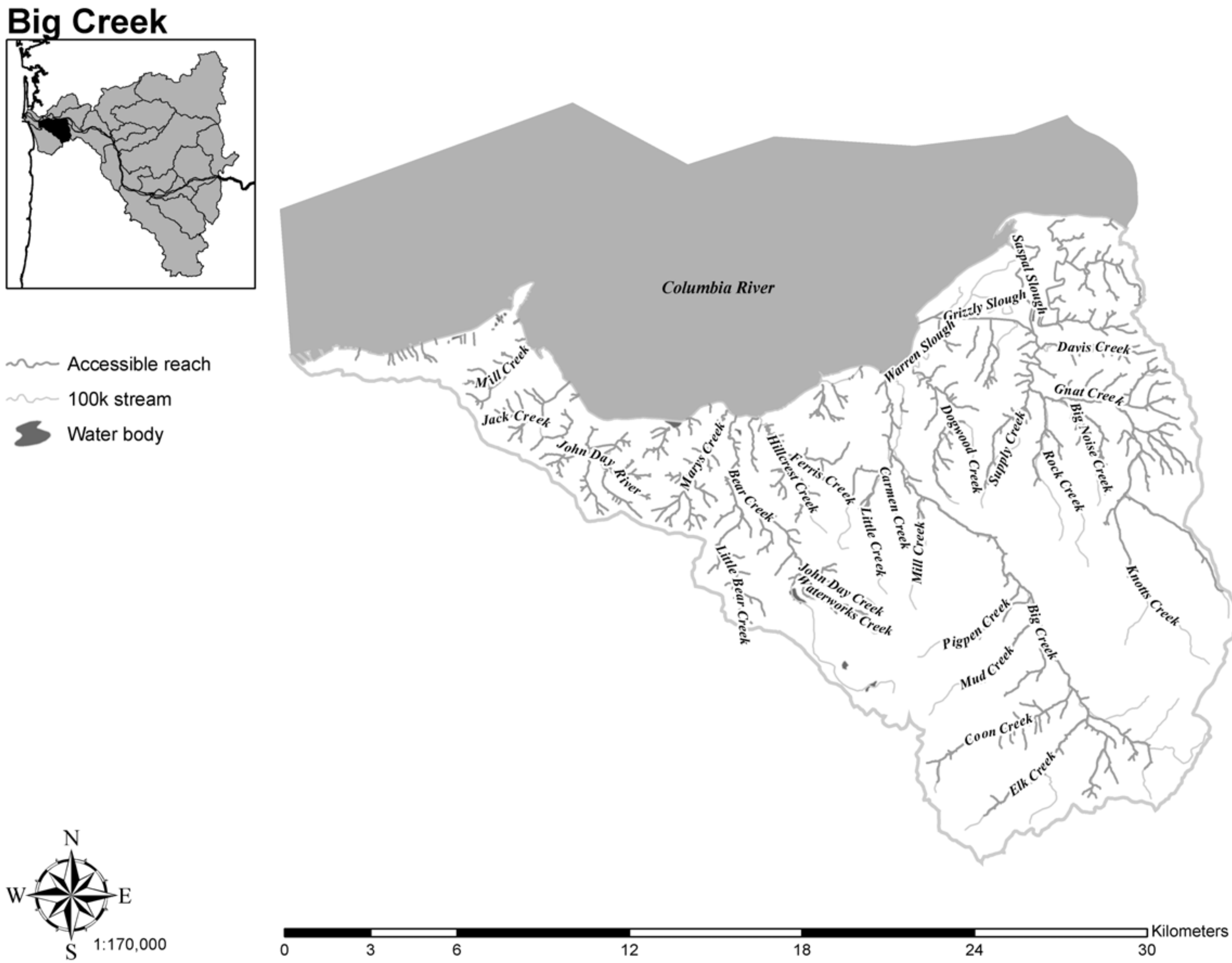


Figure E-2. Historical accessibility of fall Chinook salmon to Big Creek.

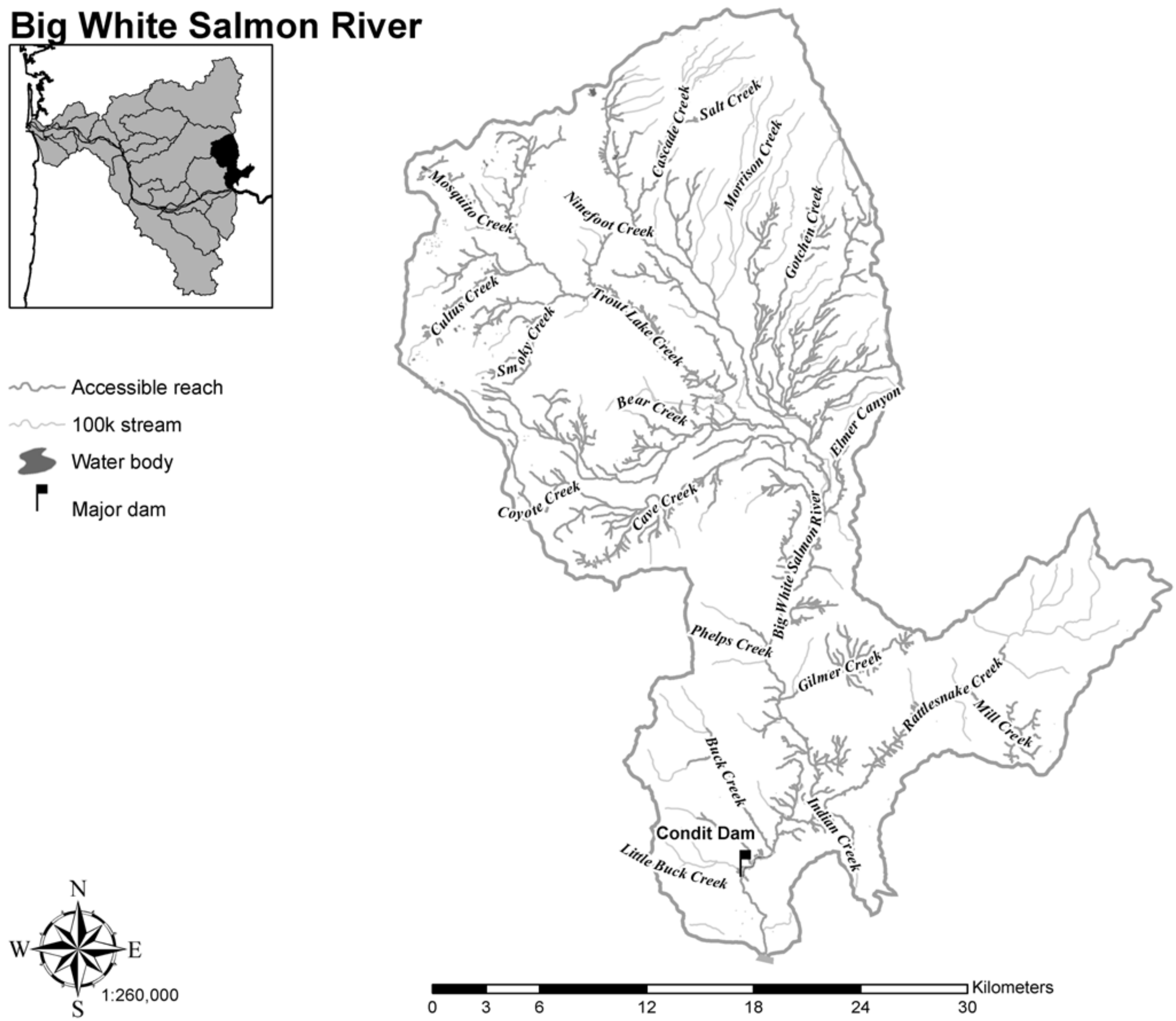


Figure E-3. Historical accessibility of fall Chinook salmon to the Big White Salmon River.

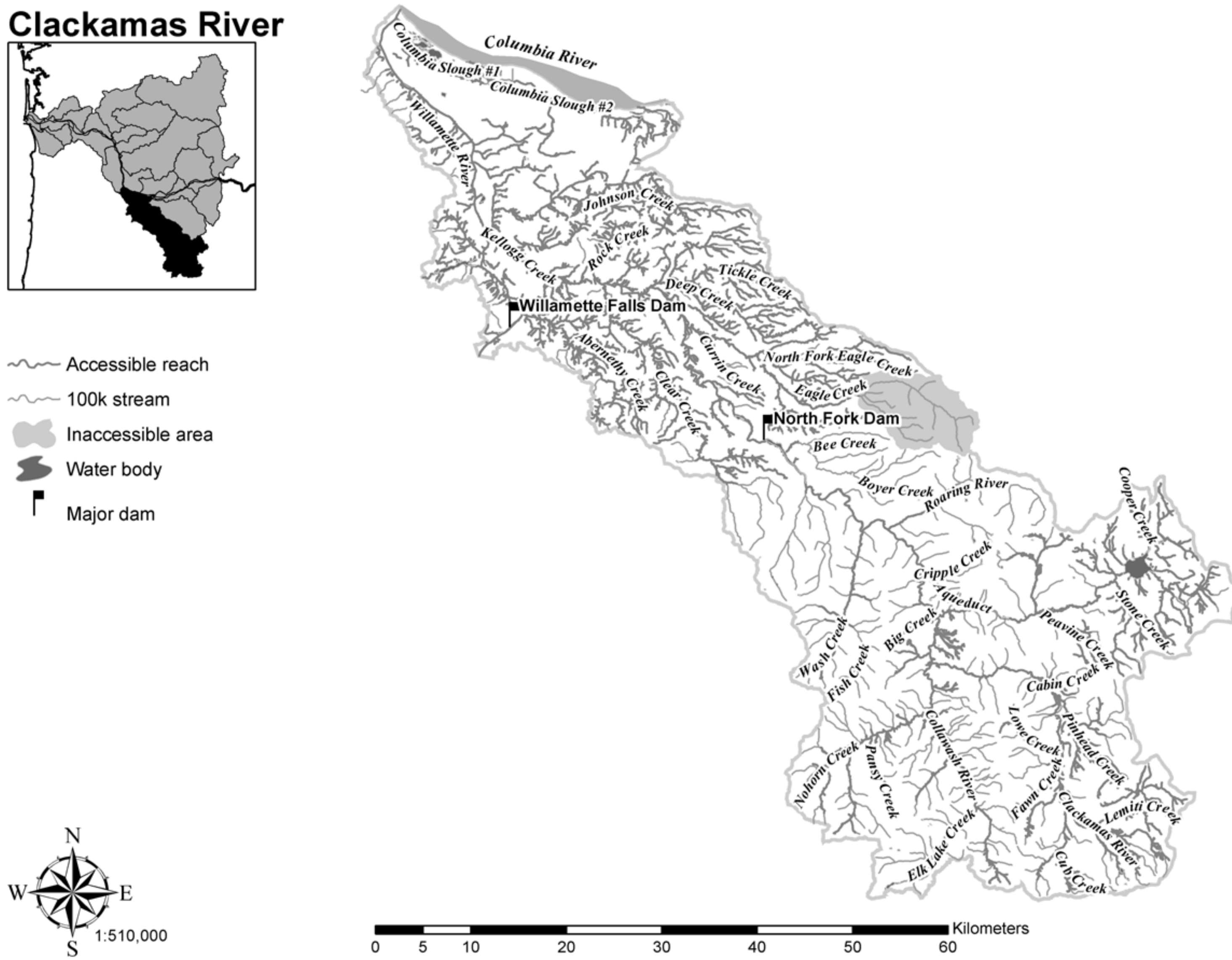


Figure E-4. Historical accessibility of fall Chinook salmon to the Clackamas River.

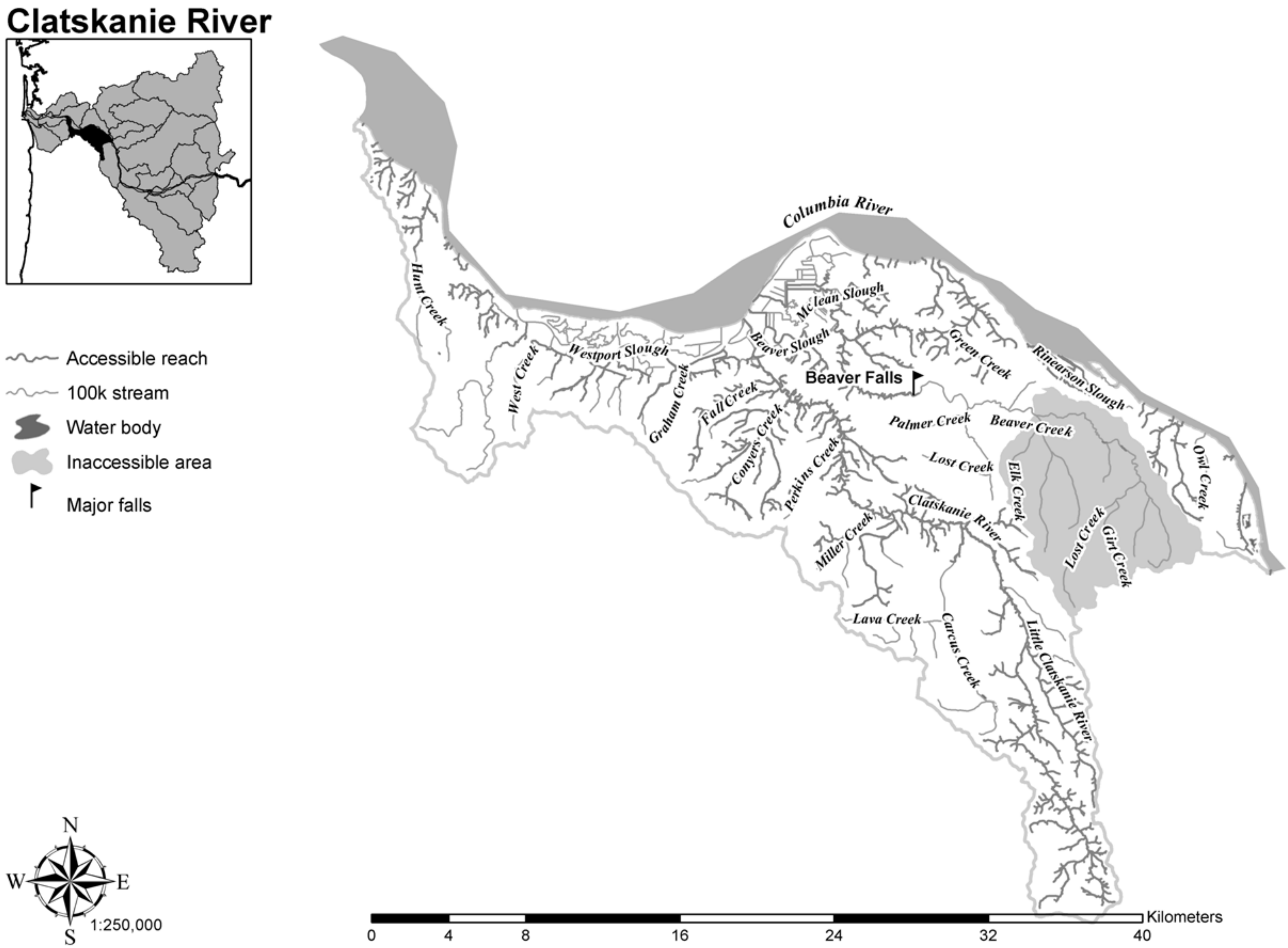


Figure E-5. Historical accessibility of fall Chinook salmon to the Clatskanie River.

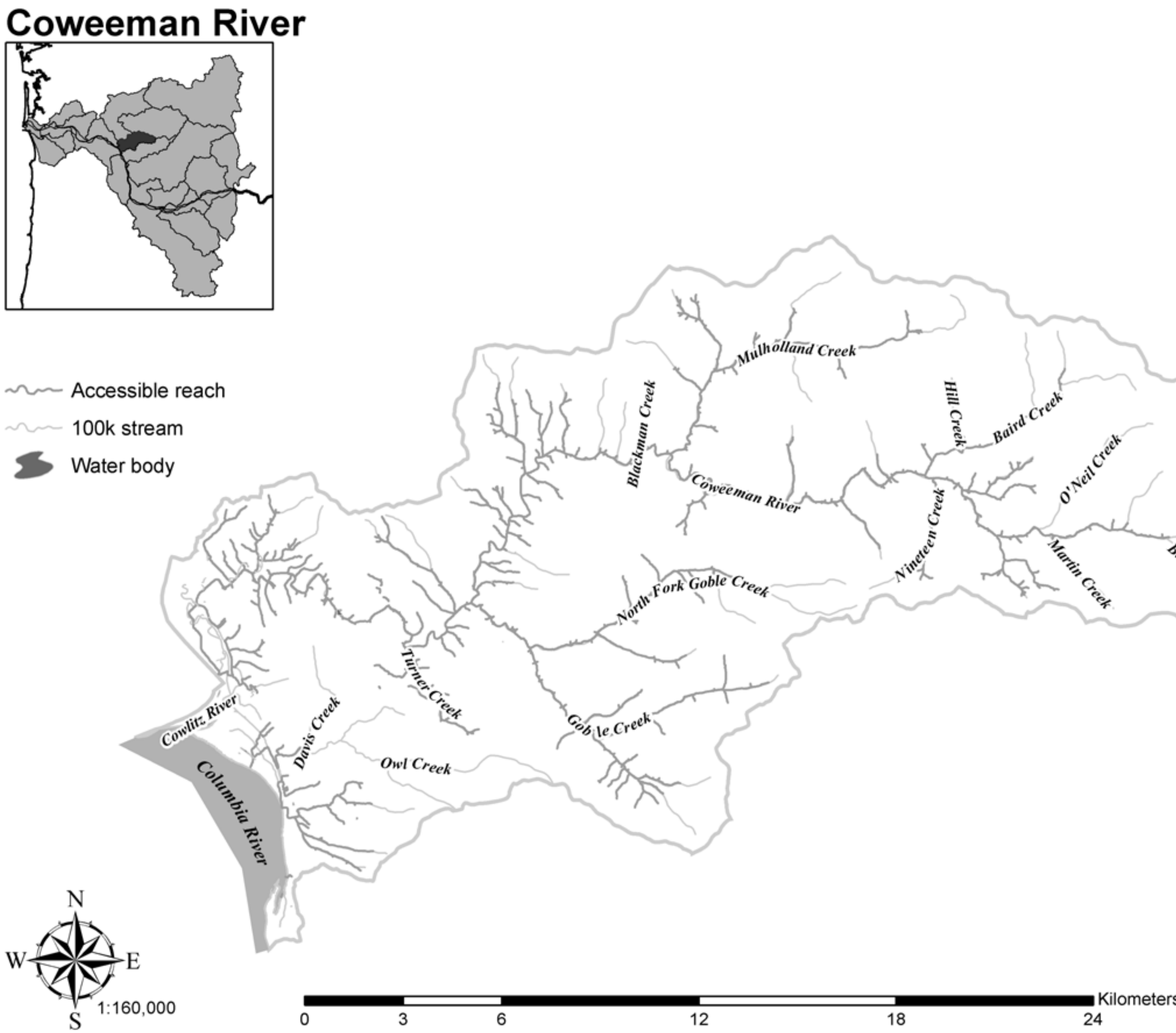


Figure E-6. Historical accessibility of fall Chinook salmon to the Coweeman River.

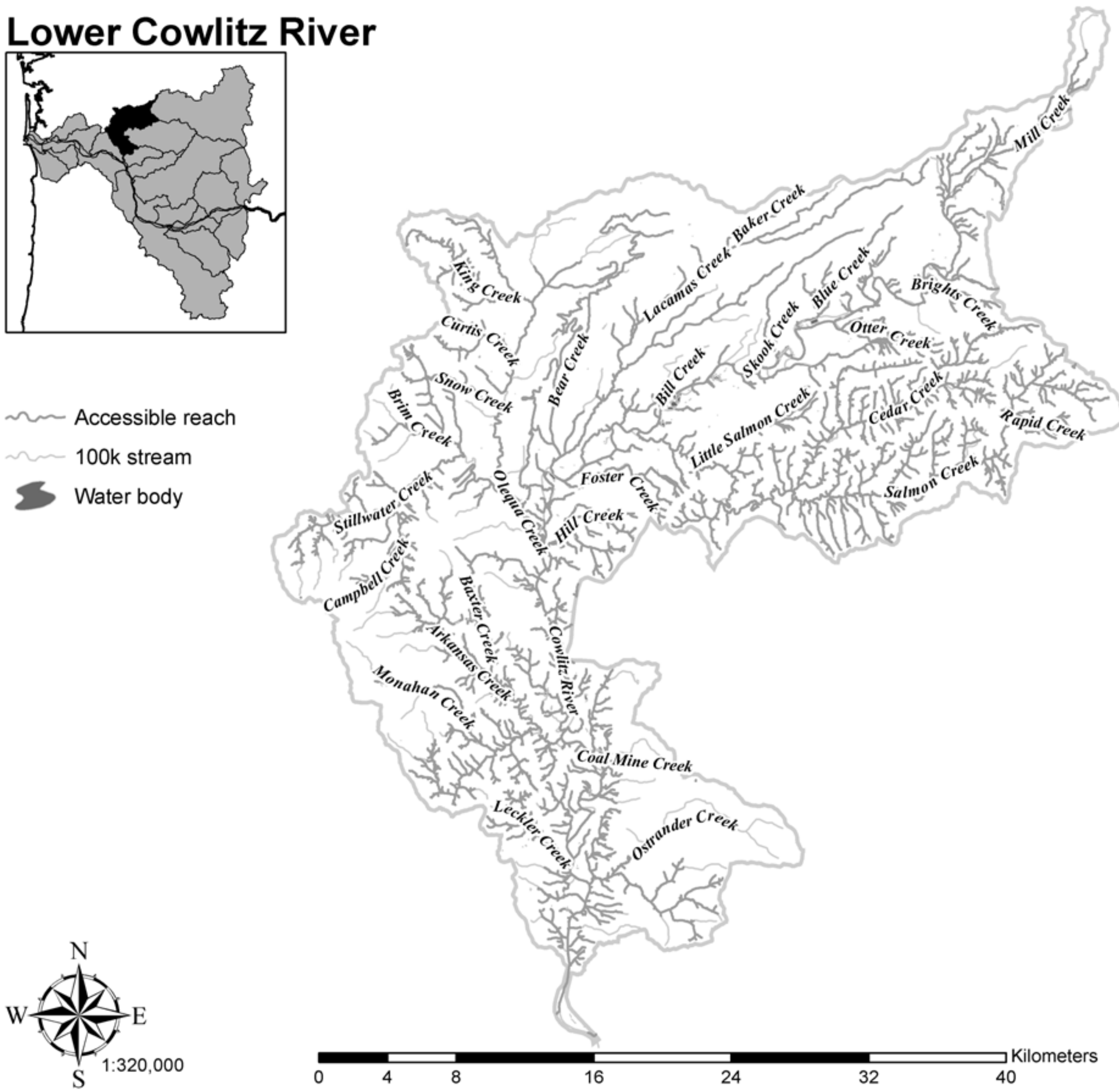


Figure E-7. Historical accessibility of fall Chinook salmon to the lower Cowlitz River.

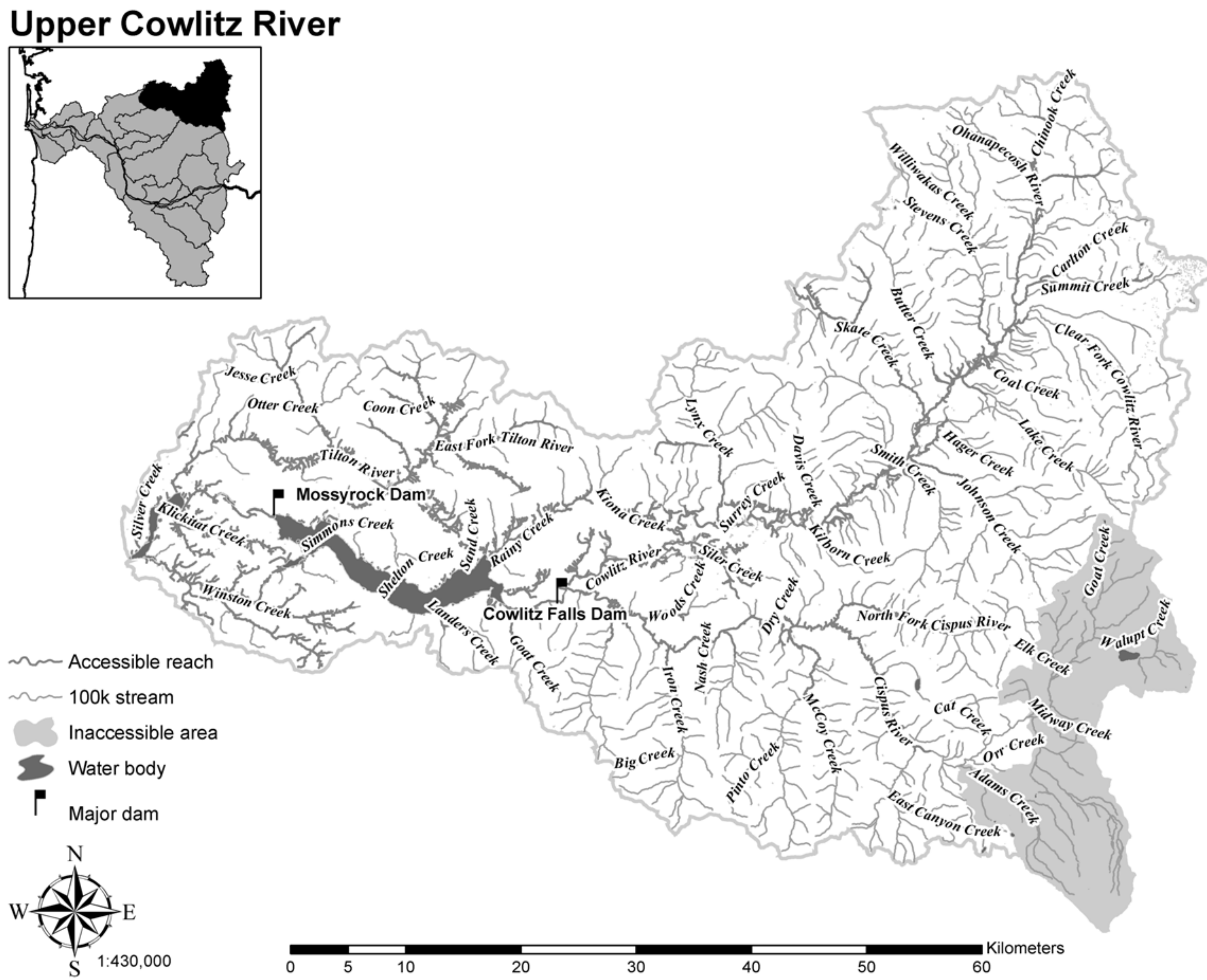


Figure E-8. Historical accessibility of fall Chinook salmon to the upper Cowlitz River.

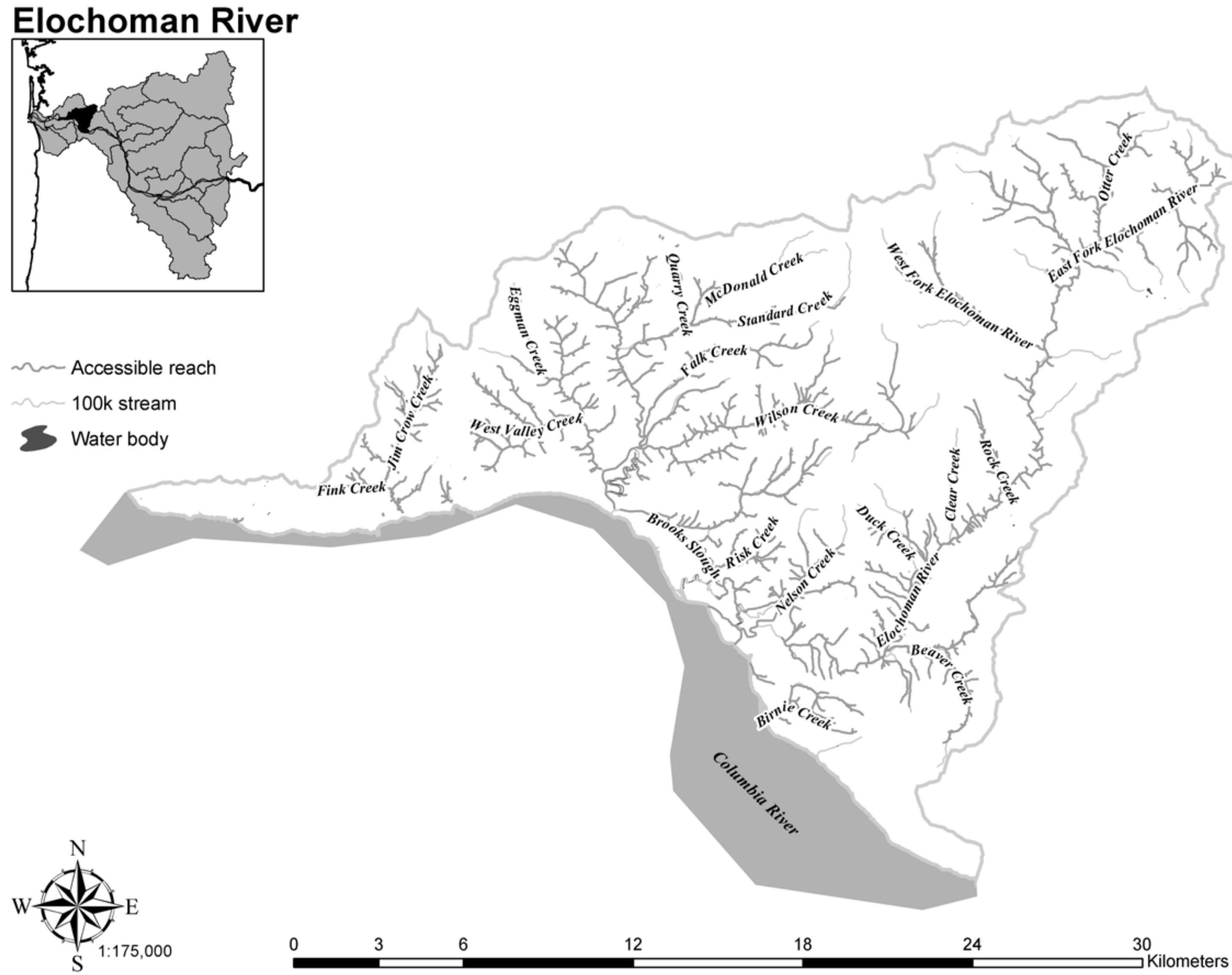


Figure E-9. Historical accessibility of fall Chinook salmon to the Elochoman River.

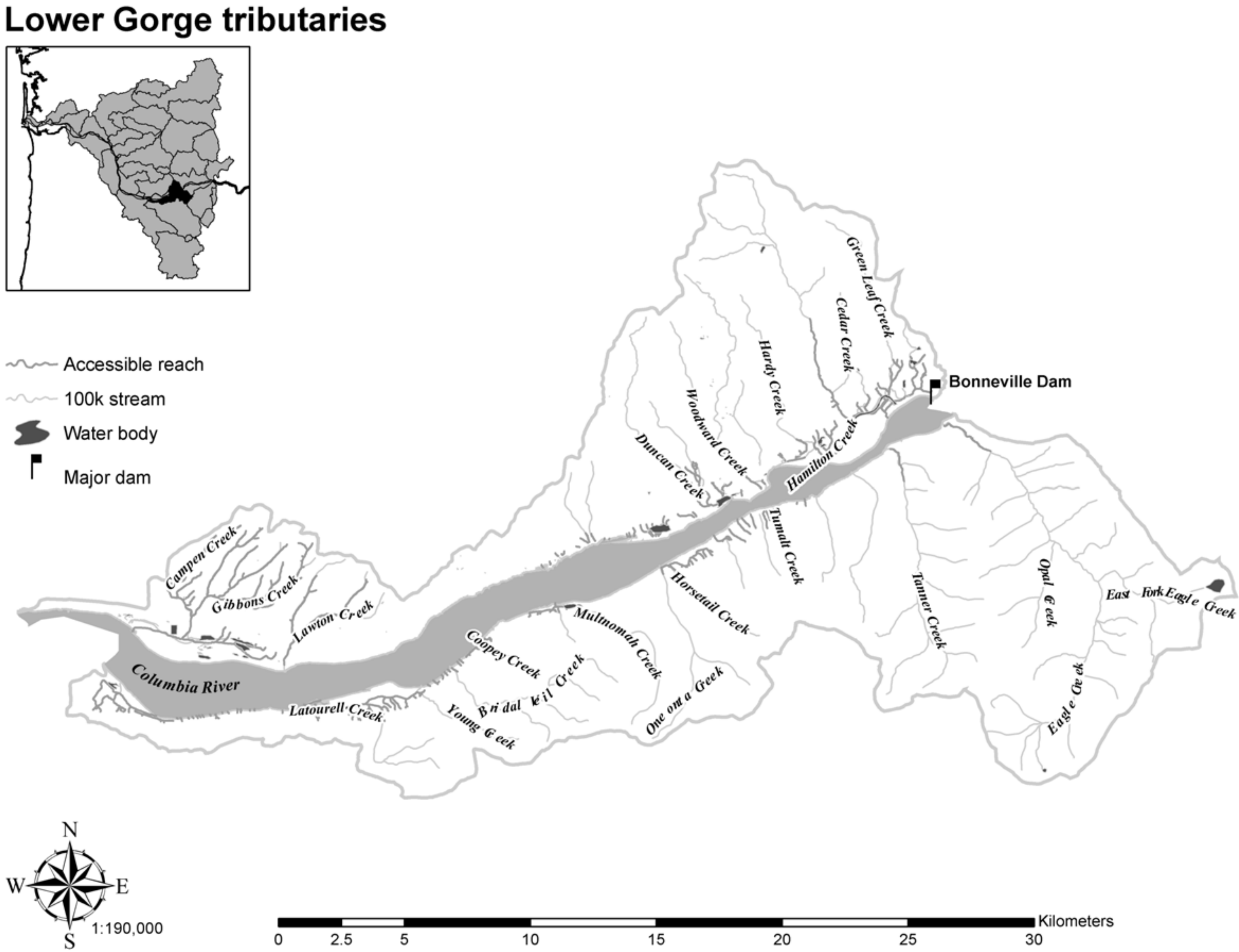


Figure E-10. Historical accessibility of fall Chinook salmon to the Columbia River lower Gorge tributaries.

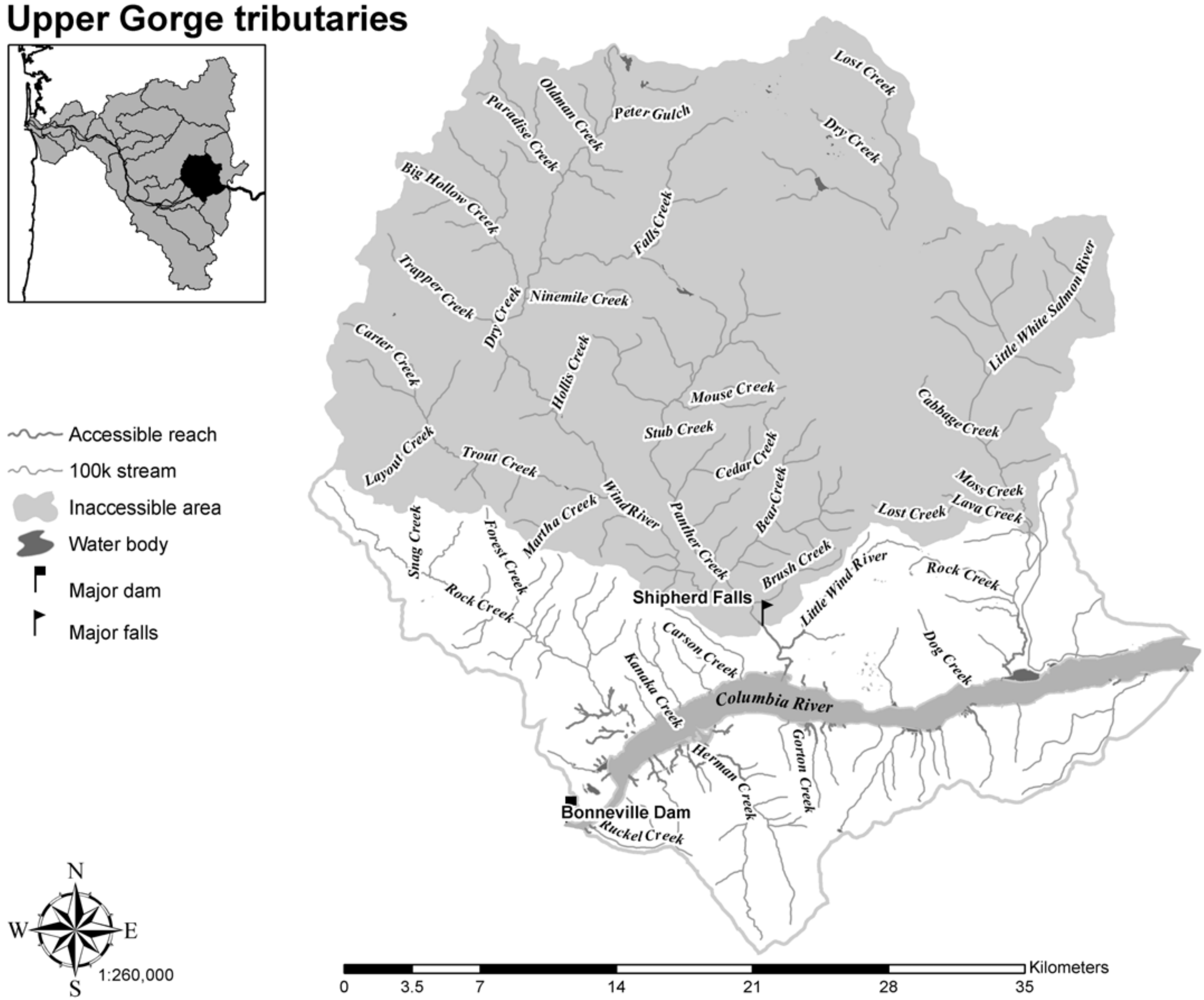


Figure E-11. Historical accessibility of fall Chinook salmon to the Columbia River upper Gorge tributaries.

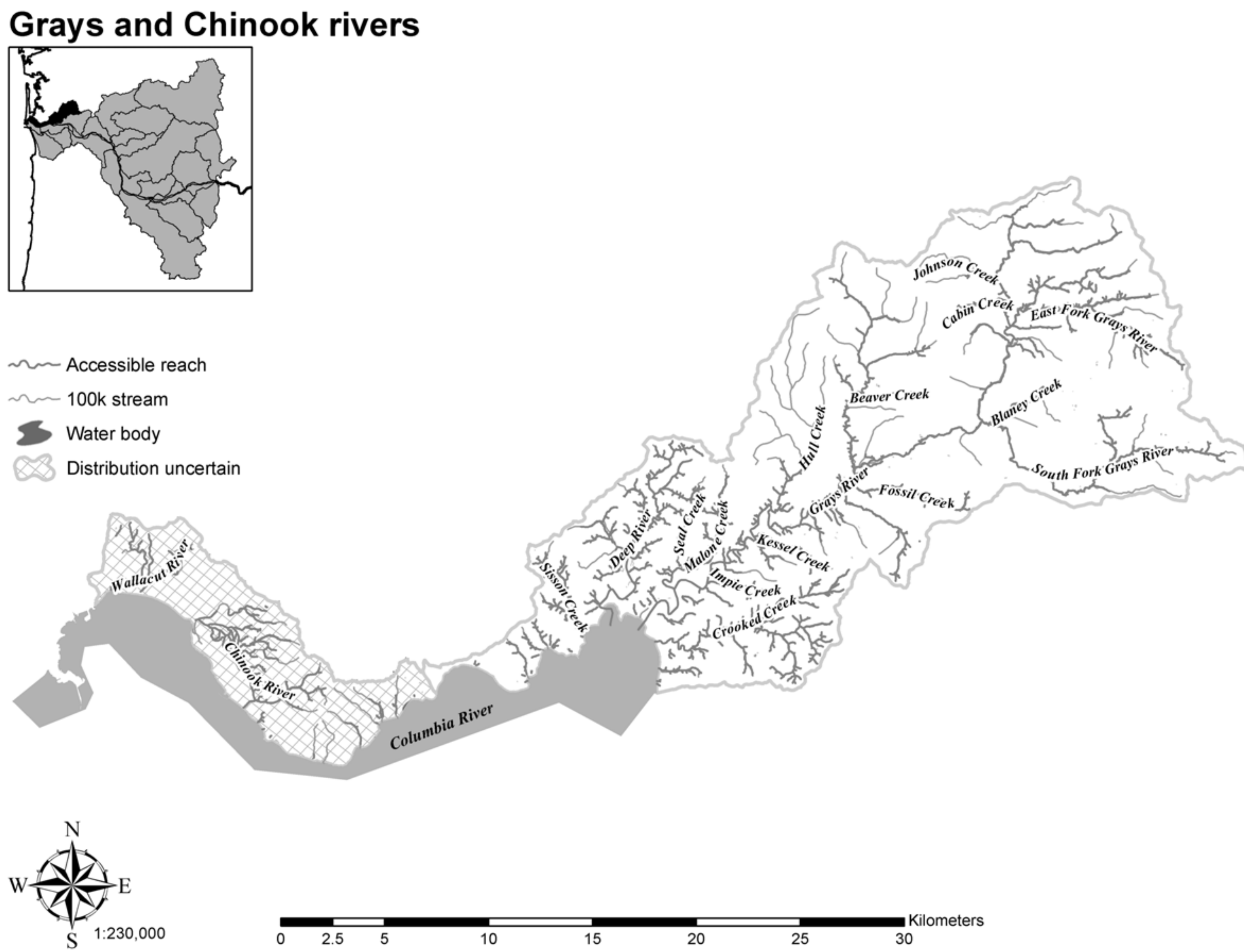


Figure E-12. Historical accessibility of fall Chinook salmon to the Grays and Chinook rivers.

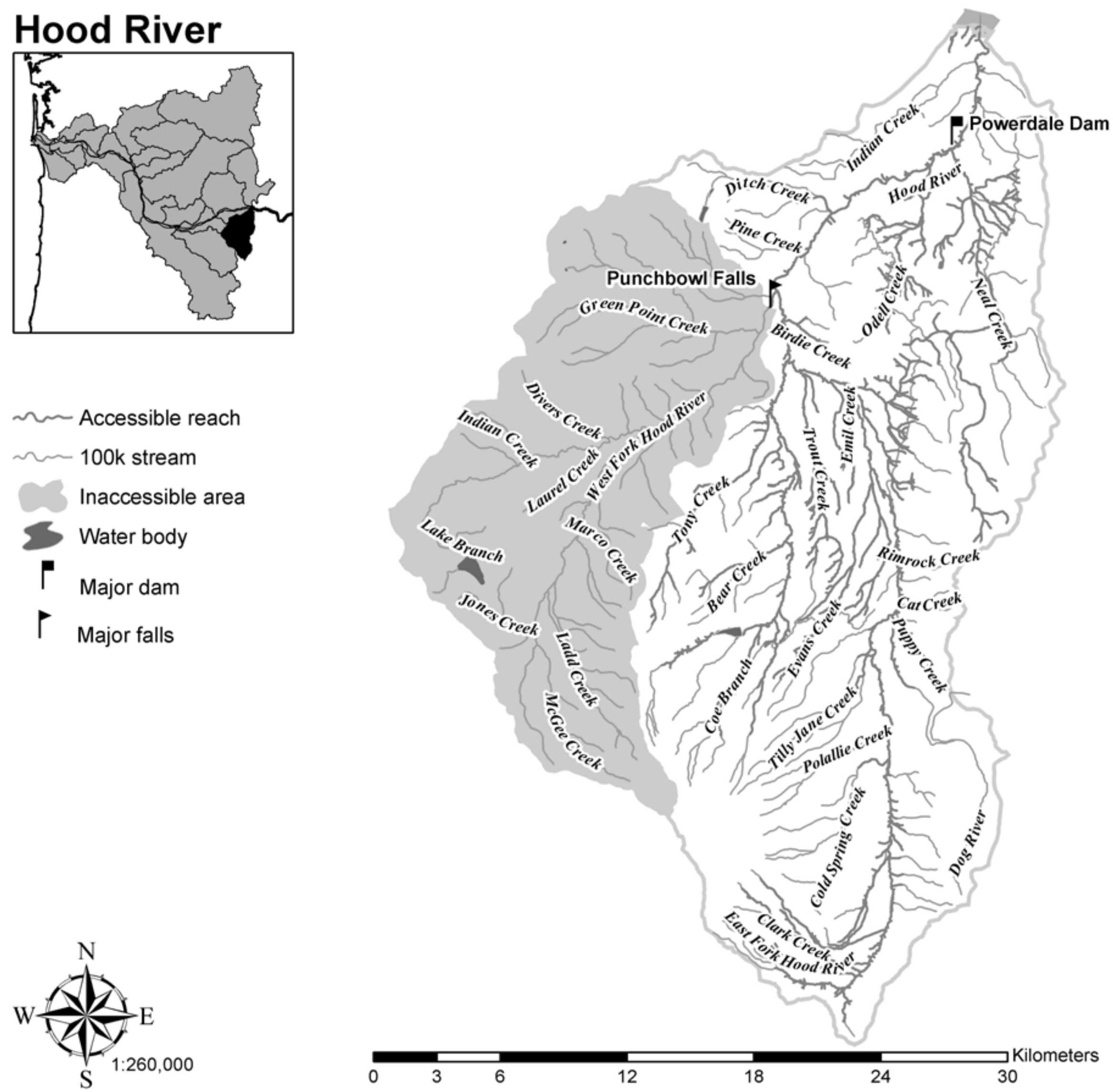


Figure E-13. Historical accessibility of fall Chinook salmon to the Hood River.

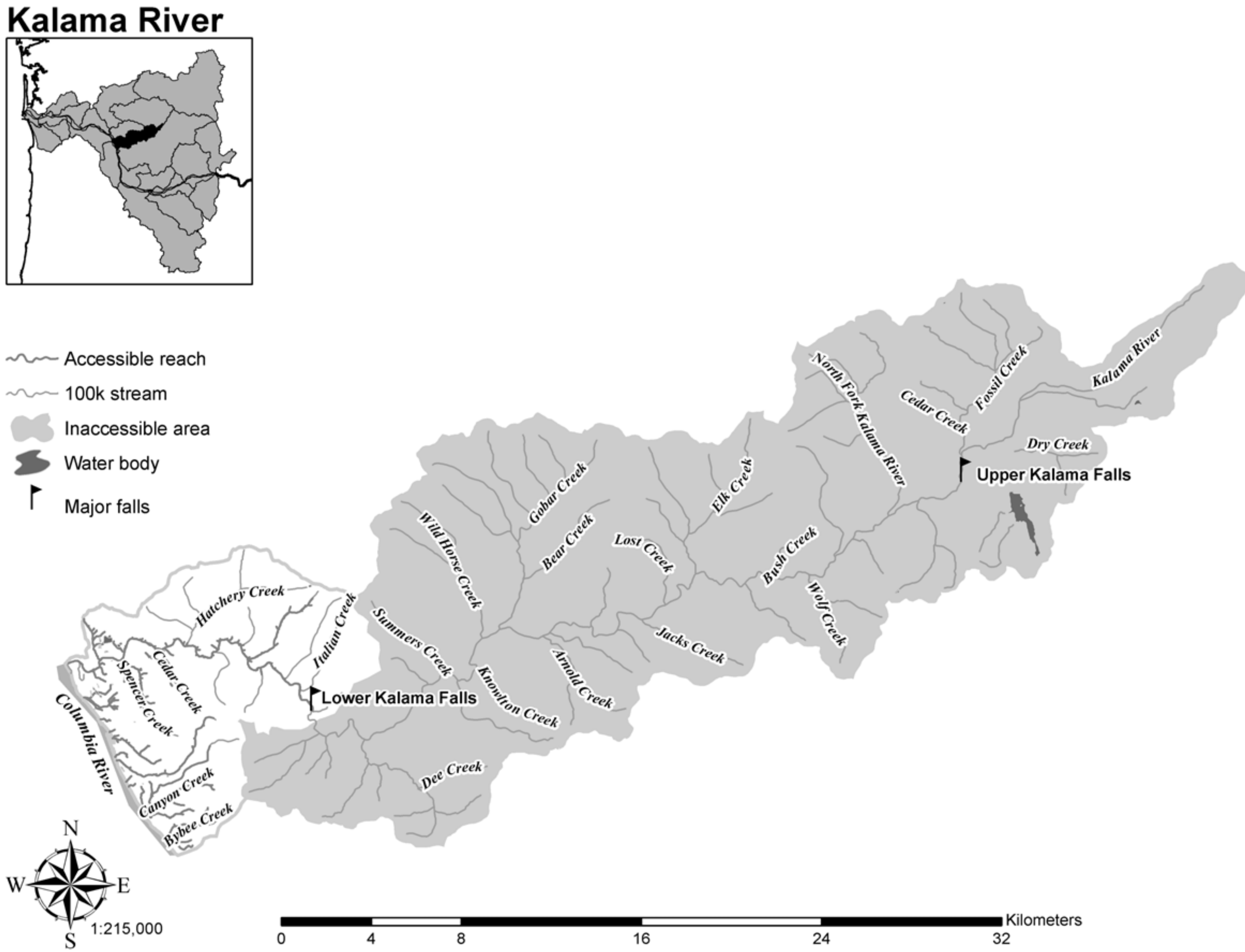


Figure E-14. Historical accessibility of fall Chinook salmon to the Kalama River.

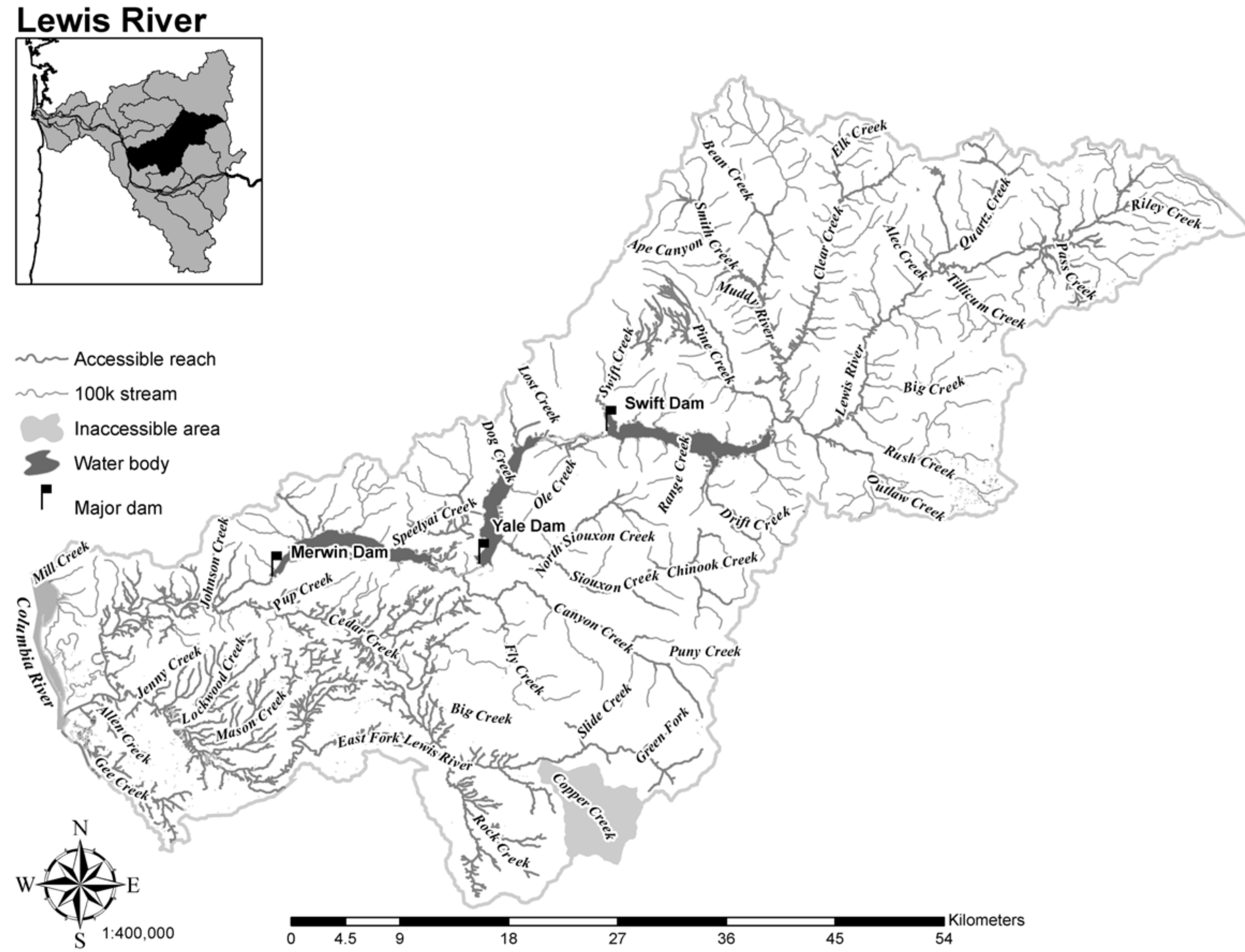


Figure E-15. Historical accessibility of fall and late fall Chinook salmon to the Lewis River.

