

# An Evaluation of Fresh Water Recoveries of Fish Released from National Fish Hatcheries in the Columbia River Basin, and Observations of Straying

STEPHEN M. PASTOR

*U.S. Fish and Wildlife Service  
9317 Highway 99, Suite I, Vancouver, Washington 98665, USA*

*Abstract.*—Approximately 80 million anadromous salmonids with coded-wire tags have been released from national fish hatcheries in the Columbia River basin. The U.S. Fish and Wildlife Service operates fish hatcheries throughout the basin, many of which are located hundreds of miles from the ocean. Spring Chinook salmon *Oncorhynchus tshawytscha* is the most widely raised species. Coho salmon *O. kisutch*, steelhead *O. mykiss*, and both tule and upriver bright fall Chinook are raised at fewer locations, with fall Chinook being raised only in the lower basin. Releases have produced over one hundred thousand observed recoveries, seventy-five thousand of which were in the Columbia River basin. Although tagging was initially inconsistent, practically all groups of fish released since brood year 1989 have been coded-wire tagged. In spite of uncertainties in the coding of recovery locations, and inconsistencies in the sampling and reporting of returning coded-wire tagged fish, recovery patterns can be distinguished.

## Introduction

Fish released from national fish hatcheries in the Columbia River basin generally have a high fidelity when returning to spawn, although there are notable exceptions. Recoveries in freshwater outside of the Columbia River basin are extremely rare. The location of a hatchery relative to the main stem of the Columbia River is an important determinant of the recovery pattern, both for fish from that hatchery and for fish migrating by or near that hatchery. Spring Chinook from hatcheries in the Snake River basin are recovered in smaller basins located further up the Columbia River than the Snake River, while spring Chinook from those same basins are not recovered in the Snake River basin. Natural and artificial barriers, and other features, are also important in determining recovery patterns.

More than 43 million coded-wire tagged fish have been released during the brood years considered in this paper, resulting in less than one thousand recoveries in dead fish and spawning ground surveys.

The U.S. Fish and Wildlife Service raises anadromous salmonids at national fish hatcheries (NFH) located in three states (Washington, Oregon, and Idaho) throughout the Columbia River basin (Figure 1). Most of these hatcheries are located hundreds of miles from the ocean, requiring fish to migrate hundreds of miles

and pass many tributaries to return to the releasing hatchery. Spring Chinook salmon *Oncorhynchus tshawytscha* is the most widely raised species. Coho salmon *O. kisutch*, steelhead *O. mykiss*, and both Tule and upriver bright fall Chinook are raised at fewer locations, with fall Chinook being raised only in the lower basin. Most of these hatchery production programs have been ongoing for decades and were initiated in response to the damming of the Columbia River and its tributaries. Quinn (1991) wrote of the Columbia River basin that “the natural production of the entire basin is also sampled for coded wire tag,” and “The extensive tagging and sampling make this system well suited for studies of homing patterns.”

None of the coded-wire tagged fish discussed in this paper were raised at one hatchery and released at another location. Although the routine coded-wire tagging of fish to assess the total contribution of all production fish did not begin until the late 1980s, earlier coded-wire tagging for specific studies should represent the migratory behavior of all returning fish.

Although a “stock assessment” is prepared annually for all coded-wire tagged fish released from national fish hatcheries in the Columbia River basin, that assessment presents a summarized version of recovery information, rather than considering specific recovery

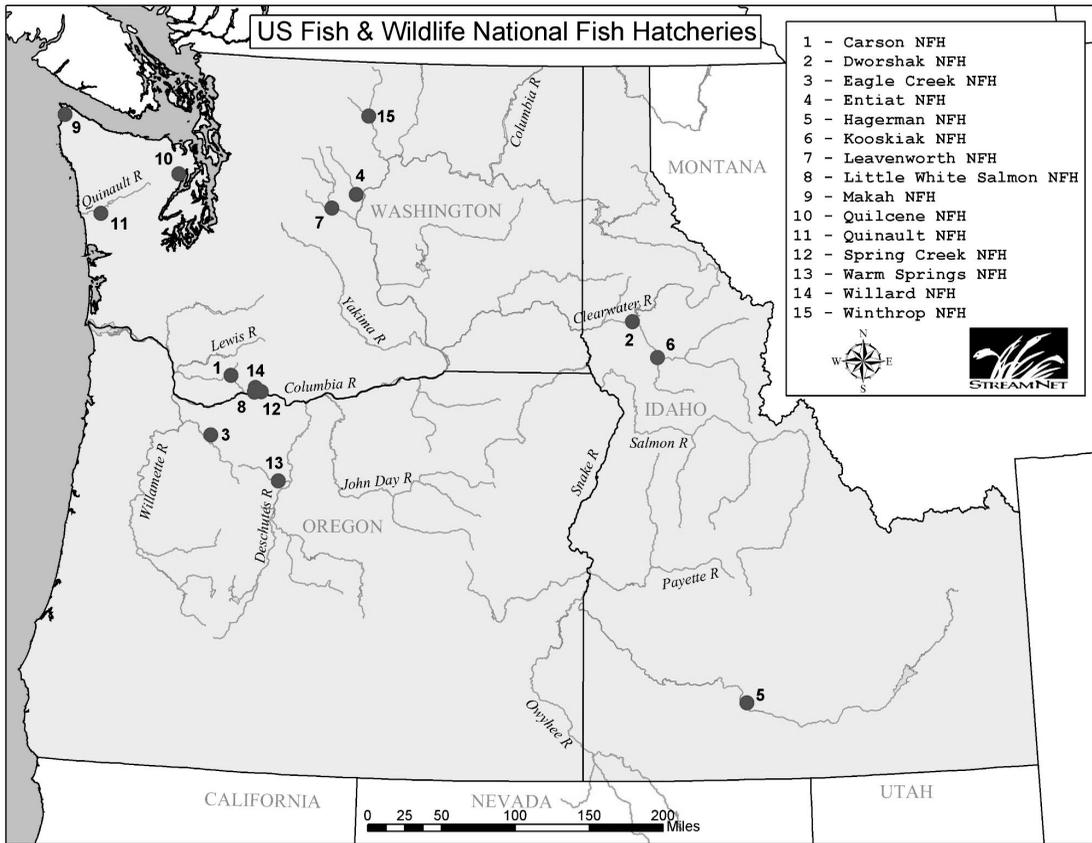


Figure 1. U.S. Fish and Wildlife Service national fish hatcheries in the Pacific Northwest

locations. This is the first comprehensive accounting of recoveries with an emphasis on recovery locations.

## Methods

Lists of coded-wire tags released from national fish hatcheries were created from database files in the Columbia River information System (CRiS), a U.S. Fish and Wildlife Service database, which contains information from, and related to, national fish hatcheries in the Columbia River basin. Coded-wire tag recovery information was obtained March through August of 2002 from the Regional Mark Information System (RMIS) coded-wire tag database administered by the Pacific States Marine Fisheries Commission. There are 82 state, federal, Indian, and private entities in the United States and Canada presently participating in the coastwide coded-wire tagging effort to provide this essential data for the conservation and management of Pacific salmonid stocks.

The following fields of information were down-

loaded from the RMIS coded-wire tag database: tag code, run\_year, recovery\_site\_code, and est\_num. Each downloaded record represents an actual, or observed, recovery. Values in the est\_num field are currently defined as the “estimated number of fish in the catch represented by this tag recovery.” These estimated numbers of fish are also referred to as expanded recoveries.

Additional queries for dead fish and spawning ground survey recoveries (fishery codes 65 and 54) were performed in April of 2003. Marine recoveries are outside the purview of this paper. Detail oriented readers may note inconsistencies between the data sets, since new recoveries are added to the database at any time.

Spring Chinook and coho salmon discussed in this paper were released as yearlings at the hatchery where they were raised. The sole exception to this is at Warm Springs NFH, which allows a volitional release in the fall. Tule and upriver bright fall Chinook were released in the spring of their first year.

I have chosen to use the term “on route” rather than “en route” since “en route” may be defined as “on

the way.” “On route” is a shortening of “on the route” and is a more precise term than “en route,” given the lack of precision regarding the future behavior of intercepted fish. We can easily identify the rivers and streams from the ocean to the hatchery. This is the route to the hatchery for migrating salmon. We know from recovery codes where fish were recovered and whether or not the recovery was on the route. We cannot know, however, where a fish intended to go. Recoveries made somewhere other than “on route” were “off route.”