Mill, Abernathy, and Germany Creeks

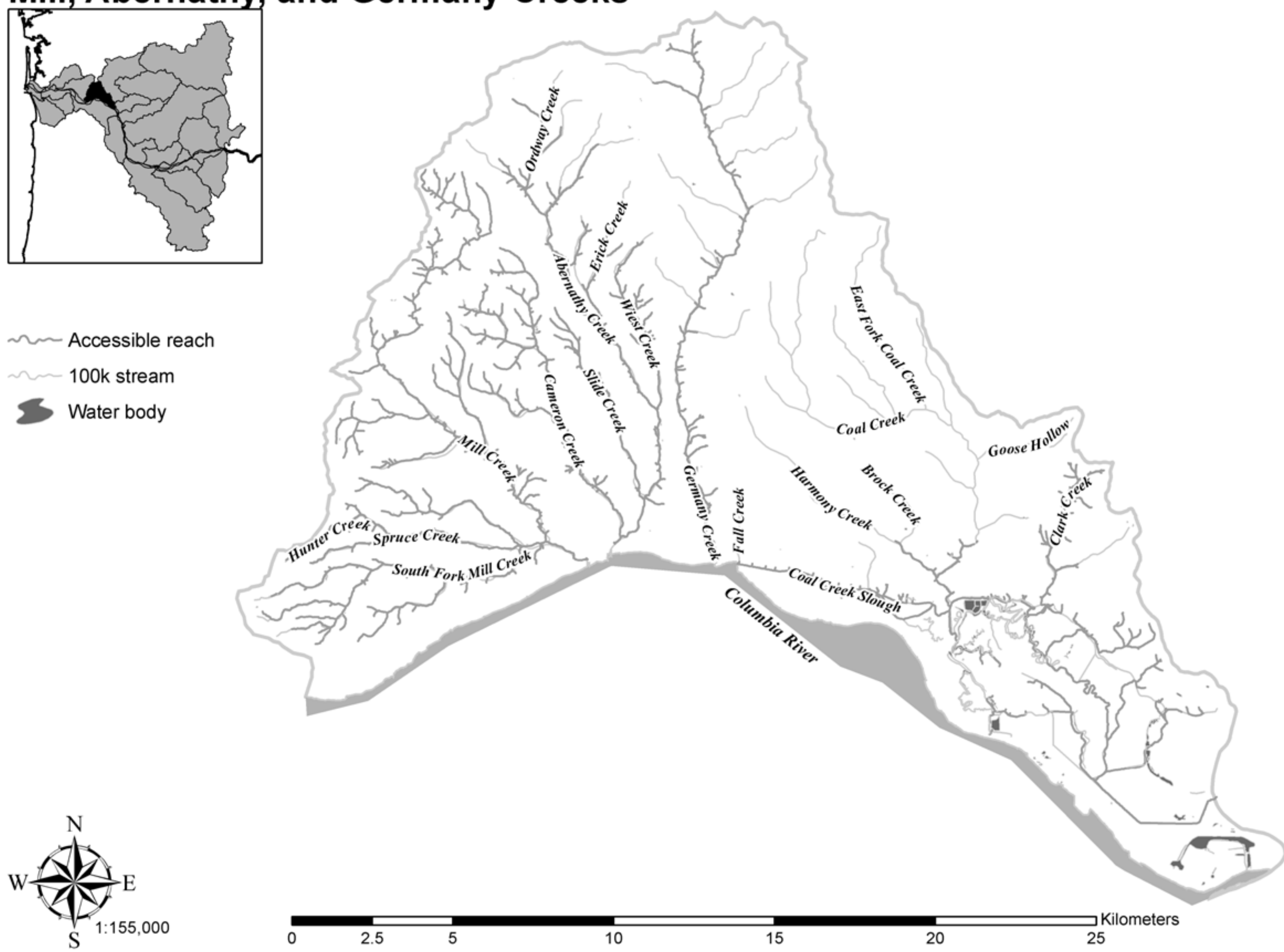


Figure E-16. Historical accessibility of fall Chinook salmon to Mill, Abernathy, and Germany creeks.

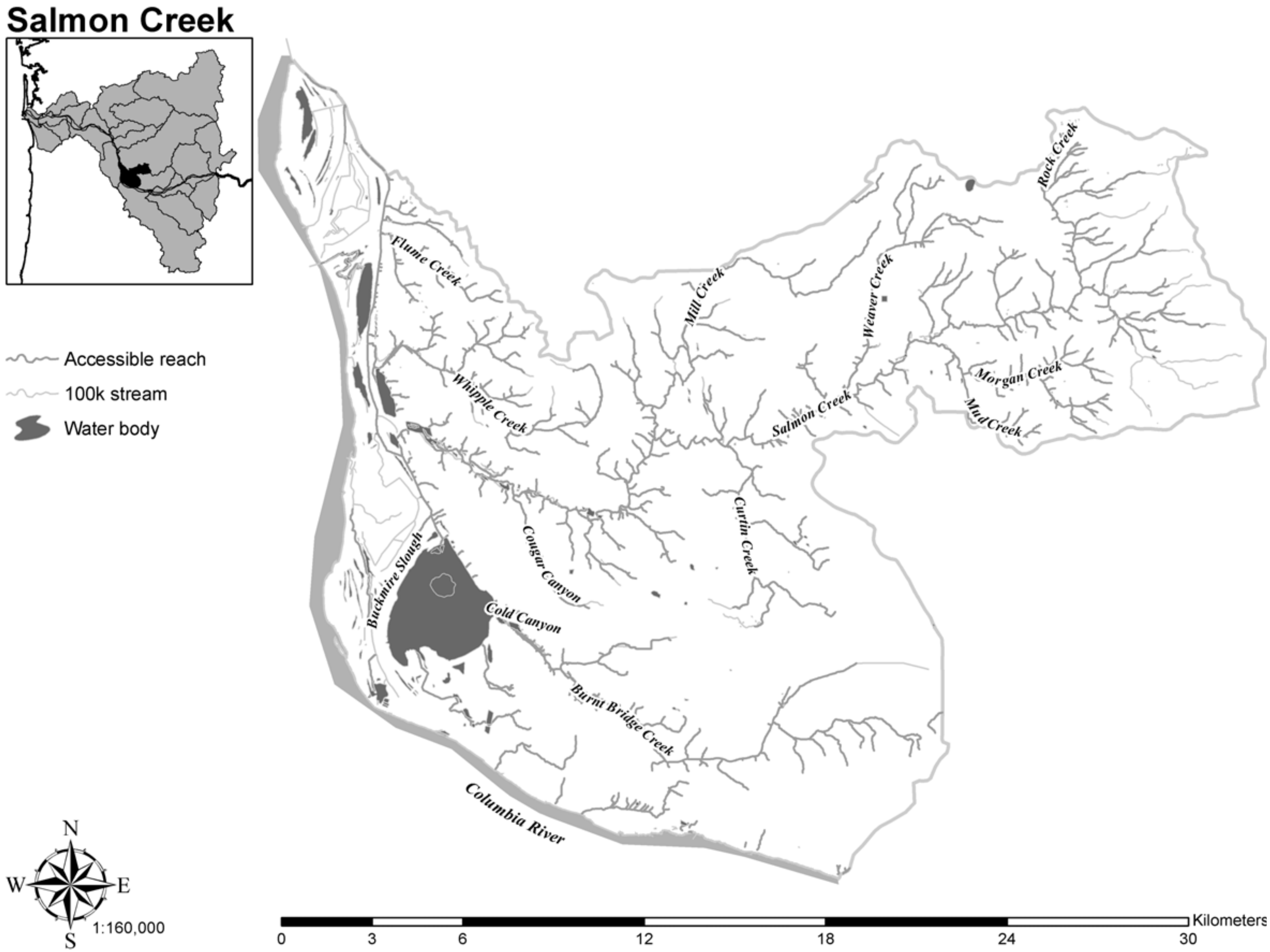


Figure E-17. Historical accessibility of fall Chinook salmon to Salmon Creek.

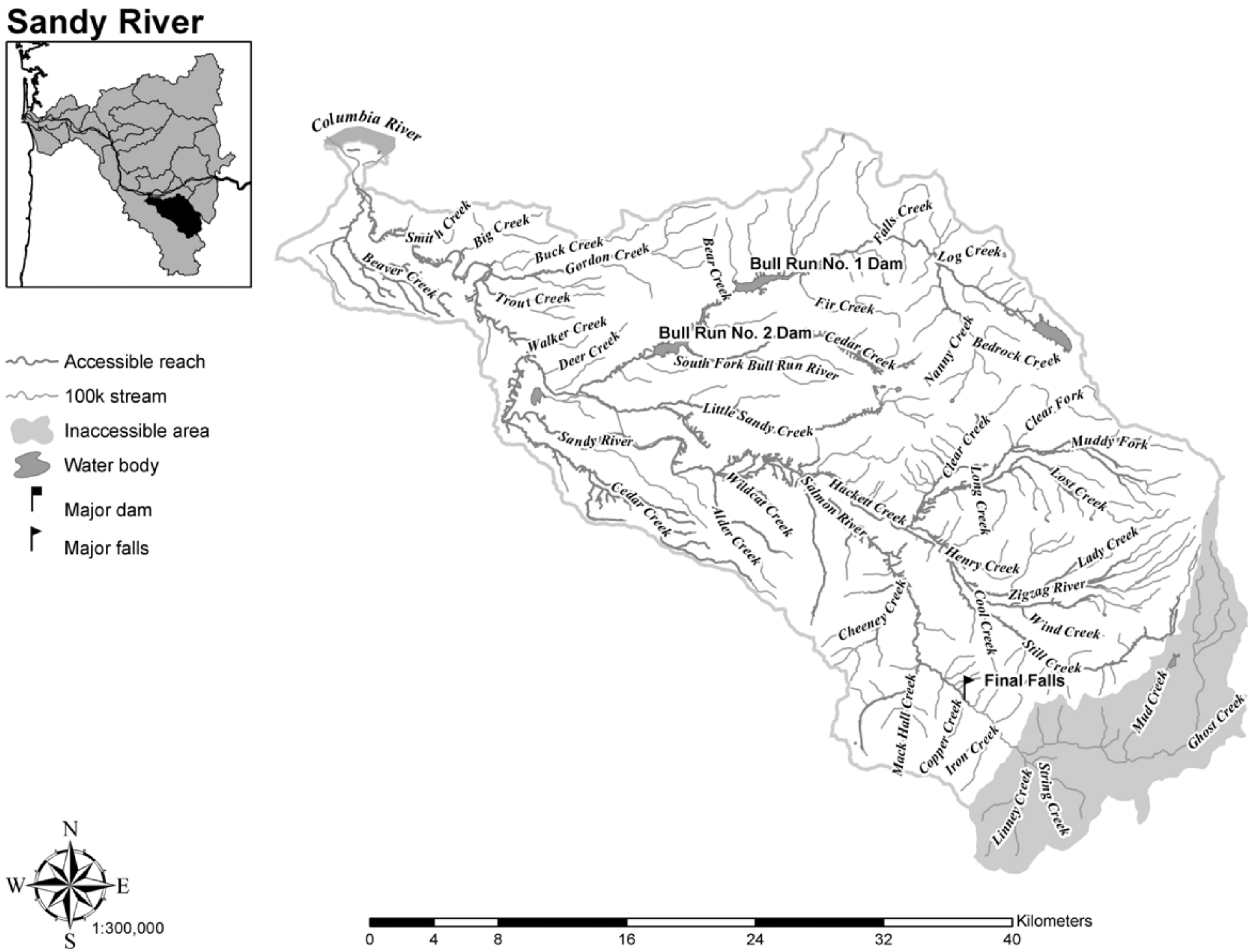


Figure E-18. Historical accessibility of fall and late fall Chinook salmon to the Sandy River.

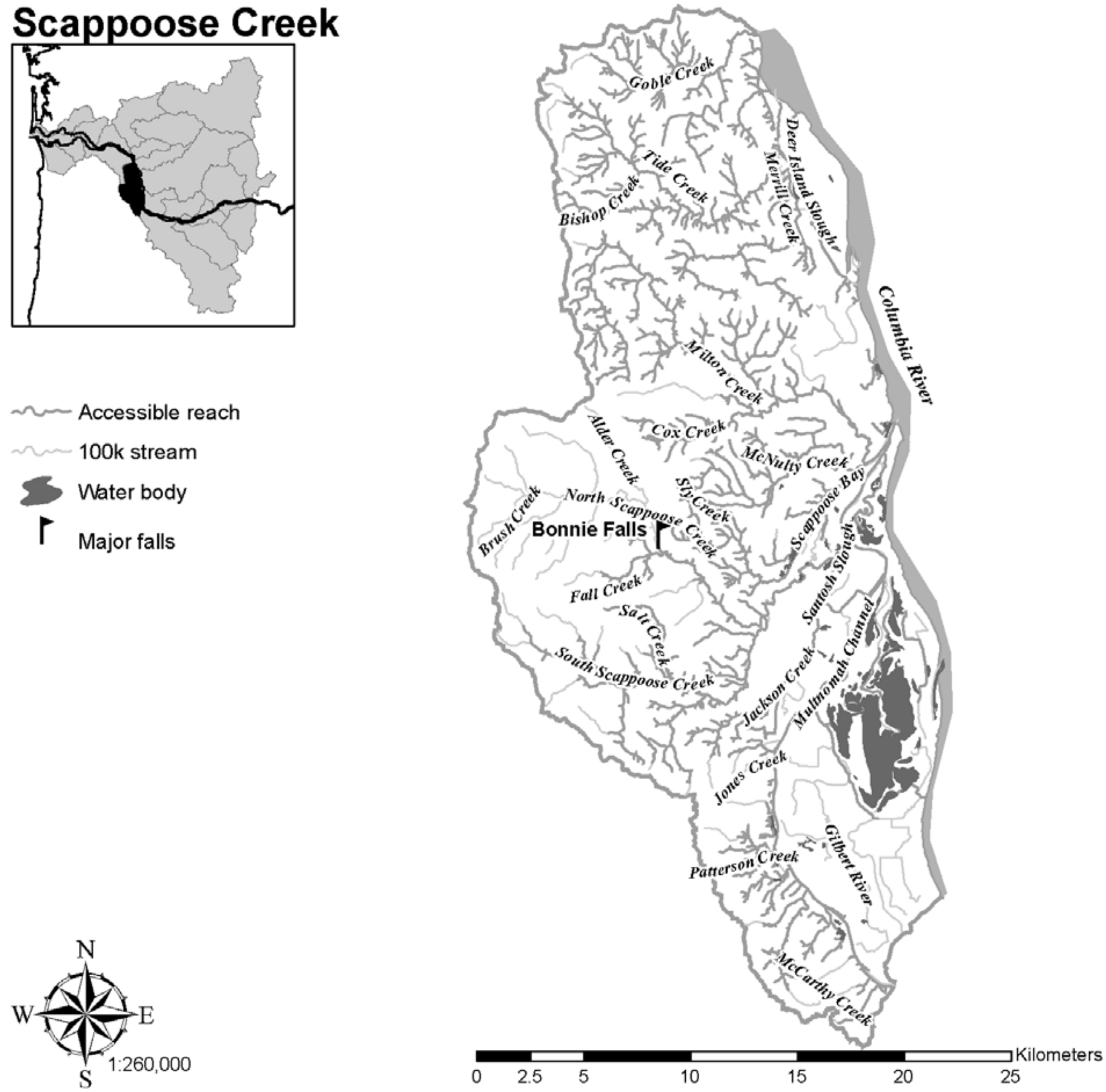


Figure E-19. Historical accessibility of fall Chinook salmon to the Scappose Creek.

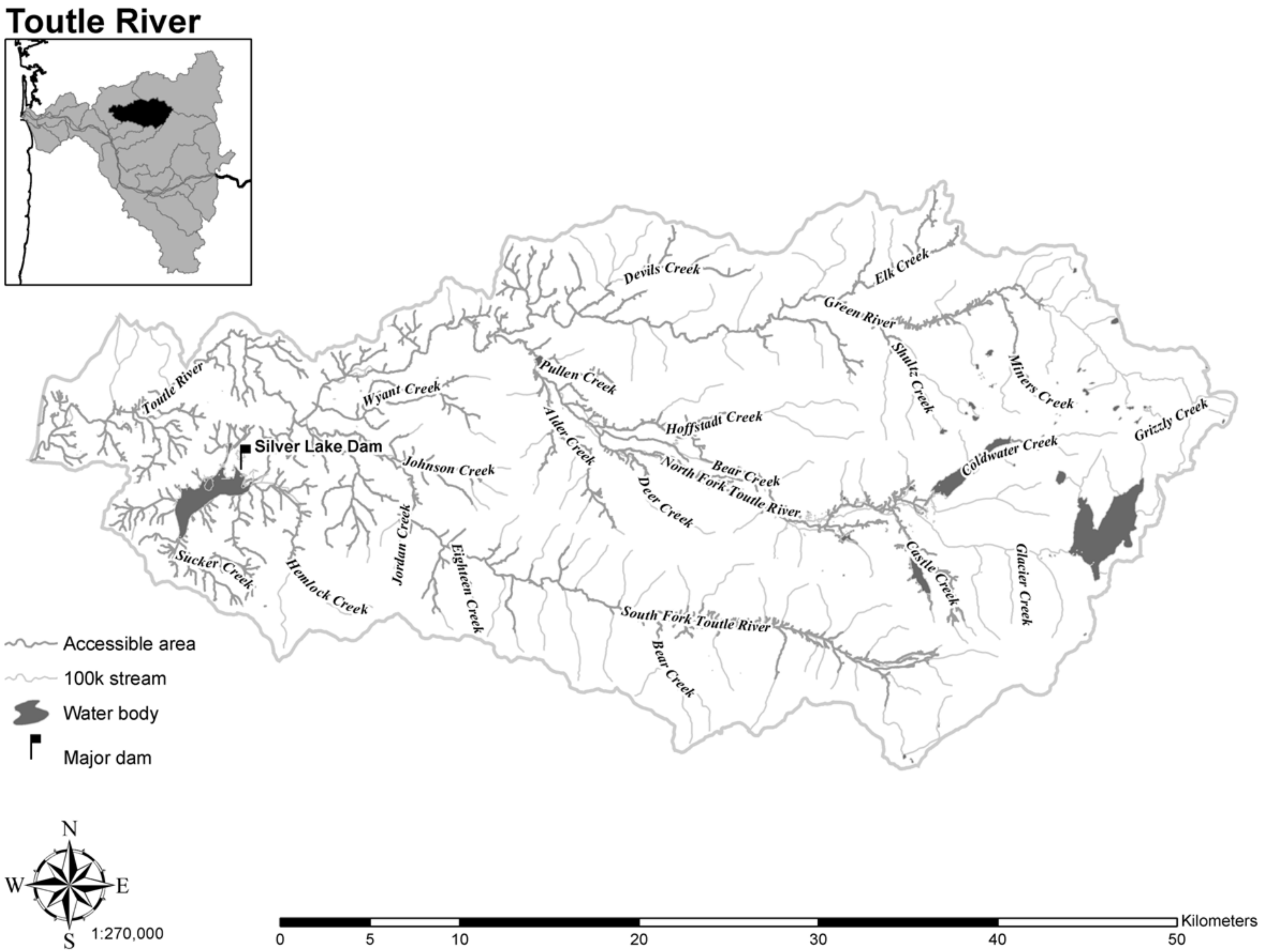


Figure E-20. Historical accessibility of fall Chinook salmon to the Toutle River.

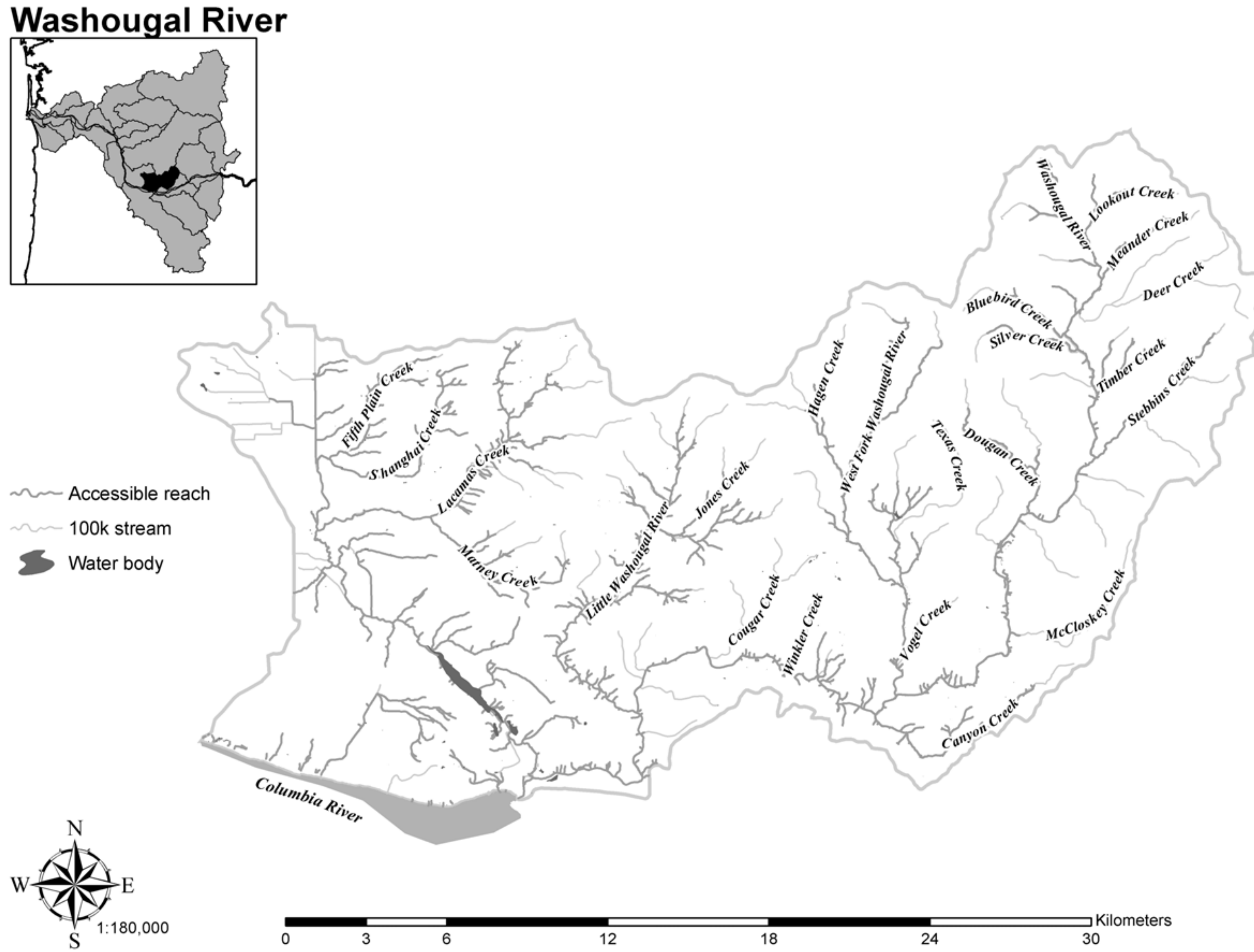


Figure E-21. Historical accessibility of fall Chinook salmon to the Washougal River.

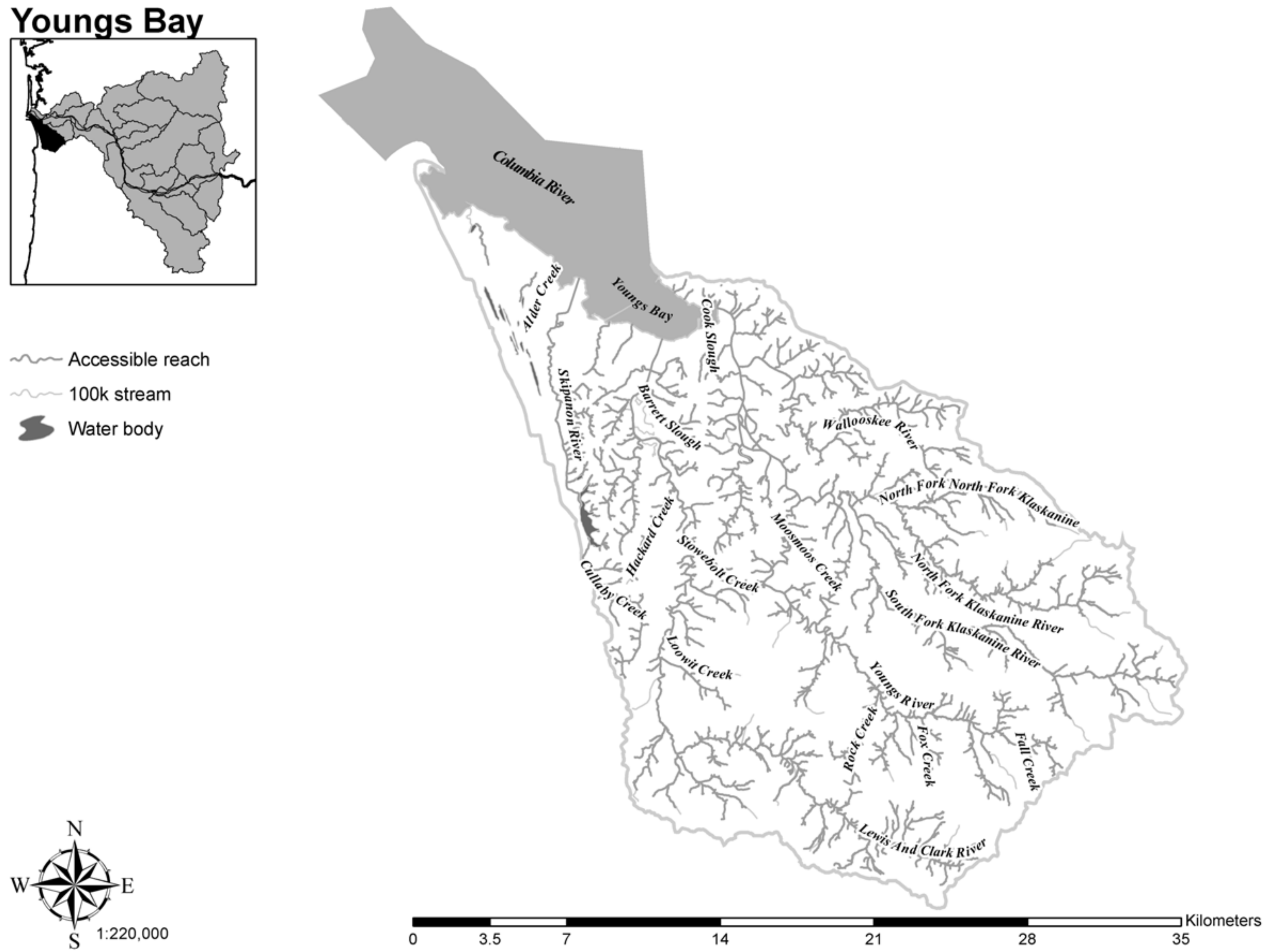


Figure E-22. Historical accessibility of fall Chinook salmon to Youngs Bay.

Lower Columbia River Spring Chinook Salmon Historical Accessibility

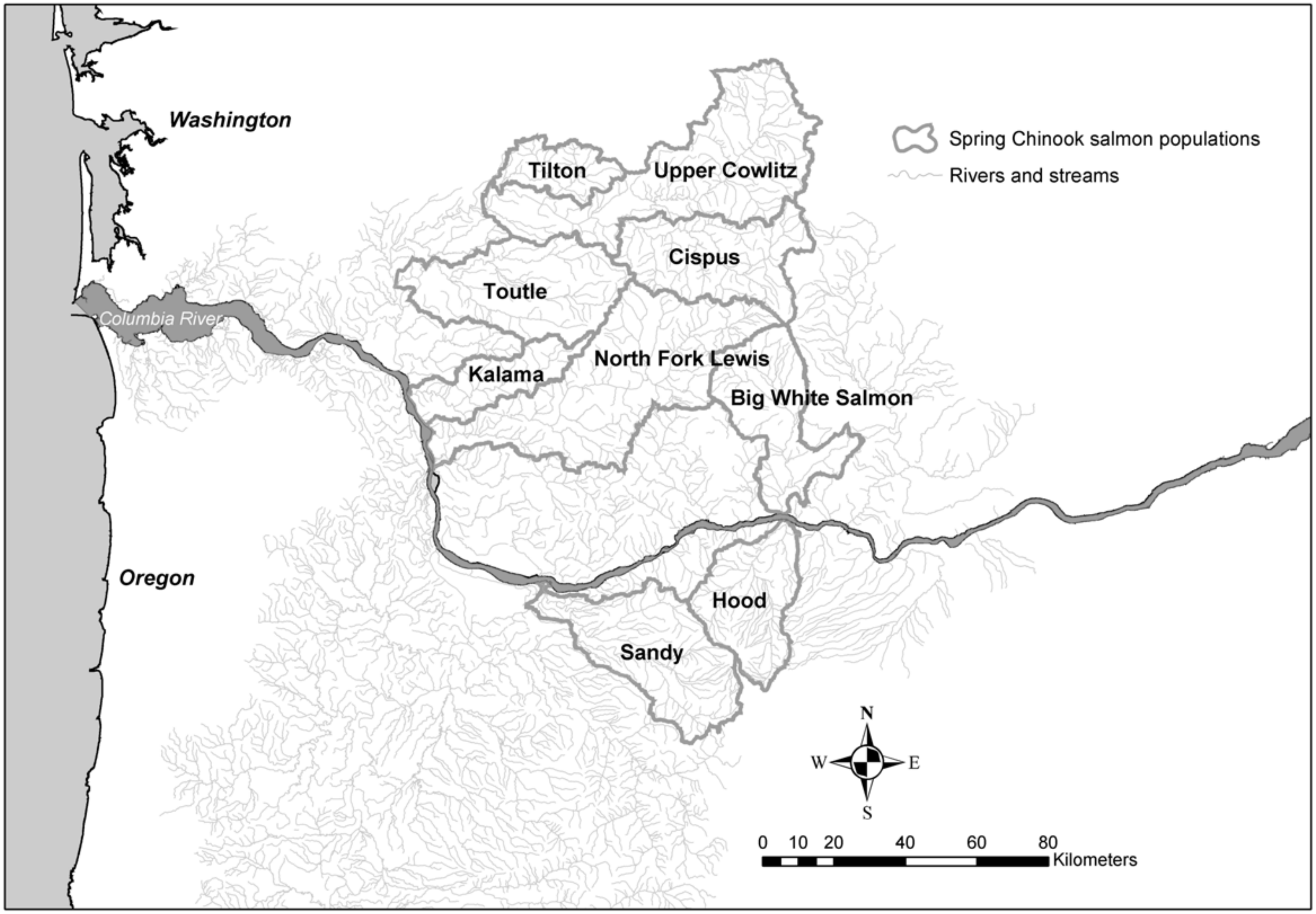


Figure E-23. Lower Columbia River spring Chinook salmon population areas.

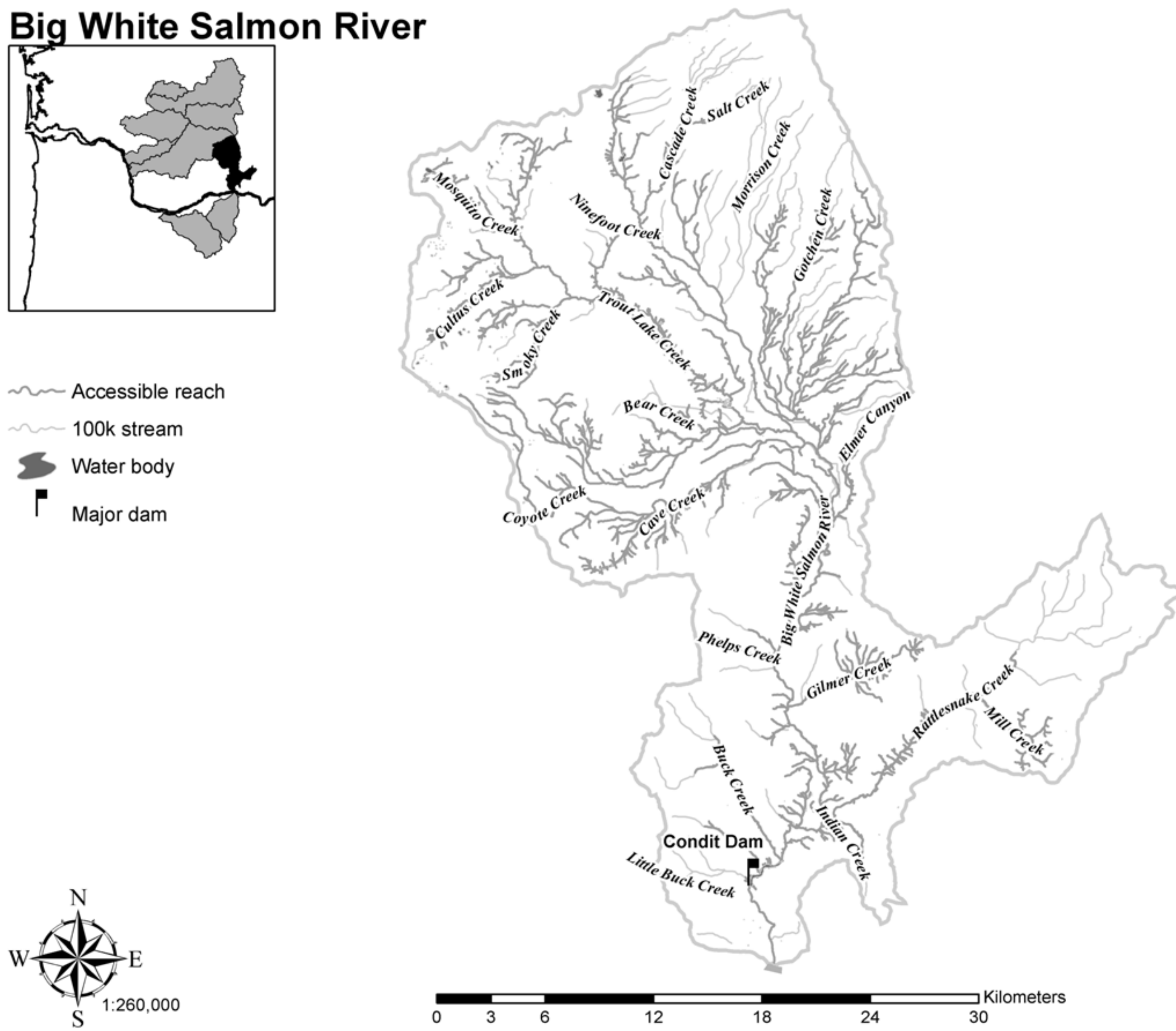


Figure E-24. Historical accessibility of spring Chinook salmon to the Big White Salmon River.

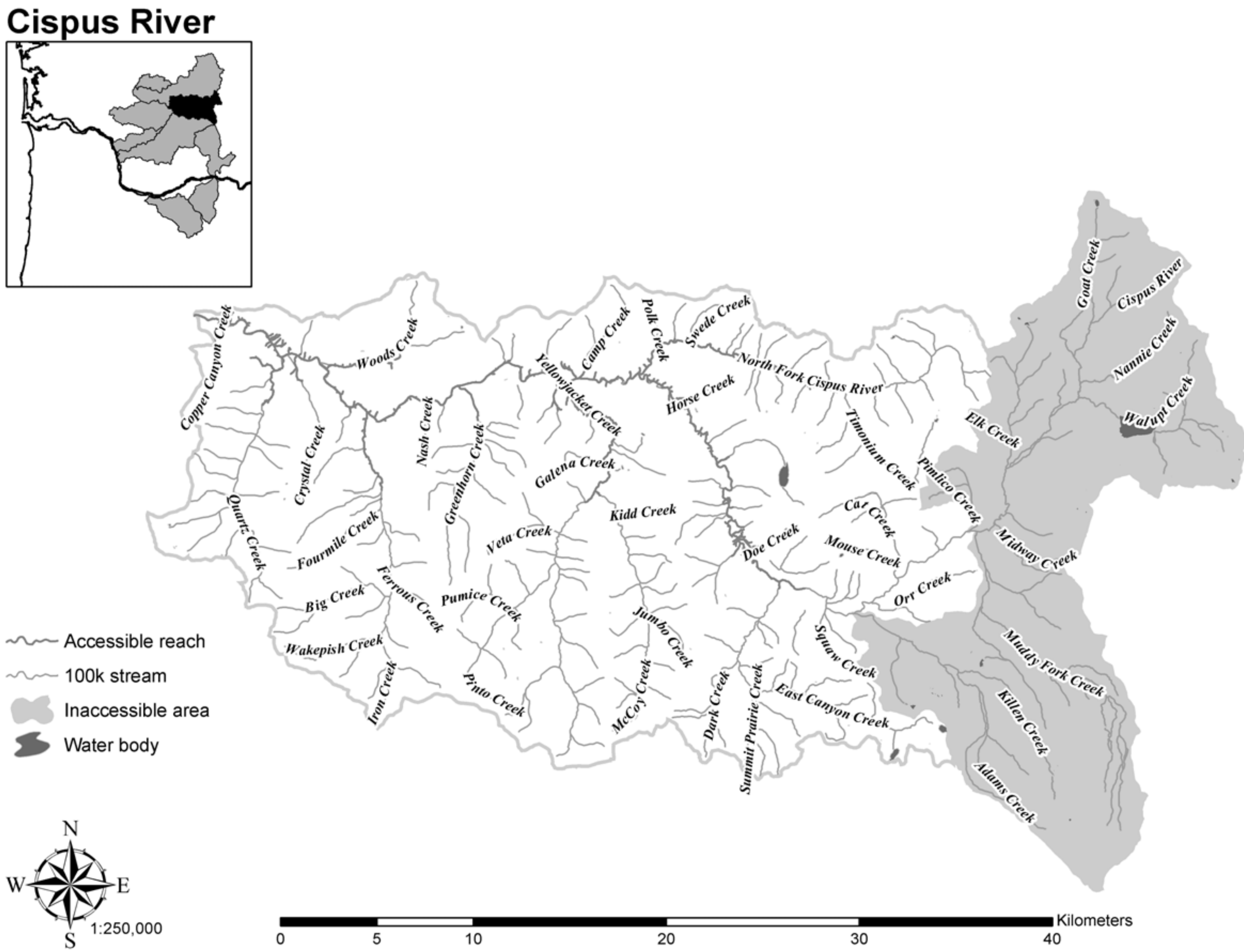


Figure E-25. Historical accessibility of spring Chinook salmon to the Cispus River.

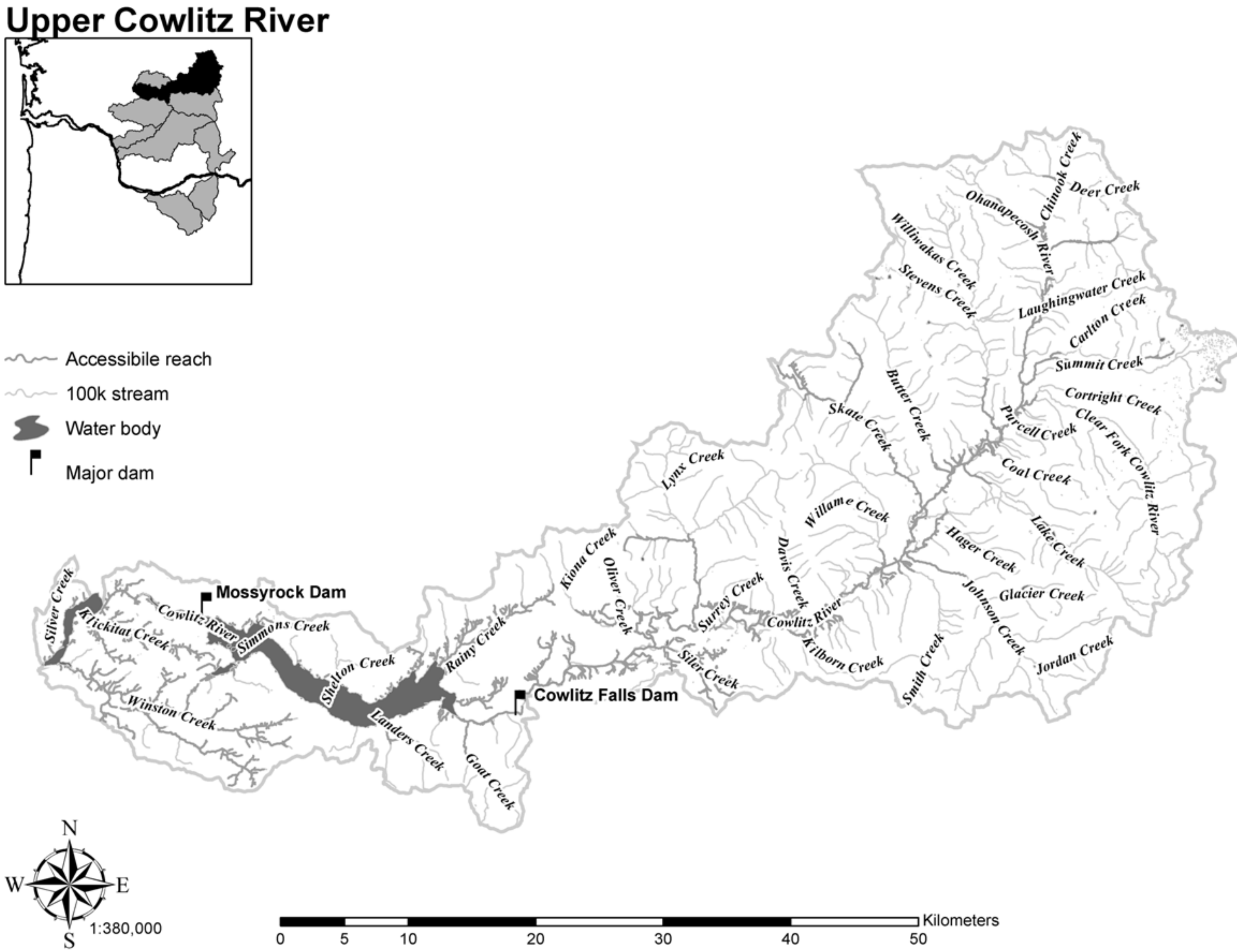


Figure E-26. Historical accessibility of spring Chinook salmon to the upper Cowlitz River.

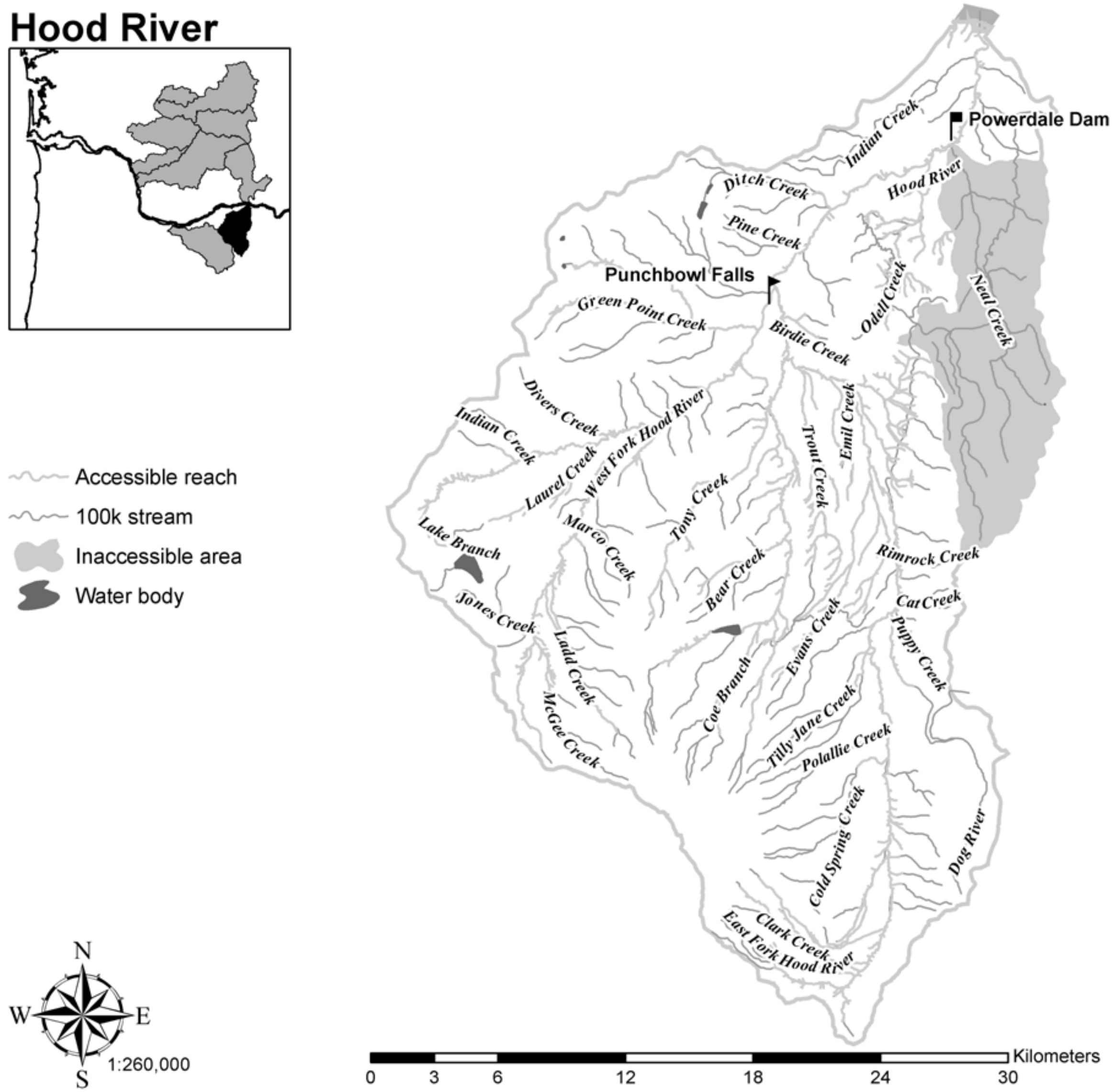


Figure E-27. Historical accessibility of spring Chinook salmon to the Hood River.

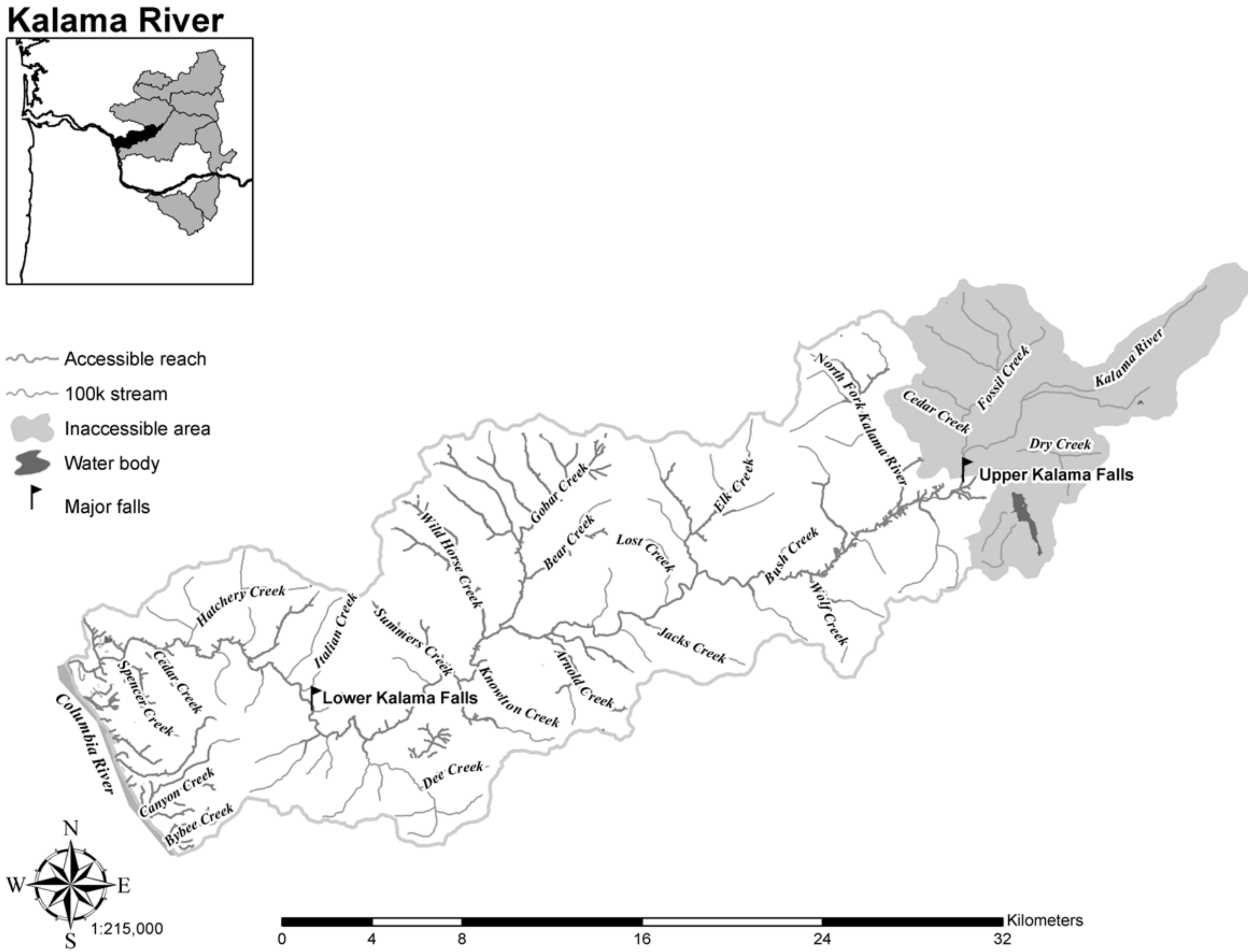


Figure E-28. Historical accessibility of spring Chinook salmon to the Kalama River.

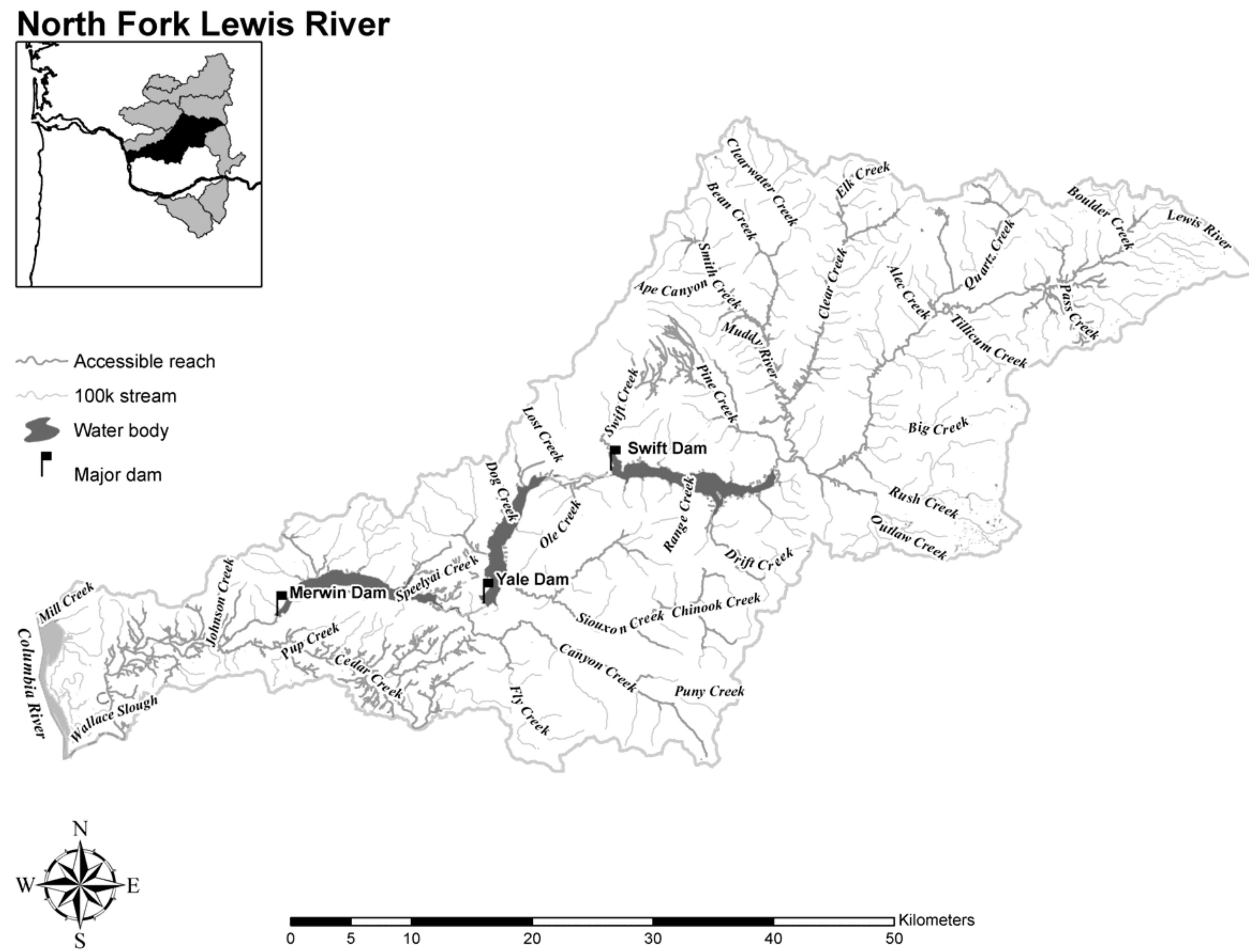


Figure E-29. Historical accessibility of spring Chinook salmon to the North Fork Lewis River.

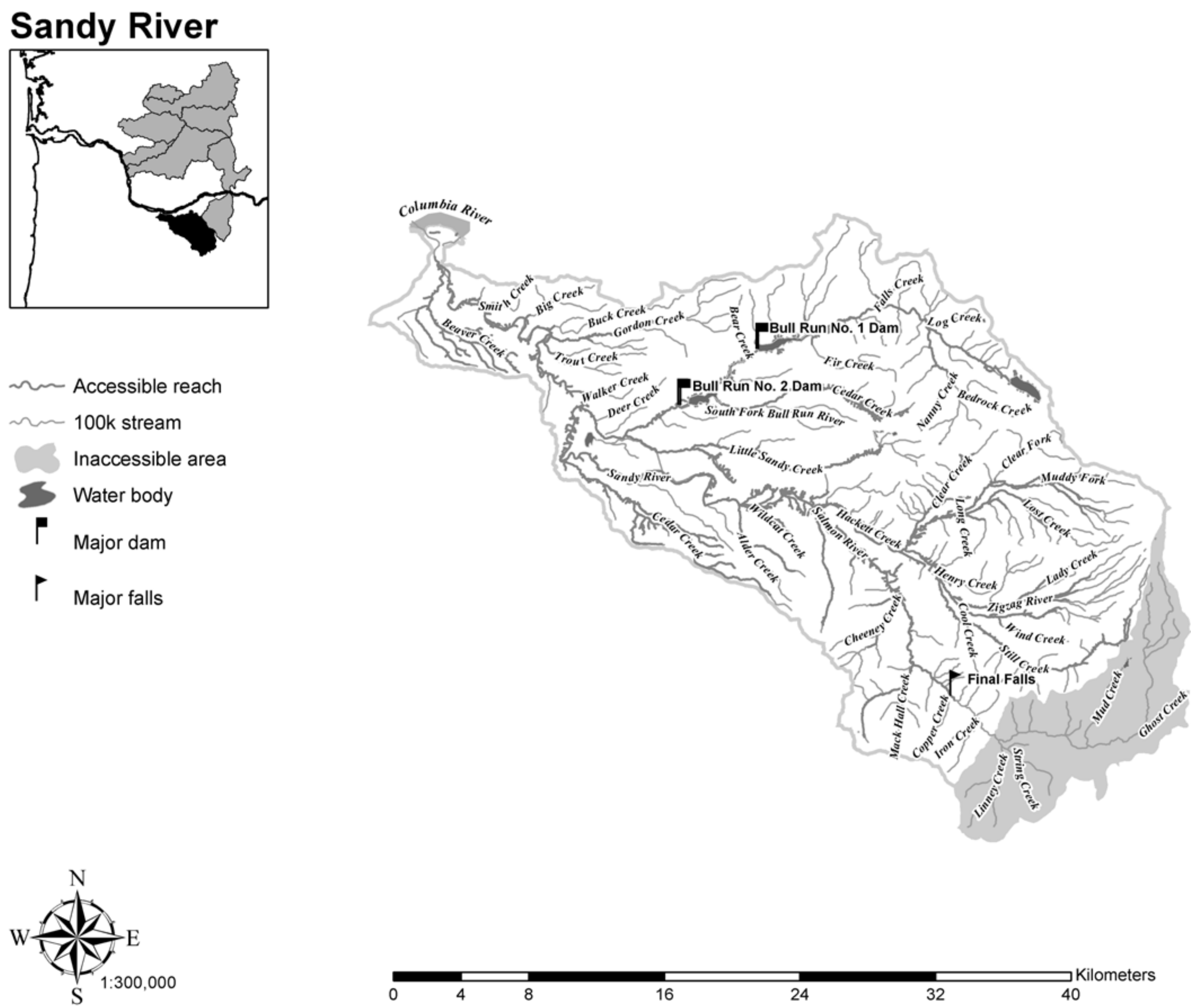


Figure E-30. Historical accessibility of spring Chinook salmon to the Sandy River.

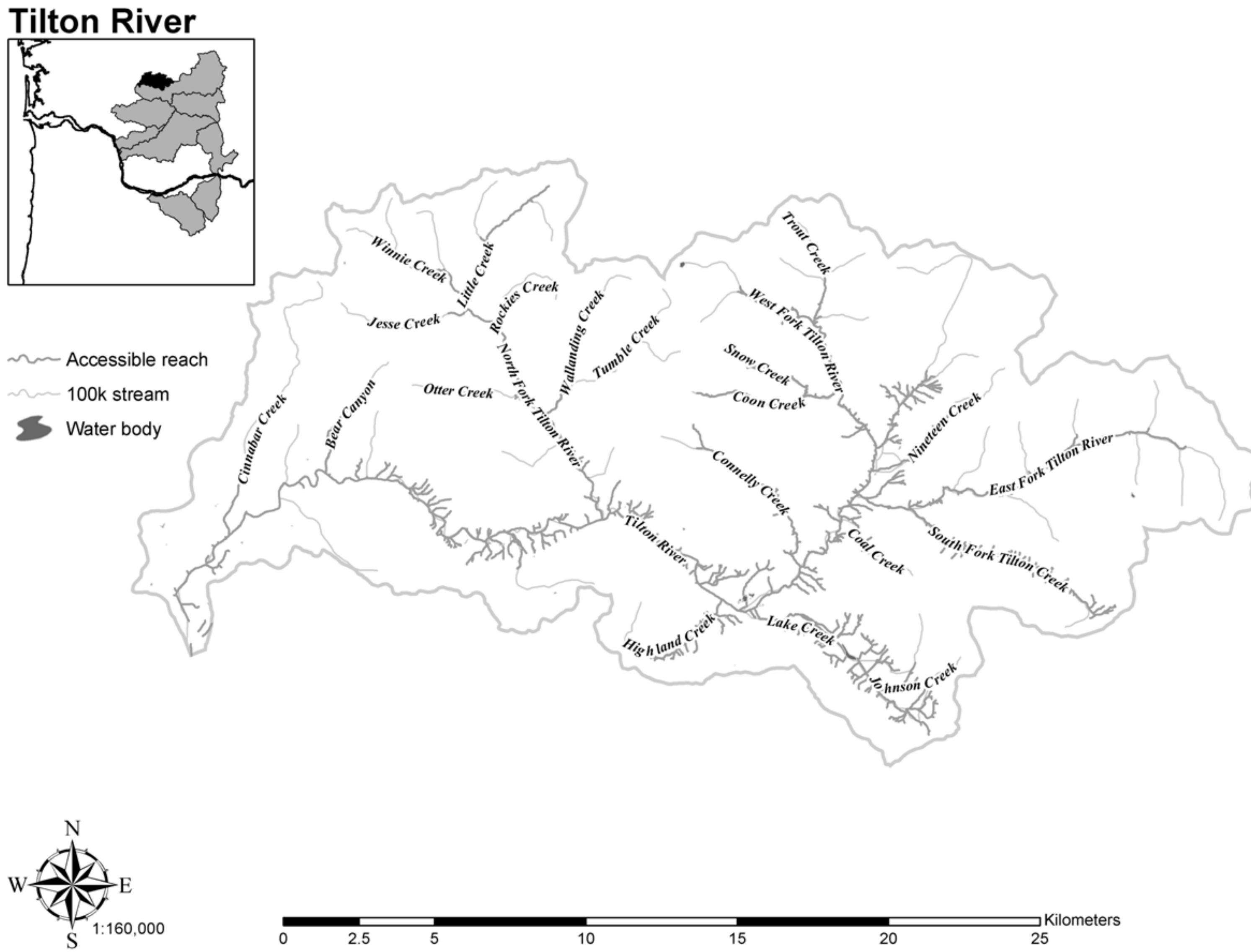


Figure E-31. Historical accessibility of spring Chinook salmon to the Tilton River.

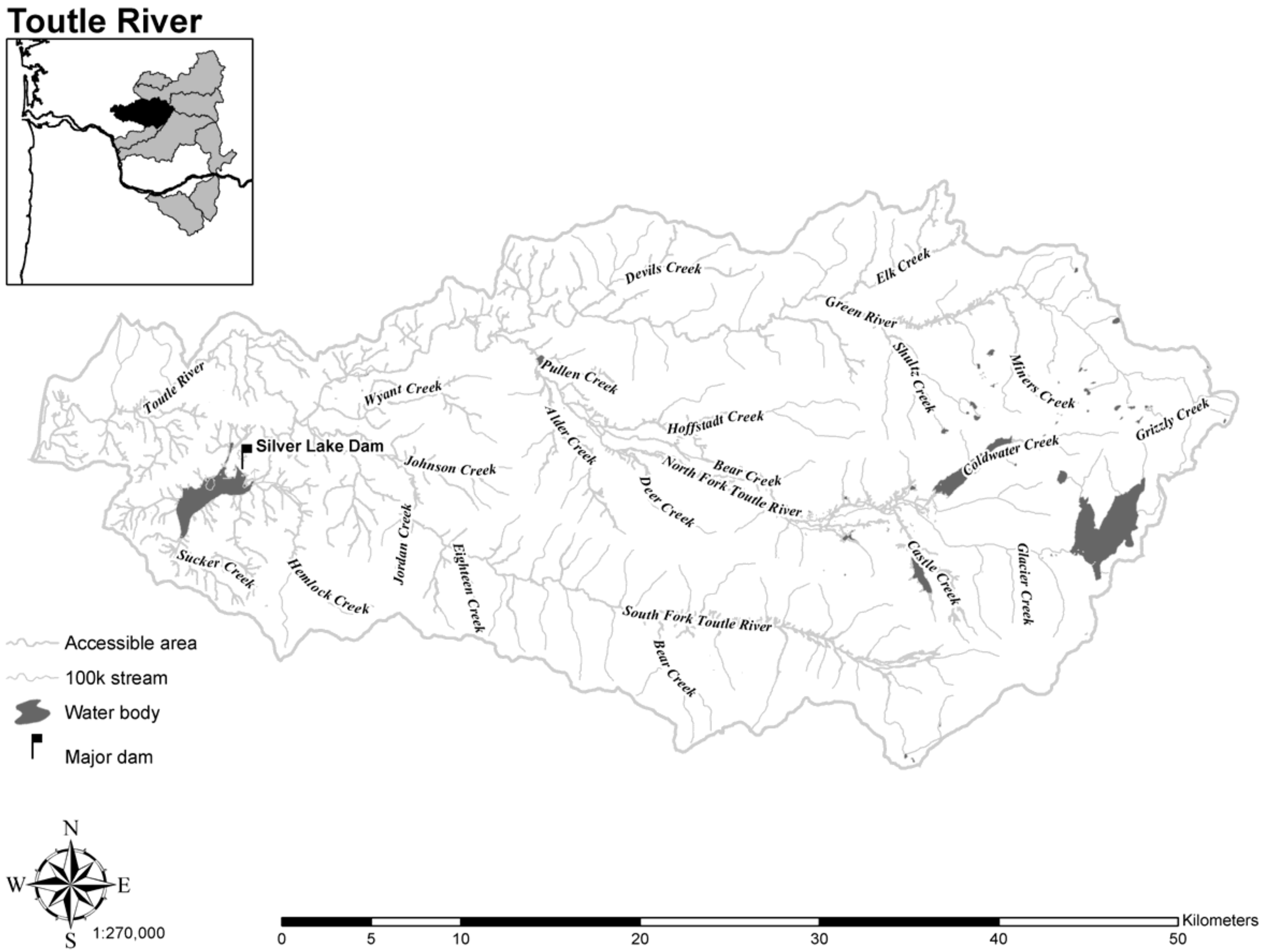


Figure E-32. Historical accessibility of spring Chinook salmon to the Toutle River.

Upper Willamette River Spring Chinook Salmon Historical Accessibility

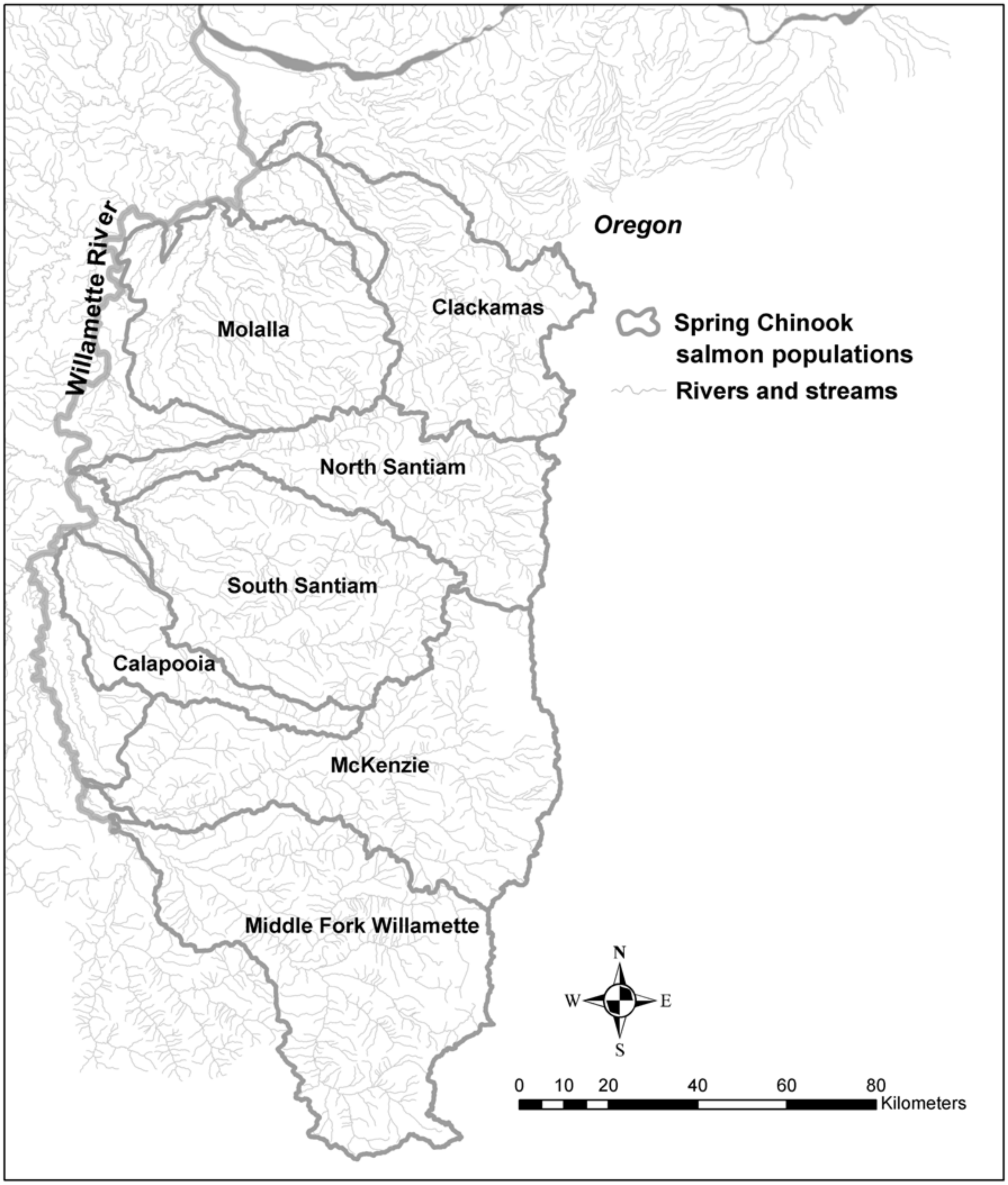


Figure E-33. Upper Willamette River spring Chinook salmon population areas.

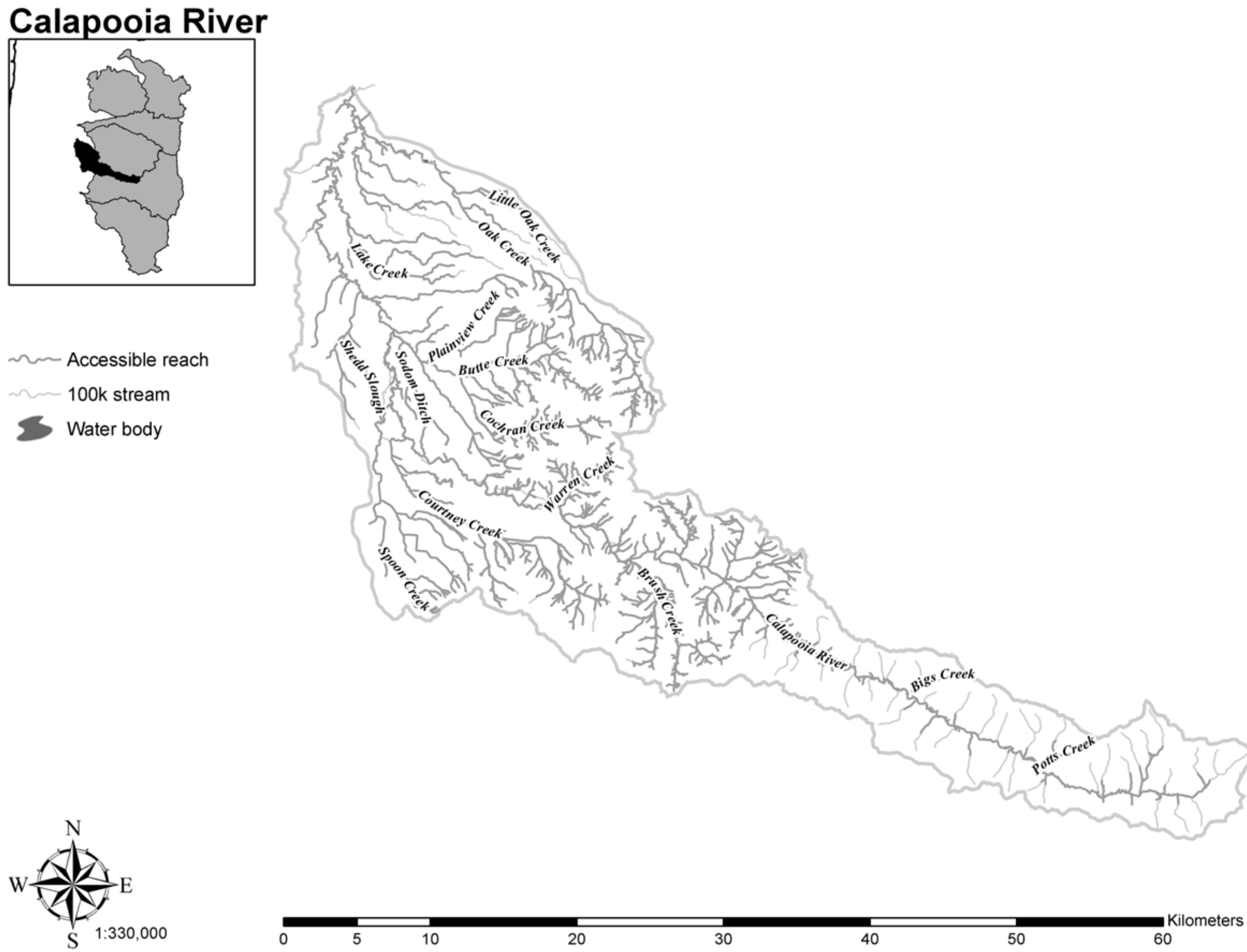


Figure E-34. Historical accessibility of spring Chinook salmon to the Calapooia River.

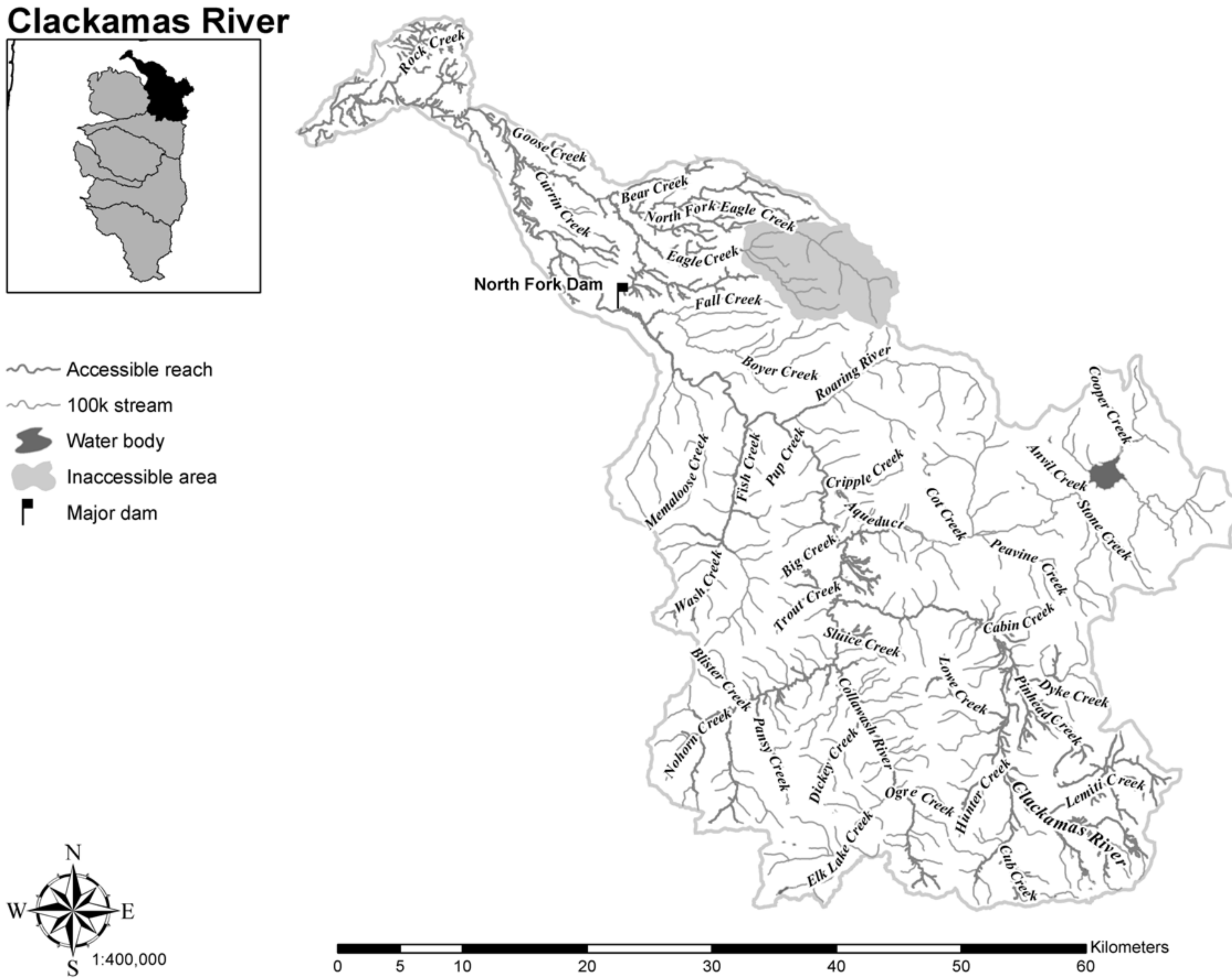


Figure E-35. Historical accessibility of spring Chinook salmon to the Clakamas River.

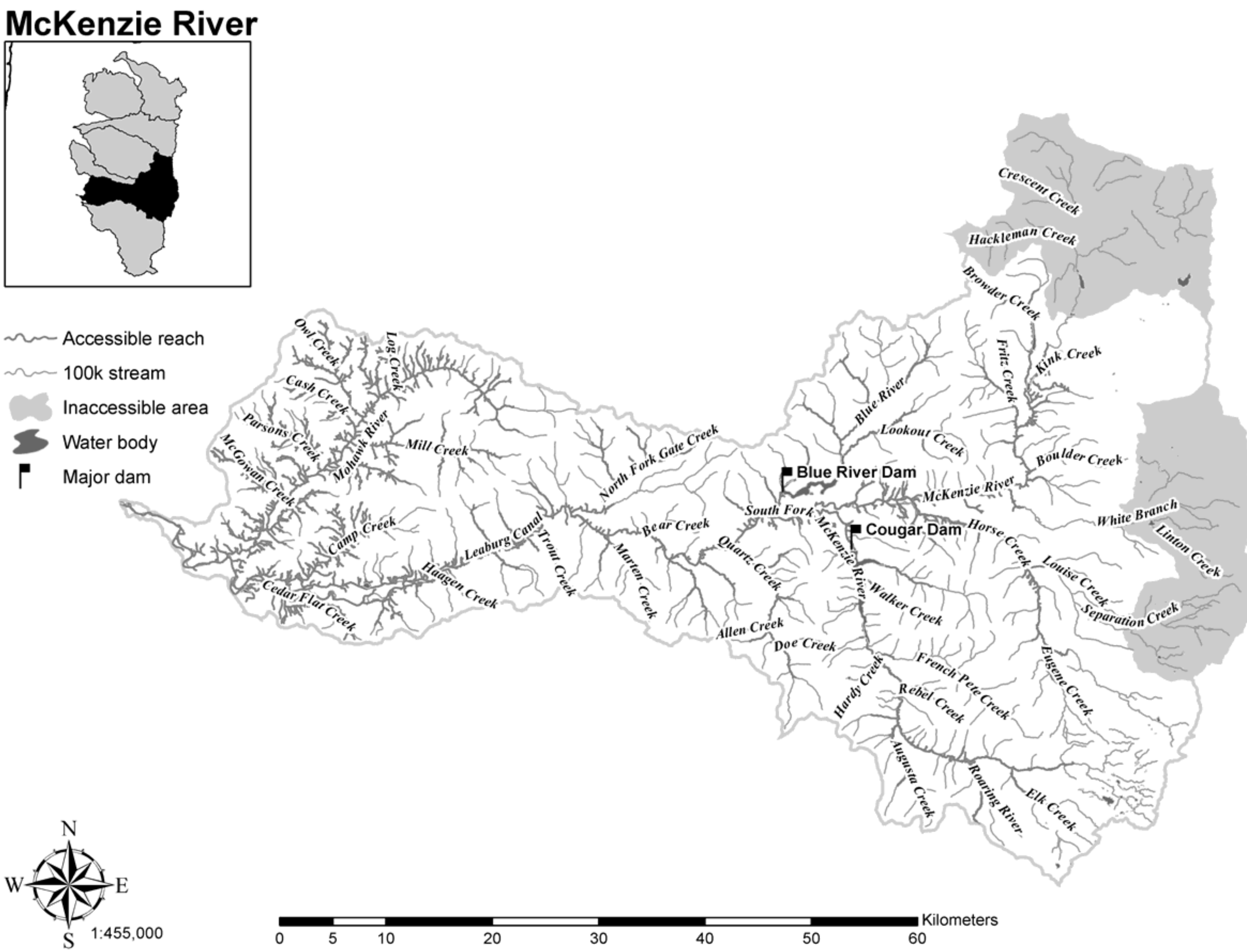


Figure E-36. Historical accessibility of spring Chinook salmon to the McKenzie River.

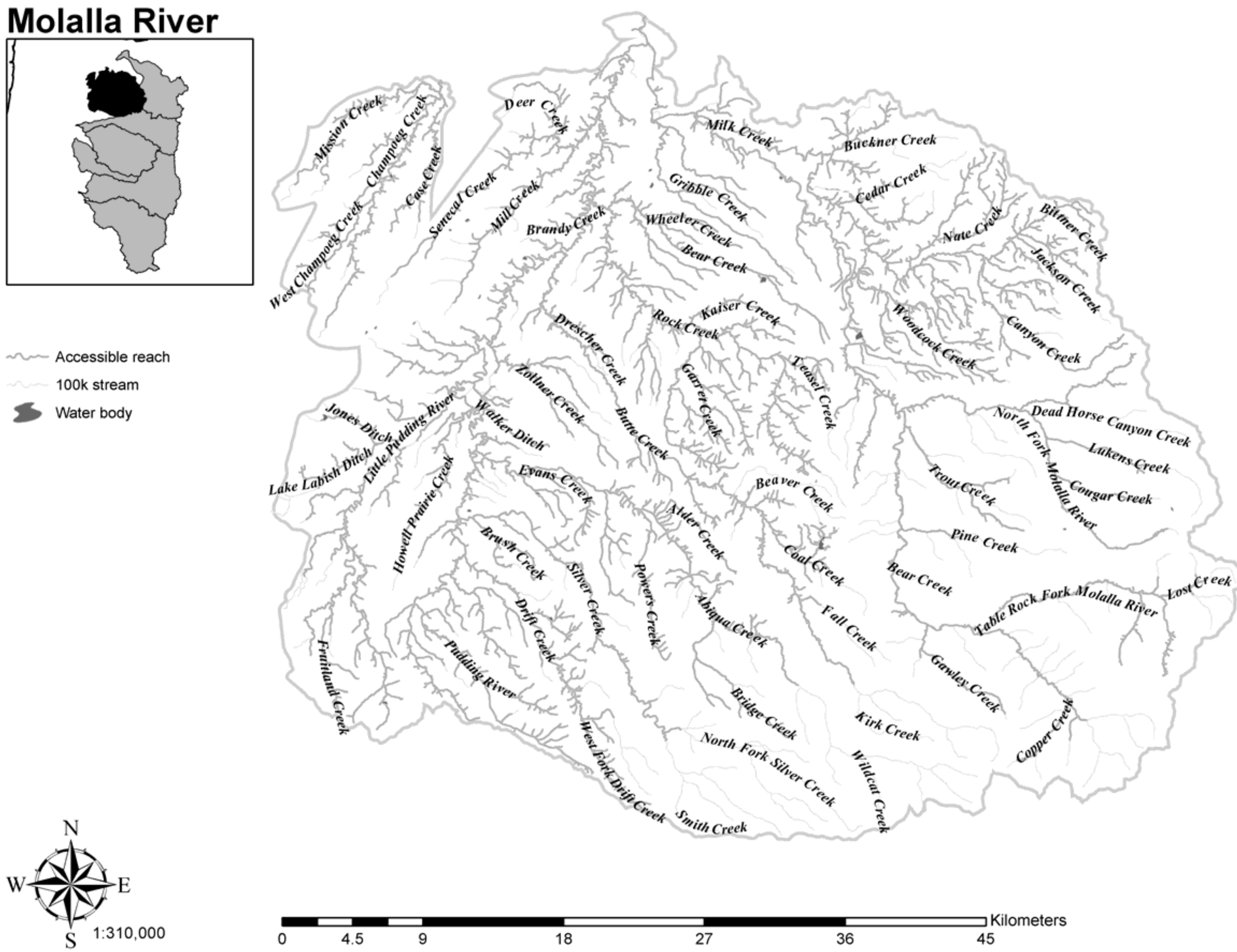


Figure E-37. Historical accessibility of spring Chinook salmon to the Molalla River.

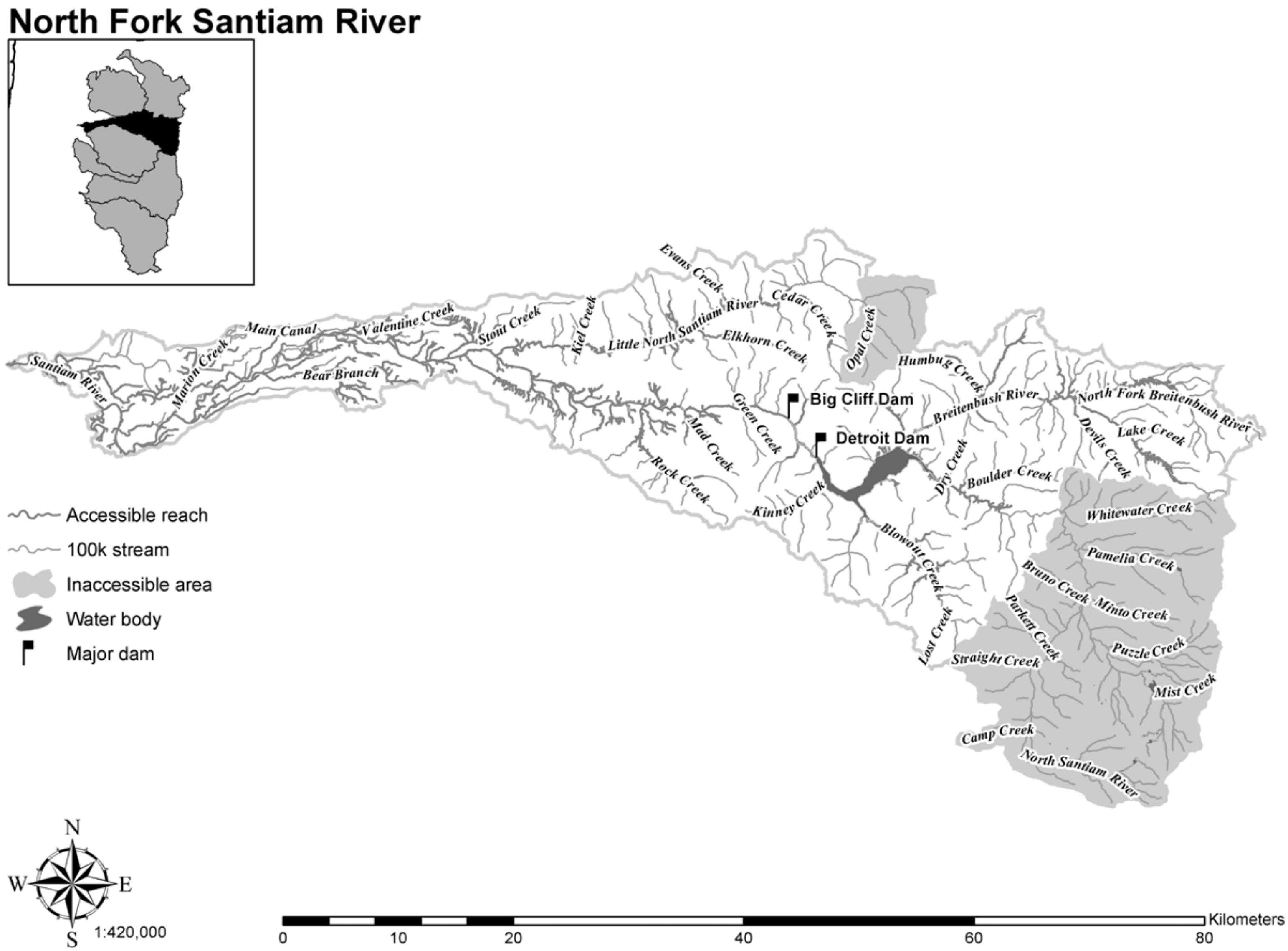


Figure E-38. Historical accessibility of spring Chinook salmon to the North Fork Santiam River.

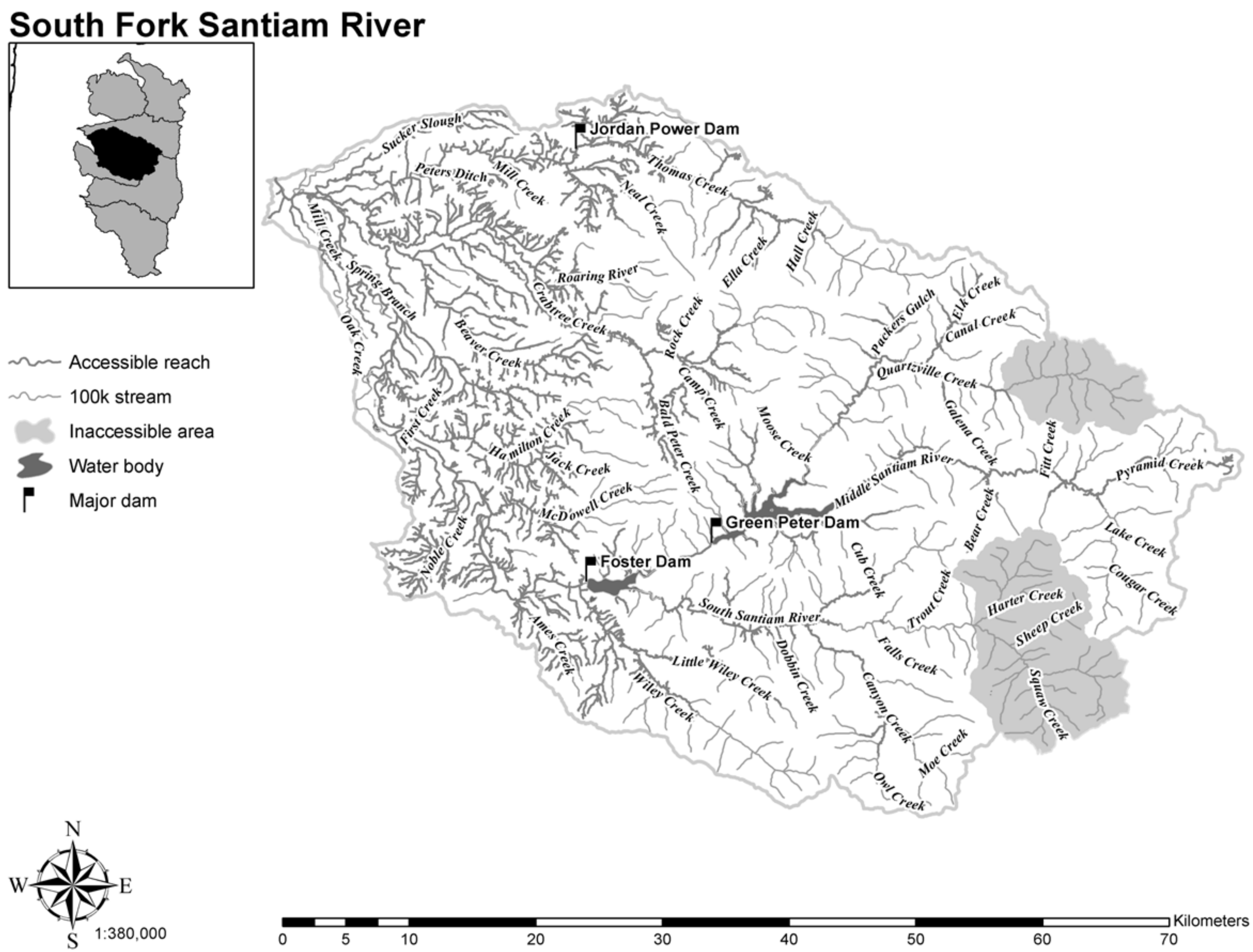


Figure E-39. Historical accessibility of spring Chinook salmon to the South Fork Santiam River.

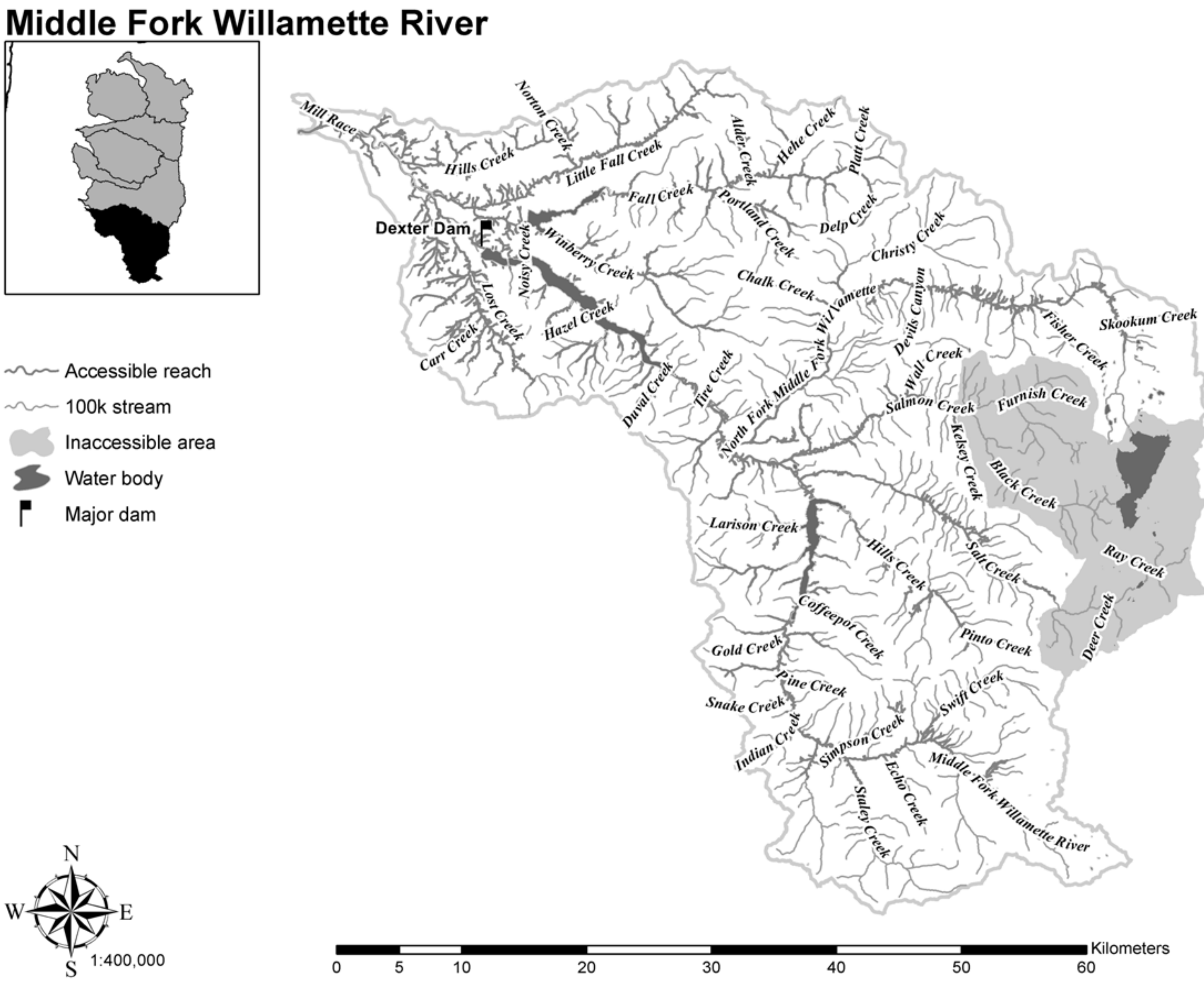


Figure E-40. Historical accessibility of spring Chinook salmon to the Middle Fork Willamette River.

Lower Columbia River Summer Steelhead Historical Accessibility

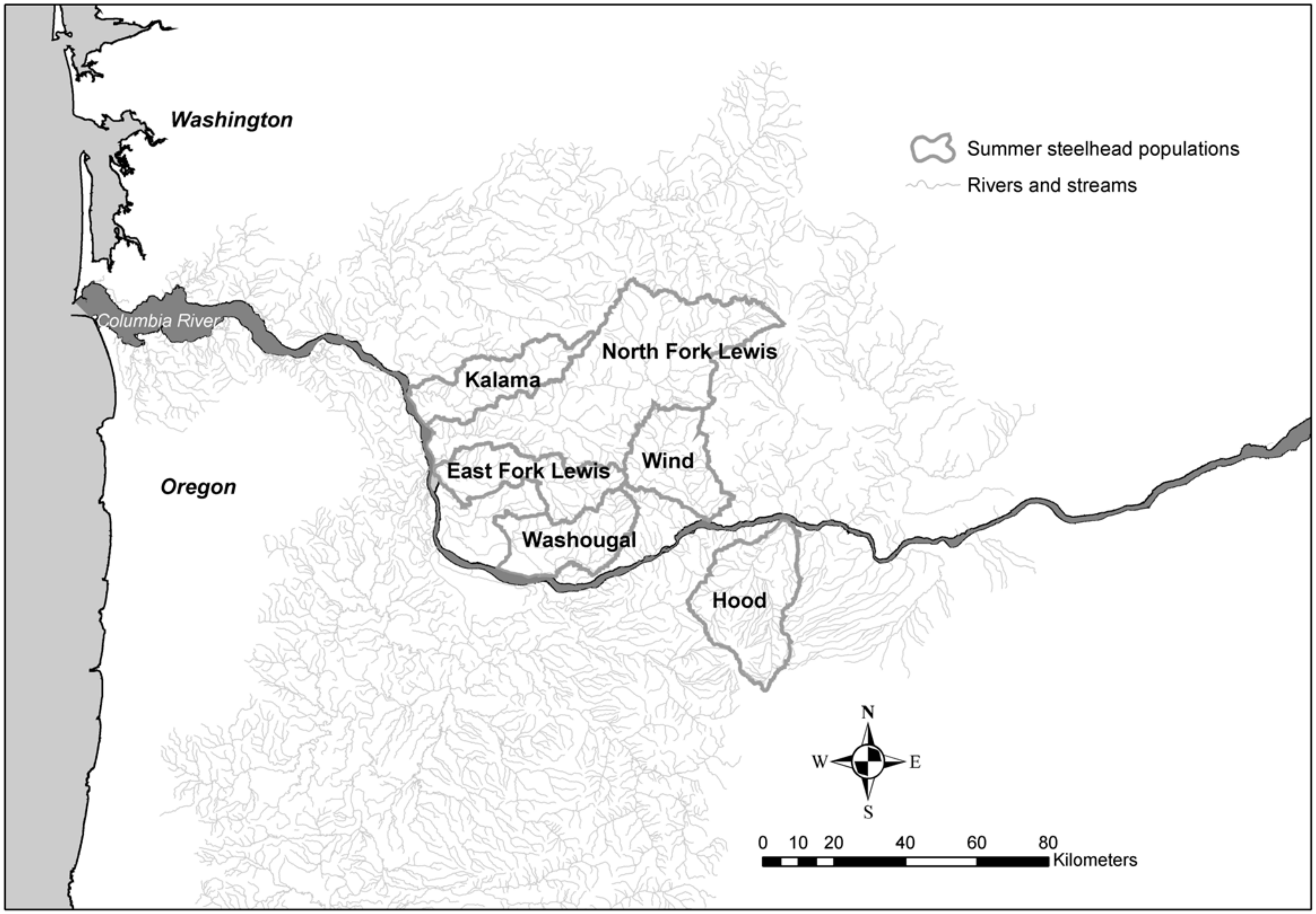


Figure E-41. Summer steelhead population areas.

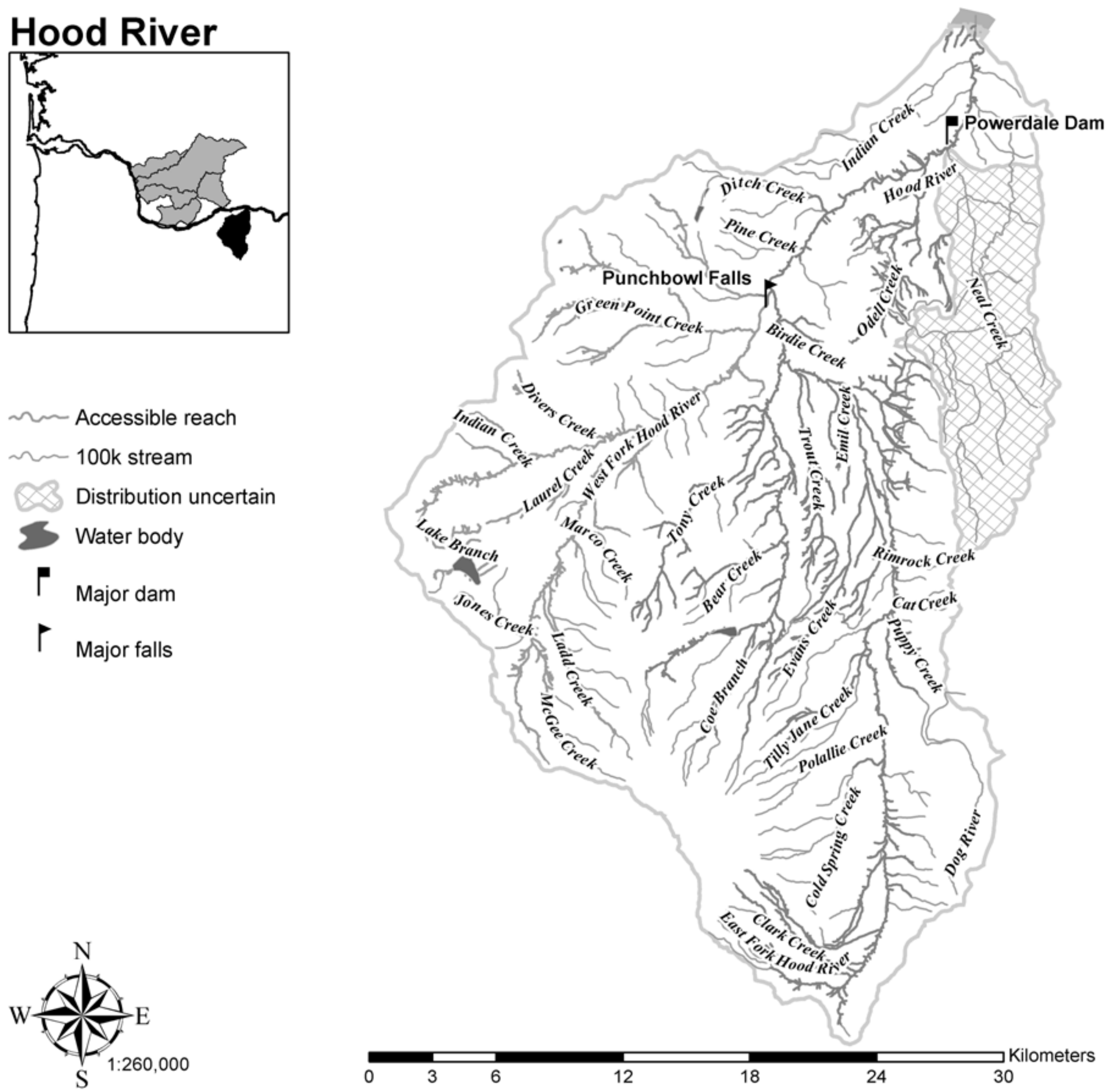


Figure E-42. Historical accessibility of summer steelhead to the Hood River.

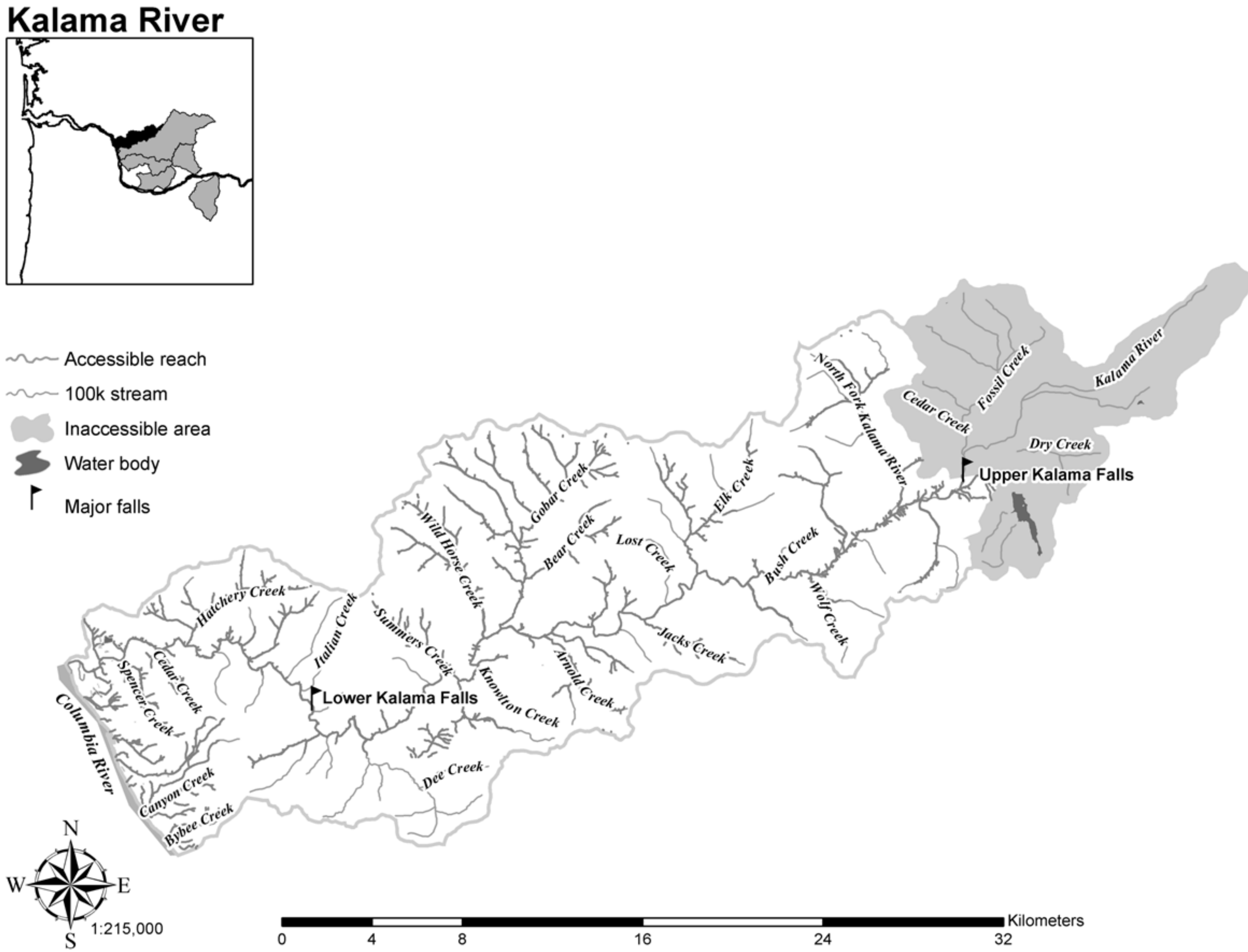


Figure E-43. Historical accessibility of summer steelhead to the Kalama River.