The term “interception” is used to describe the recovery of a fish, which makes further migration impossible. Examples of interceptions are fish that are killed in hatchery spawning operations or taken in a sport or other fishery. The author is under no illusion that all returning fish with coded-wire tags have been observed and entered in the RMIS coded-wire tag database and wishes to emphasize that this database is the sole source of recovery information on which this paper is based.

## Results

### *Carson NFH Spring Chinook*

Carson NFH (Figure 1) is located 13 mi northwest of Carson, Washington, at the confluence of the Wind River and Tyee Springs at 1,180 ft above sea level. Fish returning to Carson NFH must swim through 154.5 mi of the Columbia River and 18 mi of the Wind River. Bonneville Dam on the Columbia River and the Wind River Fish Passage structure at Shipperd Falls (river mile 2.1) are on the route to the hatchery. Returning fish cannot pass further up Tyee Springs, but can continue up the Wind River.

From 1955 through 1964, approximately 500 spring Chinook salmon were trapped annually at Bonneville Dam, transported to Carson, and spawned there. The progeny of those adults continue to be raised and released at Carson NFH and are referred to as the “Carson stock.” Recently collected genetic data indicate that these fish are a mixture of upper Columbia and Snake River populations (Don Campton, U.S. Fish and Wildlife Service, unpublished data).

Except for brood years 1986 and 1987, coded-wire tagged fish have been released from Carson since brood year 1982. Through brood year 1998, a total of 5,147,896 tagged fish have been released along with a total number of 33,119,553.

A total of 92.5% of all recoveries were on the route to, or at, Carson NFH. Fifty-two percent of all

recoveries were at Carson NFH. The greatest number of off route recoveries were at Drano Lake, in the Little White Salmon River, and at the Little White Salmon NFH. The Little White Salmon River is 7.5 mi upstream from the Wind River, and Little White Salmon NFH is 0.9 mi from the Columbia River. These recoveries represent 7.2% of the recoveries for fish from Carson NFH. The Big White Salmon River, which enters the Columbia about 14 mi above the Wind River, attracted 0.15% of all recoveries. Recoveries also occurred in the Kalama River (0.07%), in the Deschutes River (0.03%), and in the John Day Pool (0.07%). Carson NFH releases resulted in a total of 30 observed recoveries in dead fish and/or spawning ground surveys, all of which were in the Wind River. Expanding these observed recoveries for fish not sampled yields a total of 136 fish. Although these fish did not return to the hatchery, they did return to the Wind River, where they were (had been) released.

### *Little White Salmon NFH Spring Chinook*

Little White Salmon NFH is located on the Little White Salmon River, 12 mi east of Stevenson, Washington, at an elevation of 90 ft. Fish returning to Little White Salmon traverse 162 mi of the Columbia River, Drano Lake and a short, free flowing stretch of the Little White Salmon River. The hatchery is only 0.9 mi from the Columbia River. Bonneville Dam is about 16 mi below the mouth of Little White Salmon River and is the only dam between the ocean and Little White Salmon NFH. Upstream migration above the hatchery is blocked by a waterfall.

Spring Chinook at Little White Salmon NFH are derived from a handful of different sources brought to the hatchery from the mid-1960s through the mid-1970s. For example, the majority of brood year 1971 fish released were from Eagle Creek NFH. The present stock is, nevertheless, considered a derivative of the Carson stock. Part of the 1995 brood included adult fish trapped on the Big White Salmon River. These fish which were most likely progeny of Carson stock reared and released at Big White Salmon ponds.

Except for brood years 1985 through 1987, and 1990, coded-wire tagged fish were released with each brood year since 1982. Through brood year 1997, there were 1,007,738 tagged fish among the 9,157,902 yearling fish released at the hatchery.

A total of 98.9% of the estimated recoveries of Little White Salmon NFH spring Chinook released at the hatchery as yearlings were recovered either at the hatchery or on the route to it. A total of 0.62% of

recoveries were in the Wind River, 7.5 mi down the Columbia River from the mouth of the Little White Salmon River, and 0.35% of the recoveries were in the Big White Salmon River 6.3 mi above the Little White Salmon River. There were two recoveries of Little White Salmon NFH-tagged spring Chinook at other national fish hatcheries: one each at Leavenworth NFH, 354 mi upstream in the Columbia River basin, and at Warm Springs NFH in the Deschutes River basin. There were eight (observed) recoveries of Little White Salmon NFH spring Chinook in dead fish and spawning ground surveys. Seven of those recoveries were in Drano Lake, created by Bonneville Dam where the Little White Salmon River flows into the Columbia. The estimated number for these recoveries in Drano Lake is 30 fish. One recovery was reported from the Big White Salmon River, 6.3 mi upstream of the Little White Salmon River, with an estimated recovery of 10 fish.