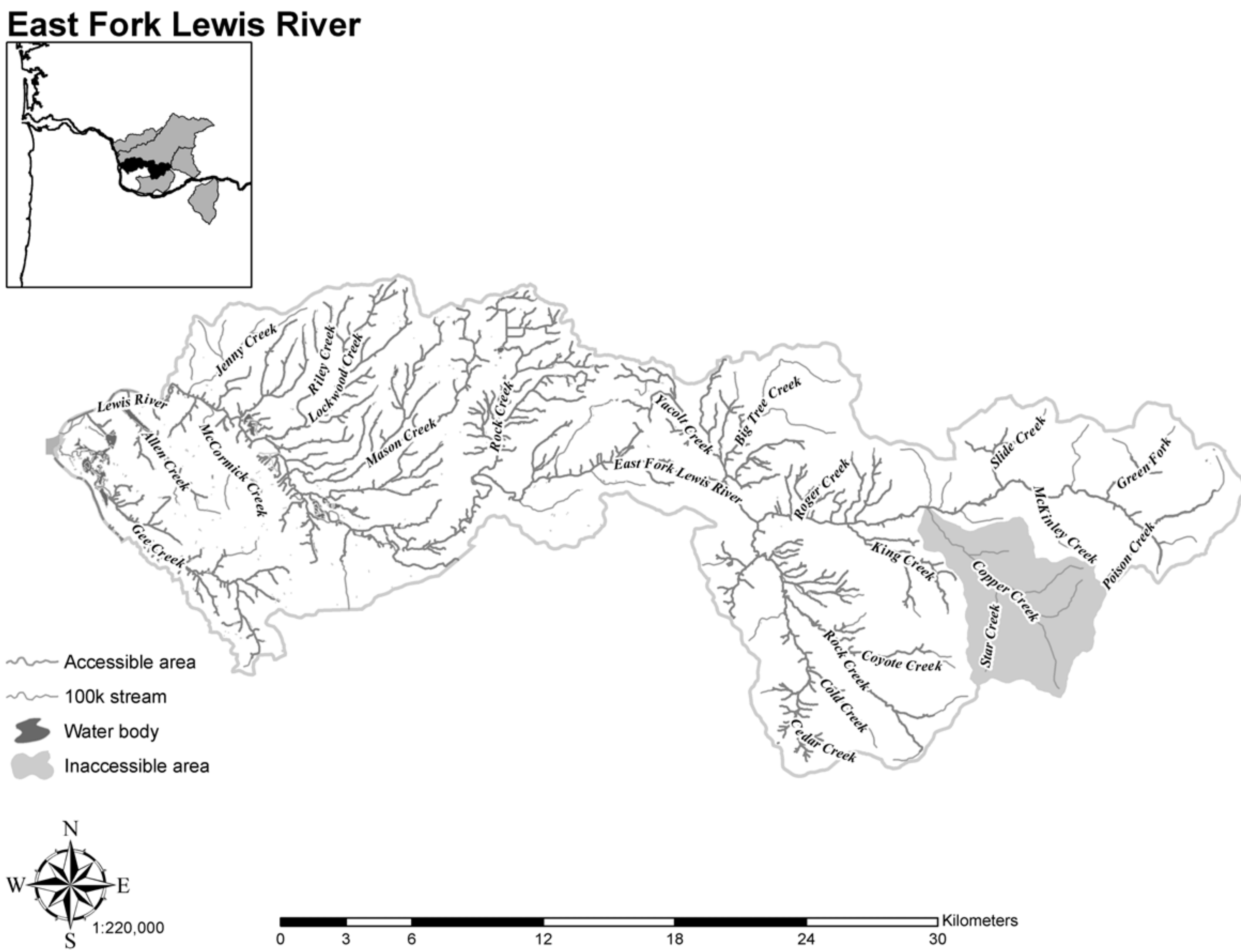


Figure E-44. Historical accessibility of summer steelhead to the East Fork Lewis River.

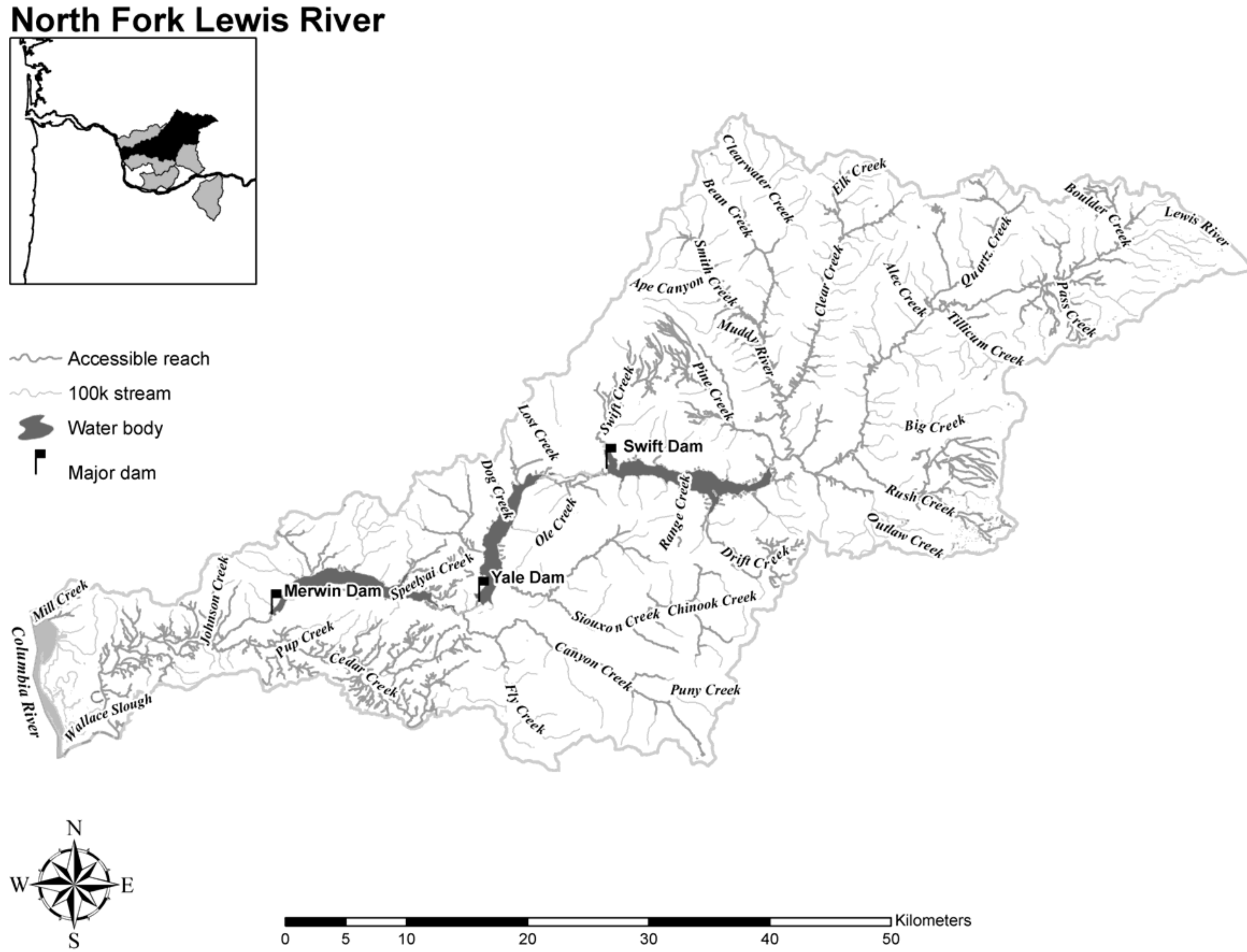


Figure E-45. Historical accessibility of summer steelhead to the North Fork Lewis River.

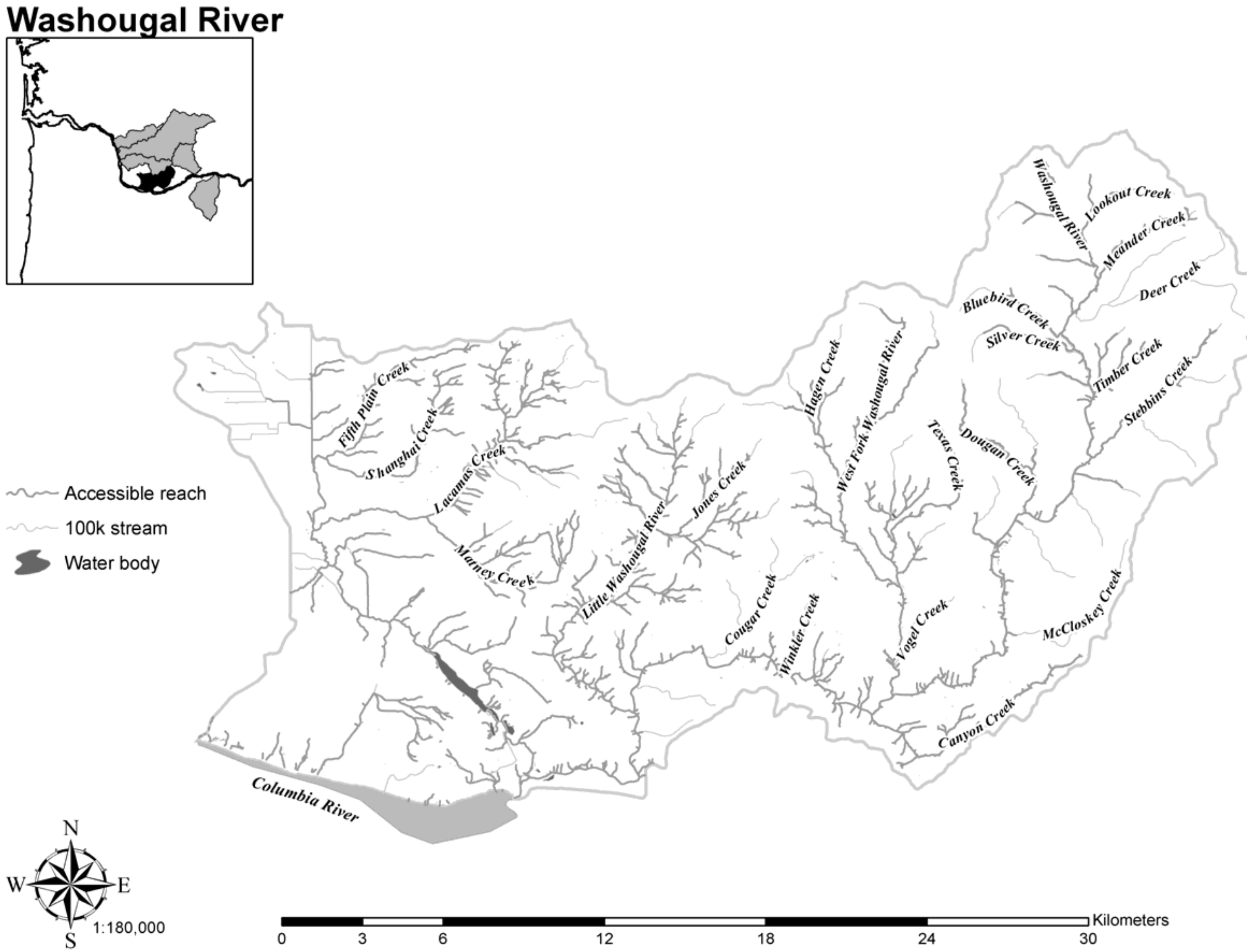


Figure E-46. Historical accessibility of summer steelhead to the Washougal River.

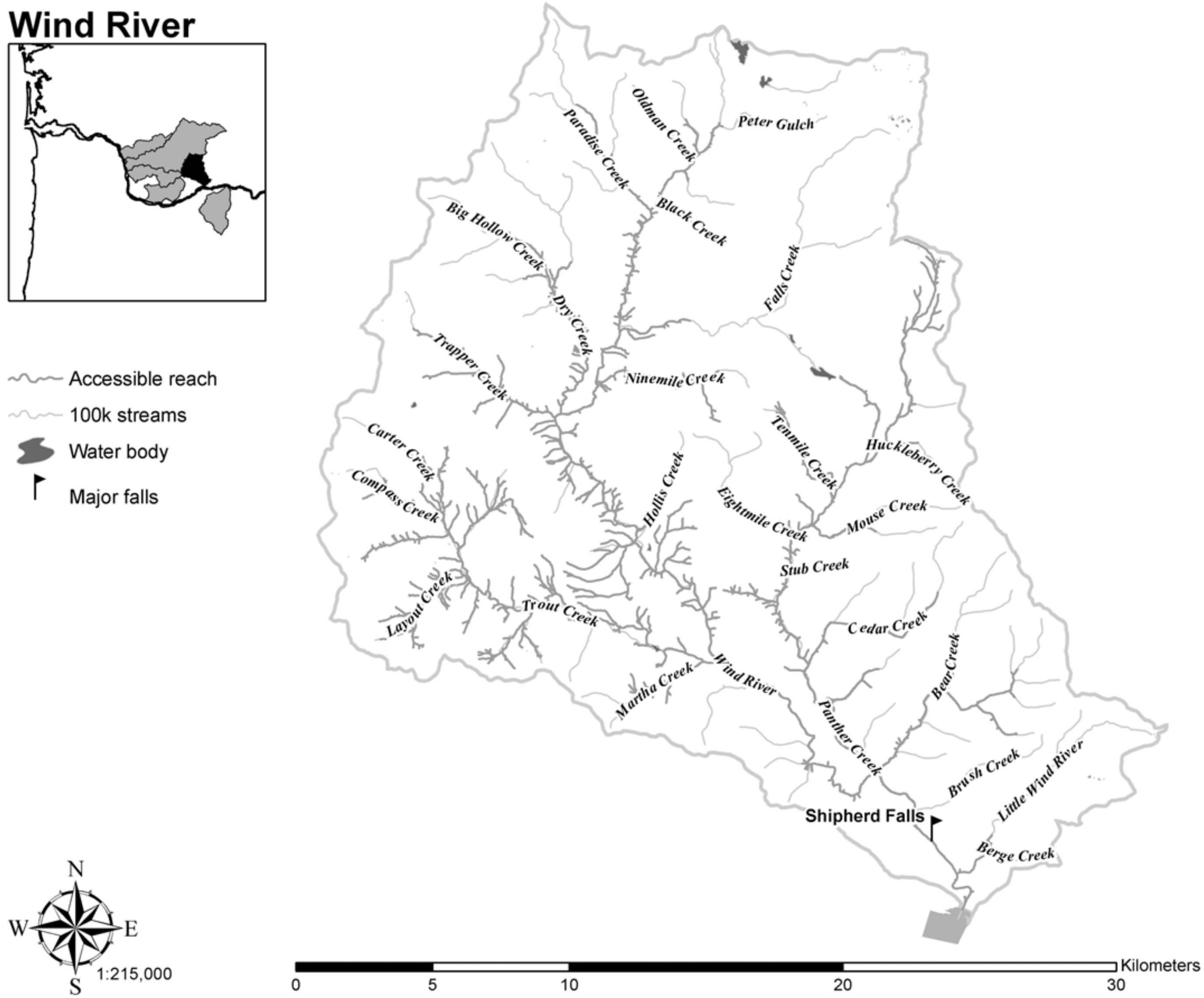


Figure E-47. Historical accessibility of summer steelhead to the Wind River.

Lower Columbia River Winter Steelhead Historical Accessibility

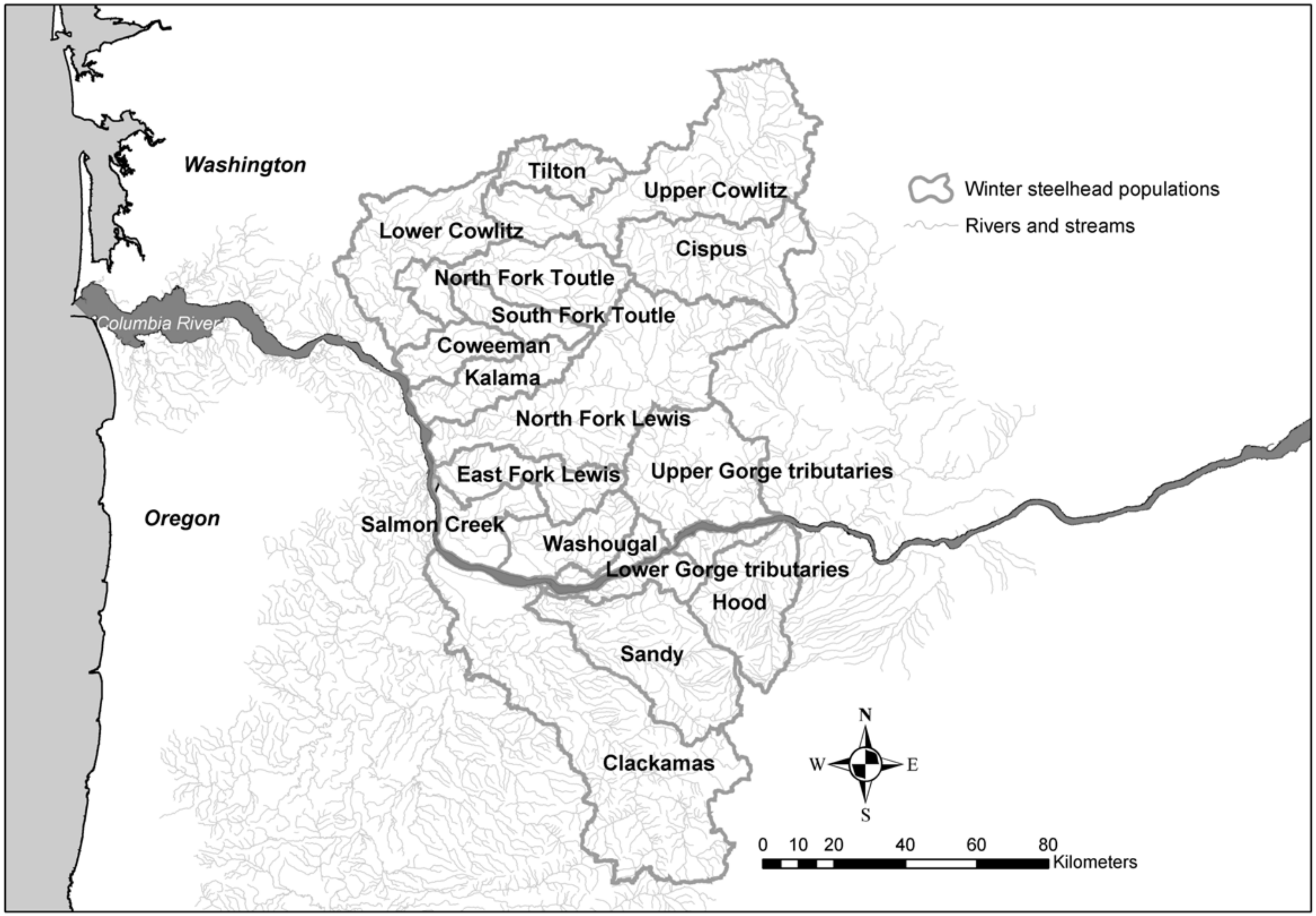


Figure E-48. Lower Columbia River winter steelhead population areas.

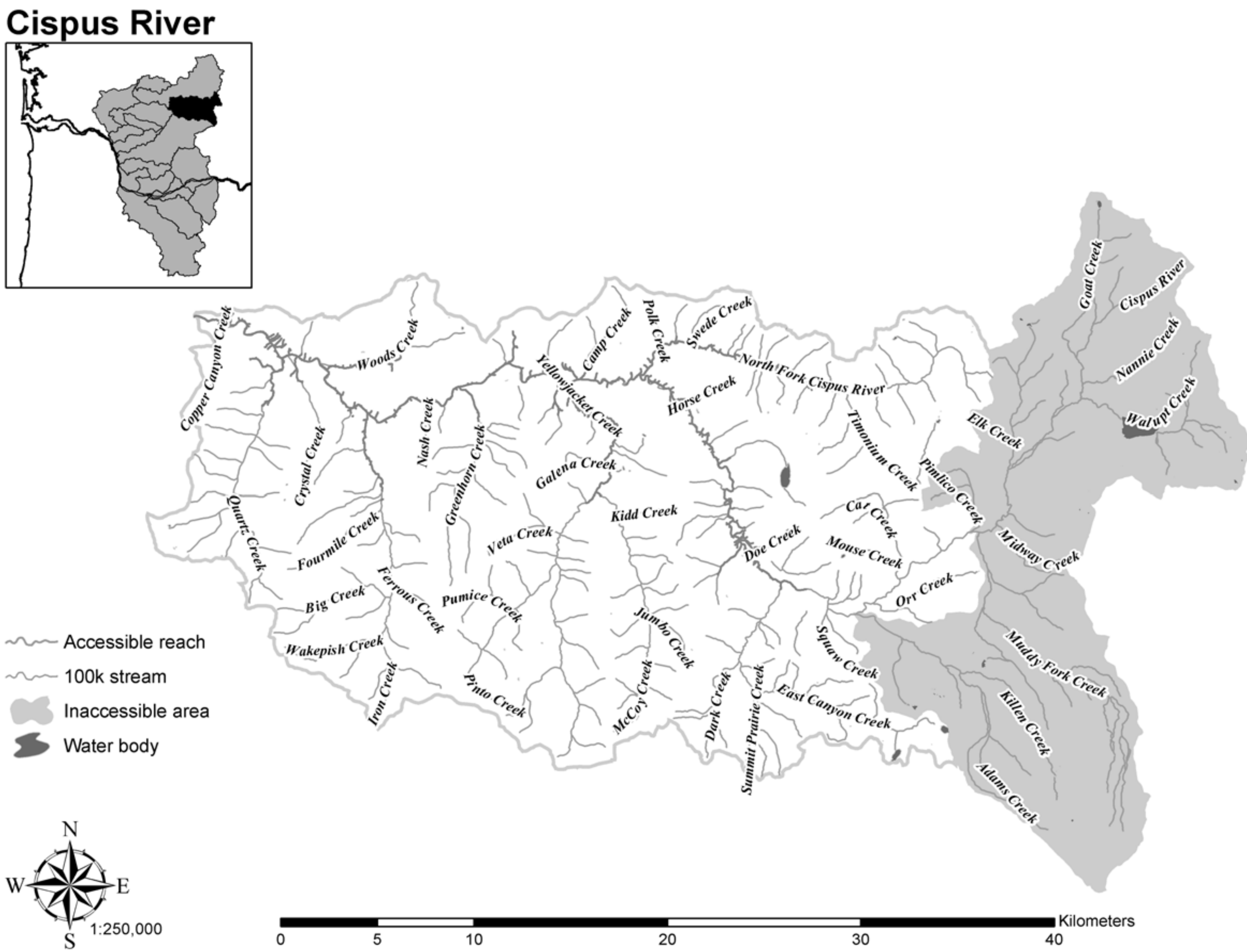


Figure E-49. Historical accessibility of winter steelhead to the Cispus River.

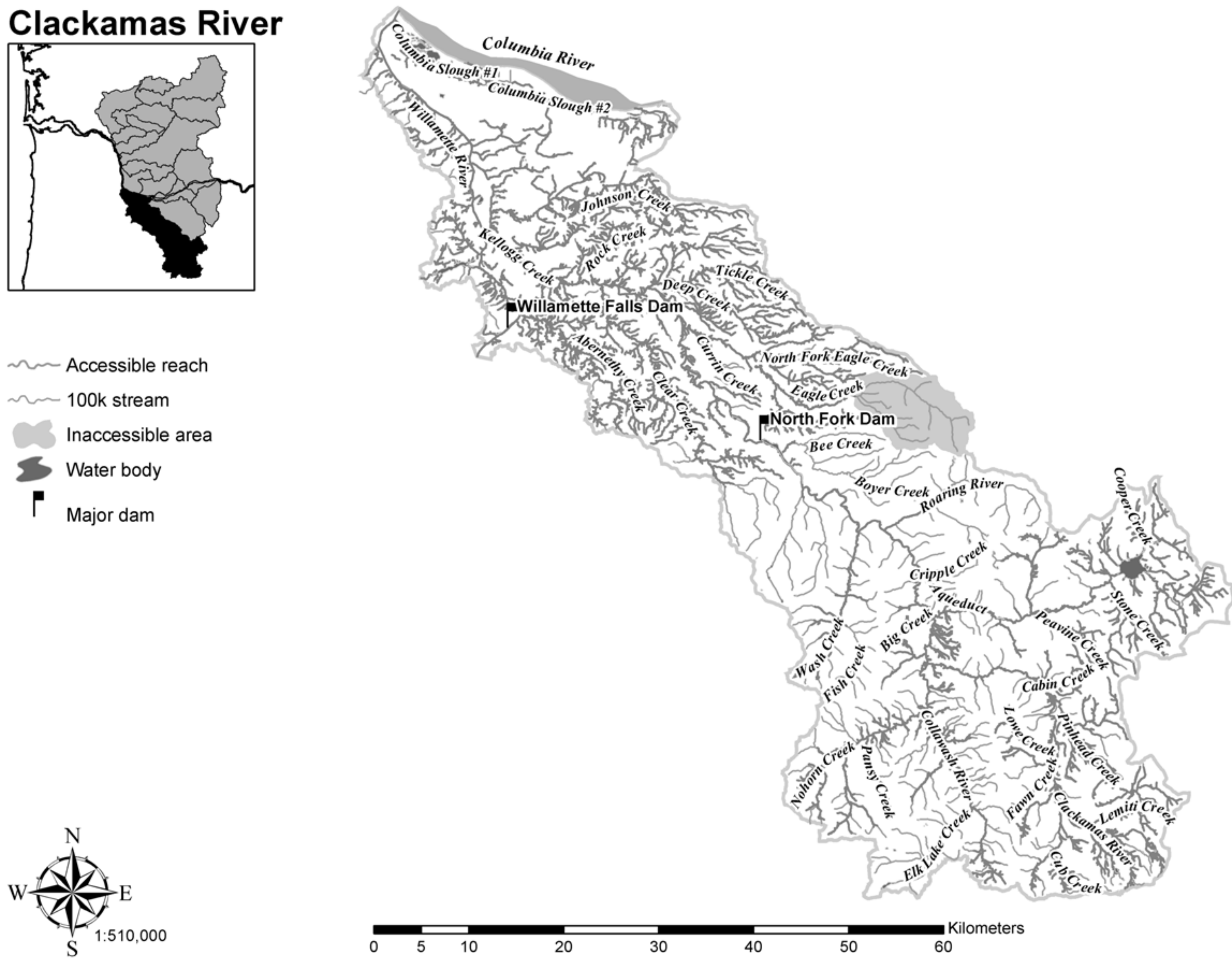


Figure E-50. Historical accessibility of winter steelhead to the Clackamas River.

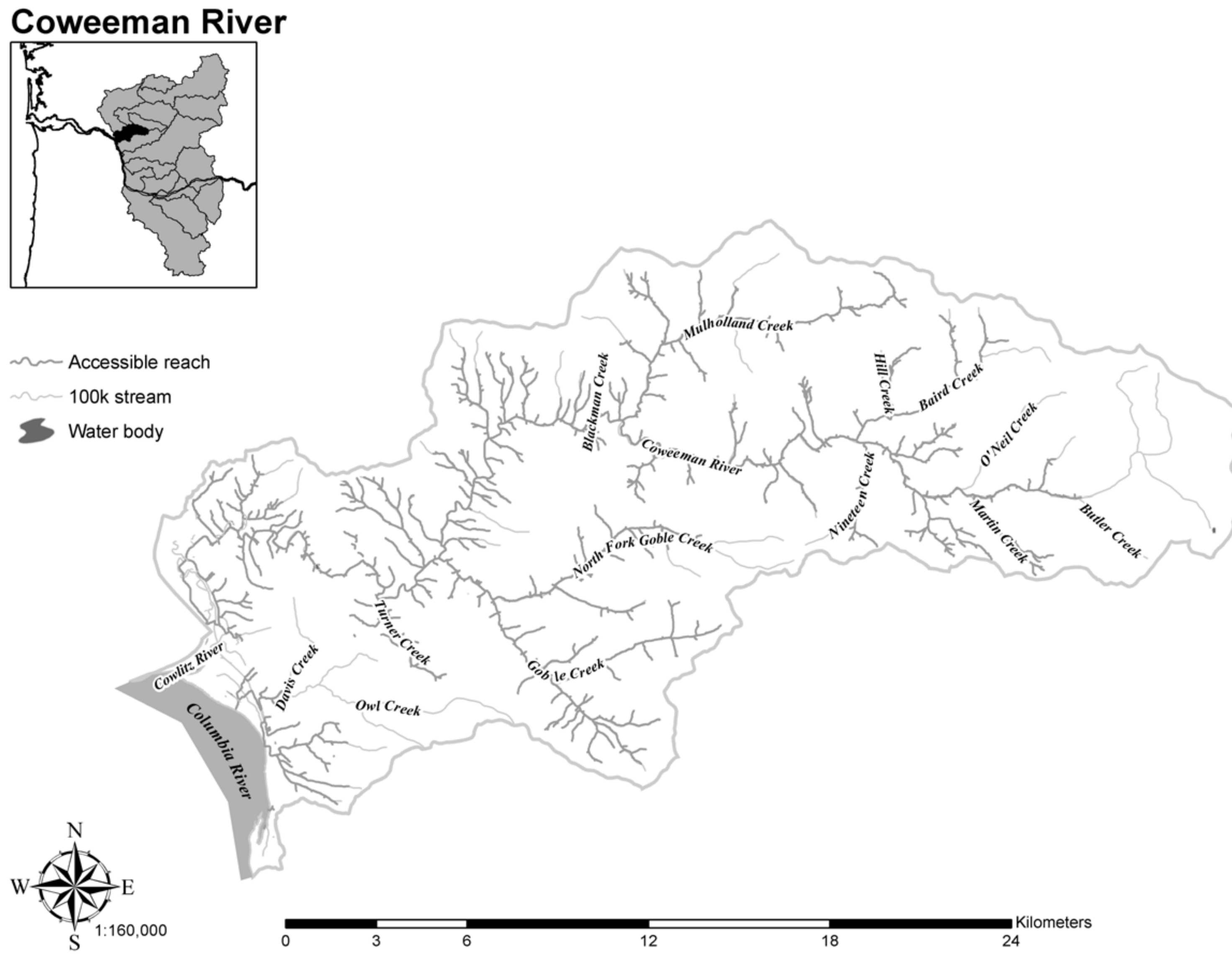


Figure E-51. Historical accessibility of winter steelhead to the Coweeman River.

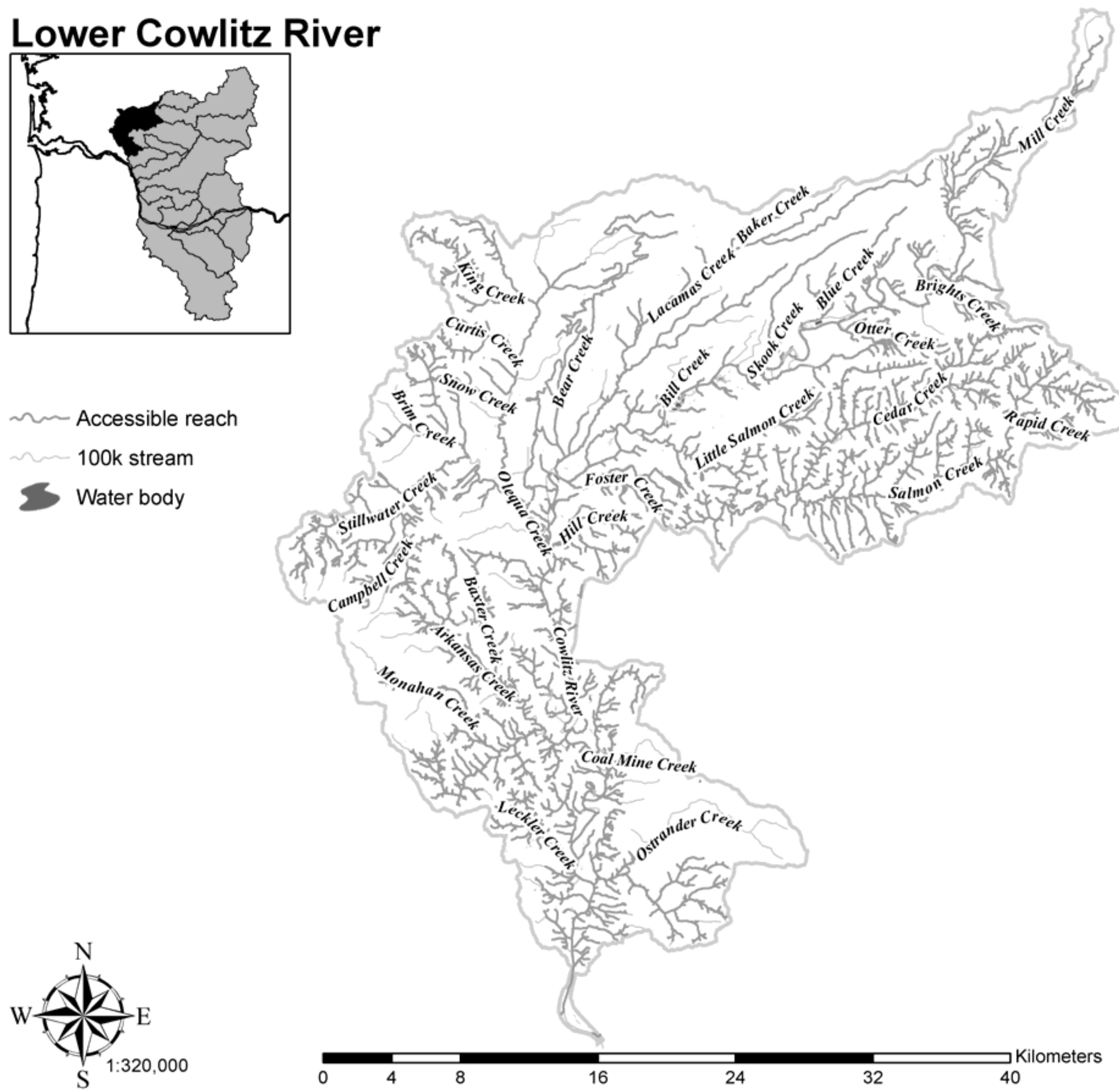


Figure E-52. Historical accessibility of winter steelhead to the lower Cowlitz River.

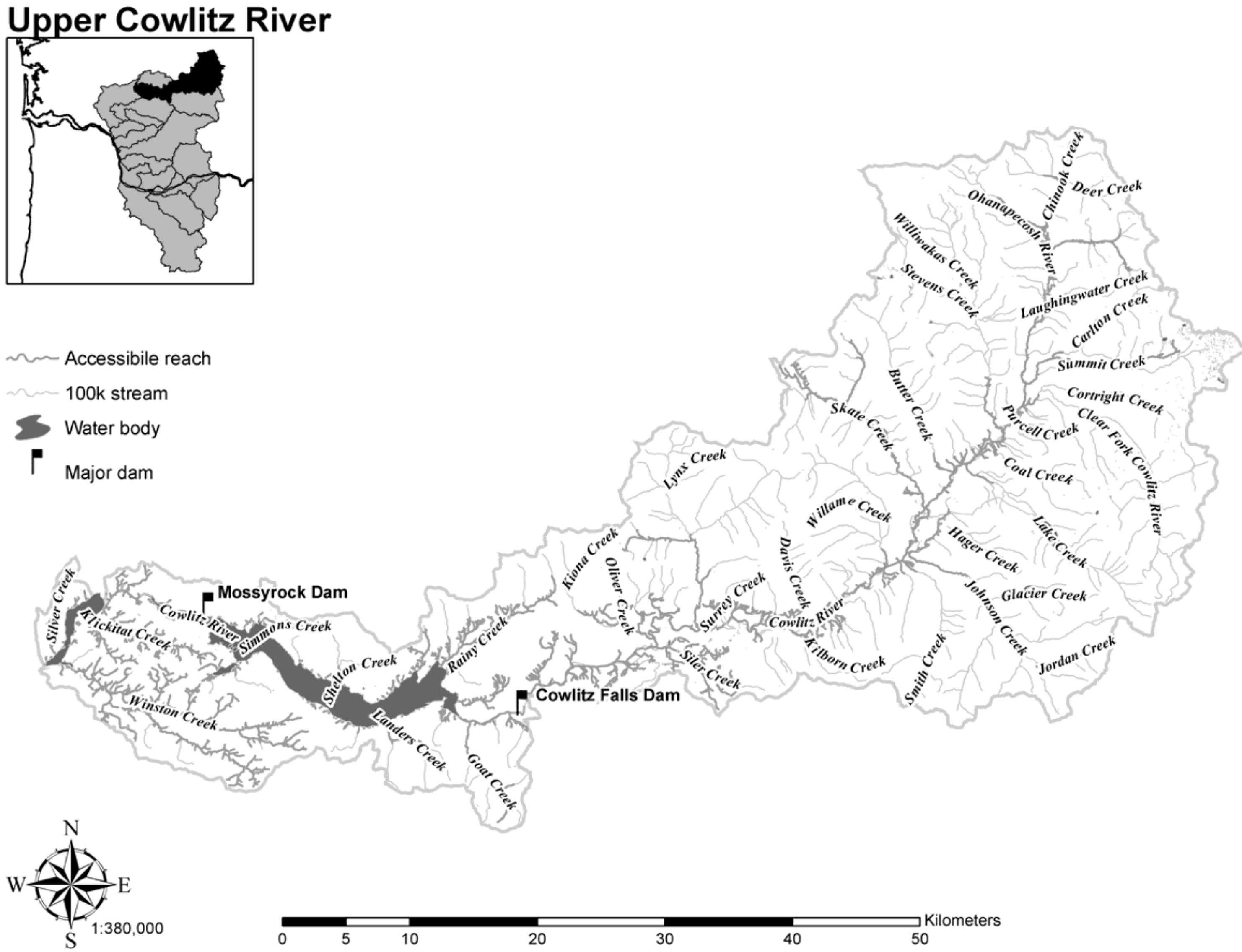


Figure E-53. Historical accessibility of winter steelhead to the upper Cowlitz River.

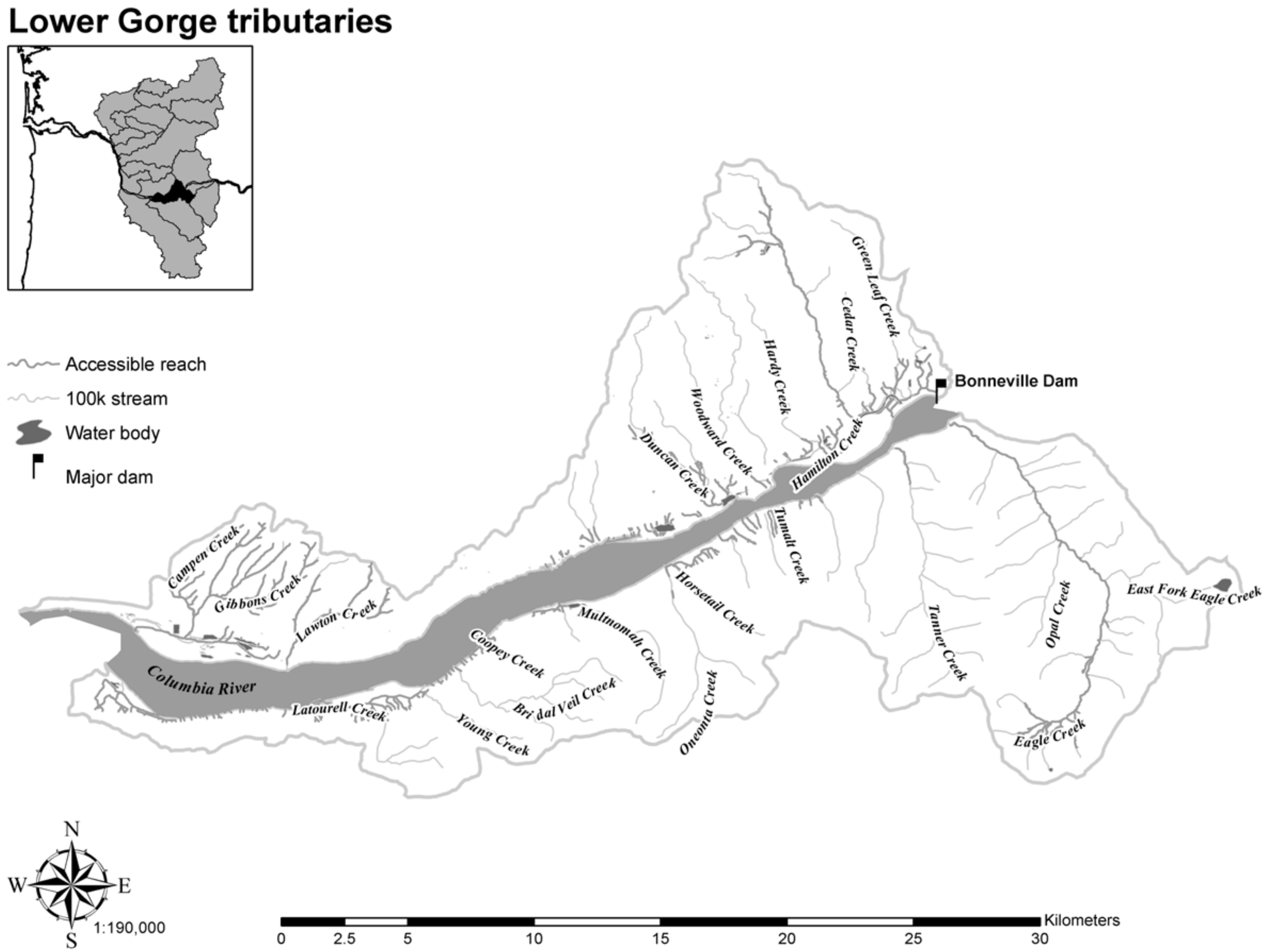


Figure E-54. Historical accessibility of winter steelhead to the Columbia River lower Gorge tributaries.

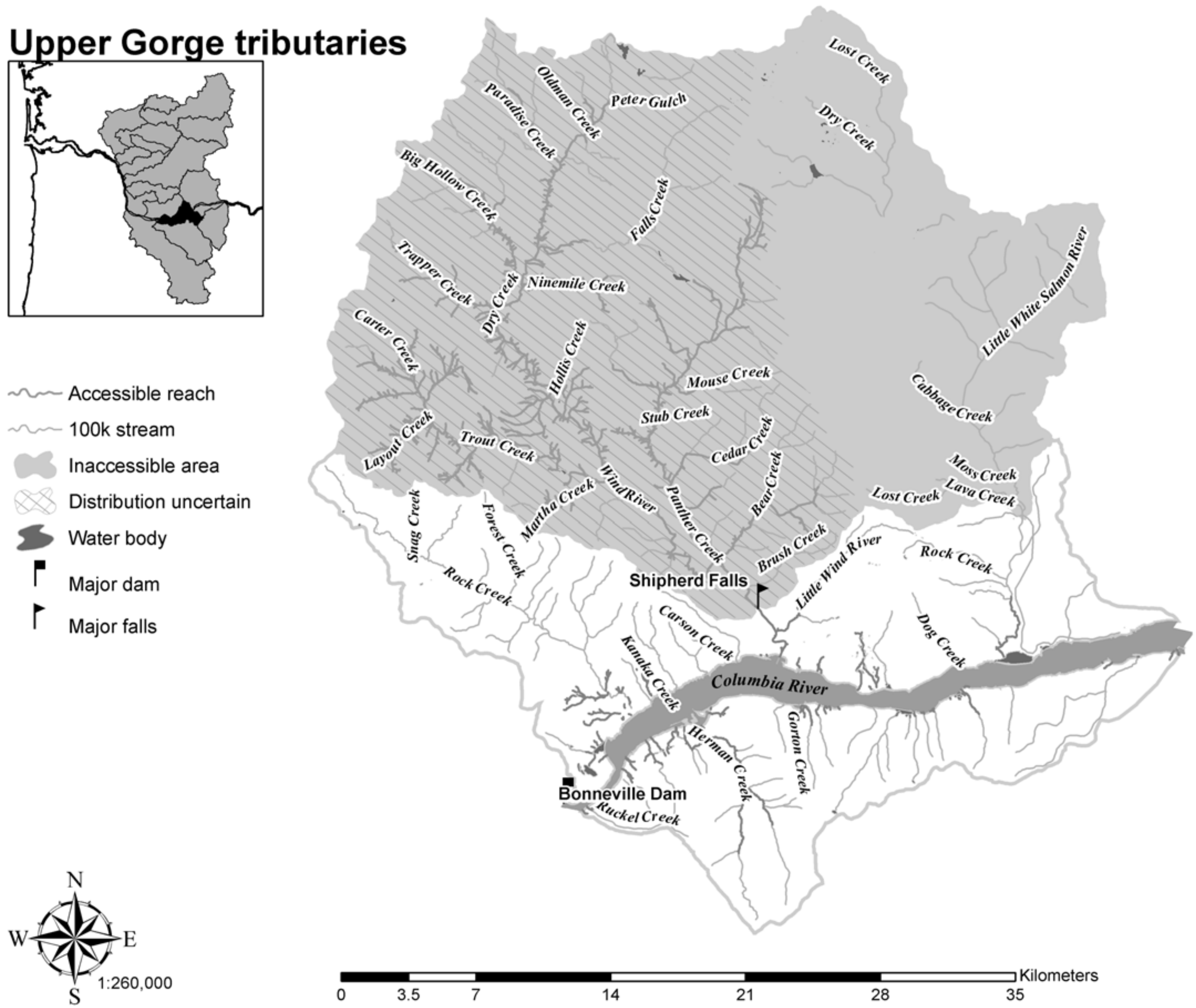


Figure E-55. Historical accessibility of winter steelhead to the Columbia River upper Gorge tributaries.

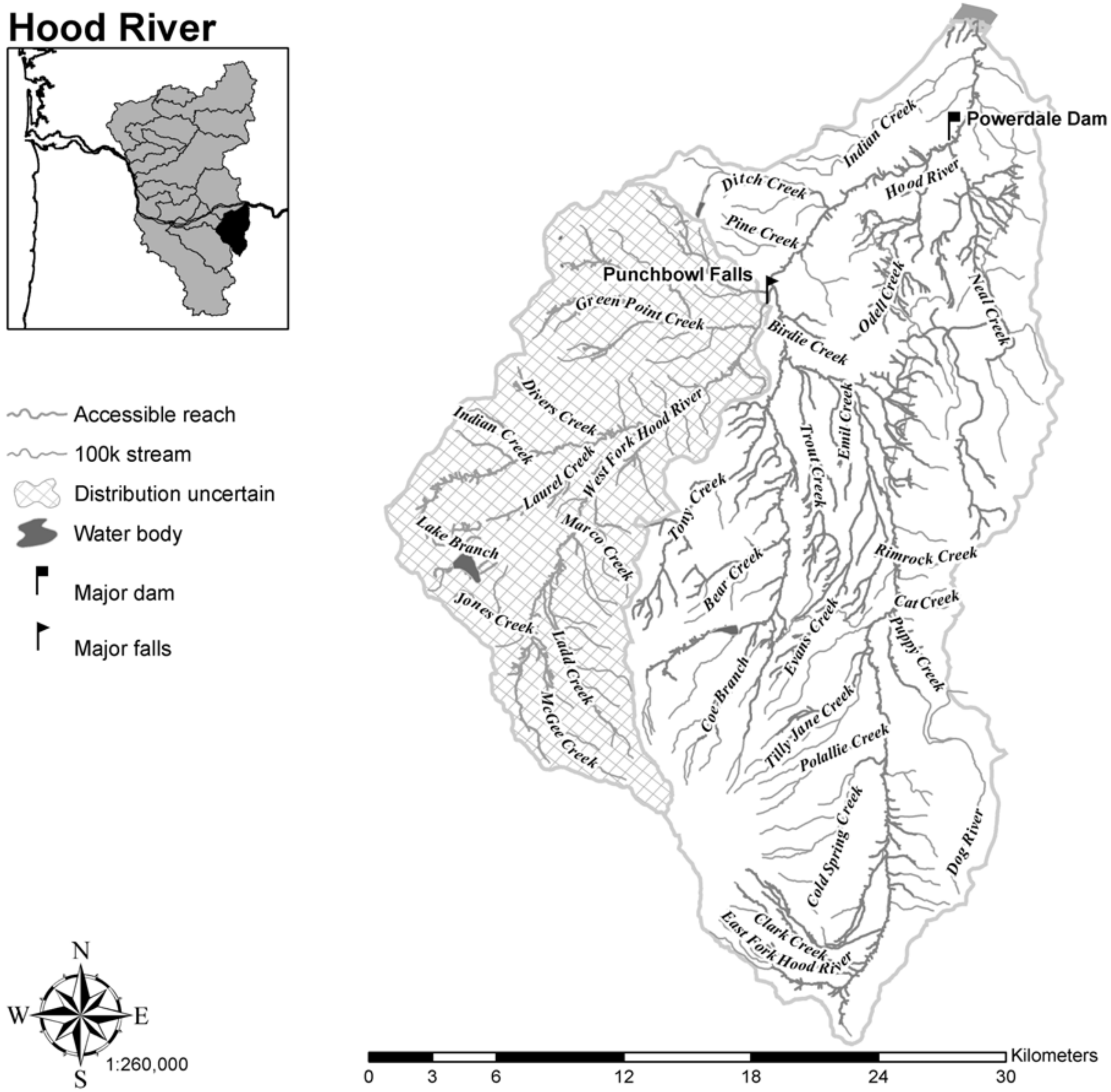


Figure E-56. Historical accessibility of winter steelhead to the Hood River.

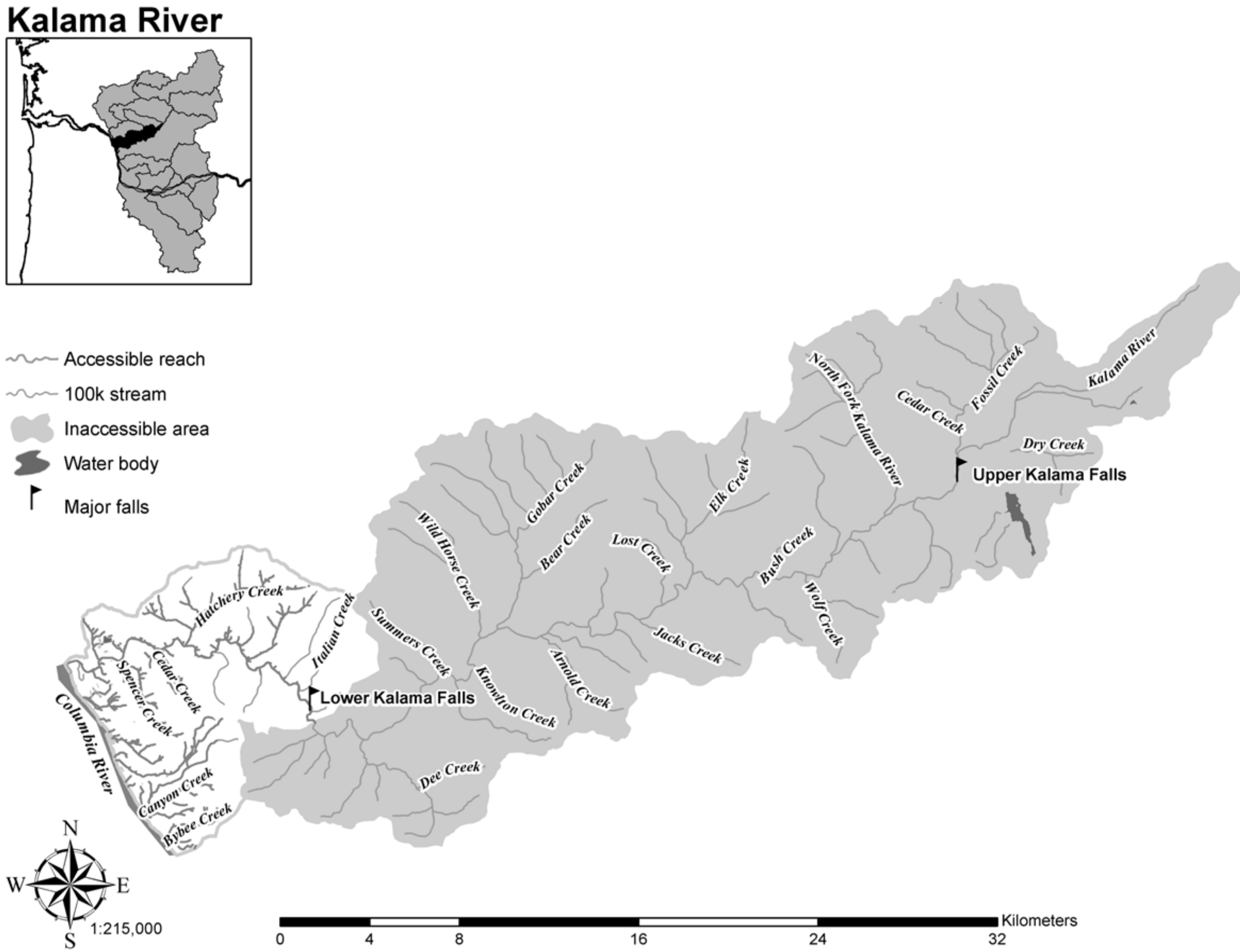


Figure E-57. Historical accessibility of winter steelhead to the Kalama River.

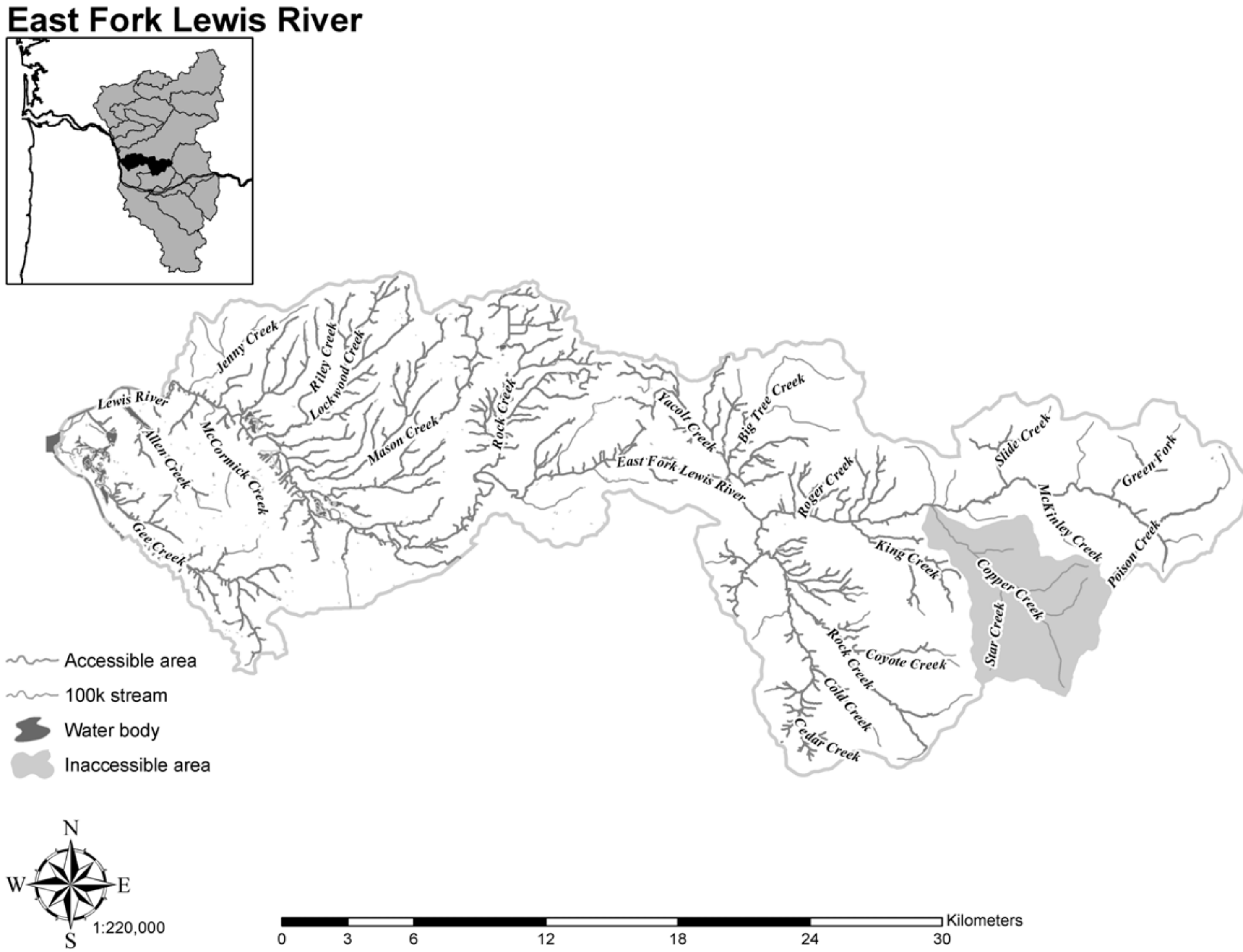


Figure E-58. Historical accessibility of winter steelhead to the East Fork Lewis River.

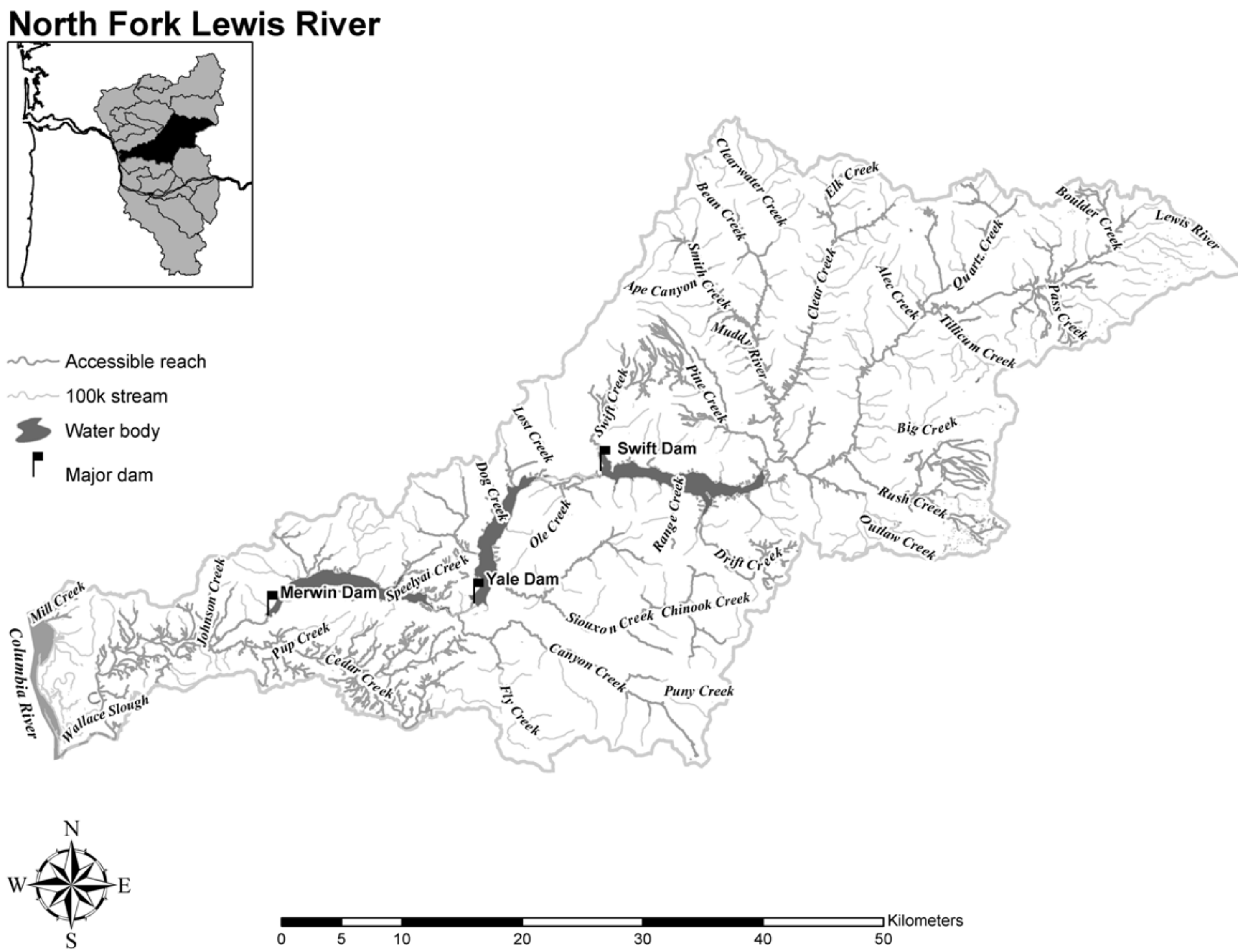


Figure E-59. Historical accessibility of winter steelhead to the North Fork Lewis River.

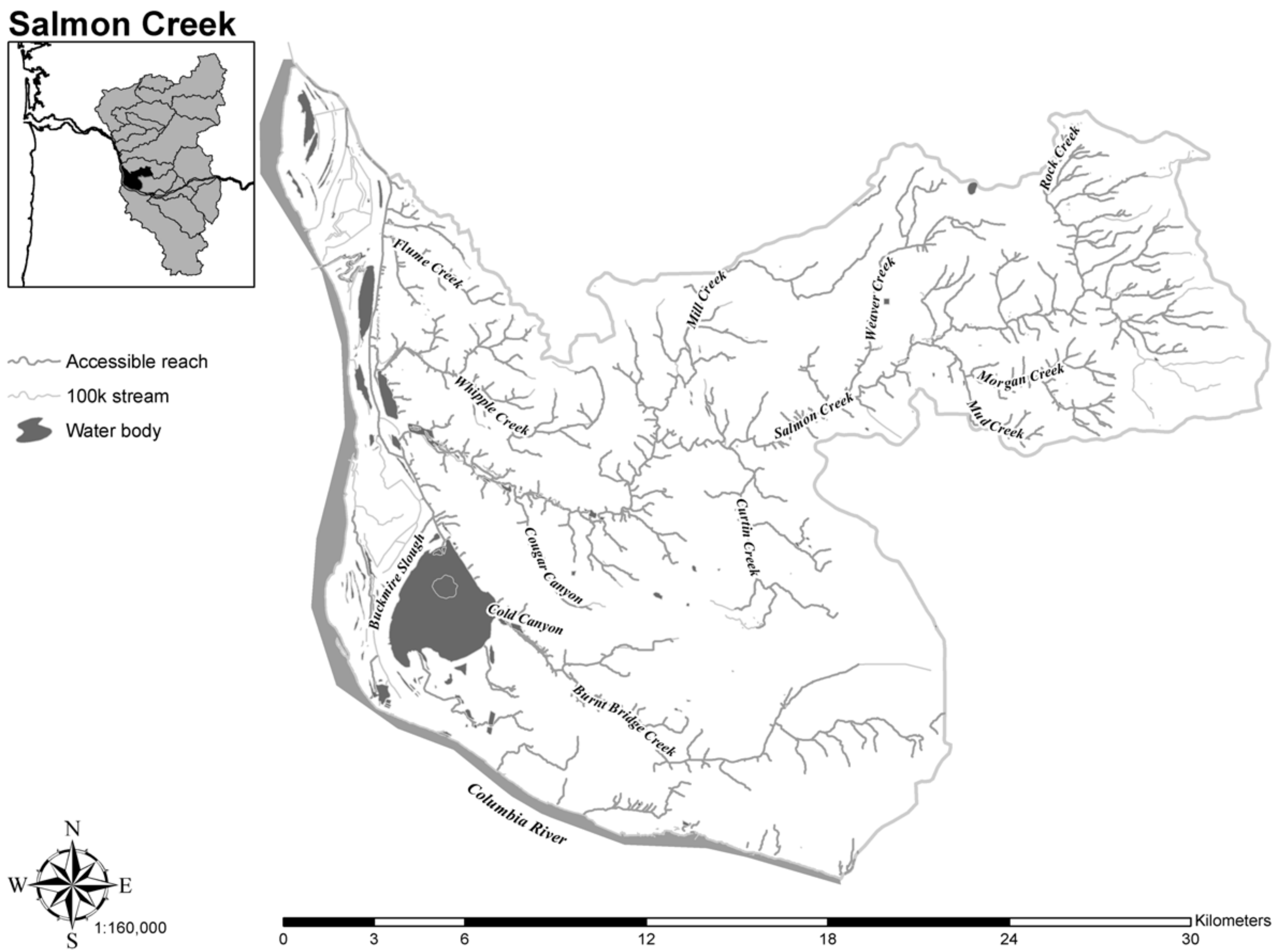


Figure E-60. Historical accessibility of winter steelhead to Salmon Creek.

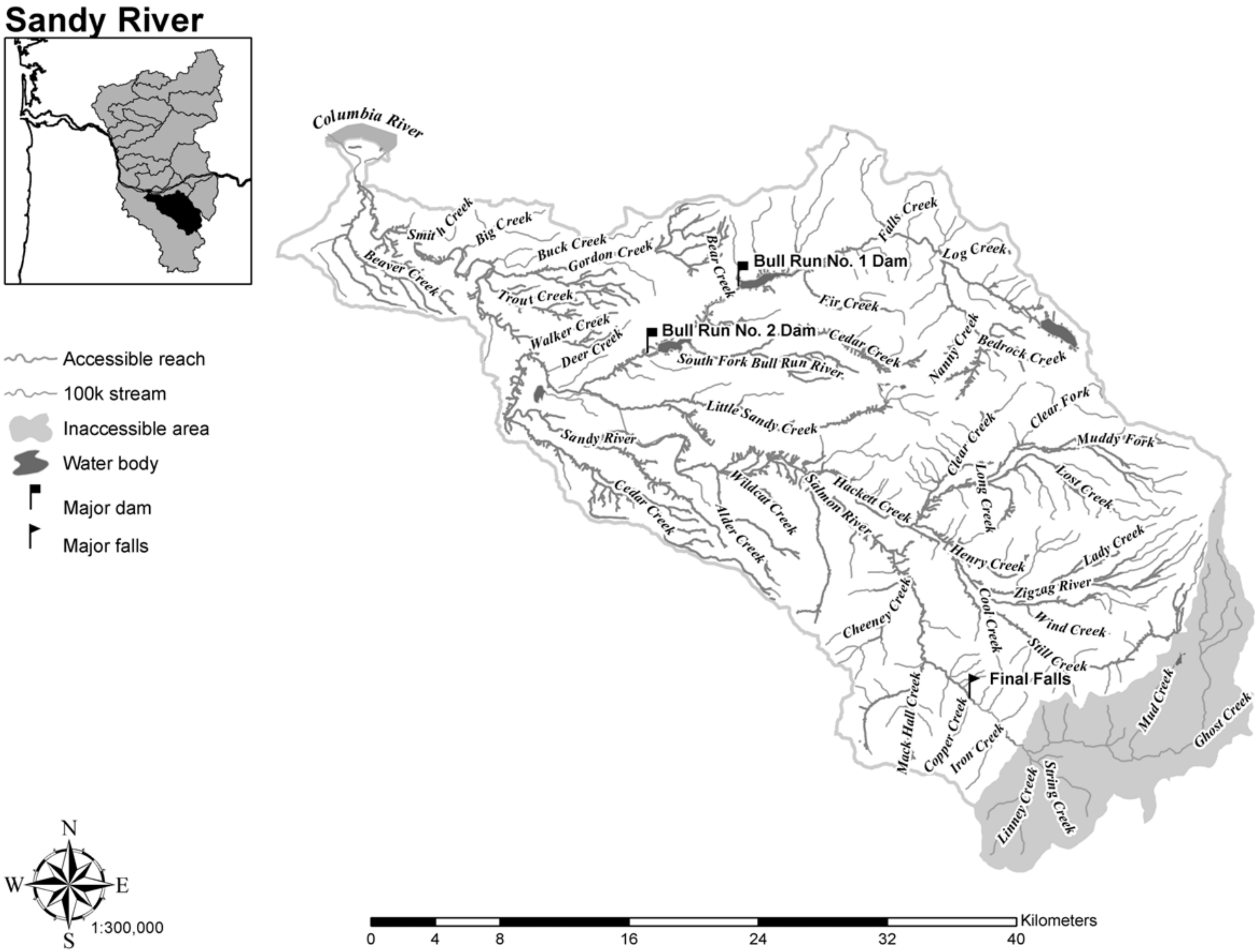


Figure E-61. Historical accessibility of winter steelhead to the Sandy River.

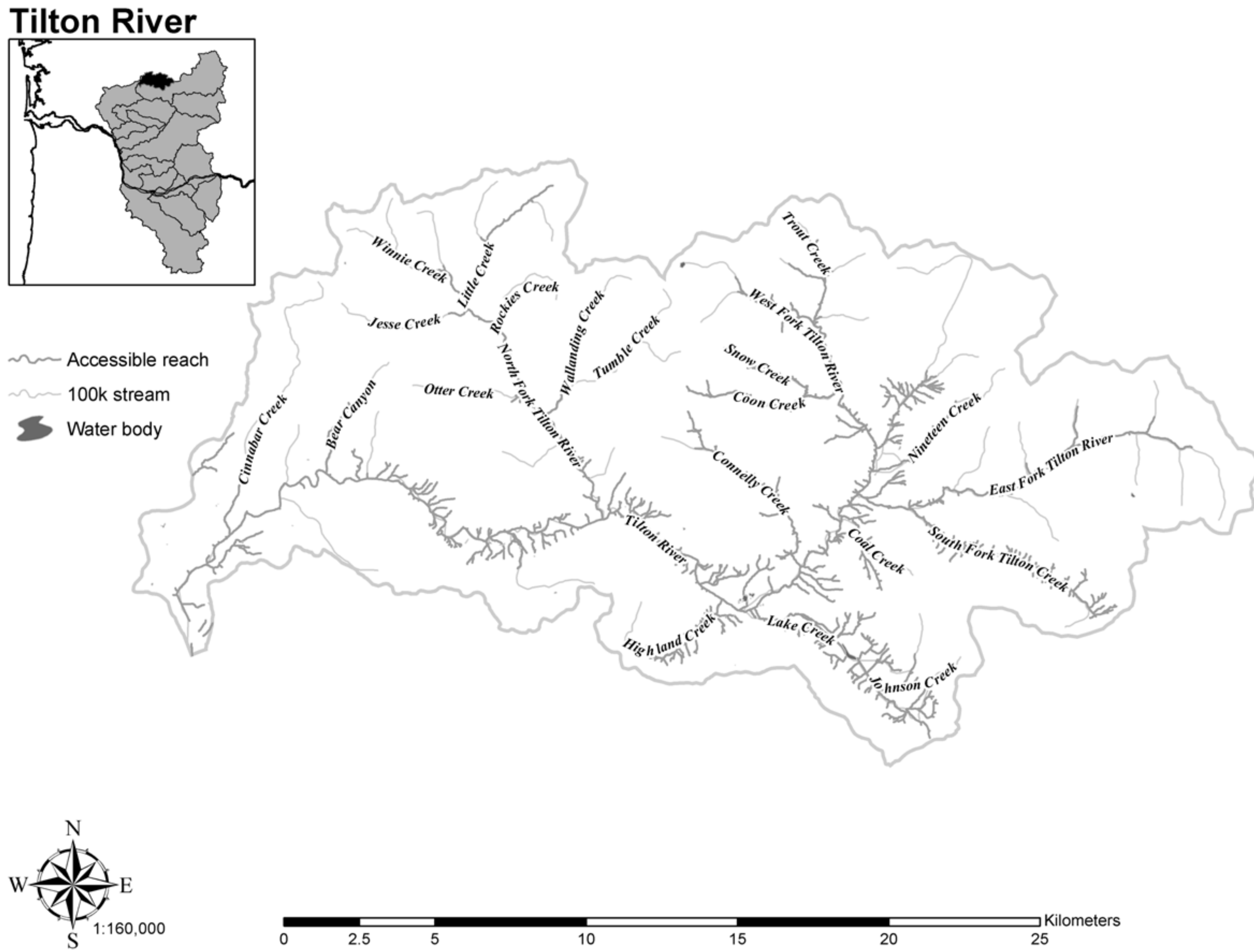


Figure E-62. Historical accessibility of winter steelhead to the Tilton River.

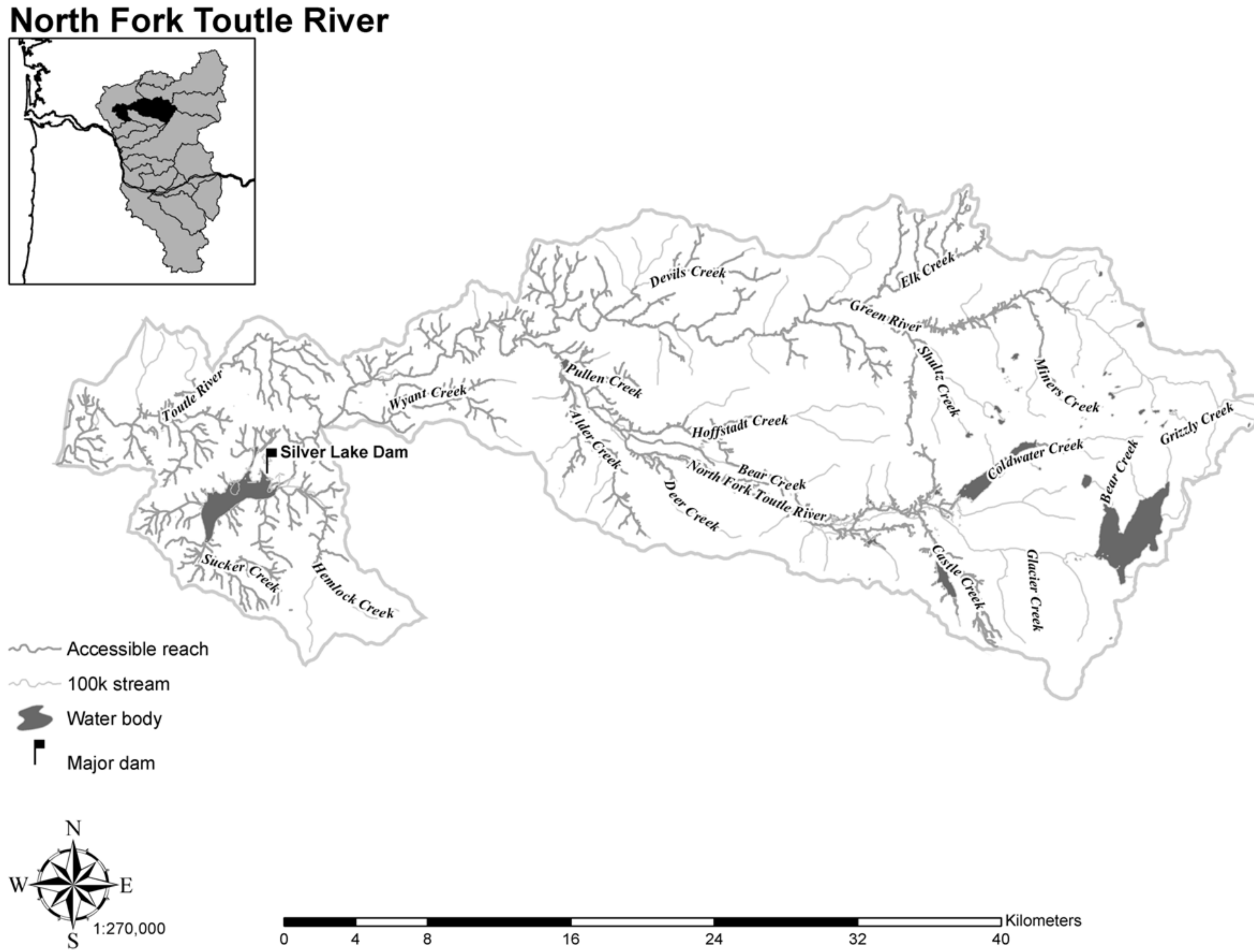


Figure E-63. Historical accessibility of winter steelhead to the North Fork Toutle River.

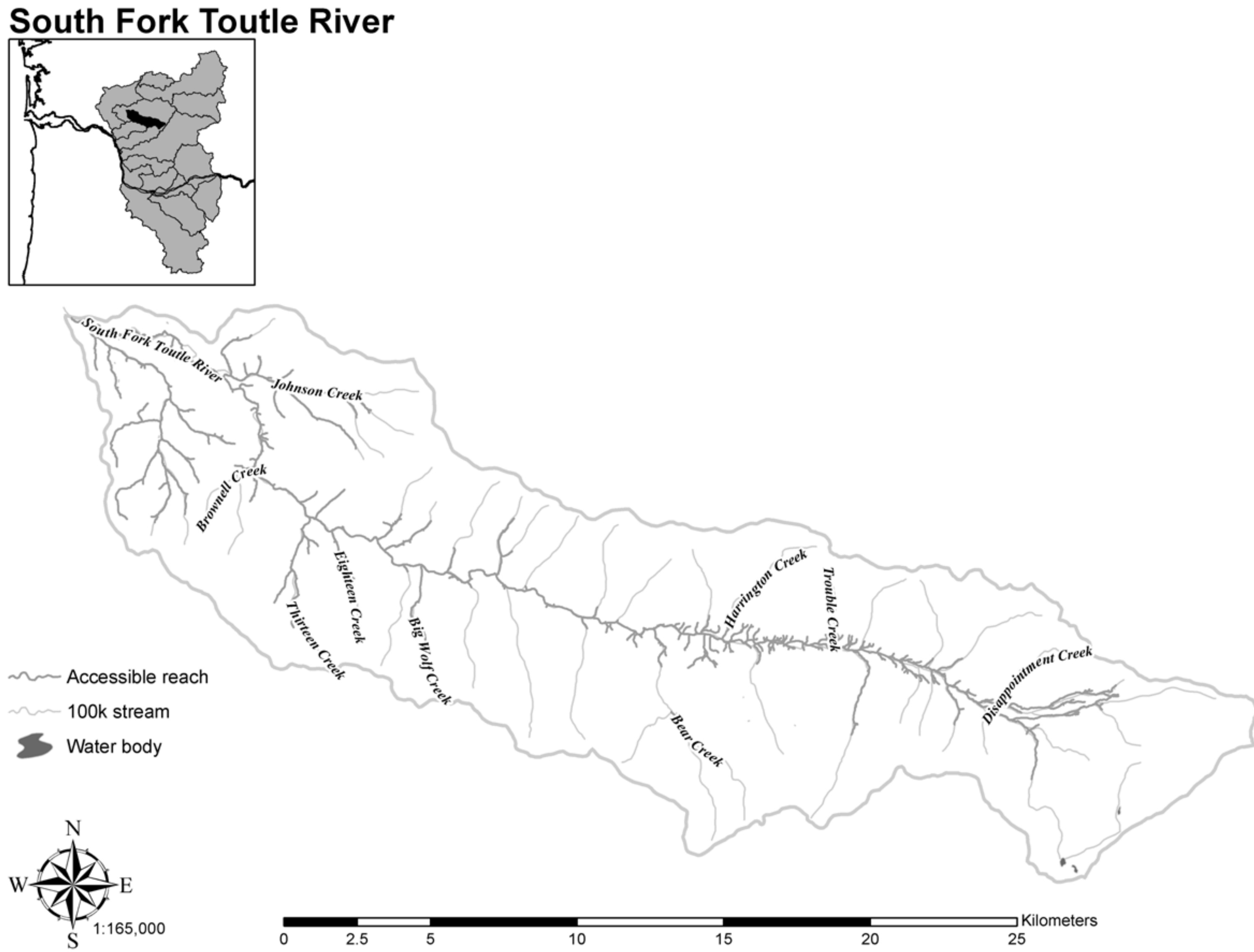


Figure E-64. Historical accessibility of winter steelhead to the South Fork Toutle River.

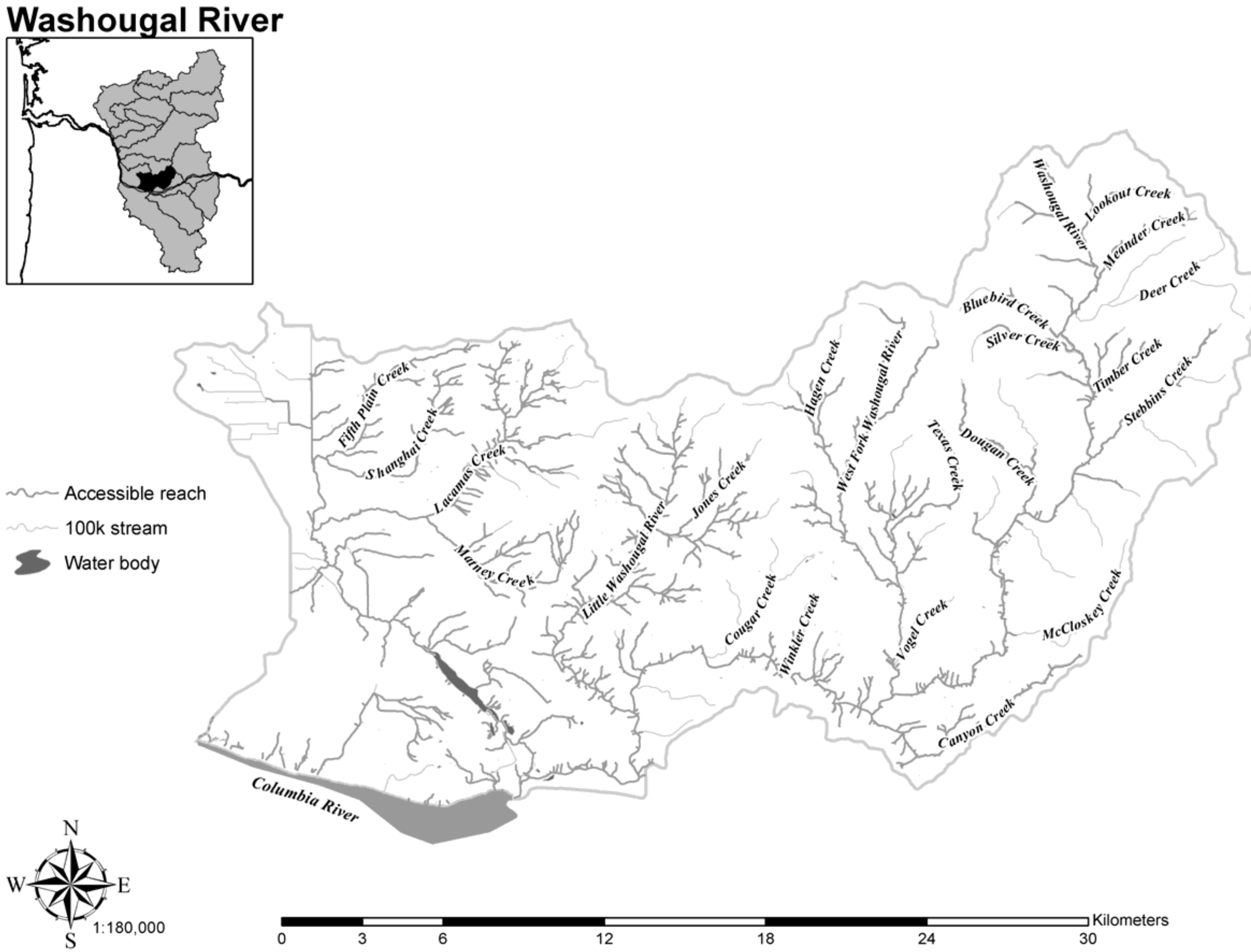


Figure E-65. Historical accessibility of winter steelhead to the Washougal River.

Upper Willamette River Winter Steelhead Historical Accessibility

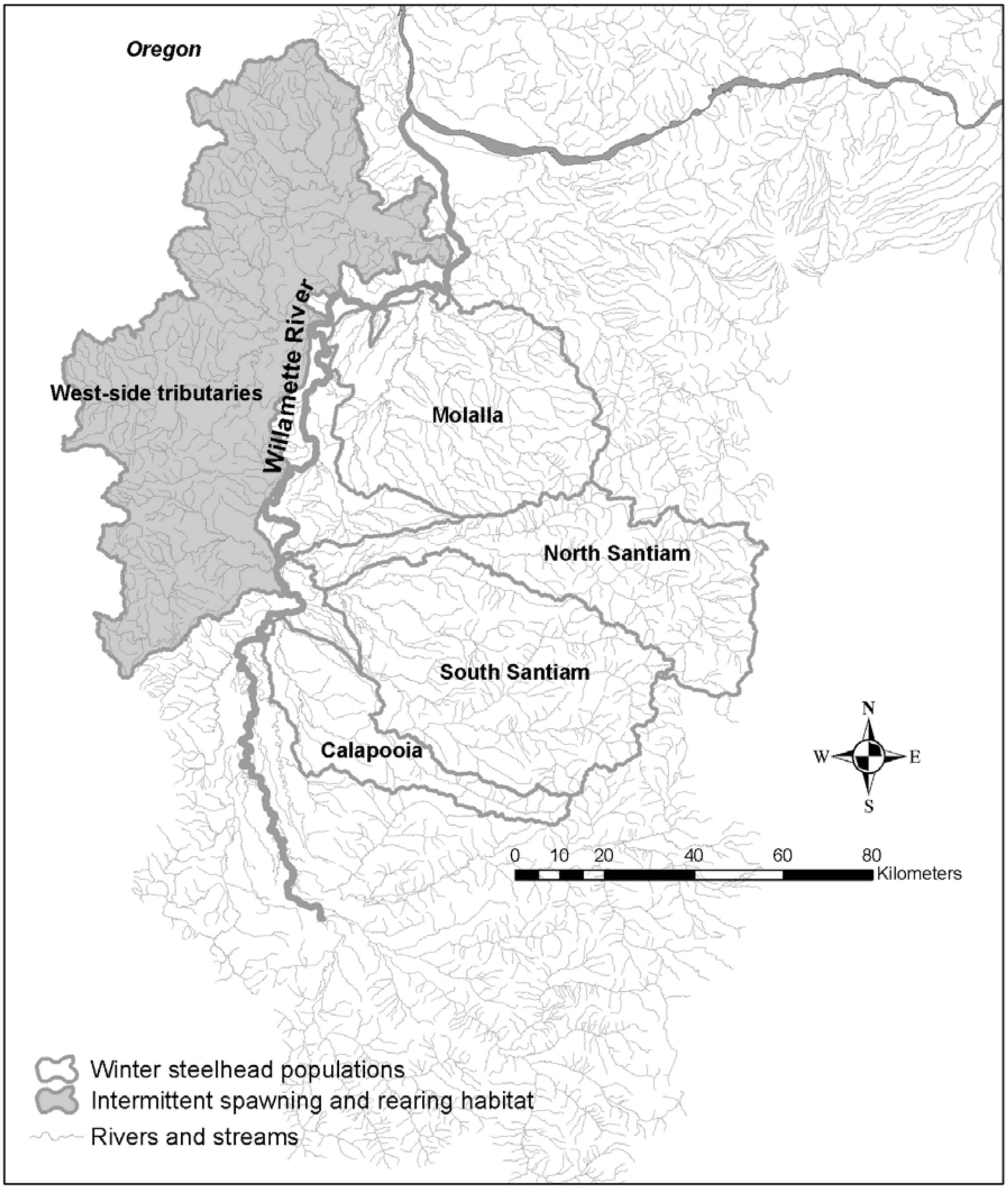


Figure E-66. Upper Willamette River winter steelhead population areas. The west-side tributaries were not designated as an independent population but are included because of their importance to the ESU as a whole.

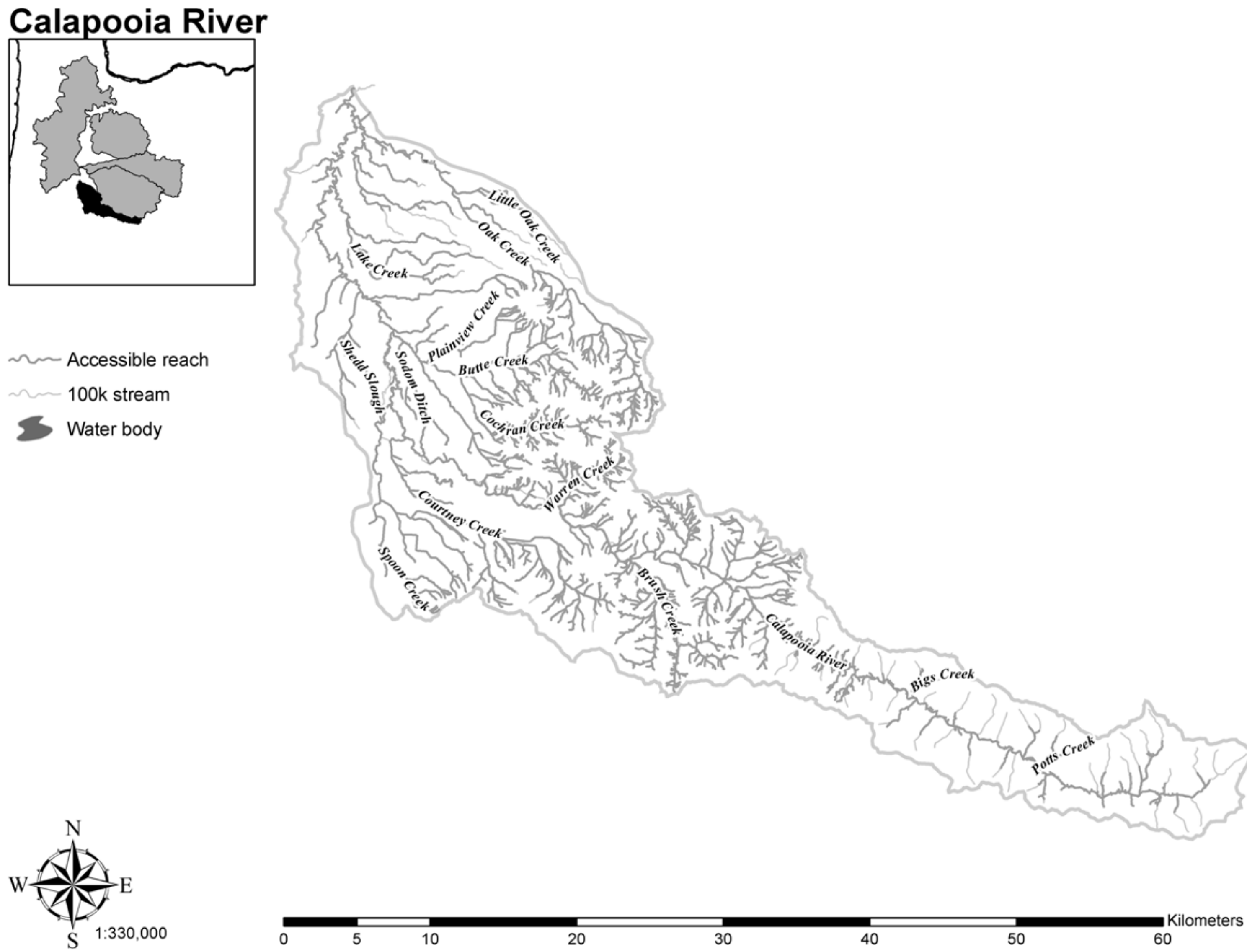


Figure E-67. Historical accessibility of winter steelhead to the Calapooia River.

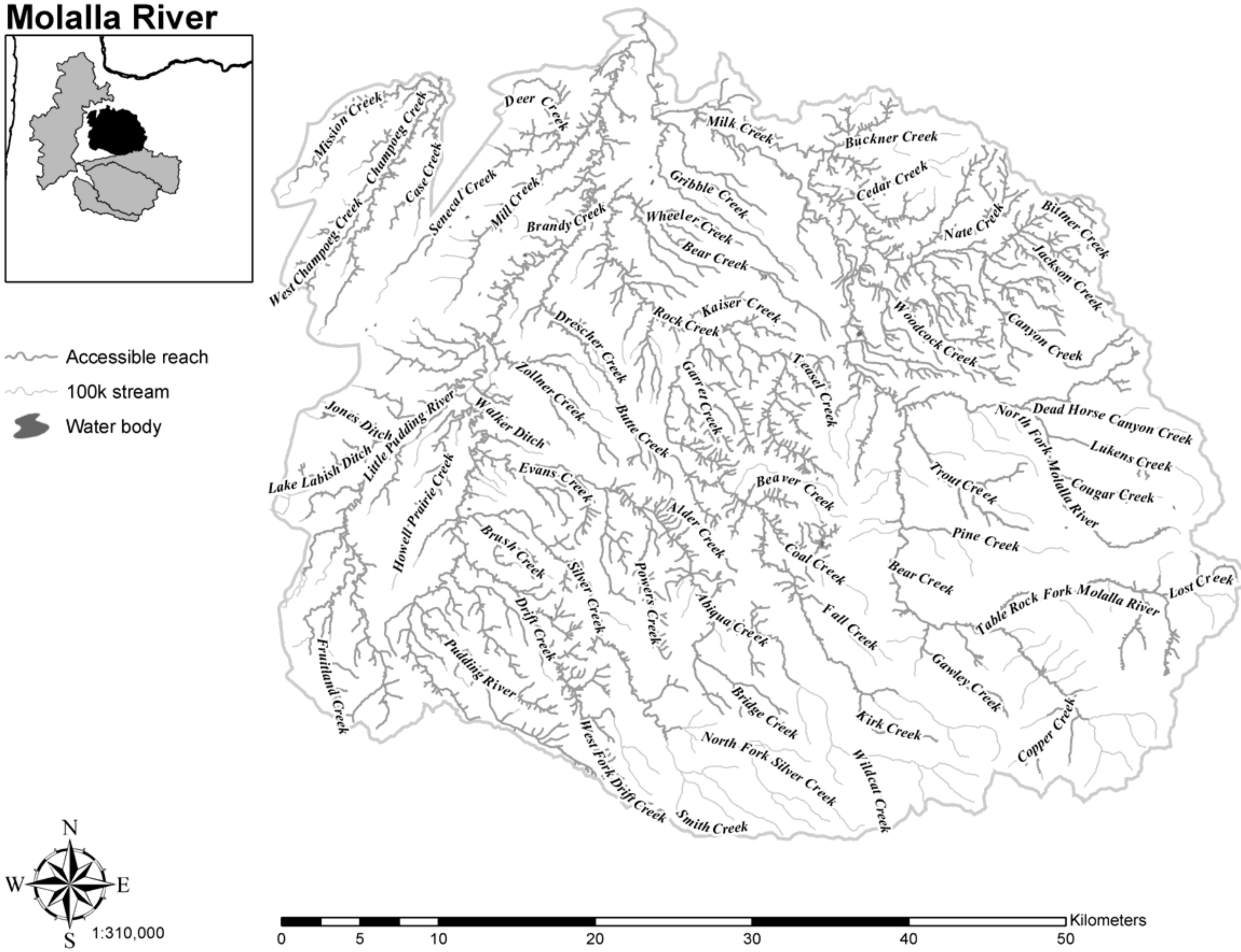


Figure E-68. Historical accessibility of winter steelhead to the Molalla River.

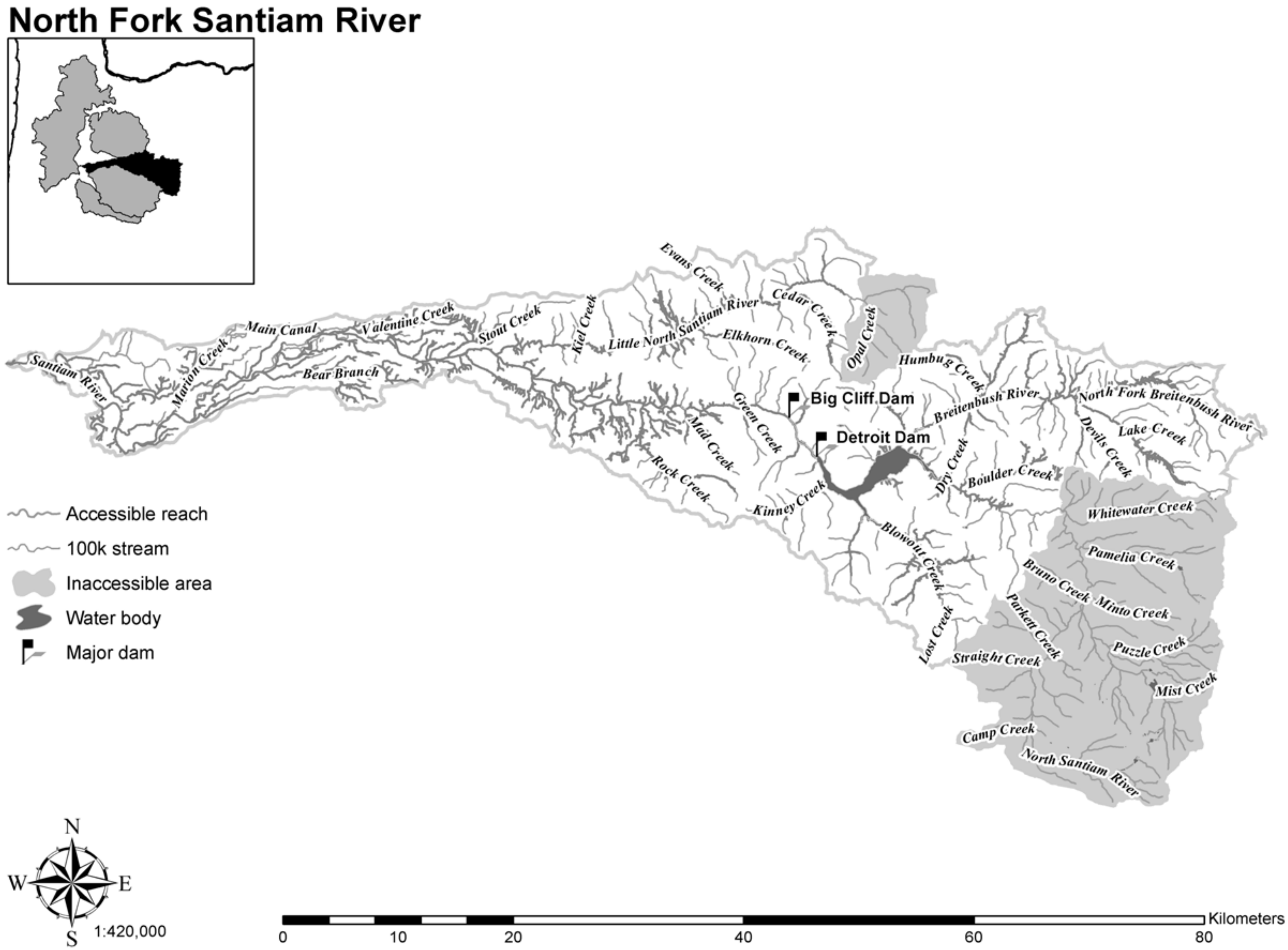


Figure E-69. Historical accessibility of winter steelhead to the North Fork Santiam River.

South Fork Santiam River

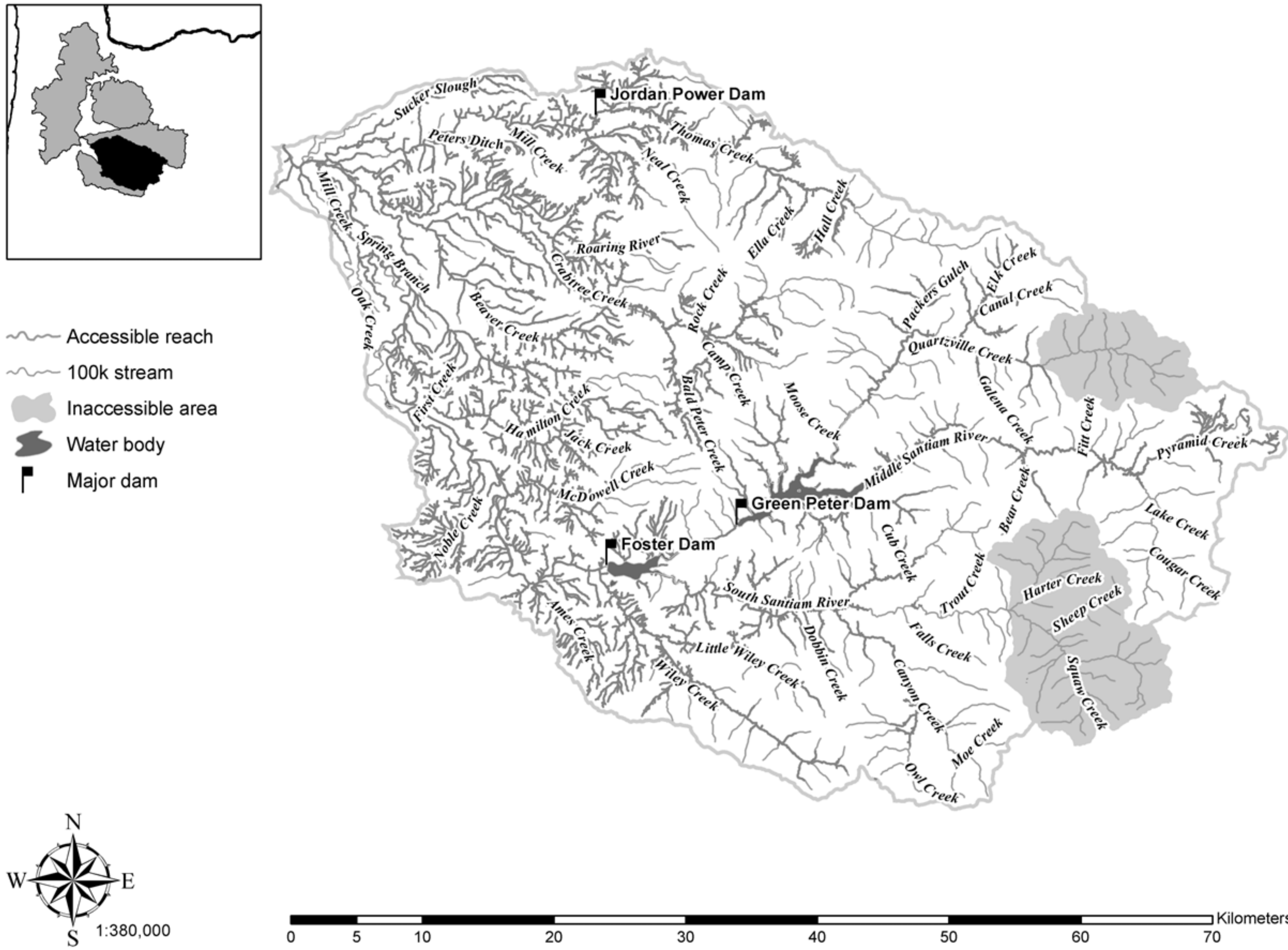


Figure E-70. Historical accessibility of winter steelhead to the South Fork Santiam River.

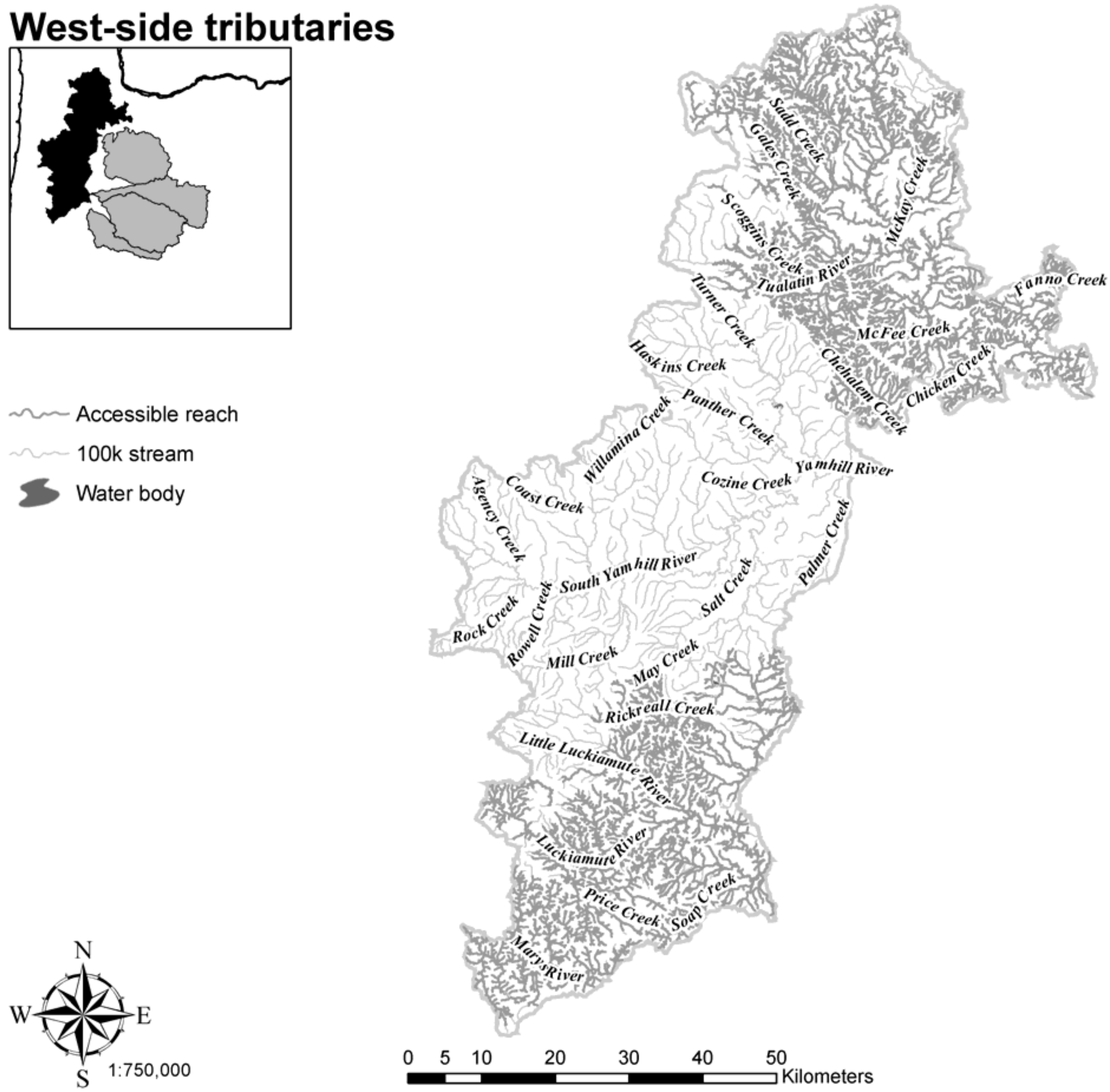


Figure E-71. Historical accessibility of winter steelhead to the west-side tributaries.