### *Warm Springs NFH Spring Chinook*

Warm Springs NFH is located on the Warm Springs River, approximately 14 mi north of Warm Springs, Oregon at 1,525 ft above sea level. A fish returning to the hatchery must swim 204.1 mi up the Columbia River, 84 mi up the Deschutes River, and 10 mi up the Warm Spring River. Bonneville Dam and The Dalles Dam in the Columbia River must be negotiated. All fish migrating up the Warm Springs River must pass through Warm Springs NFH.

The Warm Springs spring Chinook run is unique among National Fish Hatchery spring Chinook brood stocks in the Columbia River basin. This is the only stock derived from, and continually interbred with, the stock of fish endemic to the river on which the hatchery is located. The Warm Springs program is also unique in that, except for brood years 1980 through 1986, all released fish were coded-wire tagged. In all, 7,102,600 tagged fish released have been released through and including brood year 1997. Another distinguishing feature of the program is the release of fish in the fall of the year. These fall-released fish cannot be distinguished from yearling fish released the following spring, since they have the same tag codes.

Two-hundred twelve fish (1.72% of total recoveries) swam by the Warm Springs River and were intercepted 16 and 19 mi further up the Deschutes River at Pelton Dam and the Round Butte Trap. Seventeen recoveries were reported in the Wind River (0.15% of total recoveries). Two fish were recovered at the Klickitat Hatchery 44 mi off the Columbia River and three recoveries were reported in the lower

Willamette River Boat fishery. Ninety-eight percent of recoveries were on the route to, or at Warm Springs NFH.

There has only been one recovery in a dead fish or spawning ground survey. This fish was in the Deschutes River, down stream from the hatchery.

### *Leavenworth NFH Spring Chinook*

Leavenworth NFH is located about four miles south of Leavenworth, Washington, along Icicle Creek, a tributary to the Wenatchee River. Elevation is 1,155 ft. Fish returning to Leavenworth NFH must swim through 468 mi of the Columbia River, 30 mi of the Wenatchee River, and 3 mi of Icicle Creek, a total of 501 mi. Fish must also pass over seven dams on the Columbia River, and one dam on the Wenatchee River. Spring Chinook raised and released at Leavenworth are derived from Carson stock. Over 23 million eggs were transferred to Leavenworth from the Carson and Little White Salmon hatcheries from 1970 through 1986.

There were a total of 22,222,896 yearling fish released from brood year 85 through brood year 1996, along with 3,165,846 tagged fish. A total of 3,172 fish with coded-wire tags were recovered at Leavenworth NFH. An expanded number of 522 fish were intercepted in Icicle Creek, and 260 in the Wenatchee River. Another 578 expanded recoveries occurred in various fisheries in the main stem of the Columbia River for a total of 4,532.

Within the Wenatchee River basin a total of 12 expanded recoveries were made further up the Wenatchee River than Icicle Creek. Other fish that were recovered off route include one each at Entiat NFH and Winthrop NFH. Two other fish were recovered at the Pelton Dam at river mile 102.8 on the Deschutes River. Eight expanded recoveries occurred at Wells Dam, located 46.7 mi further up the Columbia River than the Wenatchee River. Little White Salmon NFH recorded two recoveries, and an expanded four recoveries were reported in the Wind River fishery. There were also five expanded recoveries in the lower Willamette River boat fishery.

Ninety-nine percent of recoveries were on route. Wenatchee River basin off route recoveries account for 0.23% of all recoveries. Fish recovered in the Wenatchee River basin above Icicle Creek represent 0.263% of recoveries. Interceptions at Wells Dam are 0.175% of all recoveries.

All spawning ground and dead fish survey recoveries were within the Wenatchee River basin. The following estimated recoveries have been reported: 61 in

Icicle Creek, 12 in Nason Creek, 2 in Peshastin Creek, 2 observations with an expansion of 0 in the White River, 2 in the Little Wenatchee, and 1 in the Chiwawa River.