Lower Columbia River Coho Salmon Historical Accessibility

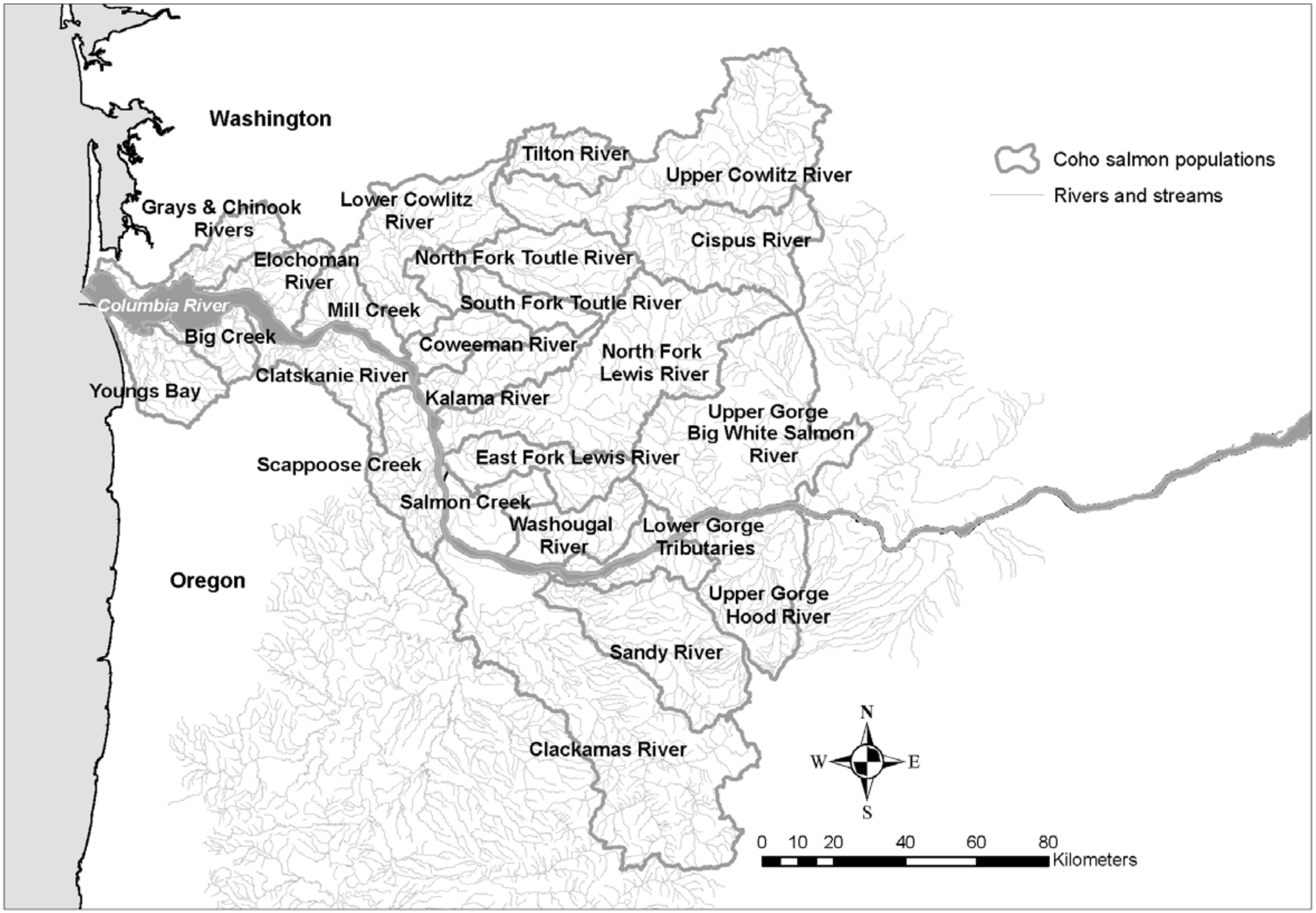


Figure E-72. Coho salmon population areas.

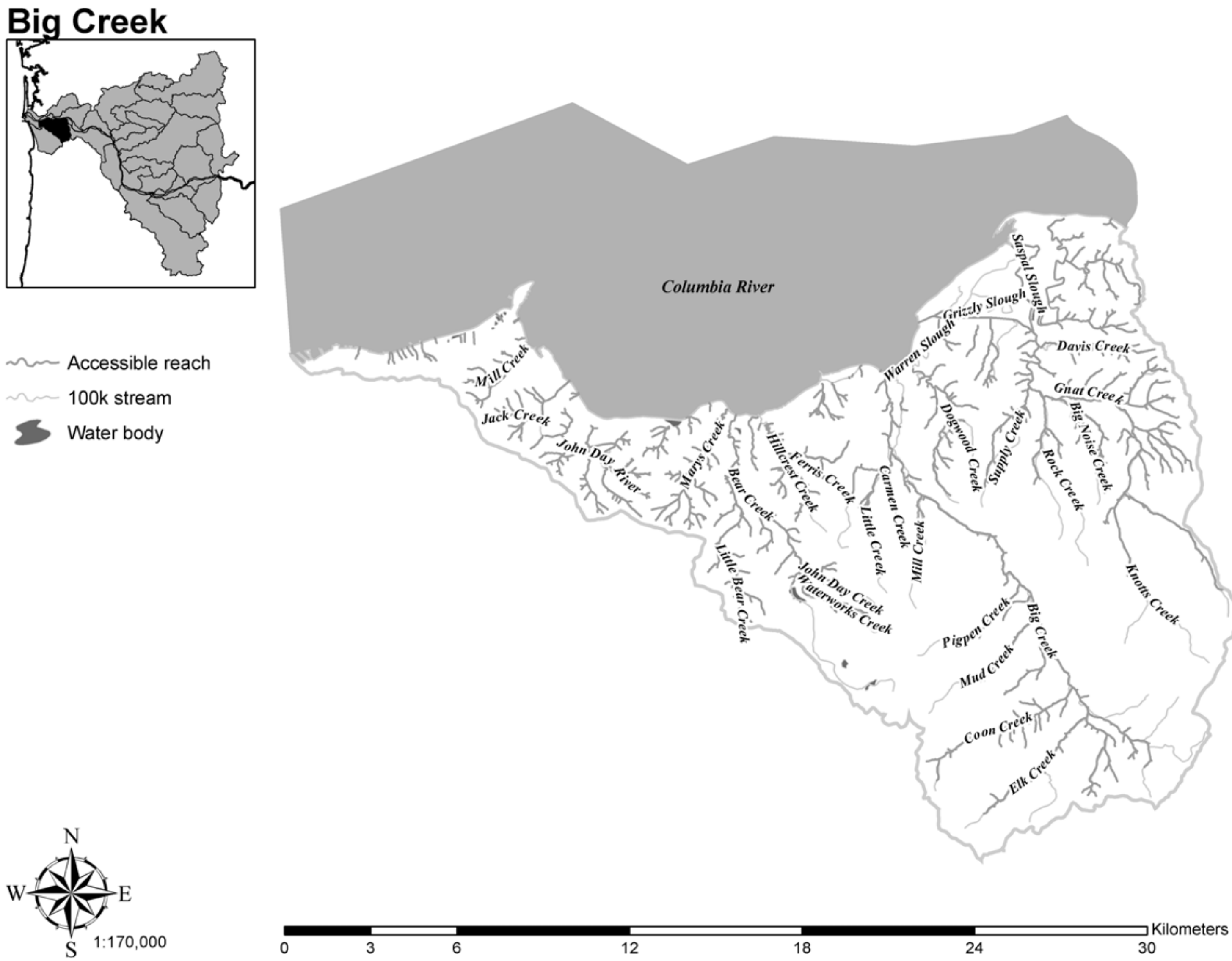


Figure E-73. Historical accessibility of coho salmon to Big Creek.

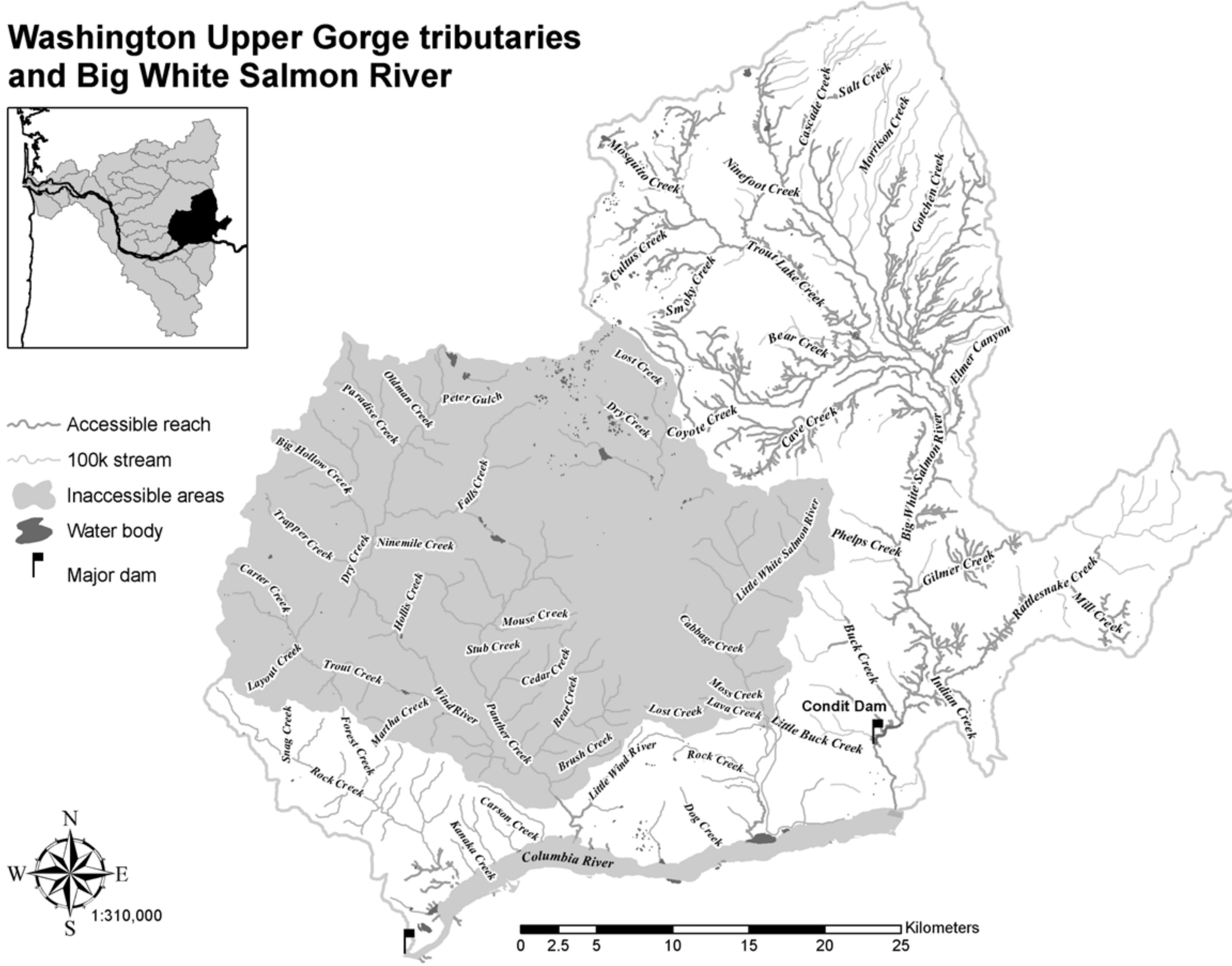


Figure E-74. Historical accessibility of coho salmon to the Washington upper Gorge tributaries and Big White Salmon River.

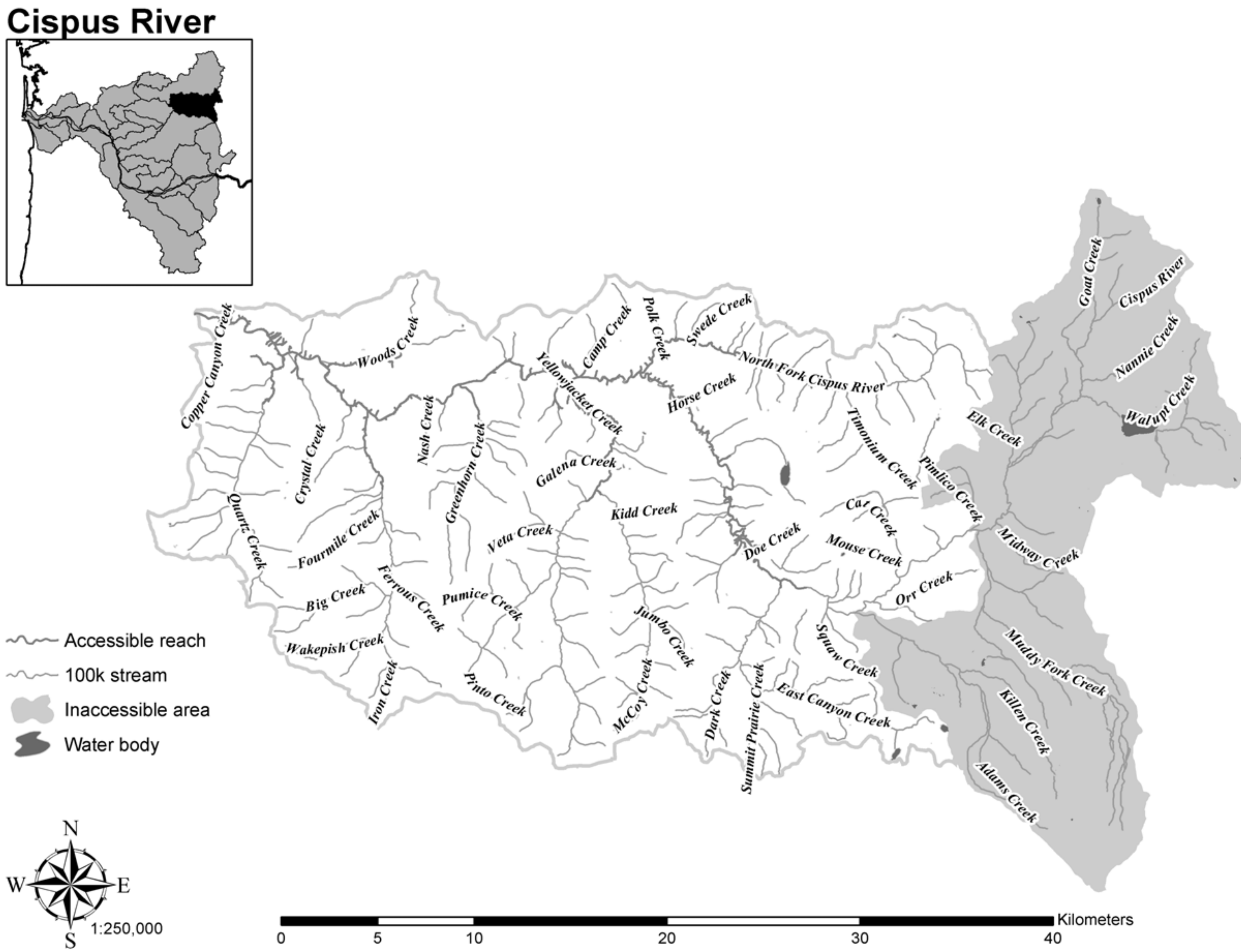


Figure E-75. Historical accessibility of coho salmon to the Cispus River.

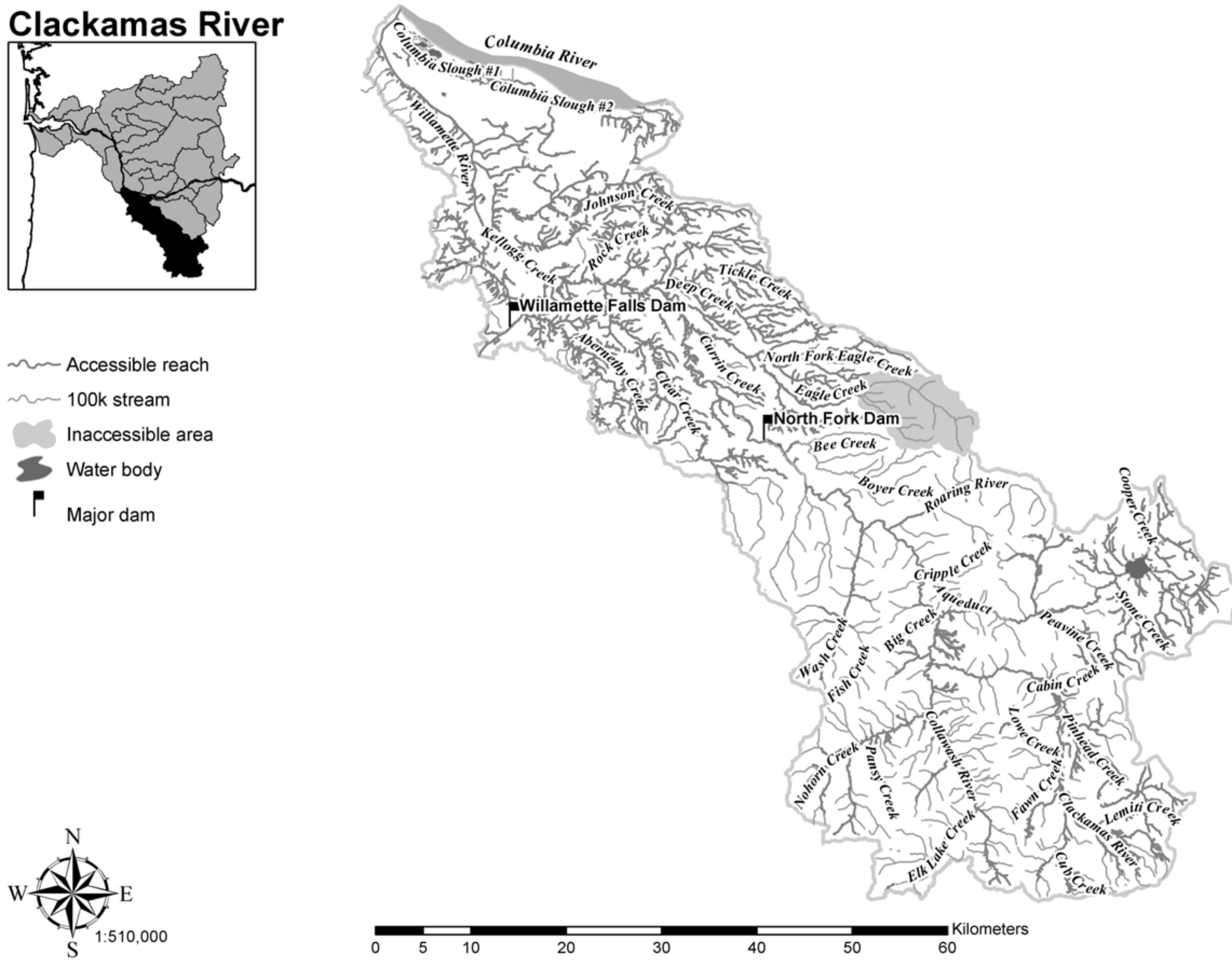


Figure E-76. Historical accessibility of coho salmon to the Clackamas River.

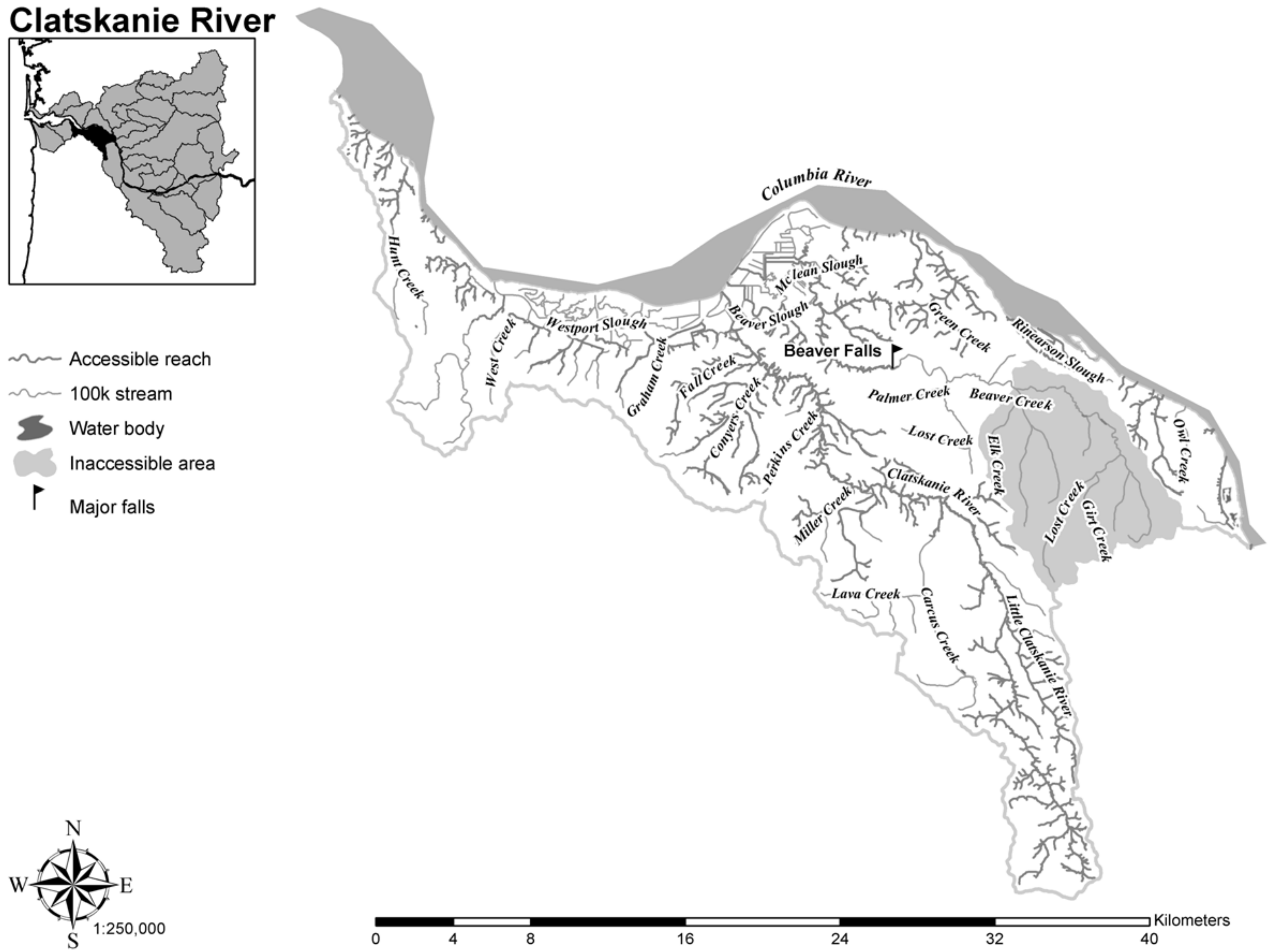


Figure E-77. Historical accessibility of coho salmon to the Clatskanie River.

Coweeman River

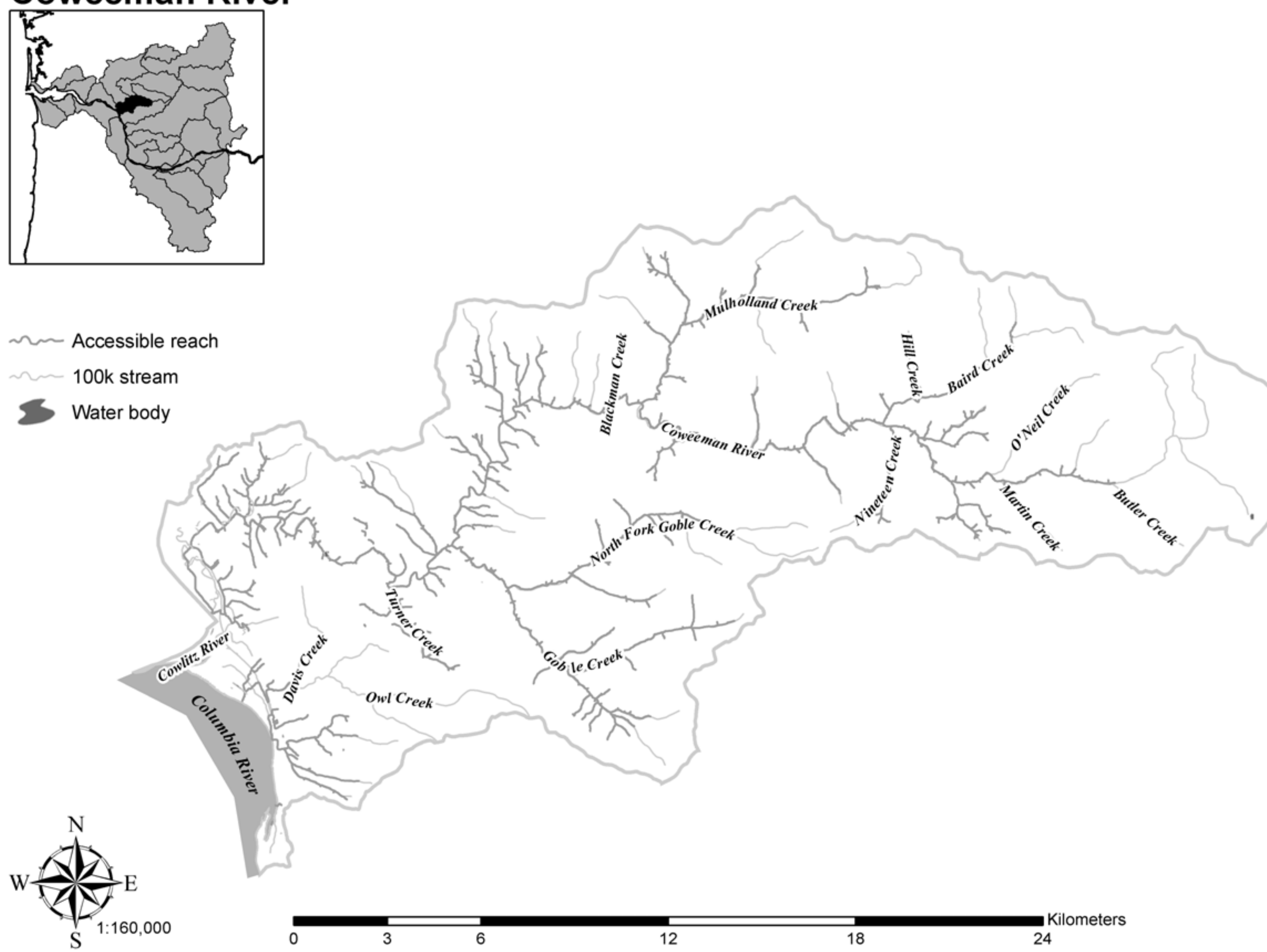


Figure E-78. Historical accessibility of coho salmon to the Coweeman River.

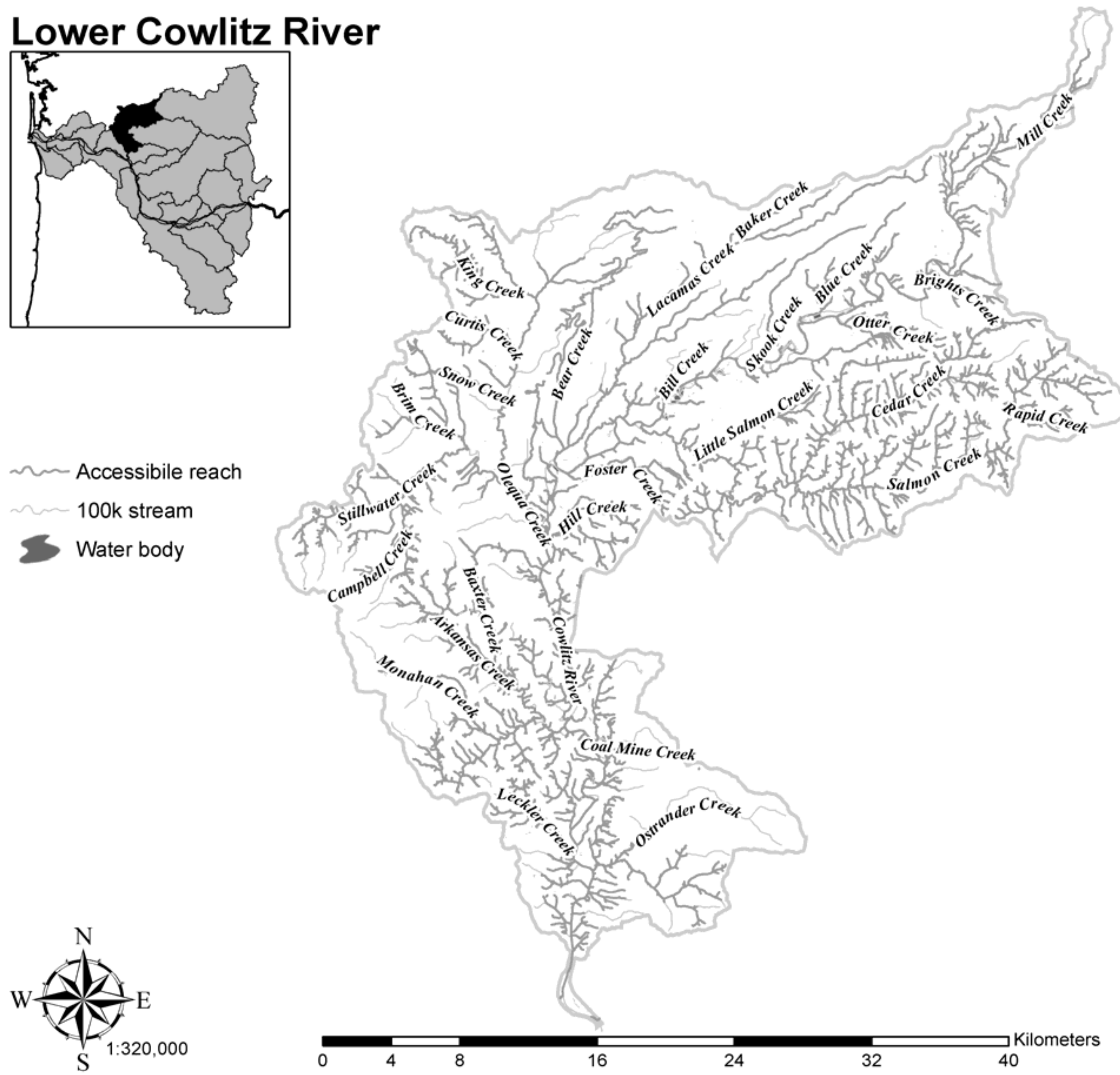


Figure E-79. Historical accessibility of coho salmon to the lower Cowlitz River.

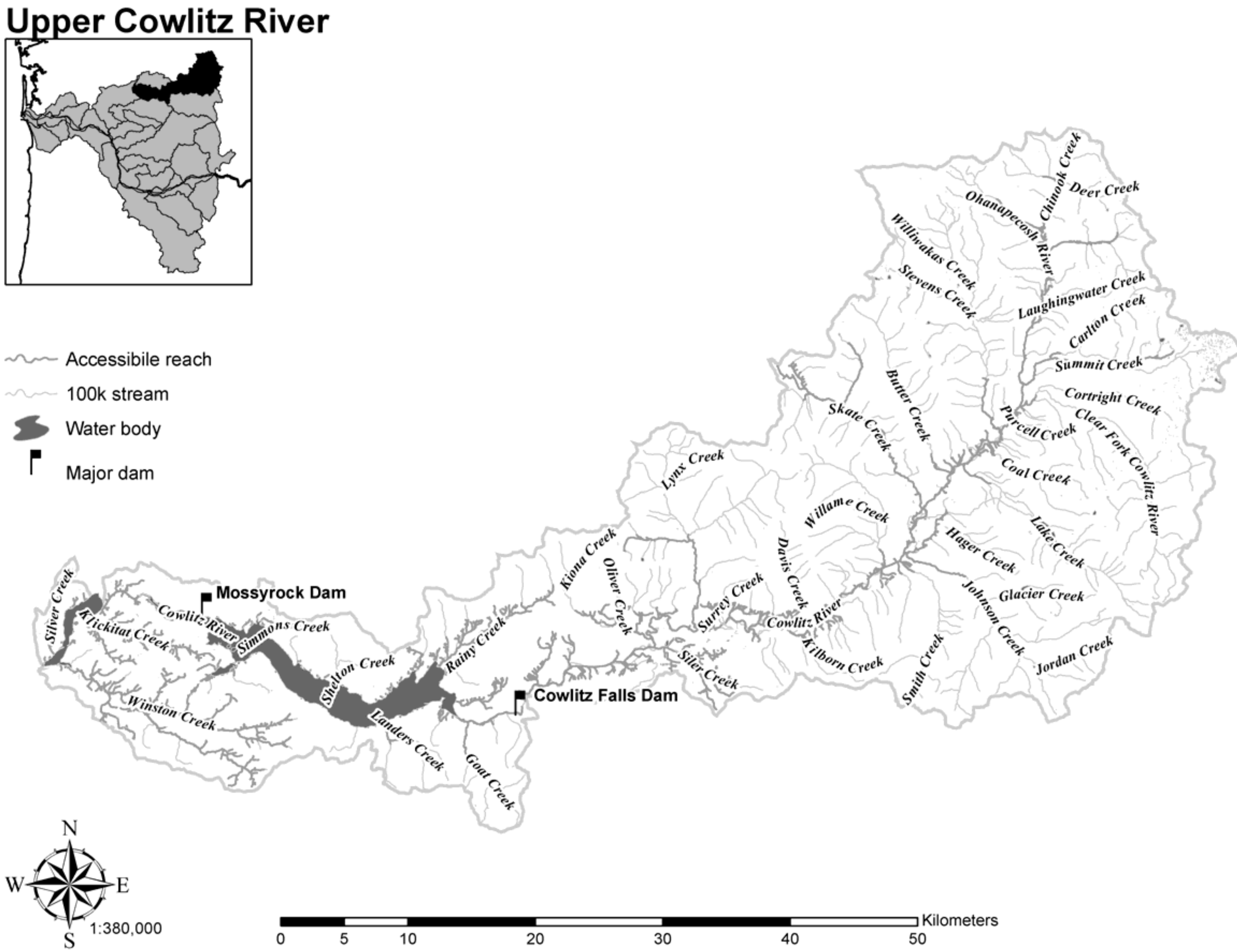


Figure E-80. Historical accessibility of coho salmon to the upper Cowlitz River.

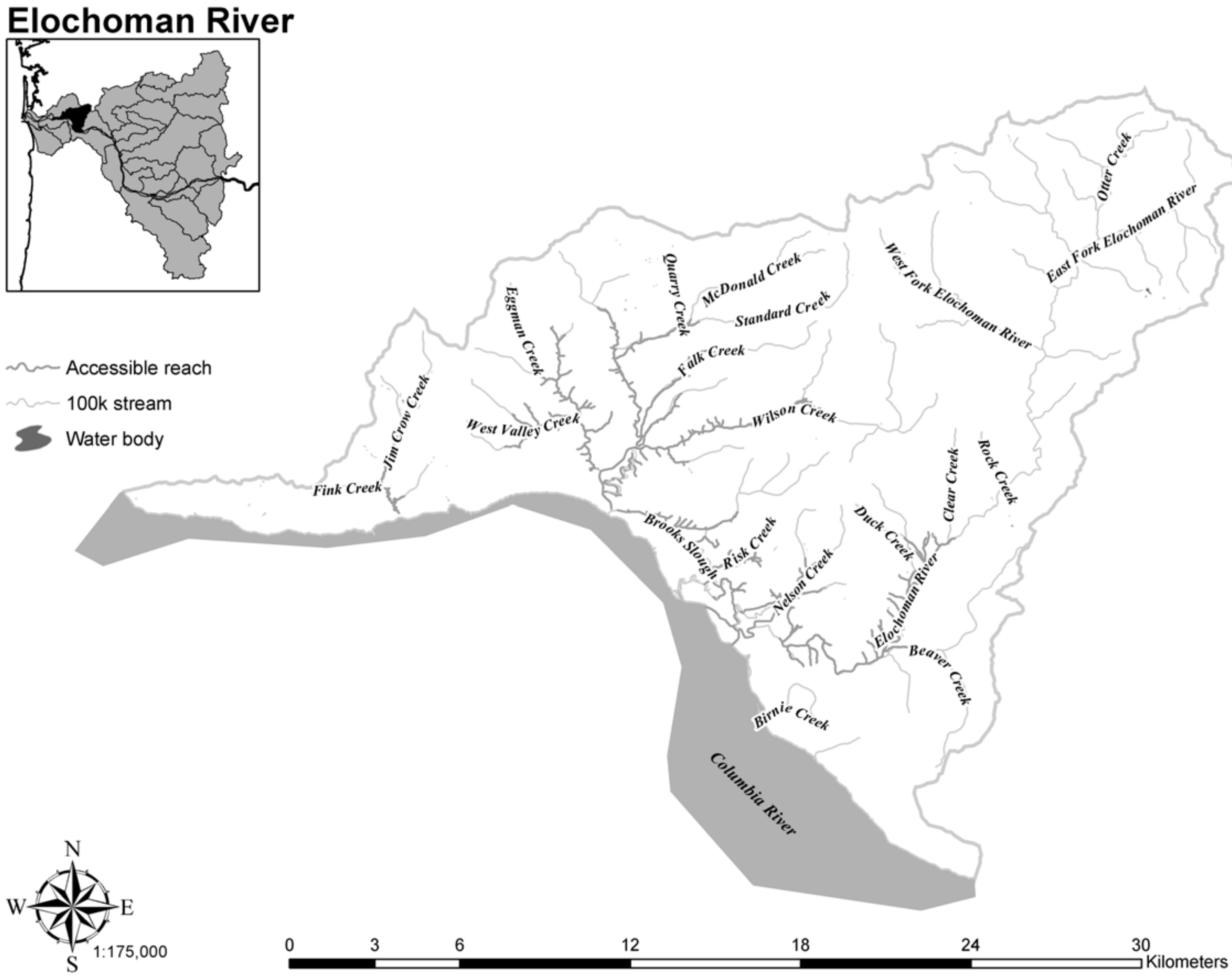


Figure E-81. Historical accessibility of coho salmon to the Elochoman River.

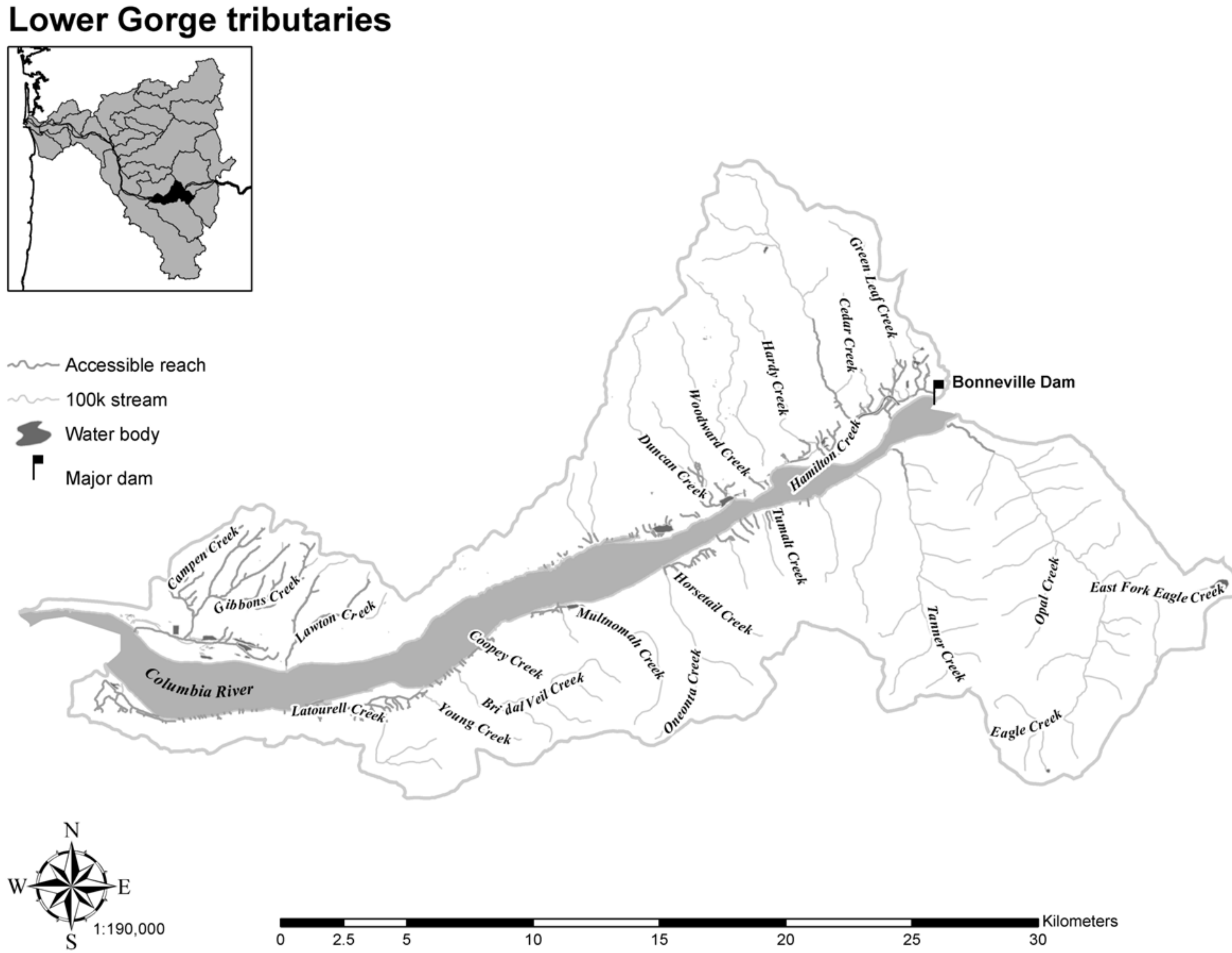


Figure E-82. Historical accessibility of coho salmon to the Columbia River lower Gorge tributaries.

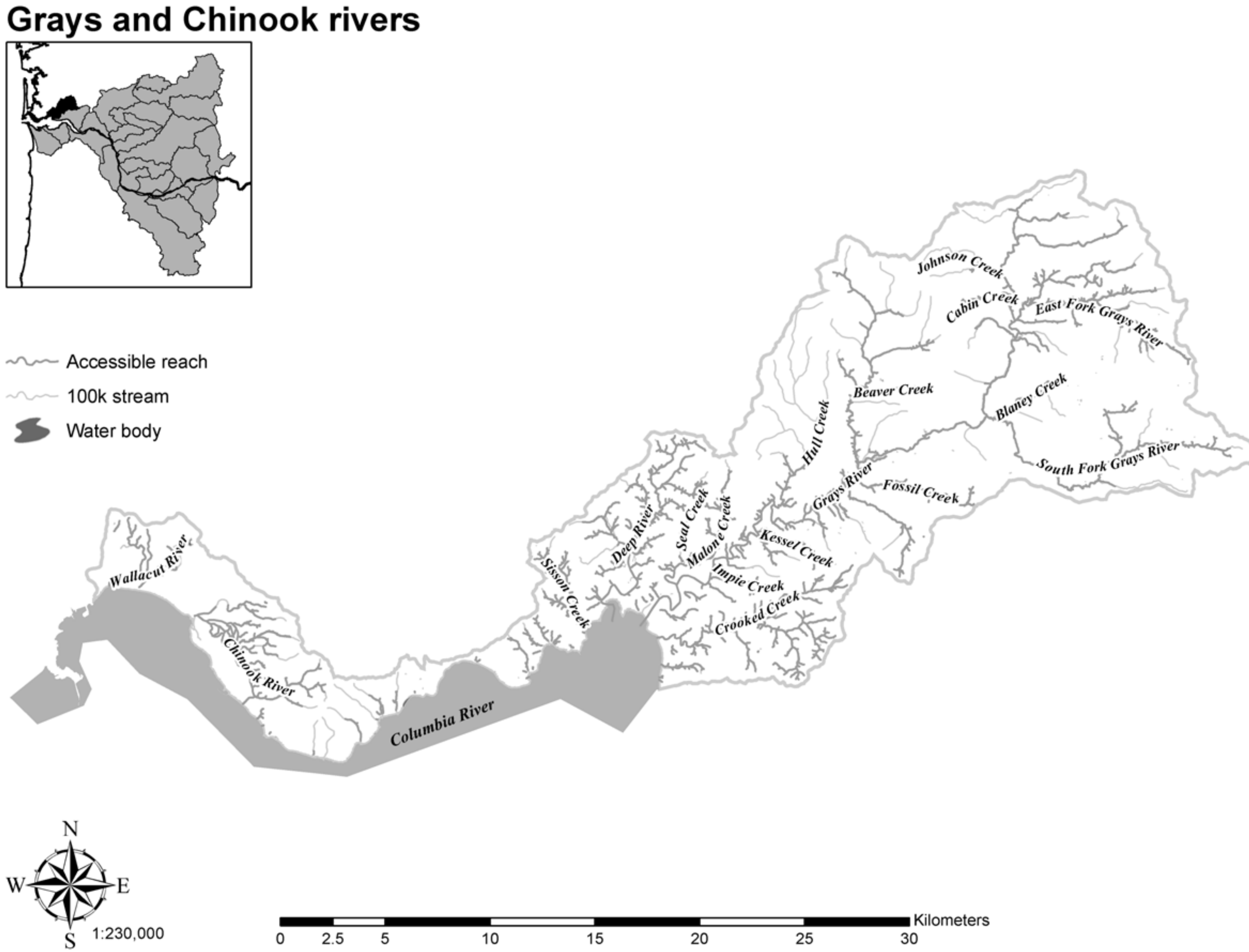


Figure E-83. Historical accessibility of coho salmon to the Grays and Chinook rivers.

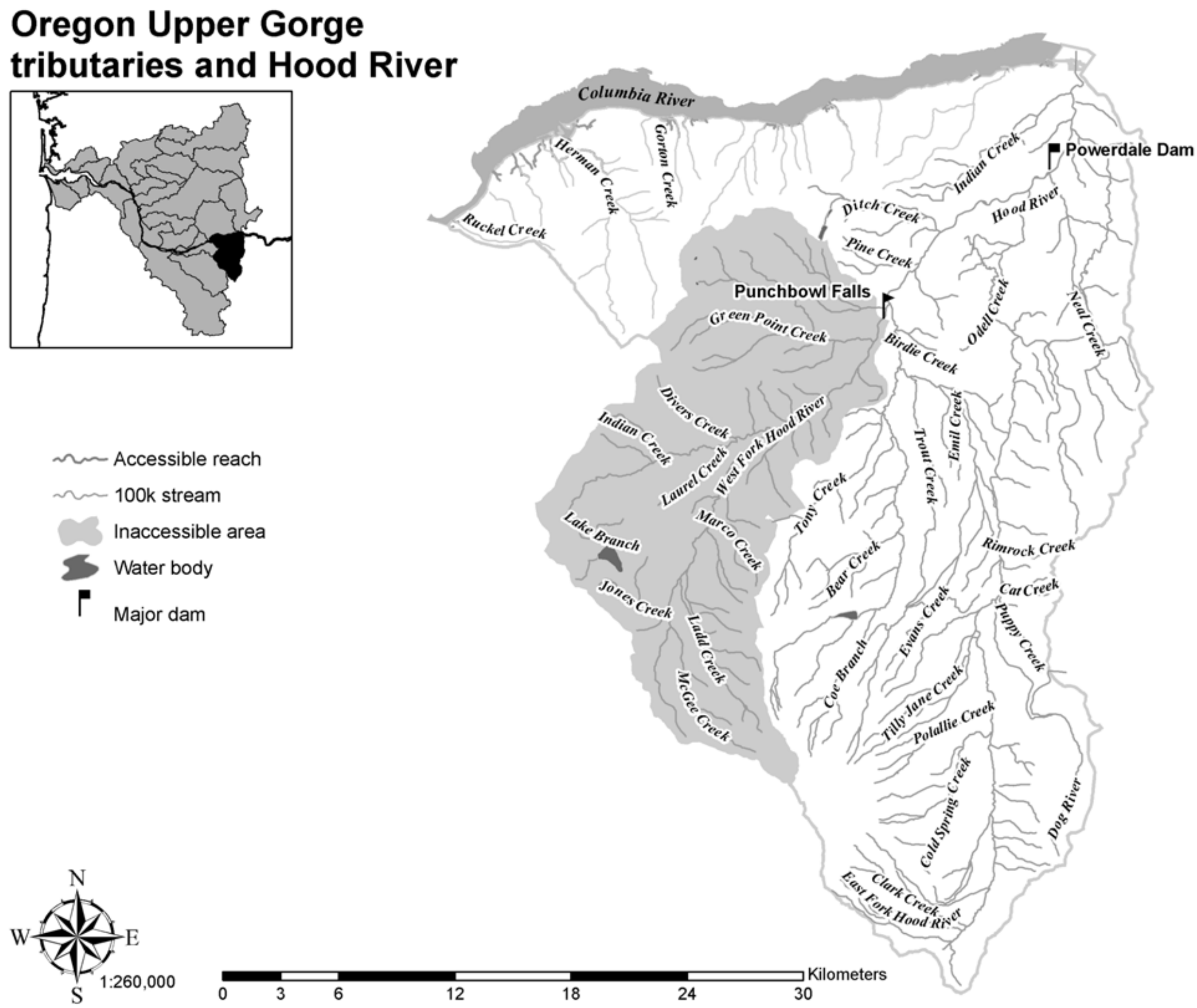


Figure E-84. Historical accessibility of coho salmon to the Oregon upper Gorge tributaries and Hood River.

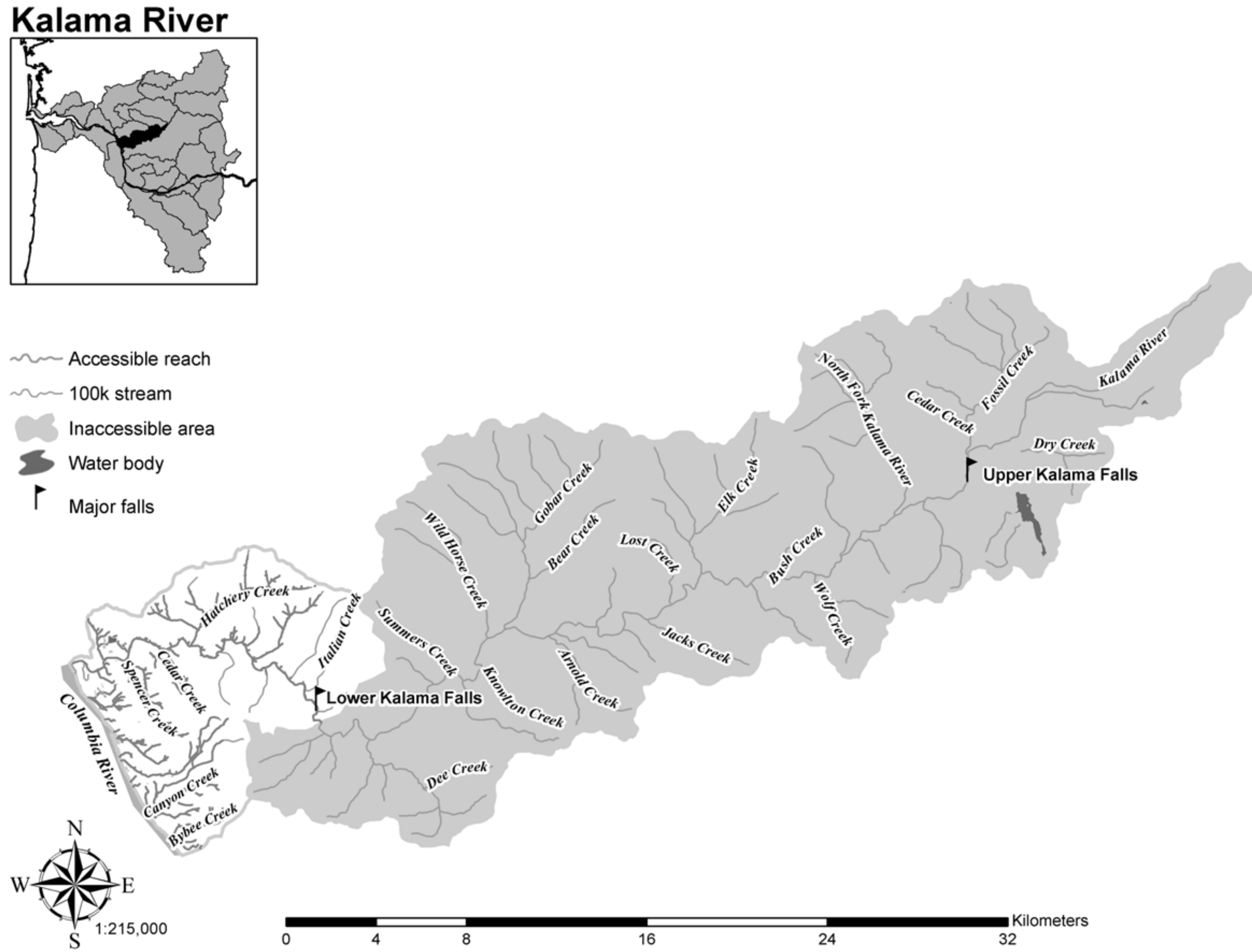


Figure E-85. Historical accessibility of coho salmon to the Kalama River.