### *Entiat NFH Spring Chinook*

Entiat NFH is located on the Entiat River, west of Entiat, Washington. Elevation is 980 ft above sea level. Fish returning to the hatchery swim through 483.7 mi of the Columbia River and 7.1 mi of the Entiat River. Fish must pass over eight dams. Entiat spring Chinook are derived from shipments of eggs and fish transferred from Carson NFH, Leavenworth NFH, and Little White Salmon NFH in the late 1970s, and from Winthrop NFH and Leavenworth NFH in brood years 1988, 1989, and 1994. The spring Chinook raised at all of these hatcheries is commonly referred to as Carson stock, as are the fish raised and released at Entiat.

Routine coded-wire tagging of spring Chinook at Entiat NFH did not begin until brood year 1988. A total of 3,780,922 fish with 1,054,165 tagged fish were released from brood year 1988 through brood year 1997.

There were 1,543 recoveries at the hatchery and 43 expanded recoveries in the Columbia River downstream from the Entiat River. Wells Dam, 31.4 mi up the Columbia River from the Entiat River, collected an expanded 82 coded-wire tags from Entiat NFH. There were five recoveries at Winthrop NFH and four expanded recoveries in the Chewack River, which is also referred to as the Chewuck River. These sites are in the Methow River basin further up the Columbia basin than the Entiat River.

Eight expanded recoveries were reported from the Wenatchee River basin: three at Leavenworth NFH and four at Tumwater Dam and Nason Creek. One fish was recovered at the Warm Springs NFH and two at the Cowlitz Hatchery. Although both of these hatcheries are hundreds of miles downstream from Entiat NFH, the Cowlitz hatchery is 52 mi from the Columbia River, and Warm Springs NFH is 94 mi off the route to Entiat NFH. Recoveries at Entiat NFH were 91.5% of total expanded recoveries. On route recoveries total 94%. A total of 5.4% of recoveries are further up the Columbia River basin than the Entiat River, and another 0.41% are in the Wenatchee River basin, 15 mi and one dam below the Entiat River.

Two observed recoveries, one in Nason Creek and one in the Chewuck River, a total of seven estimated recoveries, were reported in dead fish or spawning ground surveys. Nason Creek is in the Wenatchee River

basin, and the Chewuck River is a tributary of the Methow River.

### *Winthrop NFH Spring Chinook*

Winthrop NFH is situated along the Methow River, near the town of Winthrop, Washington. Elevation is 1,760 ft above sea level. Returning fish pass through 524 mi of the Columbia River with nine dams and 52.2 mi of the Methow River. The spring Chinook recoveries from the brood years discussed here are fish derived from eggs and fry received from Little White Salmon NFH, Carson NFH, and Leavenworth NFH. These fish are considered to be Carson stock. Coded-wire tagging of Winthrop spring Chinook began with brood year 1989. A total of 2,018,960 tagged fish were released along with 5,332,135 yearlings from brood year 1989 through brood year 1996.

Expanded recoveries totaled 1,270,726 of which were at Winthrop. There were another 403 recoveries in the Columbia River and 122 in the Methow River. Thus, 98.5% of total expanded recoveries were on the route to the hatchery. In 1996 and 1998, all returning spring Chinook were collected at Wells Dam because of low abundance.

Within the Methow River basin there were five expanded recoveries in the Twisp River, downstream from Winthrop, and four in the Chewack River. The Chewack River is surveyed from Falls Creek Camp Ground to Camp 4, approximately 6 mi. The Twisp River is surveyed from Mystery Br. (20.4 river miles) to Buttermilk Br. (12.7 river miles). There were also four recoveries at the Methow Fish Hatchery, approximately 1.5 mi up river from Winthrop NFH. These within basin recoveries represent 1.02% of the total expanded recoveries. There are no reported recoveries of Winthrop coded-wire tags in dead fish or spawning ground surveys.

### *Eagle Creek NFH Coho*

Eagle Creek NFH is located about 7 mi from Estacada, Oregon, at an elevation of 950 ft. Fish returning to Eagle Creek NFH must navigate 101.5 mi of the Columbia River, 20 mi of the Clackamas River, and 12.4 mi of Eagle Creek. Fish must ascend two ladders in Eagle Creek. Returning fish cannot pass above a waterfall in Eagle Creek, immediately above the hatchery.

Coho released at Eagle Creek have a mixed ancestry. This run began with the importation of large numbers of eggs from other basins. Both Sandy and Toutle River stocks have made major contributions to the

gene pool within the past 15 years. Coded-wire tagged fish were released in brood years 1979 through 1981 and brood year 1988 through 1997. A total of 11,754,899 yearling fish have been released for these brood years, 1,108,083 of which had coded-wire tags.

Notwithstanding the stock history, 99.9% of coded-wire tagged Eagle Creek coho were recovered either at the hatchery or on the route to it. There were two recoveries at Willamette Falls, 6.6 mi upstream of the mouth of the Clackamas River, and one reported recovery at each of the following sites: Bonneville Hatchery, Cowlitz Salmon Hatchery, Little White Salmon NFH, and lower Kalama Hatchery. There were no reported recoveries in dead fish or spawning ground surveys.

### *Willard NFH Coho*

Willard NFH is situated 4 mi upstream of Little White Salmon NFH on the Little White Salmon River at an altitude of 900 ft and is part of the Little White Salmon NFH complex. Coho returning to the complex traverse 162 mi of the Columbia River, Drano Lake, and a short, free-flowing stretch of Little White Salmon River and are trapped and spawned at Little White Salmon NFH. The list of eggs brought into, and released from, the Little White Salmon/Willard complex is too lengthy to recount here, but managers considered it to be dominated by Toutle River stock.

Brood years 1981 and 1982 were coded-wire tagged, and tagged fish have been released routinely beginning with brood year 1988. Total release of yearling coho for brood years 1981 and 1982 and brood years 1988 through 1998 is 28,090,117, including 1,625,259 coded-wire tagged fish.

A total of 95.2% of all estimated recoveries were on a direct route to the hatchery, and 84.4% of recoveries were at Little White Salmon NFH. Bonneville and Cascade hatcheries, both of which are on the Columbia River below the Little White Salmon River, accounted for 0.9% of recoveries. The Young's Bay Net fishery, 12 mi from the mouth of the Columbia River, accounted for an additional 34 recoveries or 0.65% of total estimated recoveries.

A query for dead fish and spawning ground survey recoveries shows two recoveries in the Wind River, one each in the Little White Salmon and Big White Salmon River, one in the Duncan-Ives Island area in the Columbia River below Bonneville Dam, and one in Dog Creek just below the Little White Salmon River. Although this totals six recoveries, none has an estimated number or expanded recovery.

### *Spring Creek NFH Tule Fall Chinook*

Spring Creek NFH is located on the Columbia River at Underwood, Washington, 167 mi from the mouth of the Columbia River and 20 mi upstream of Bonneville Dam. The hatchery is mere yards away from the Columbia River at an elevation of 93 ft. Returning fish cannot pass above the hatchery. They can, however, continue up the Columbia River. The Spring Creek tule fall Chinook broodstock is derived from tule fall Chinook from the nearby White Salmon River, which is also referred to as the "Big White Salmon River" to distinguish it more clearly from the nearby Little White Salmon River. Although the use of tule fall Chinook from other locations has been extremely rare, Toutle River stock fish were used in brood year 1972. In the mid-1980s, adults and eggs were collected at Bonneville Dam, Bonneville Hatchery, Big White Salmon River, and Abernathy Salmon Culture Technology Center and used to supplement low returns of adults.

A total of 11,203,095 tagged fingerling fish were released from brood years 1979 through 1998 along with 285,627,379 total fingerlings. A total of 225 different tag codes have been released during that time.

A total of 92.7% of estimated recoveries were on the route to the hatchery with 1.2% recovered higher in the basin than the hatchery. Total number of estimated recoveries was 17,345. Recoveries in the Dalles Pool (153) made up the greatest number of these recoveries further up the Columbia River. There were 48 recoveries in the Big White Salmon River and 54 in the John Day Pool. A sole recovery of a Spring Creek tule has been reported from the Priest Rapids spawning channel, 240 mi above Spring Creek NFH. There was also one recovery in the Umatilla River, 122 mi above the hatchery. Bonneville Hatchery, at the base of Bonneville Dam and 21 mi below Spring Creek NFH, attracted 5.29% of all recoveries. The Little White Salmon River and NFH had 22 recoveries or 0.127% of all recoveries.