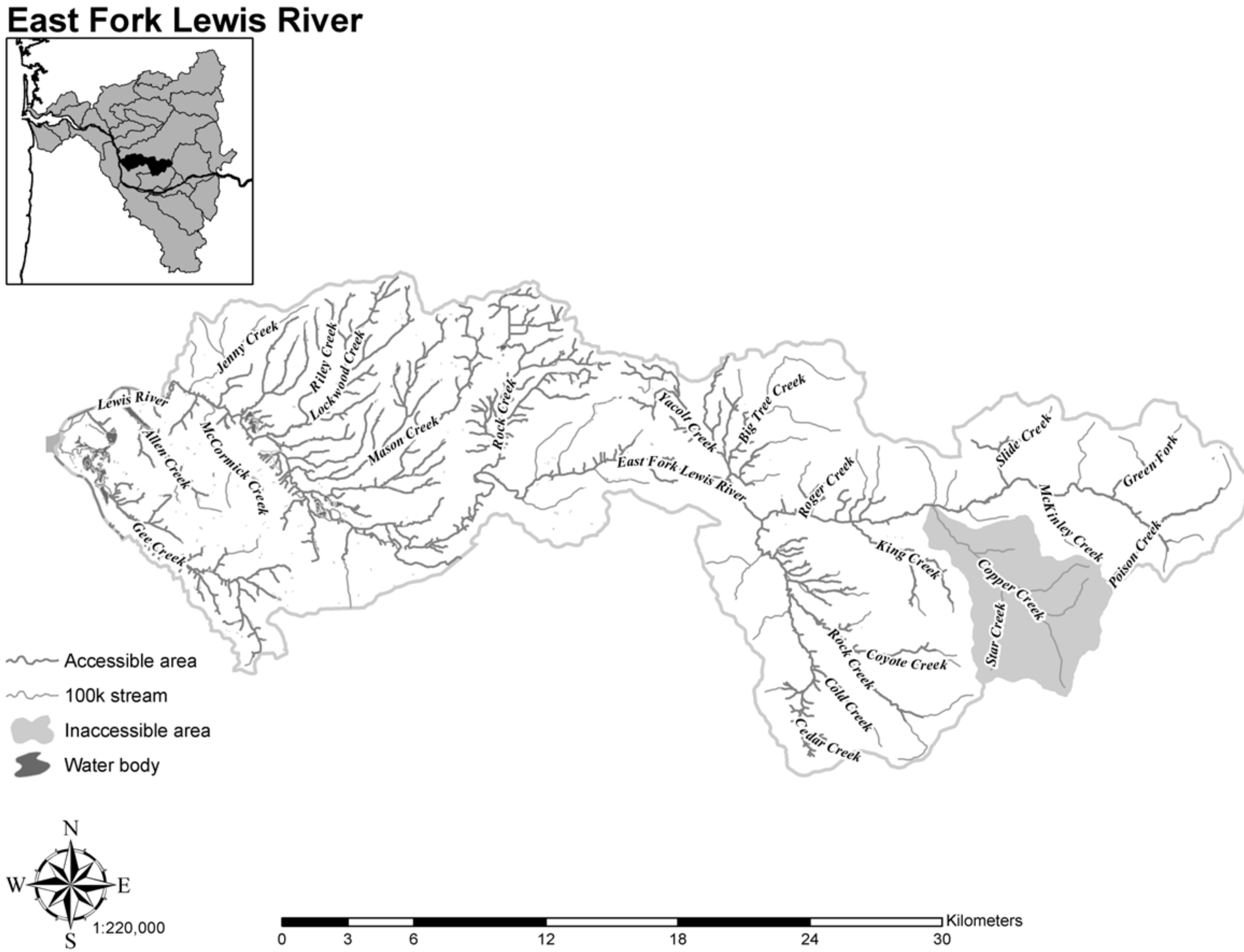


Figure E-86. Historical accessibility of coho salmon to the East Fork Lewis River.

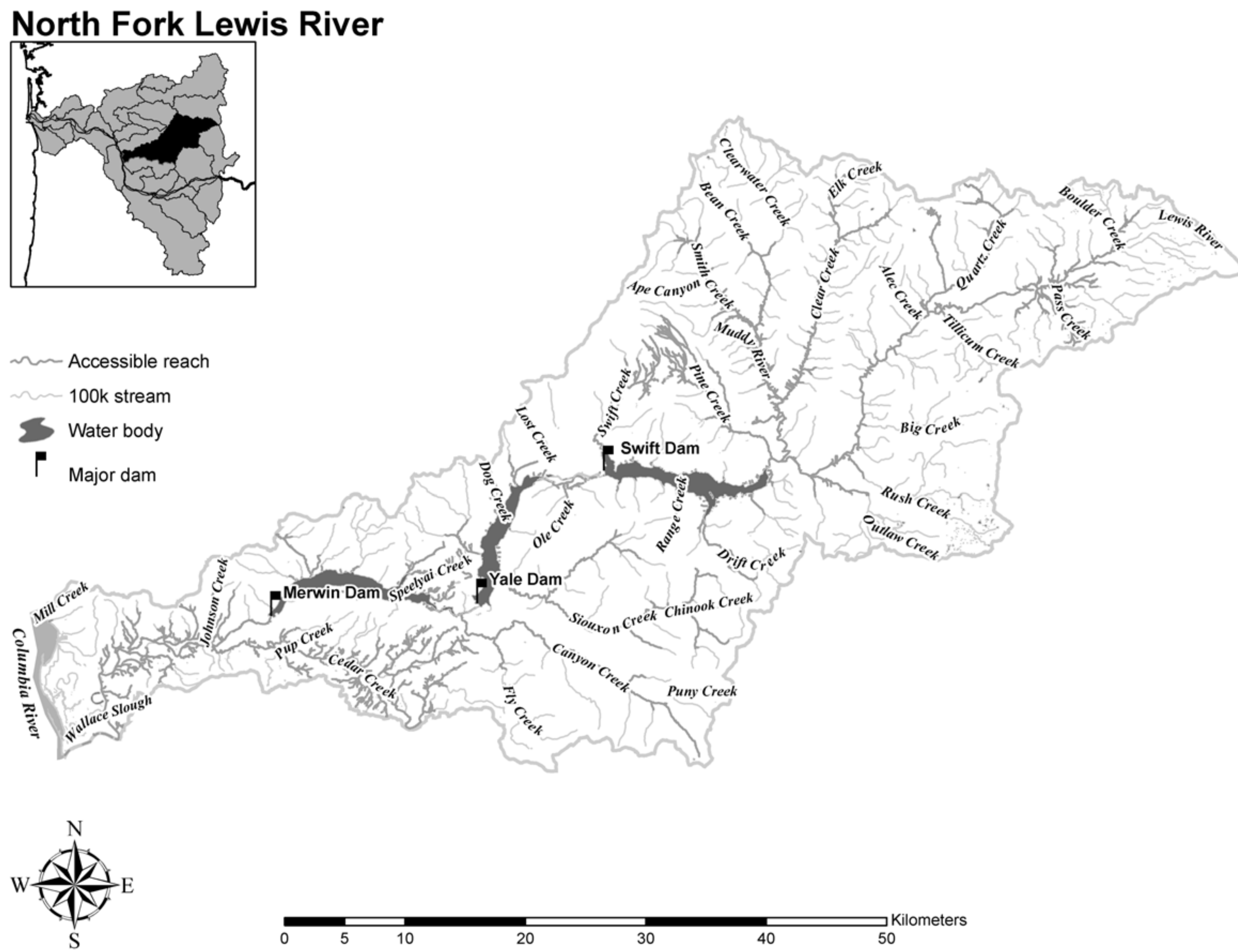


Figure E-87. Historical accessibility of coho salmon to the North Fork Lewis River.

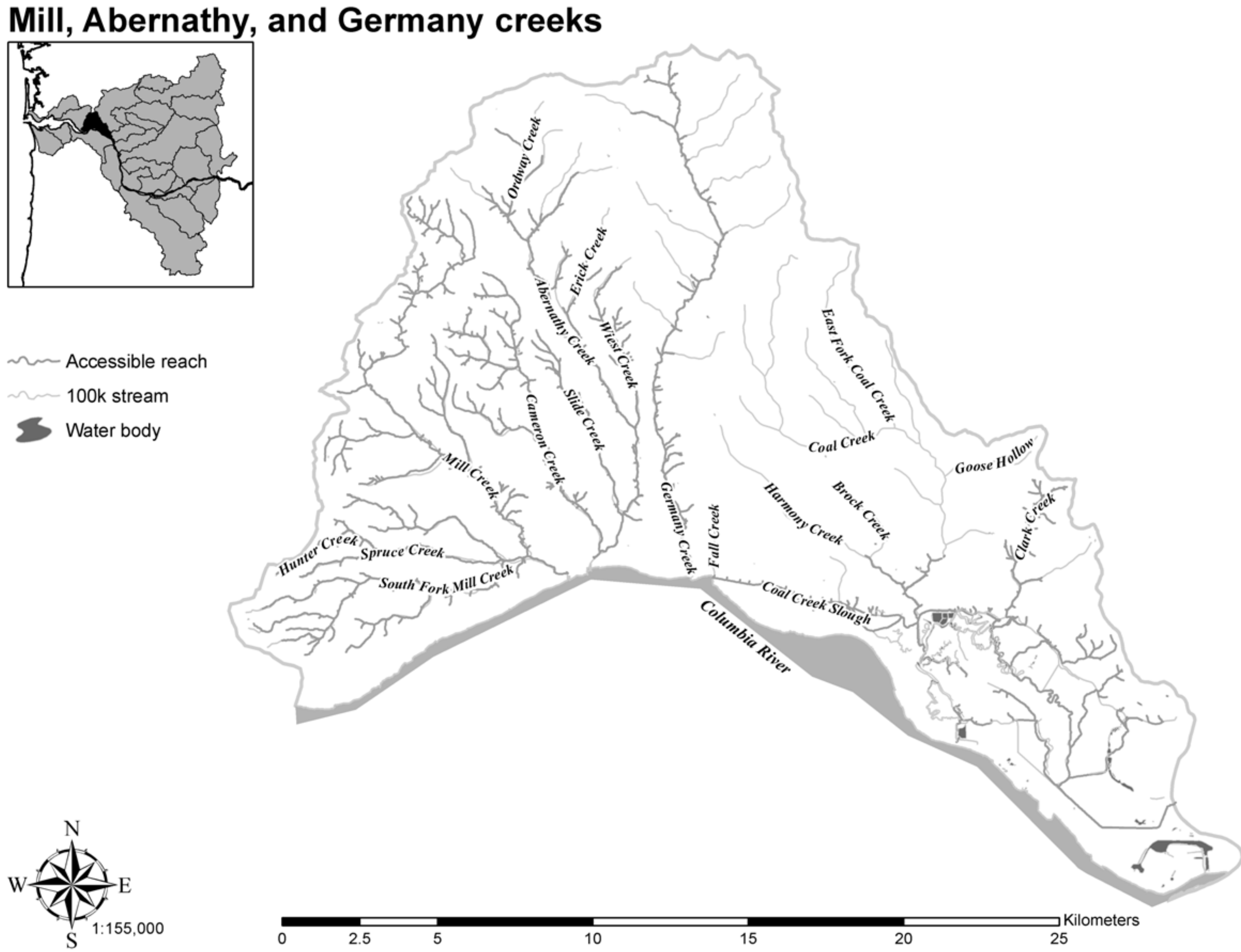


Figure E-88. Historical accessibility of coho salmon to the Mill, Abernathy, and Germany creeks.

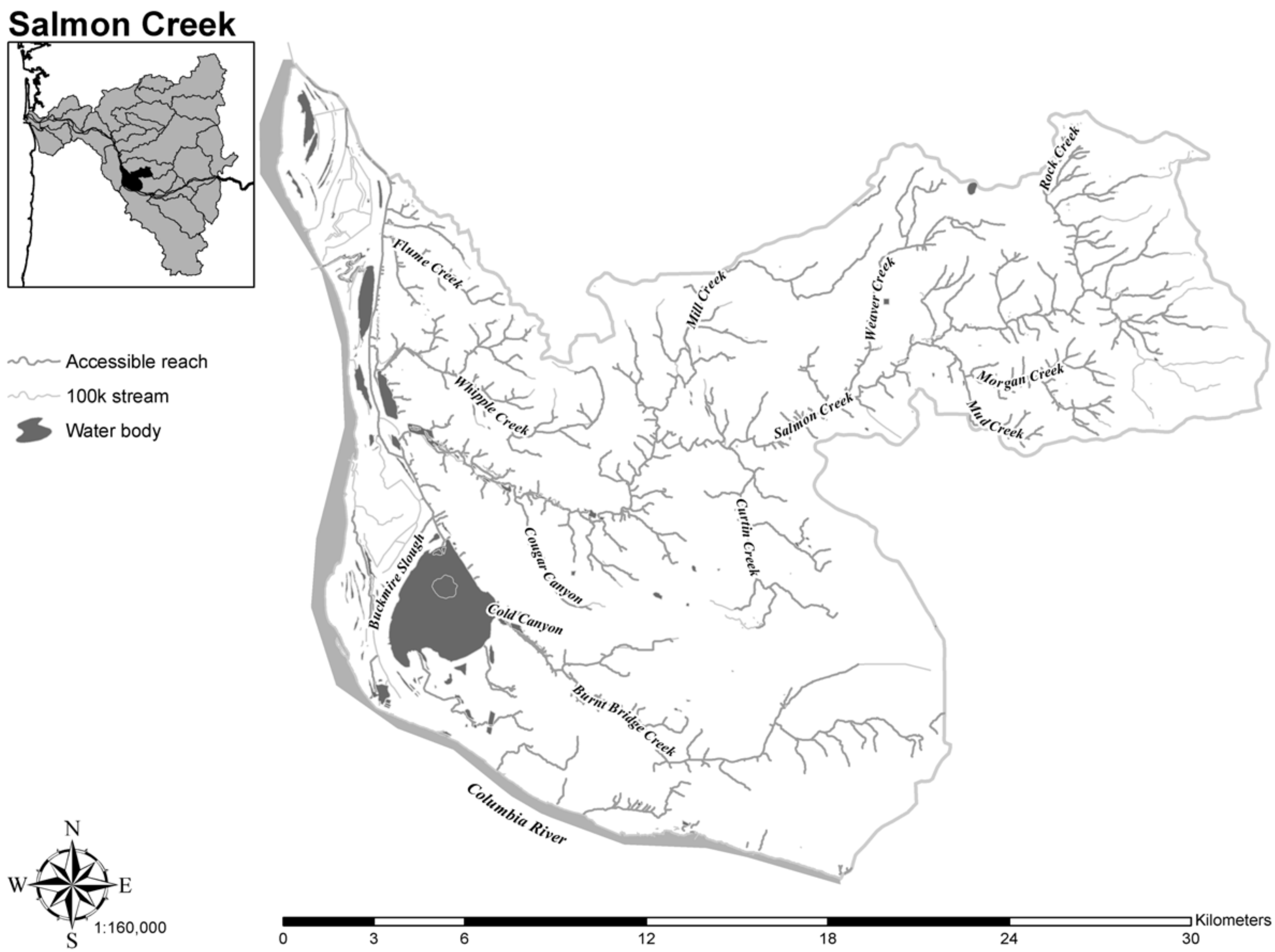


Figure E-89. Historical accessibility of coho salmon to Salmon Creek.

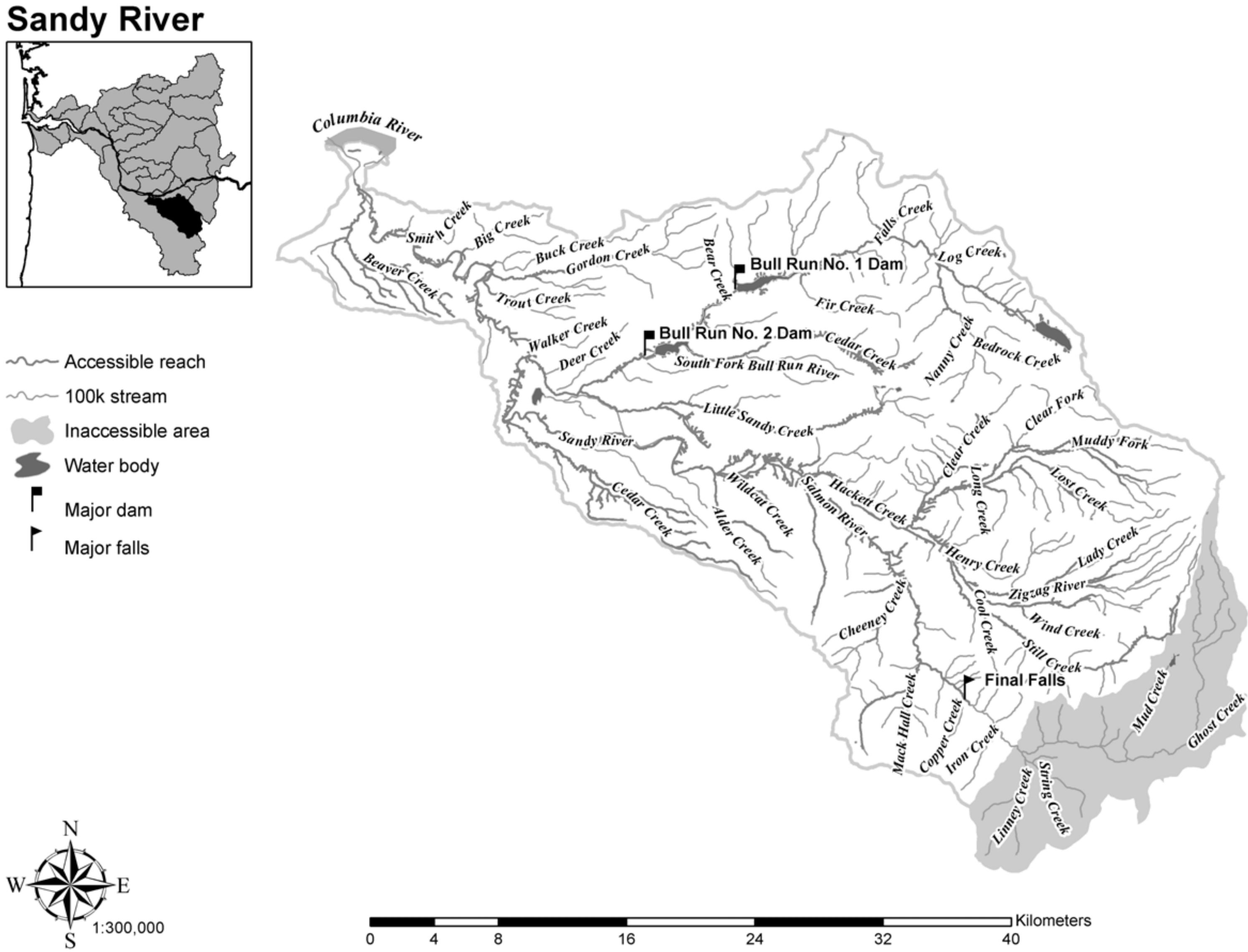


Figure E-90. Historical accessibility of coho salmon to the Sandy River.

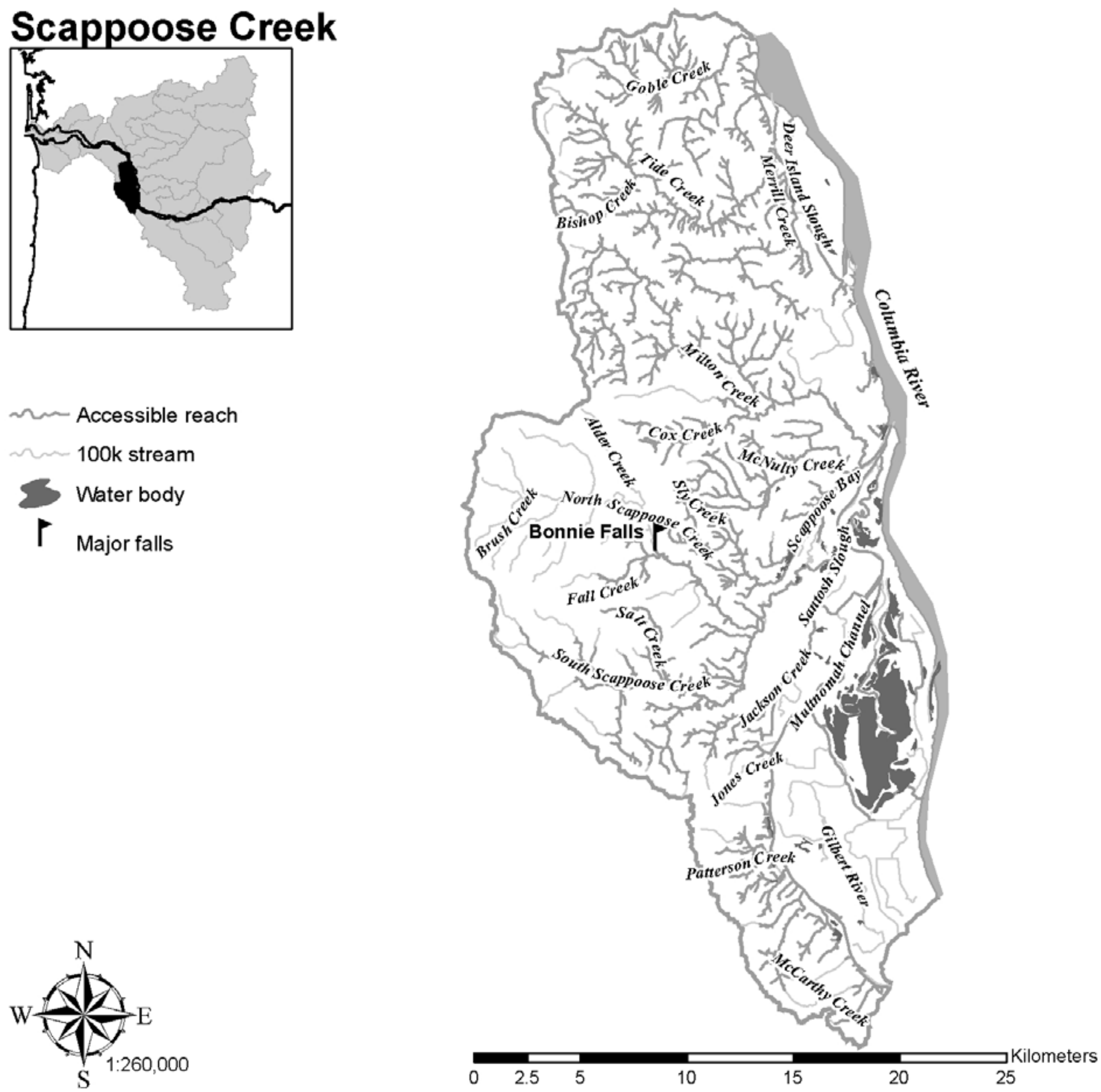


Figure E-91. Historical accessibility of coho salmon to the Scappose Creek.

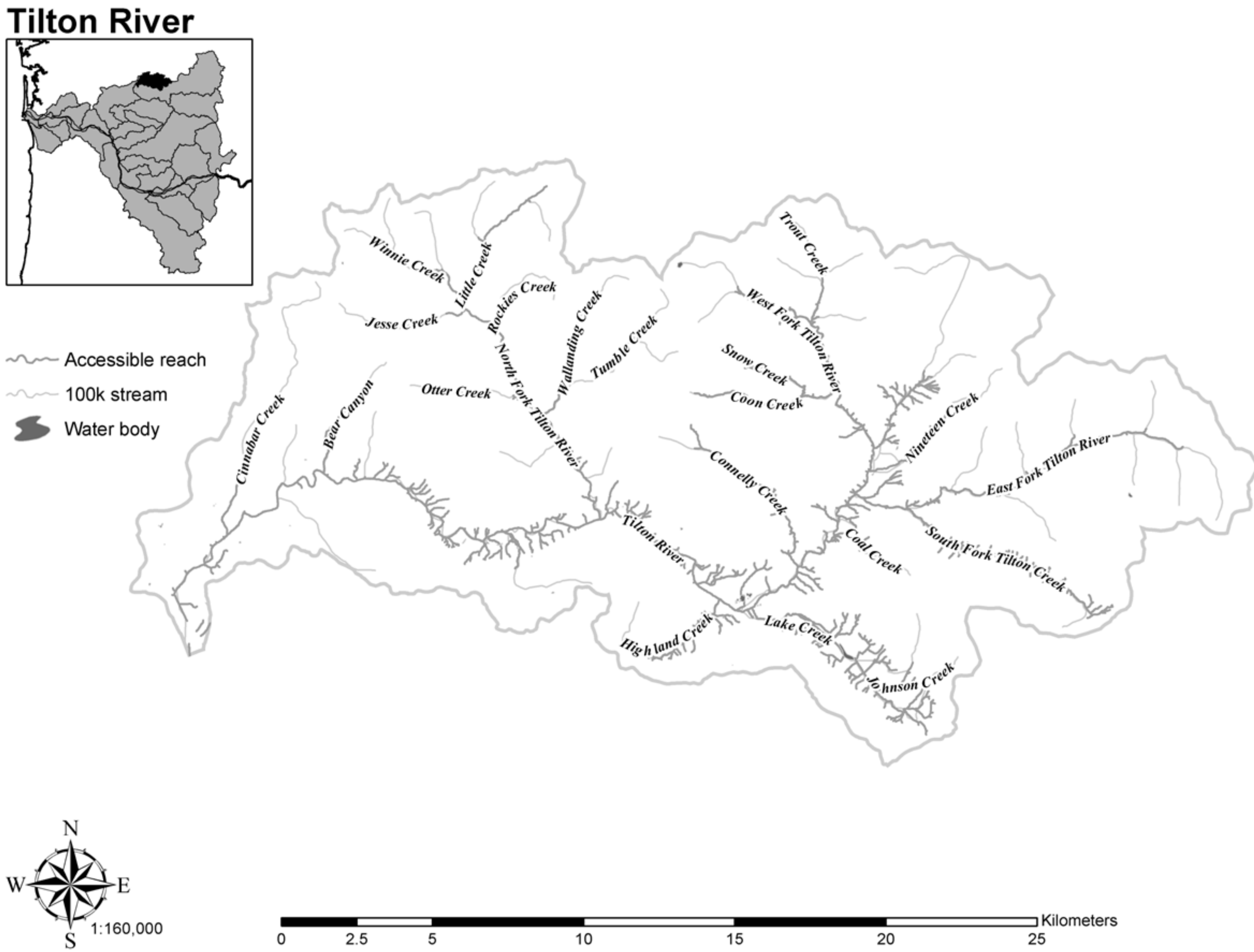


Figure E-92. Historical accessibility of coho salmon to the Tilton River.

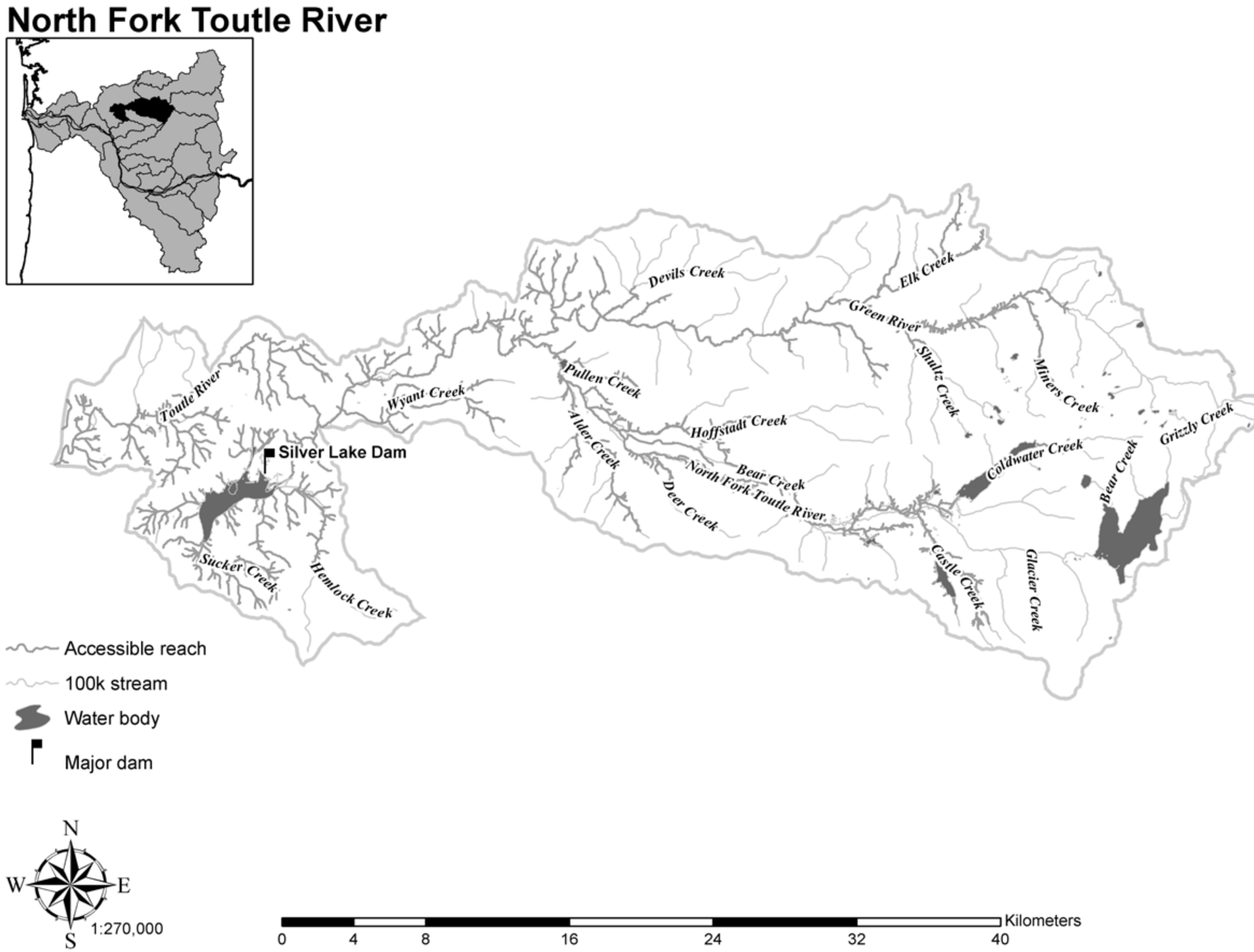


Figure E-93. Historical accessibility of coho salmon to the North Fork Toutle River.

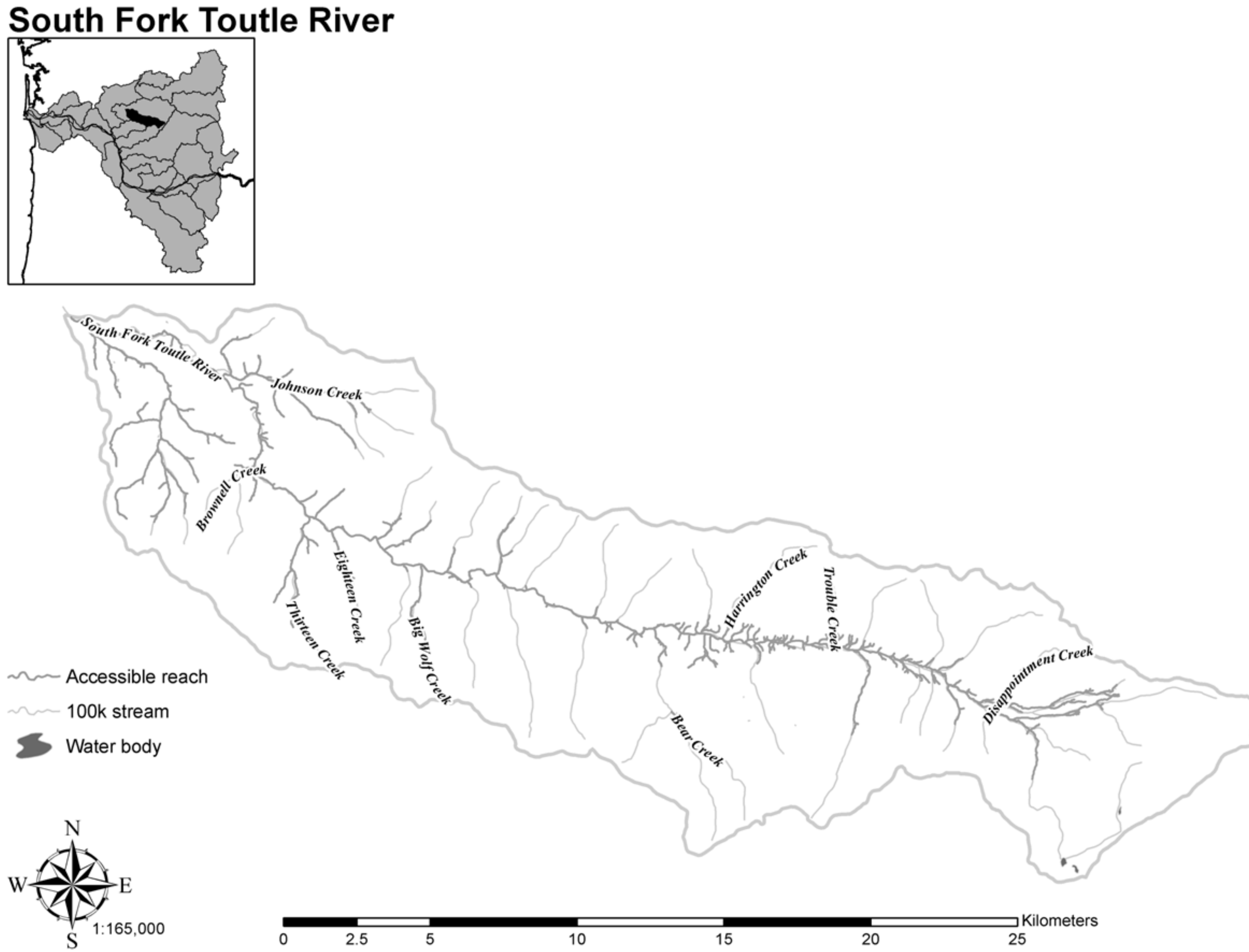


Figure E-94. Historical accessibility of coho salmon to the South Fork Toutle River.

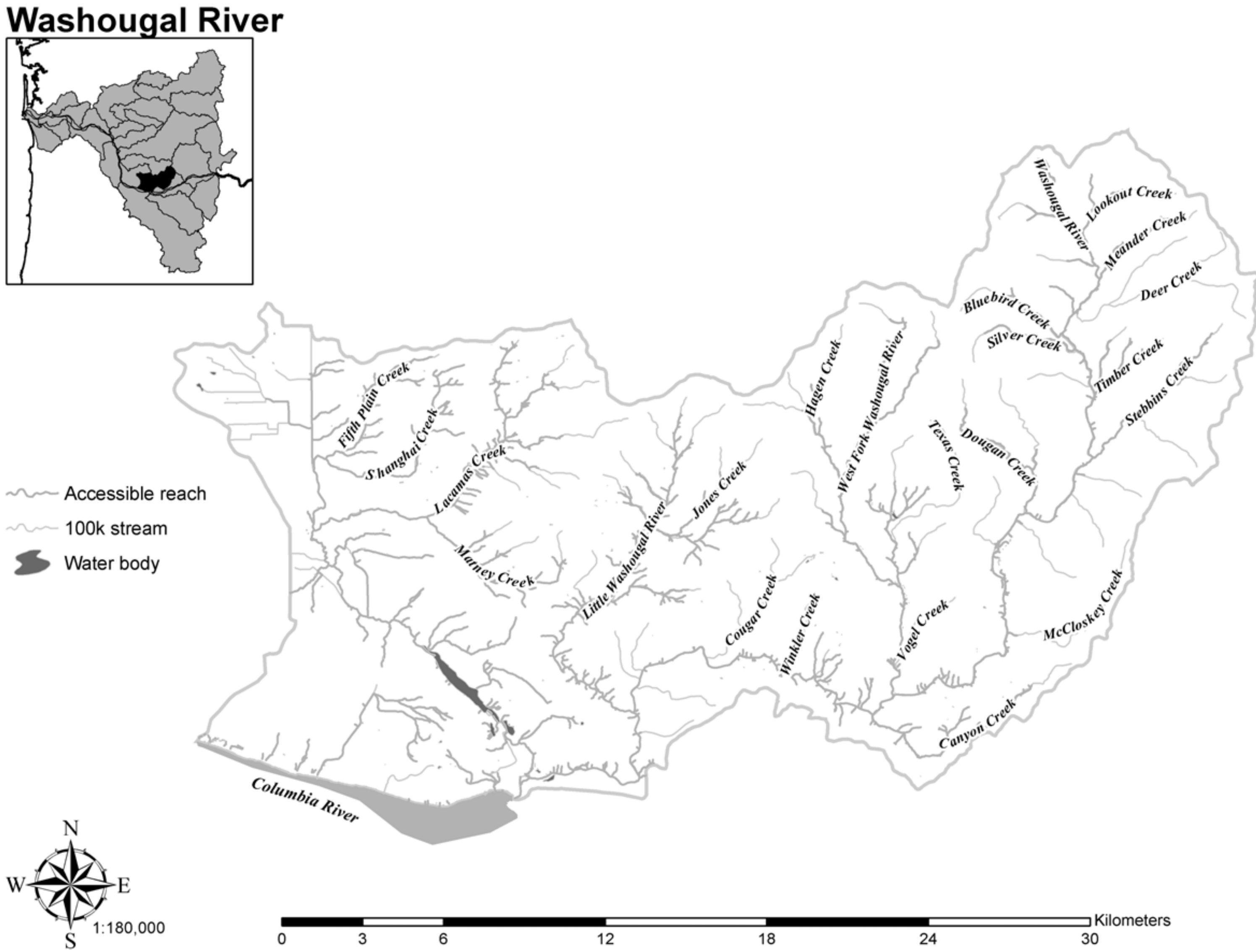


Figure E-95. Historical accessibility of coho salmon to the Washougal River.

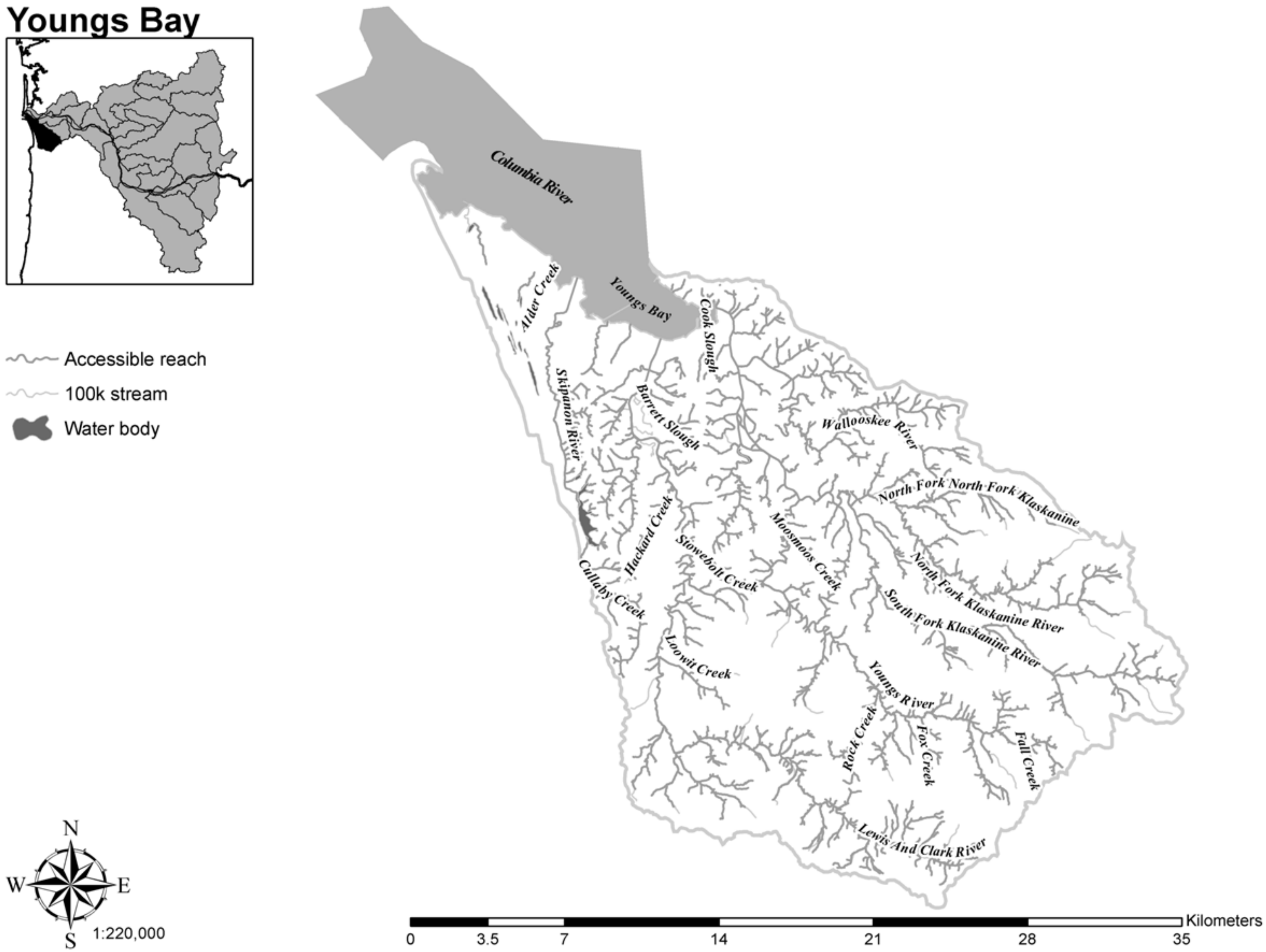


Figure E-96. Historical accessibility of coho salmon to Youngs Bay.

Lower Columbia River Chum Salmon Historical Accessibility

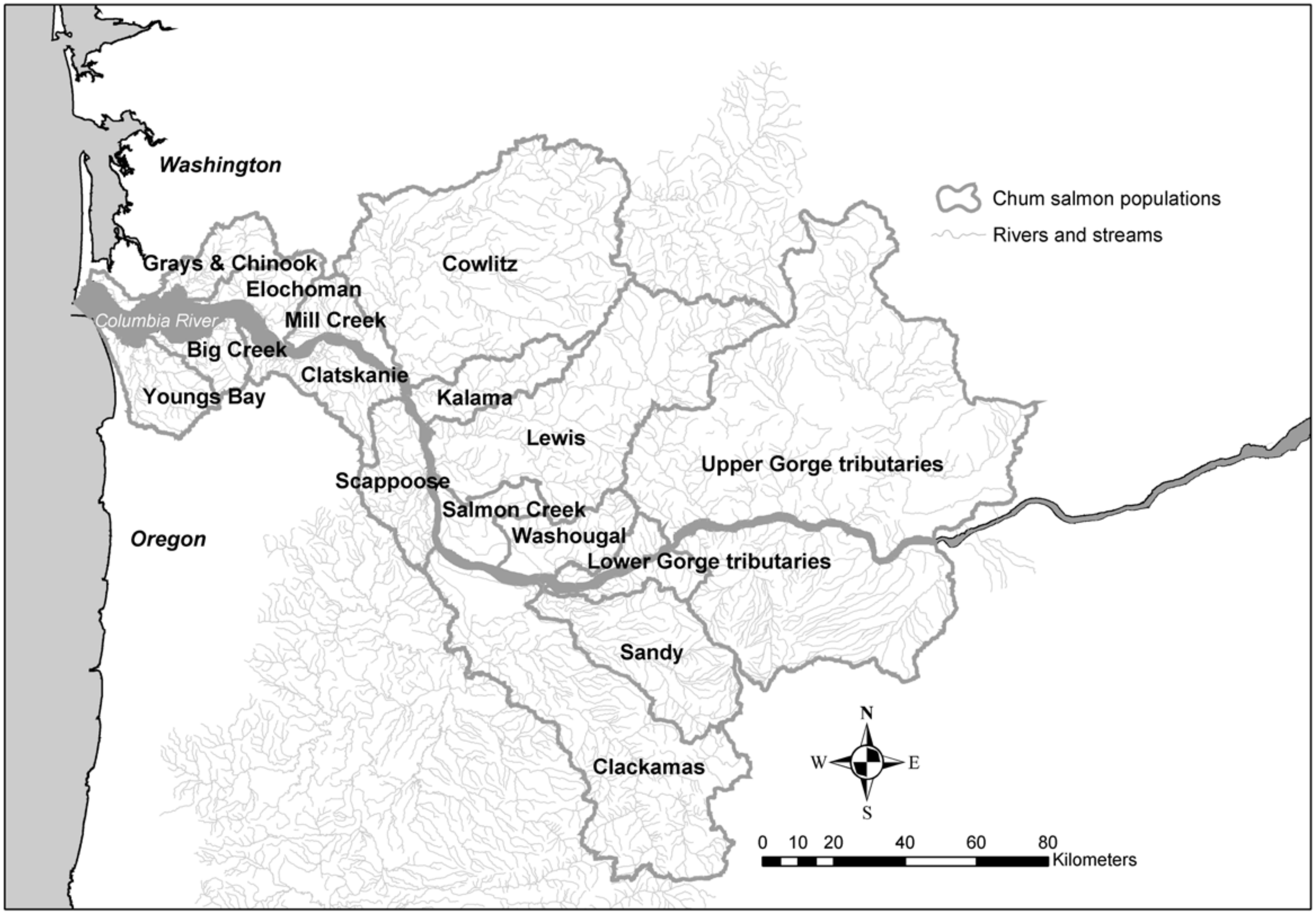


Figure E-97. Chum salmon population areas.

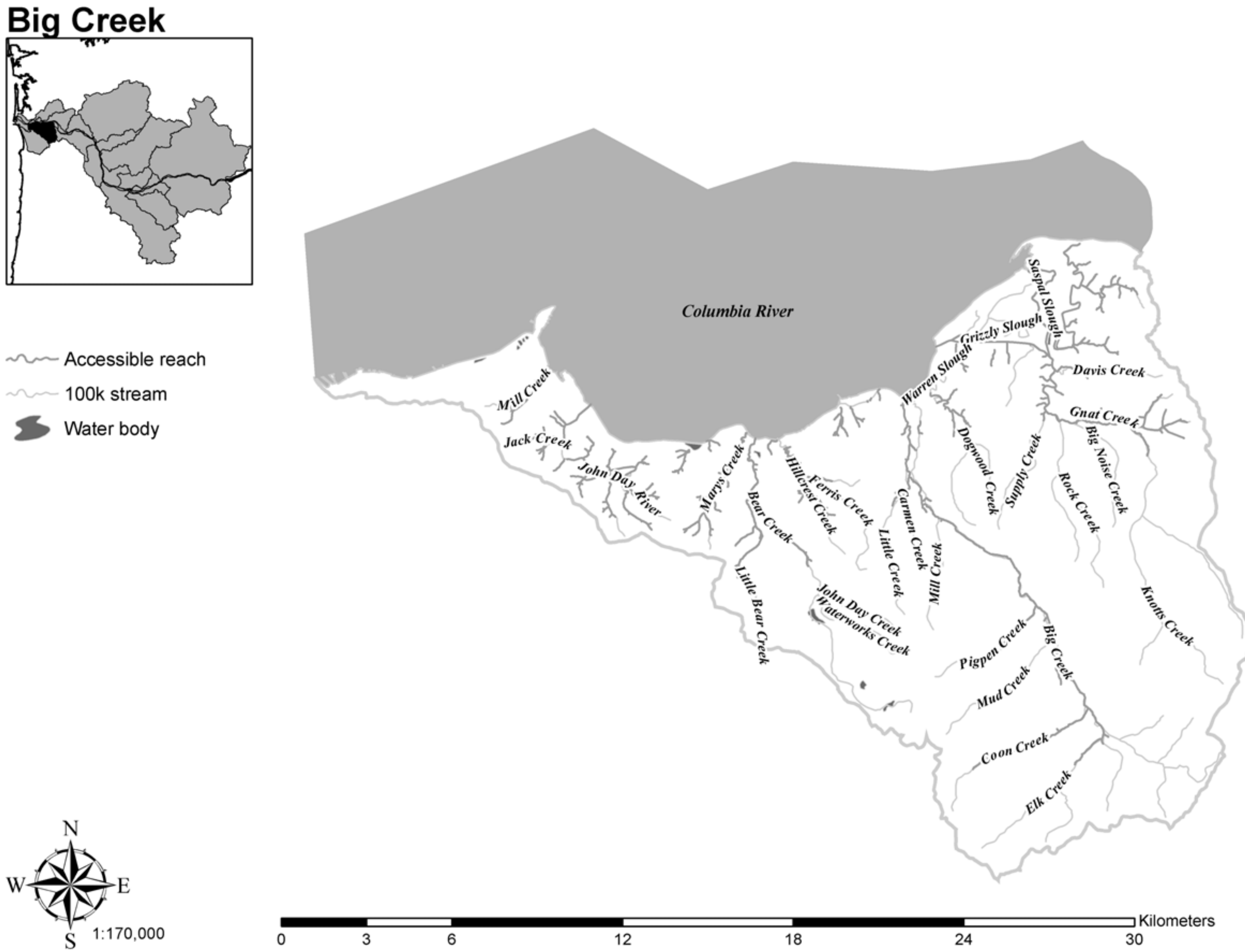


Figure E-98. Historical accessibility of chum salmon to Big Creek.

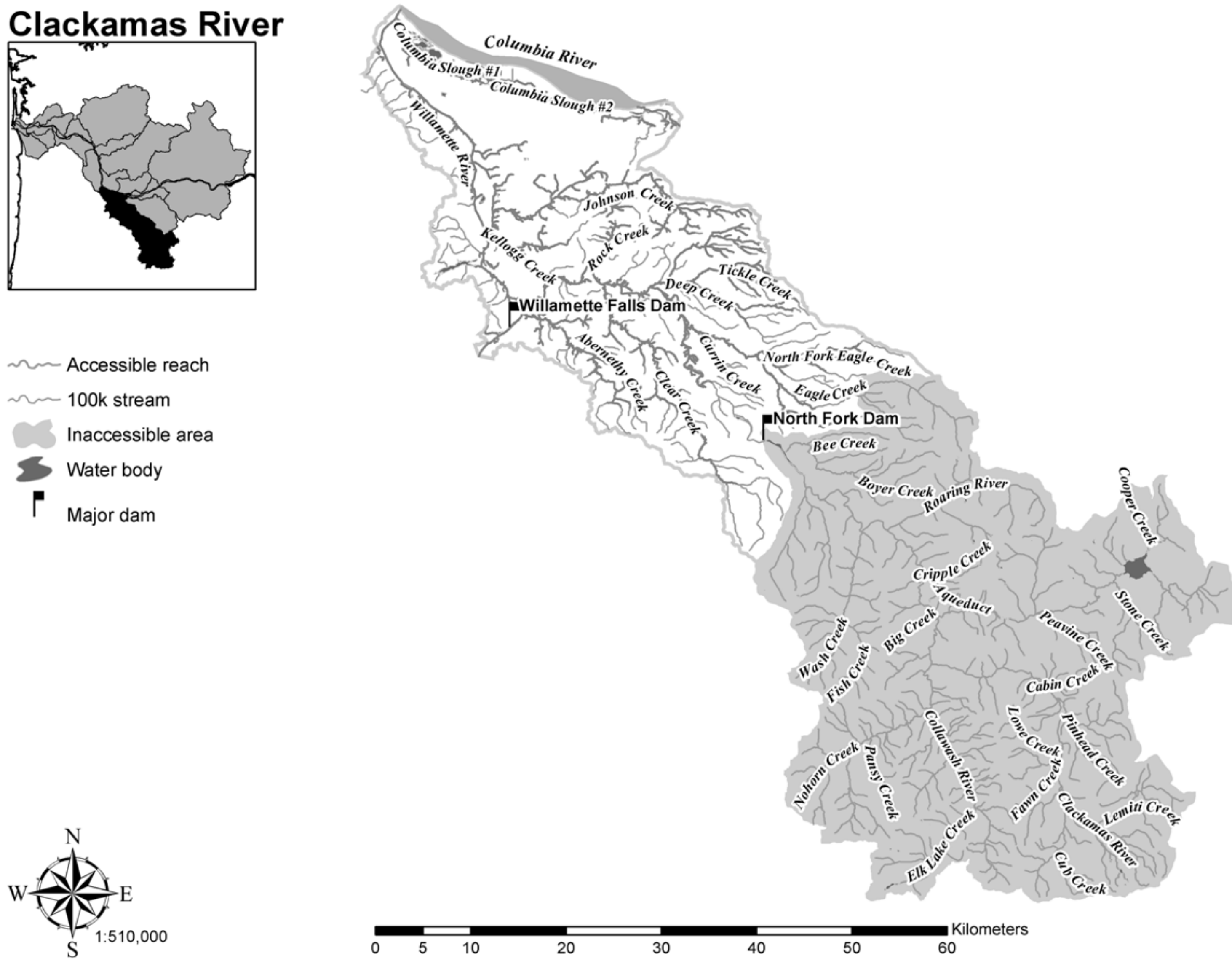


Figure E-99. Historical accessibility of chum salmon to the Clatckamas River.

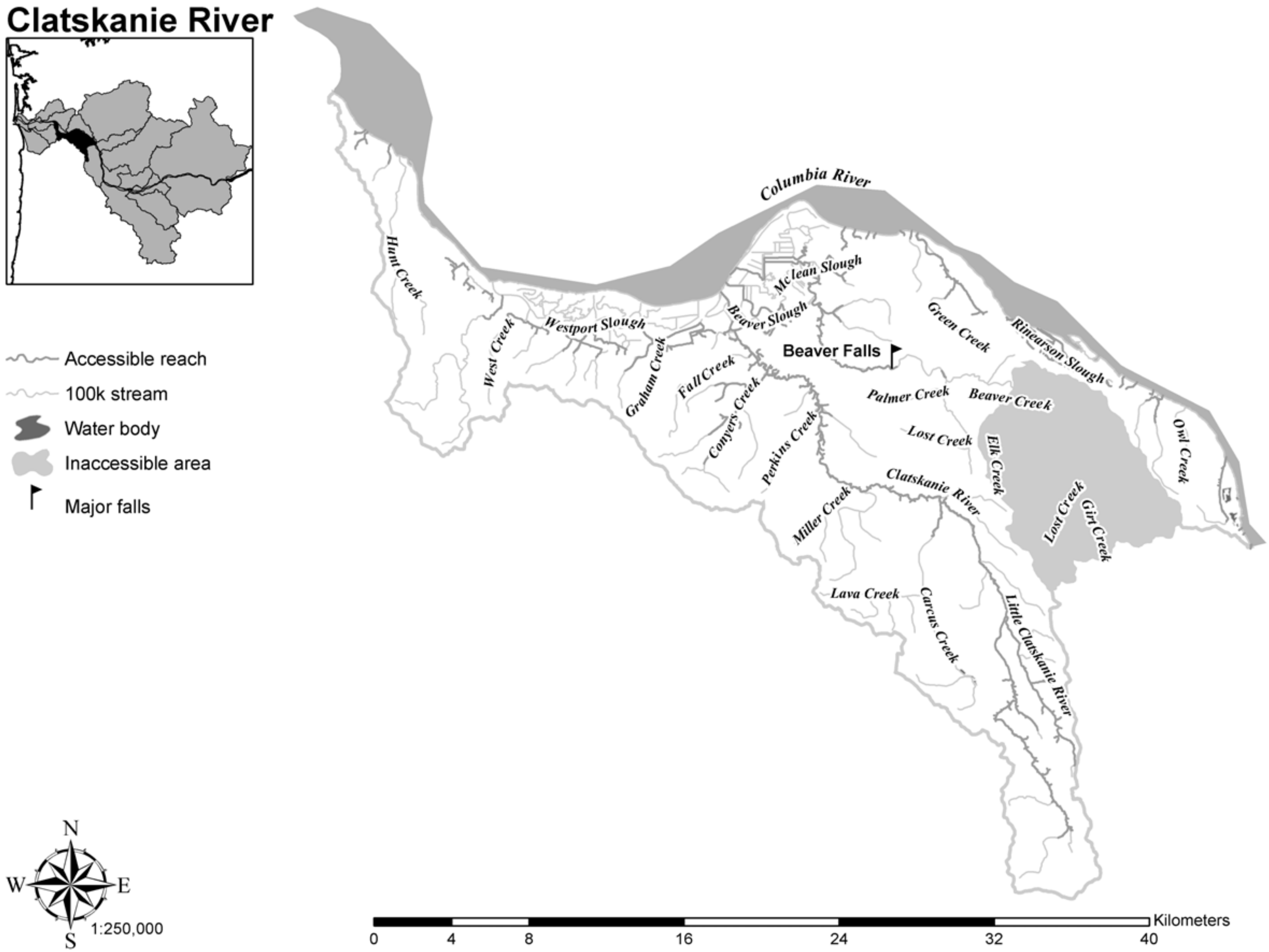


Figure E-100. Historical accessibility of chum salmon to the Clatskanie River.

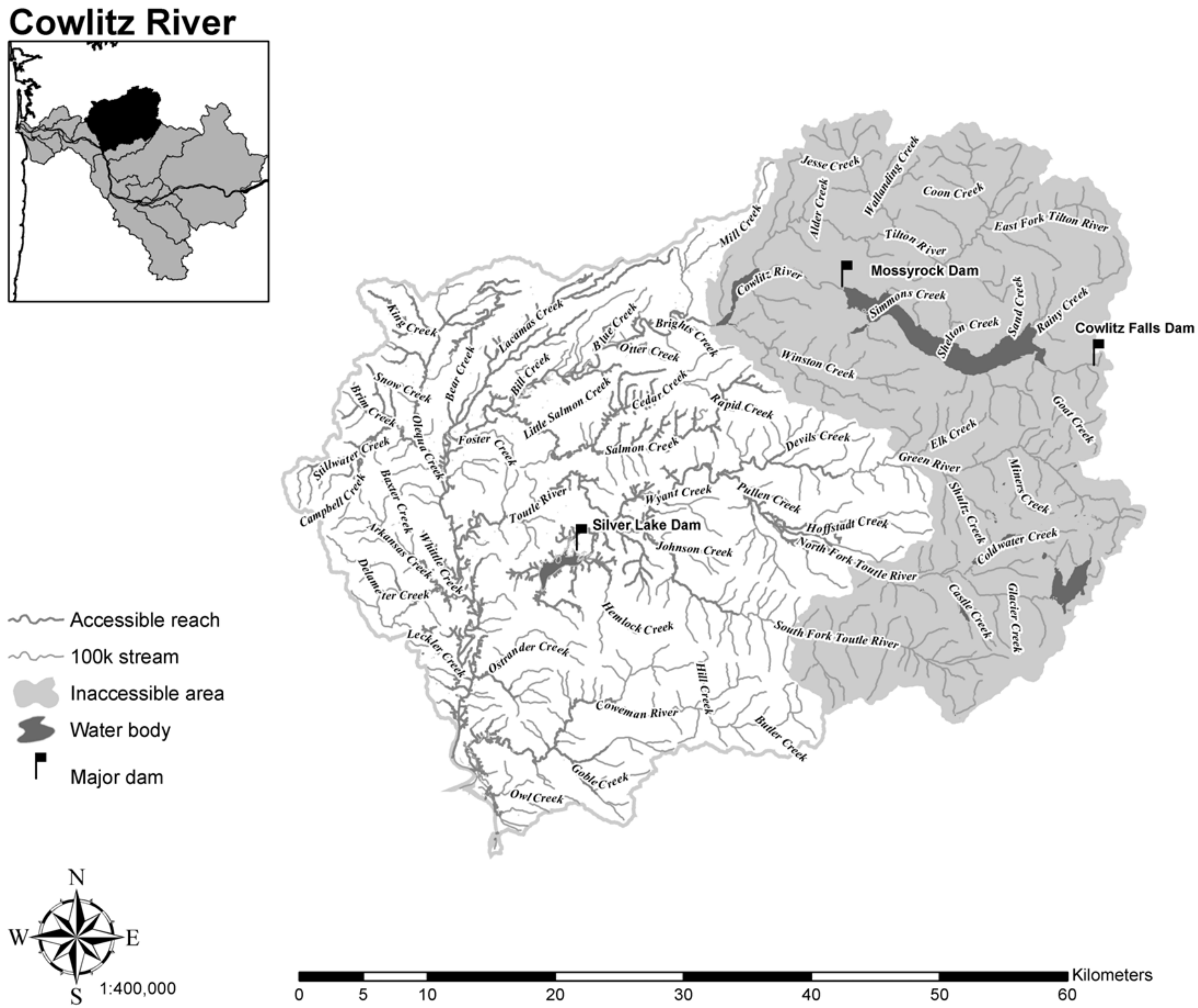


Figure E-101. Historical accessibility of chum salmon to the Cowlitz River.

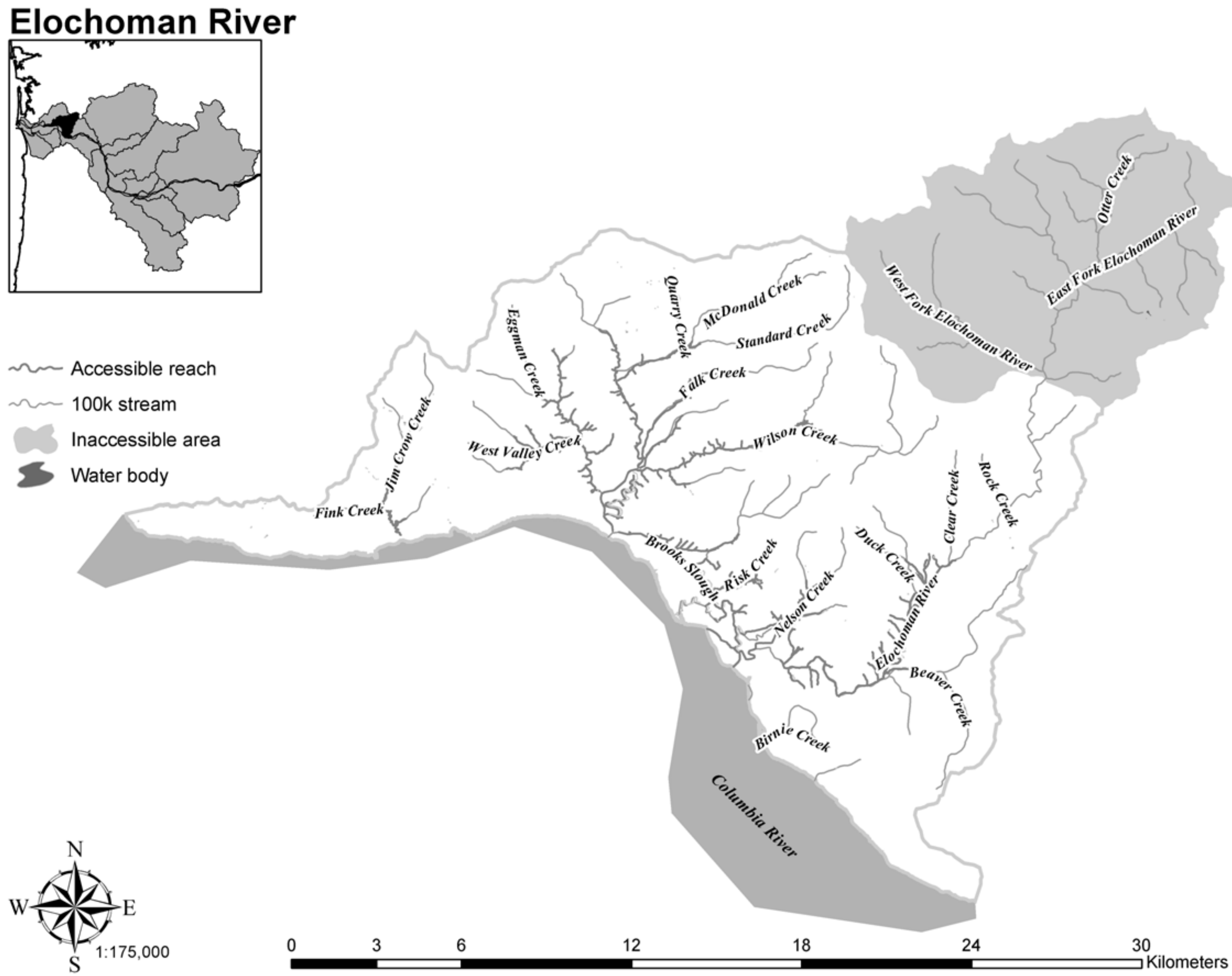


Figure E-102. Historical accessibility of chum salmon to the Elochoman River.

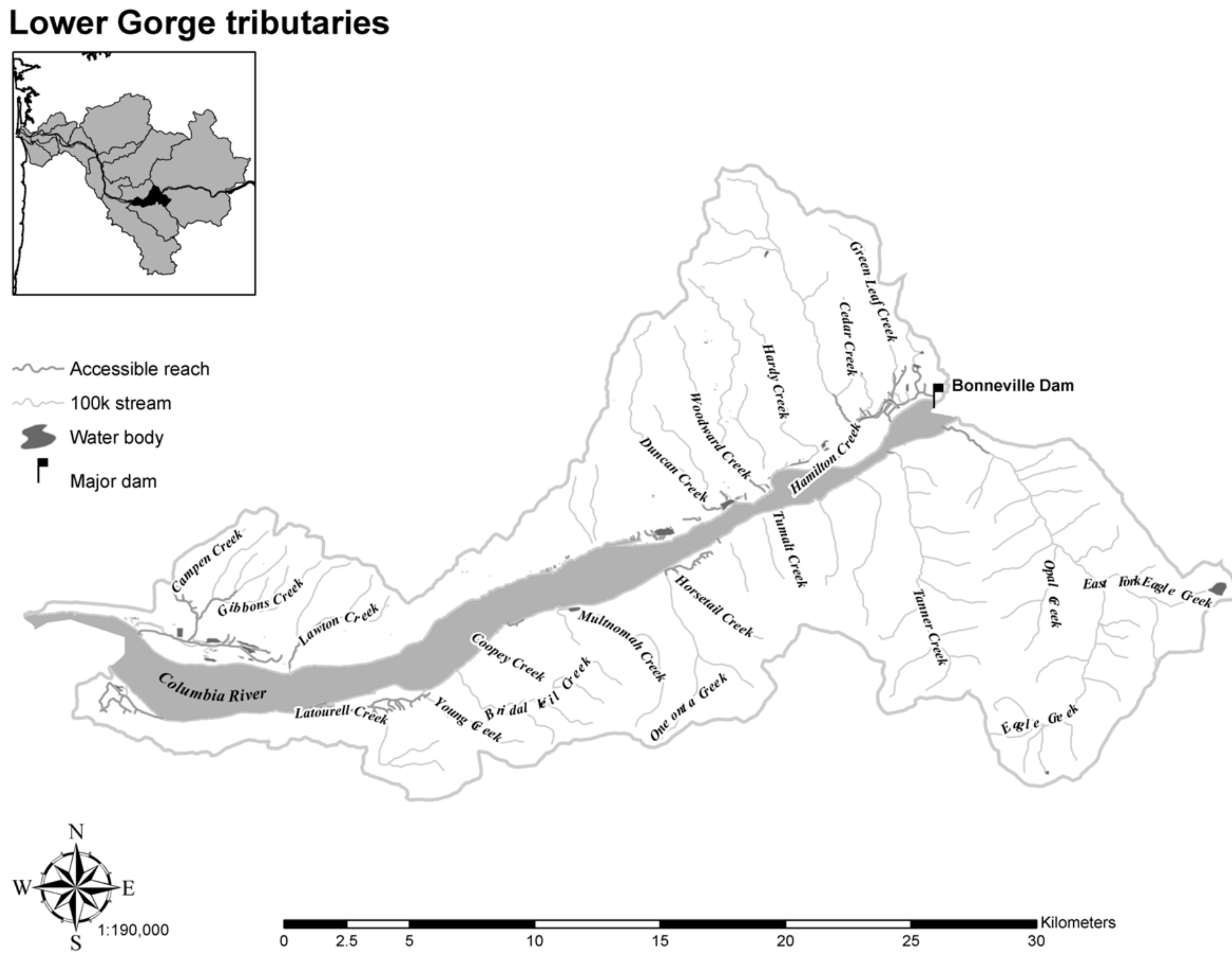


Figure E-103. Historical accessibility of chum salmon to the Columbia River lower Gorge tributaries.

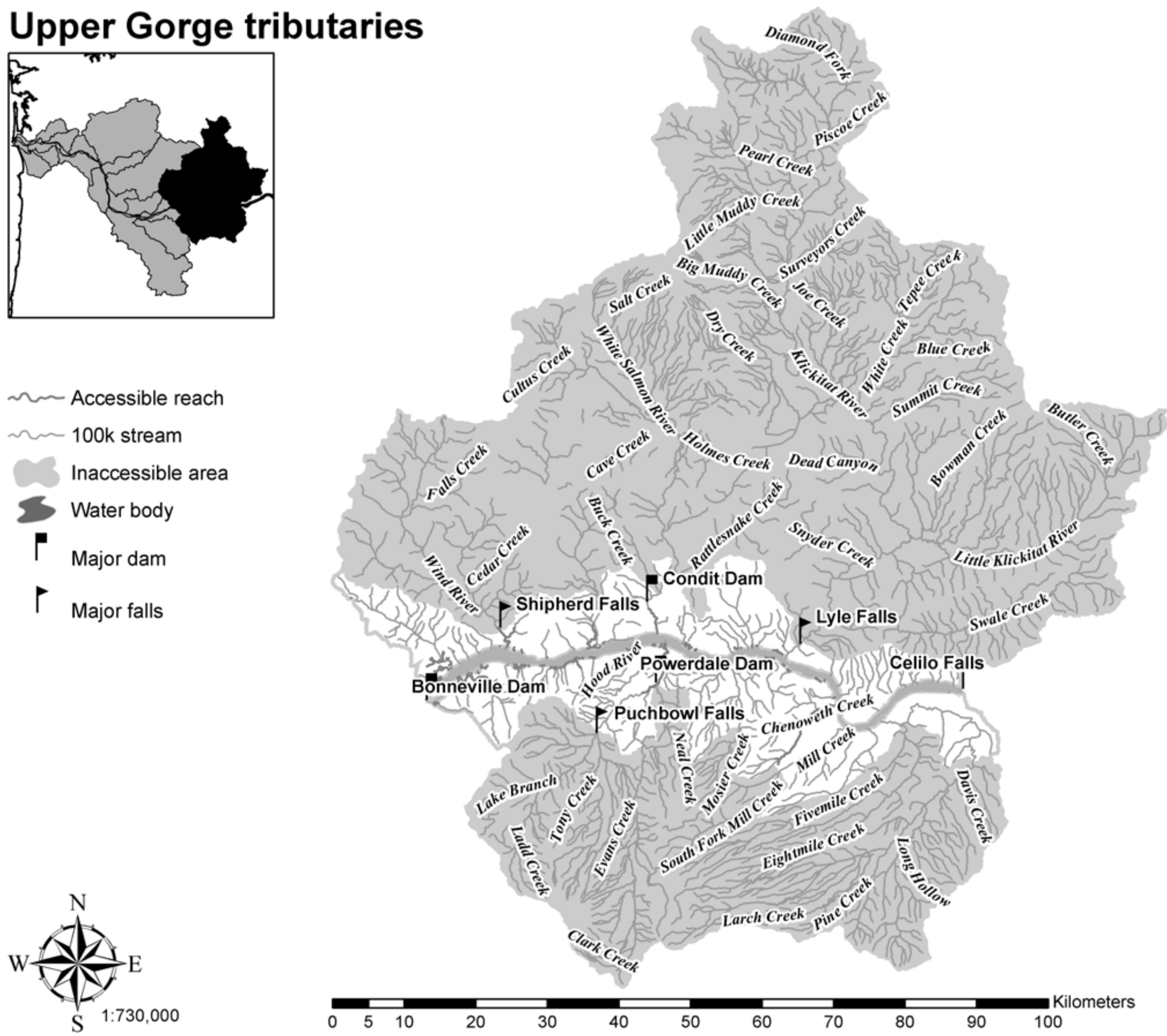


Figure E-104. Historical accessibility of chum salmon to the Columbia River upper Gorge tributaries.

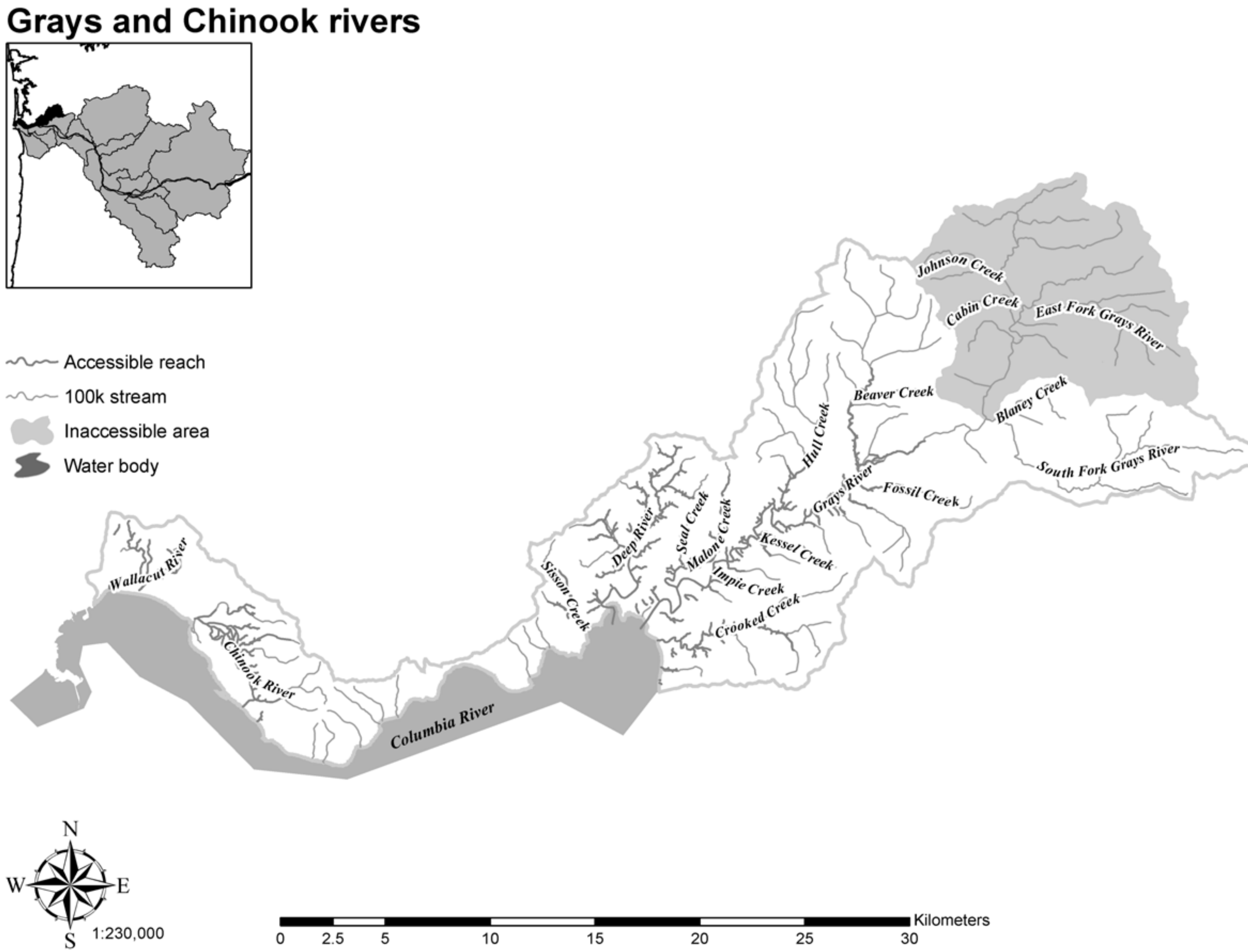


Figure E-105. Historical accessibility of chum salmon to the Grays and Chinook rivers.

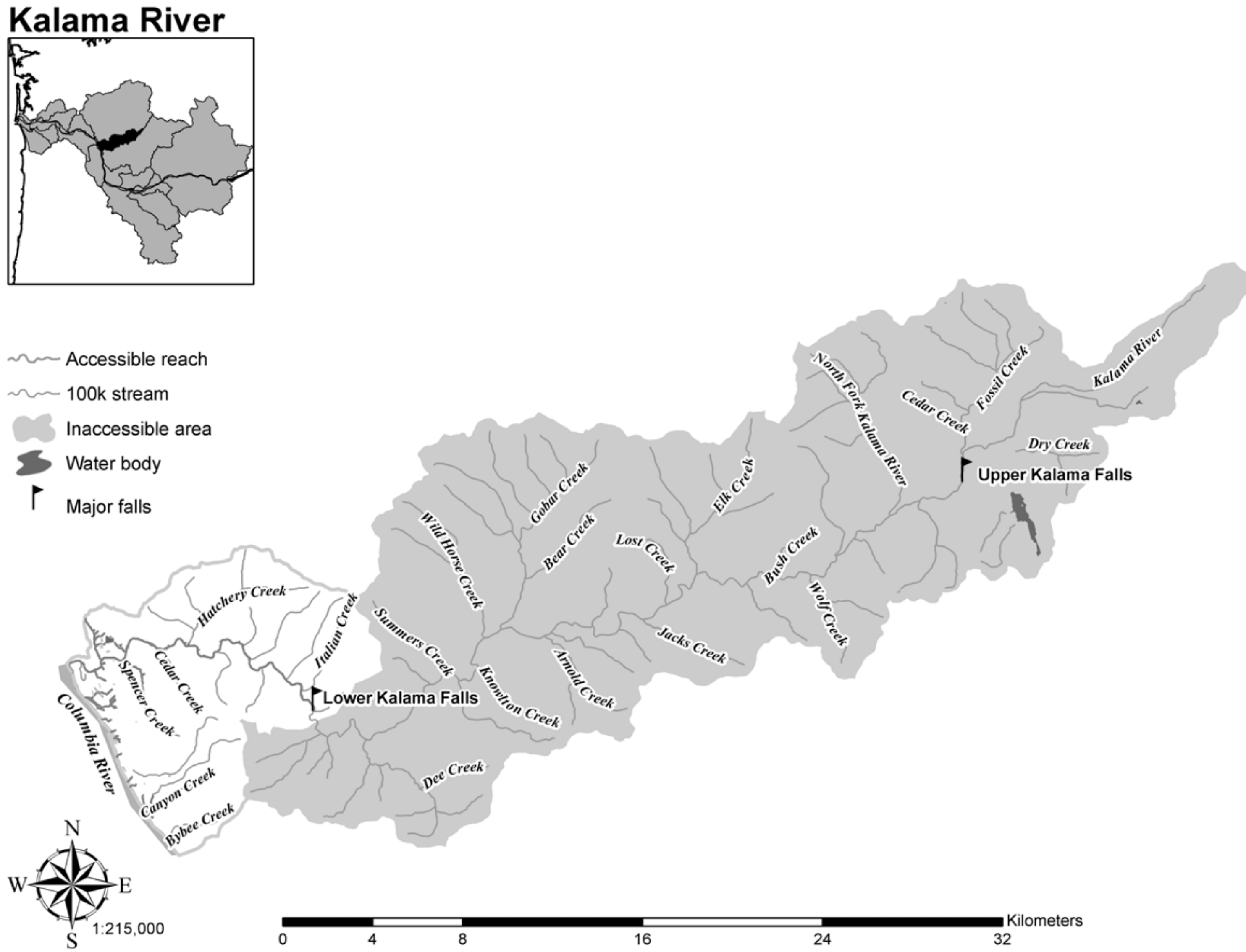


Figure E-106. Historical accessibility of chum salmon to the Kalama River.

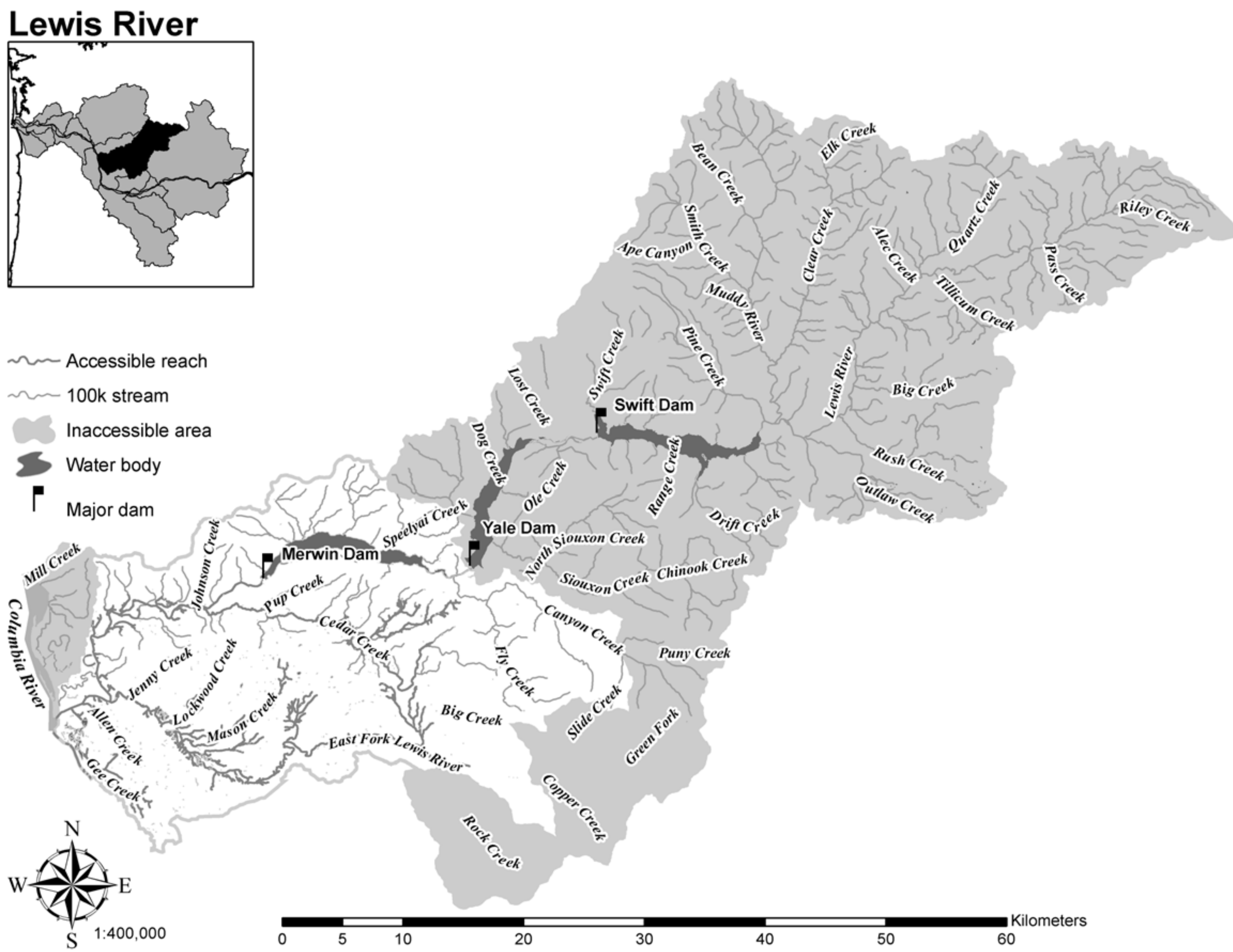


Figure E-107. Historical accessibility of chum salmon to the Lewis River.

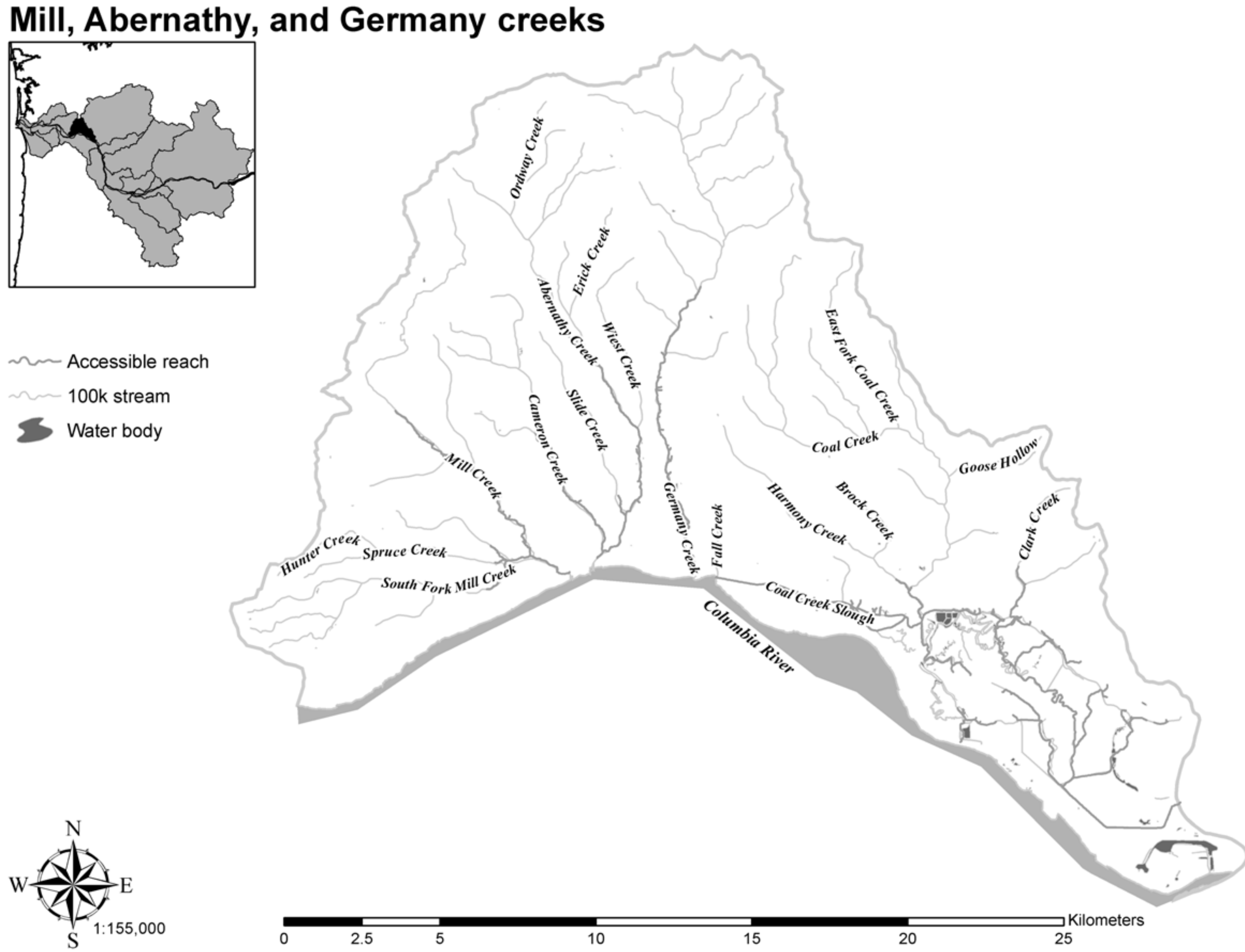


Figure E-108. Historical accessibility of chum salmon to Mill, Abernathy, and Germany creeks.

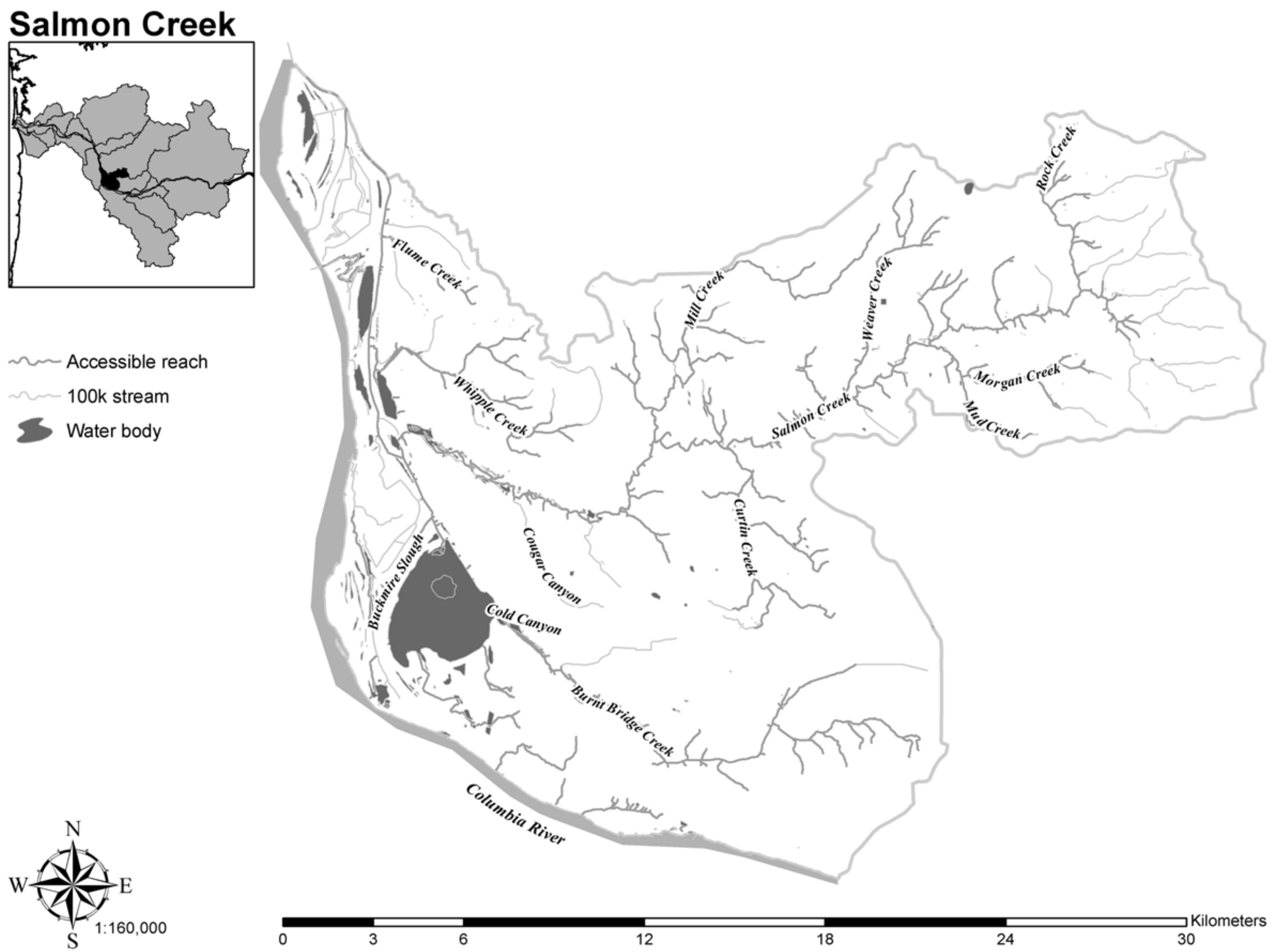


Figure E-109. Historical accessibility of chum salmon to Salmon Creek.

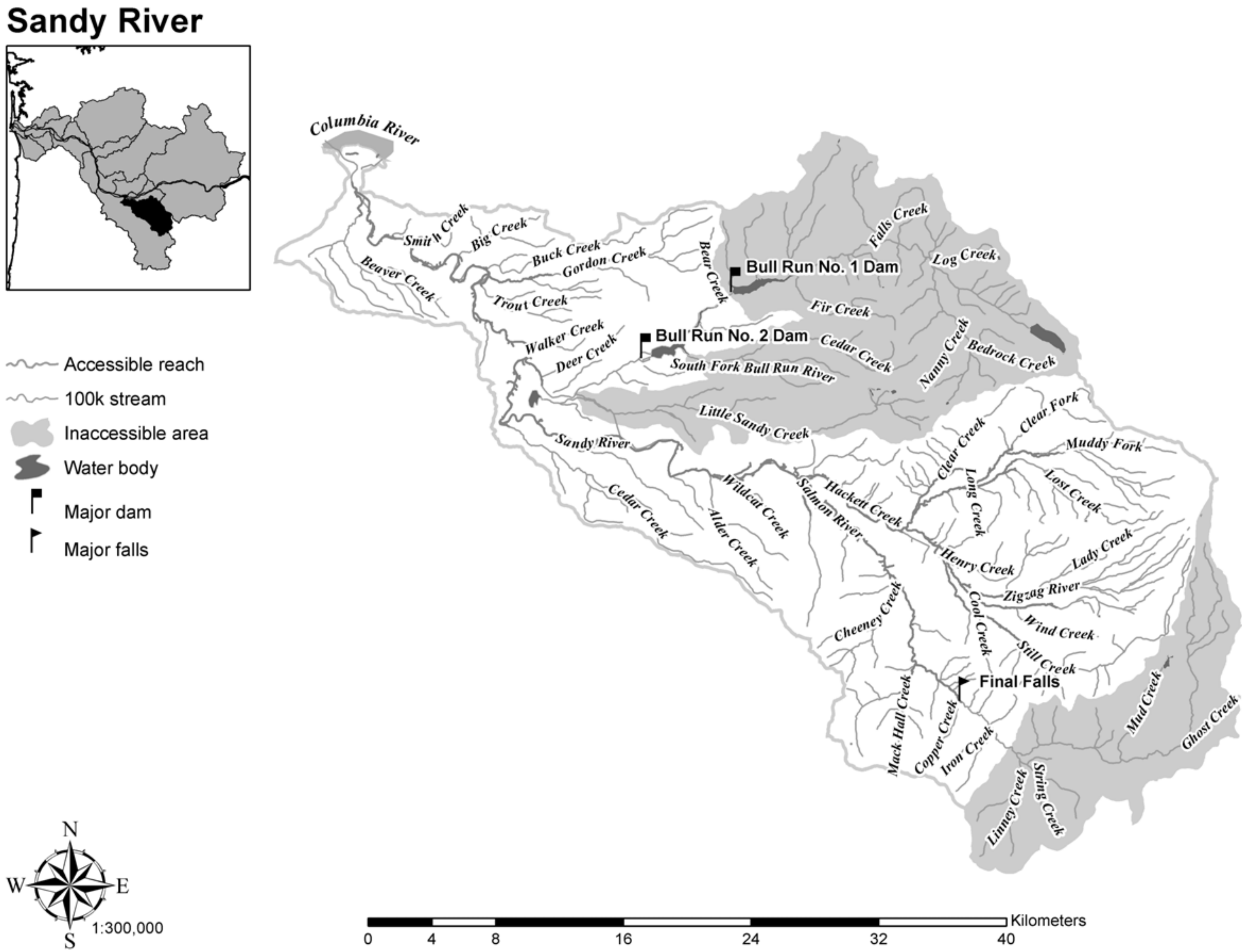


Figure E-110. Historical accessibility of chum salmon to the Sandy River.

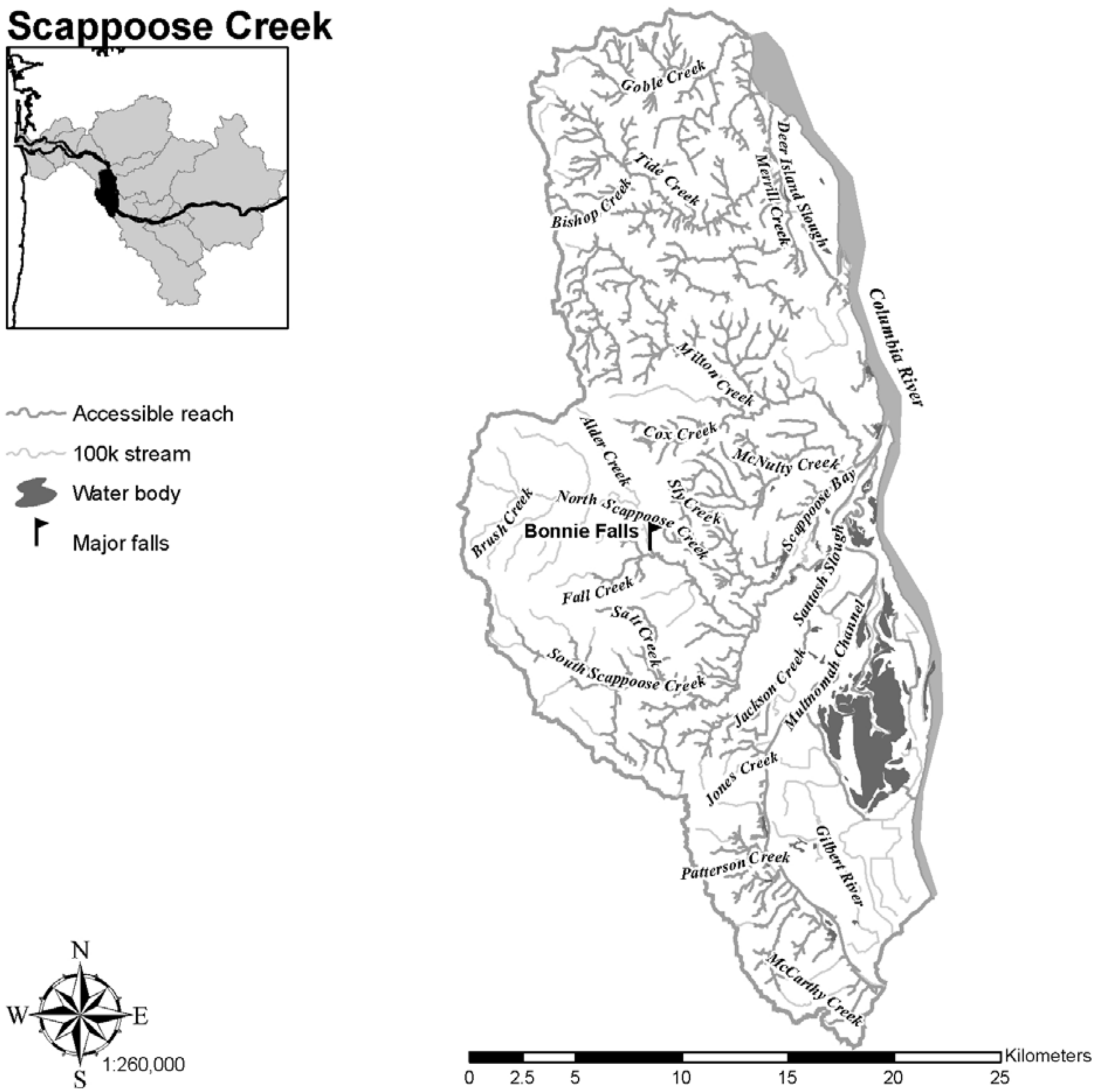


Figure E-111. Historical accessibility of chum salmon to the Scappose Creek.

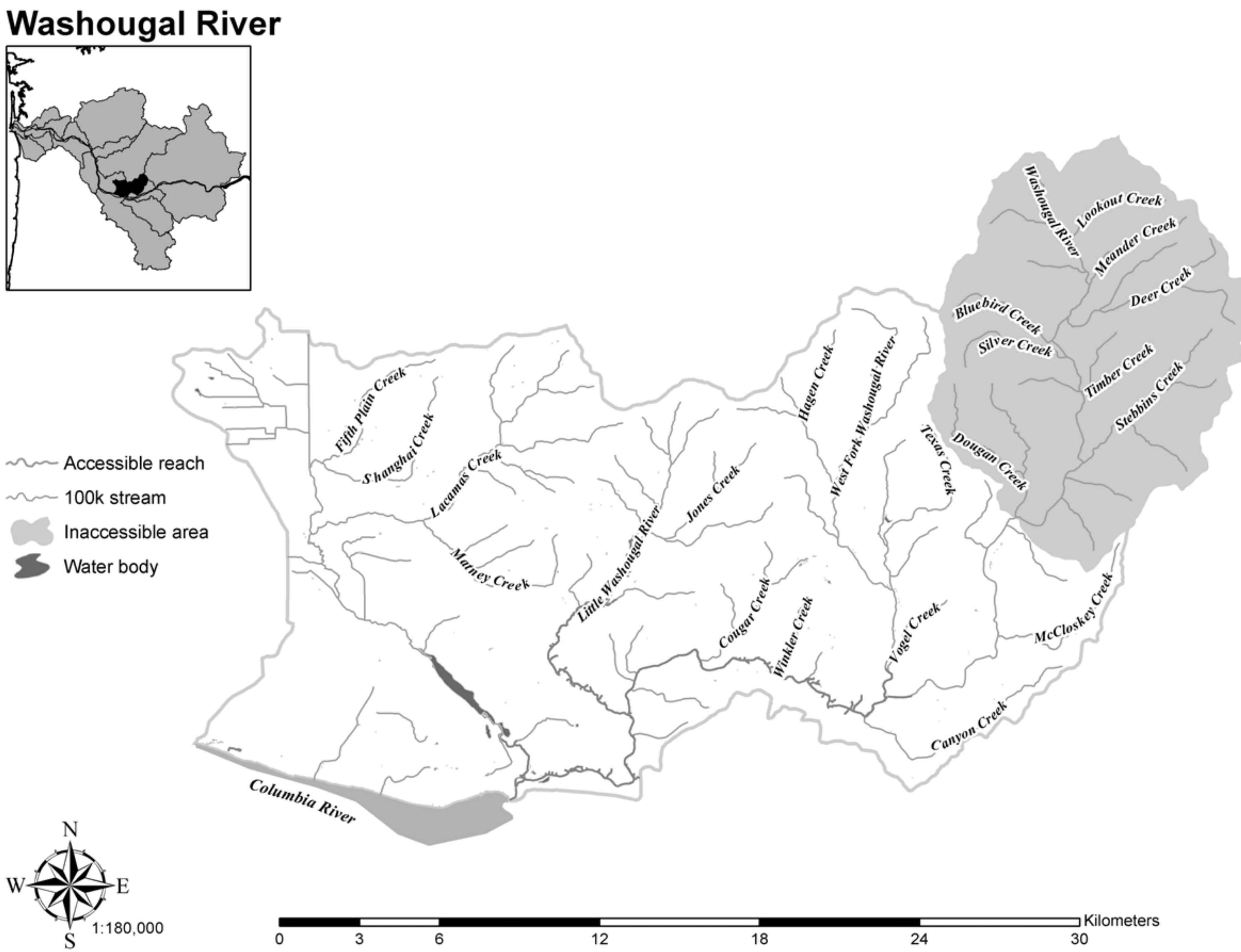


Figure E-112. Historical accessibility of chum salmon to the Washougal River.

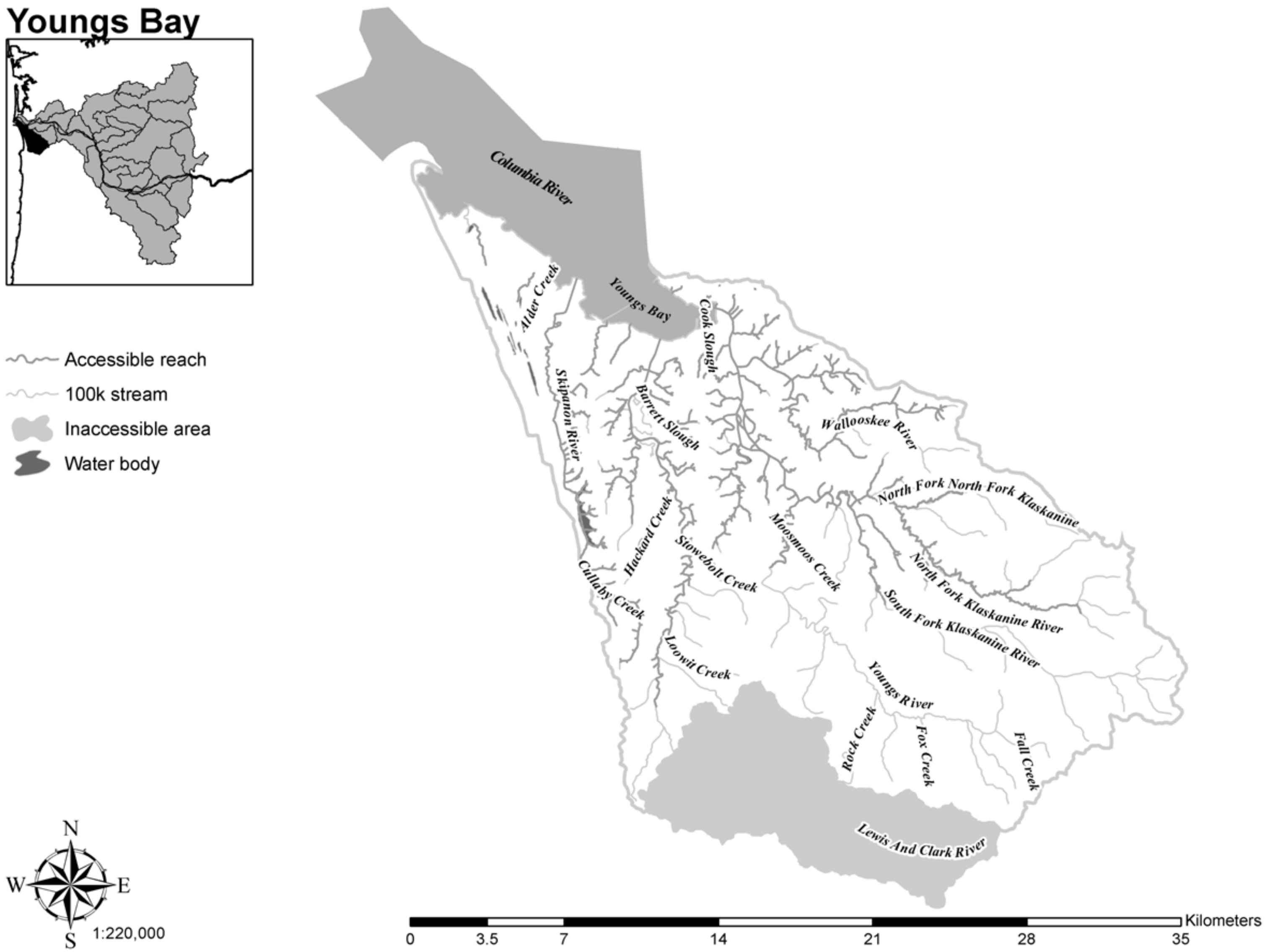


Figure E-113. Historical accessibility of chum salmon to Youngs Bay.

Recent NOAA Technical Memorandums NMFS
published by the
Northwest Fisheries Science Center

NOAA Tech. Memo.
NMFS-NWFSC-

72 **Keller, A.A., E.L. Fruh, K.L. Bosley, D.J. Kamikawa, J.R. Wallace, B.H. Horness, V.H. Simon, and V.J. Tuttle. 2006.** The 2001 U.S. West Coast upper continental slope trawl survey of groundfish resources off Washington, Oregon, and California: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-72, 175 p. NTIS number pending.

71 **Nash, C.E., P.R. Burbridge, and J.K. Volkman (editors). 2005.** Guidelines for ecological risk assessment of marine fish aquaculture. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-71, 90 p. NTIS number pending.

70 **Keller A.A., T.L. Wick, E.L. Fruh, K.L. Bosley, D.J. Kamikawa, J.R. Wallace, and B.H. Horness. 2005.** The 2000 U.S. West Coast upper continental slope trawl survey of groundfish resources off Washington, Oregon, and California: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-70, 163 p. NTIS number pending.

69 **Fresh, K.L., E. Casillas, L.L. Johnson, and D.L. Bottom. 2005**. Role of the estuary in the recovery of Columbia River basin salmon and steelhead: An evaluation of the effects of selected factors on salmonid population viability. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-69, 105 p. NTIS number pending.

68 **Bottom, D.L., C.A. Simenstad, J. Burke, A.M. Baptista, D.A. Jay, K.K. Jones, E. Casillas, and M.H. Schiewe. 2005.** Salmon at river's end: The role of the estuary in the decline and recovery of Columbia River salmon. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-68, 246 p. NTIS PB2006-101123.

67 **Holmes, E.E., W.F. Fagan, J.J. Rango, A. Folarin, J.A. Sorensen, J.E. Lippe, and N.E. McIntyre. 2005**. Cross validation of quasi-extinction risks from real time series: An examination of diffusion approximation methods. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-67, 37 p. NTIS number pending.

66 **Good, T.P., R.S. Waples, and P. Adams (editors). 2005.** Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-66, 598 p. NTIS PB2005-110650.

65 **Fleischer, G.W., K.D. Cooke, P.H. Ressler, R.E. Thomas, S.K. de Blois, L.C. Hufnagle, A.R. Kronlund, J.A. Holmes, and C.D. Wilson. 2005.** The 2003 integrated acoustic and trawl survey of Pacific hake, *Merluccius productus*, in U.S. and Canadian waters off the Pacific coast. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-65, 45 p. NTIS PB2005-110651.

Most NOAA Technical Memorandums NMFS-NWFSC are available online at the Northwest Fisheries Science Center web site (http://www.nwfsc.noaa.gov).