Off route recoveries included 35 in the Young's Bay net fishery for 0.20% of all recoveries. There were 61 other off-route recoveries below the hatchery that account for 0.31% of total recoveries. The Cascade Hatchery and the Wind River were responsible for fewer than 20 recoveries each. Spring Creek tule fall Chinook recoveries were also reported from estuaries and fresh waters outside of the Columbia River basin. The Umpqua River Estuary had the most recoveries, with 15 in the estuary and 2 in the Umpqua River. Yaquina Estuary and Coos Bay each reported four

recoveries. Two recoveries were reported from the Quinault River and one from Quinault Lake.

There have been 26 observed recoveries of Spring Creek NFH fish in the Big White Salmon River during dead fish and spawning ground surveys. Estimated recoveries total 202 fish. Observed recoveries in the Wind River correspond to an estimated number of 25 fish. A single Washougal River recovery is expanded to 15 fish, and 1 in Drano Lake is expanded to 6. There were also single observed recoveries in Plympton Creek, in the Columbia River below Bonneville Dam, and in the Kalama River, an estimated number of three fish.

### *Little White Salmon NFH Upriver Bright Fall Chinook*

The location of, and route to Little White Salmon NFH has been described previously. The upriver bright stock was developed in 1977 when migrating fall Chinook were trapped in the Bonneville Dam fish ladder, spawned, reared, released, and returned to Bonneville Hatchery. Spring Creek NFH received eggs, fry, and fingerlings from Bonneville Hatchery from brood years 1982 through 1990. Three quarters of the fish which made up the 1997 brood year release were stocks from other hatcheries. Only one coded-wire tag was released for this brood year, consisting of fish from Little White Salmon, Bonneville, Klickitat, Priest Rapids, and Umatilla hatcheries.

Consistent coded-wire tagging of Little White upriver bright fish began with brood year 1989. Prior to that, brood years 1983 through 1985 were tagged. The total number of fish released in brood years with coded-wire tags, and through brood year 1998, is 25,782,432. Within that total, there were 1,861,885 fish with coded-wire tags.

A total of 88.2% of estimated recoveries were on the route to or at the hatchery. The Youngs Bay fishery and Bonneville Hatchery accounted for 0.19%, and 0.23% of recoveries, respectively. The Cascade Hatchery and Wind River had a total of 1% of the recoveries, with the great majority of those (42 of 43) in the Wind River. Recoveries further up the Columbia River basin than the hatchery account for 10.47% of total recoveries. The Big White Salmon River, 6.3 mi upstream of the Little White Salmon River, attracted 331 of these recoveries. Two percent of total recoveries were in the two pools created by dams (Dalles Dam and John Day Dam) above the Bonneville Pool where the Little White Salmon River enters the Columbia. Recoveries more than 100 mi up the Columbia basin account for 0.394% of the recoveries. There were 13

estimated recoveries in the Hanford Reach of the Columbia and 4 in the Snake River.

Dead fish and spawning ground surveys yielded a total of 751 estimated recoveries. Five-hundred ninety-one are reported for the Big White Salmon River, 158 in the Little White Salmon River, and 42 in the Wind River.

### *Dworshak NFH Spring Chinook*

Dworshak NFH is located at the confluence of the North Fork Clearwater River and the main-stem Clearwater River about 3 mi west of Orofino, Idaho, at 1,000 ft above sea level. Returning fish pass over four Columbia River dams in the 342 mi to the Snake River, then another four dams and 224 km on the Snake River before reaching the Clearwater River. The hatchery is 65 km up the Clearwater River at the Clearwater River North Fork.

The spring Chinook stock consists of fish from a variety of hatcheries: Little White Salmon NFH, Leavenworth NFH, Carson NFH, and Rapid River. The Rapid River stock, from within the Snake River basin, became the predominate stock at Dworshak NFH in the late 1980s. The 1987 and 1988 release years were 100% Rapid River stock. Information for brood years 1986 through 1993 was downloaded from RMIS. A total of 10,565,695 yearling fish were released, including 3,834,522 fish with coded-wire tags.

A total of 71% of recoveries were on route, much lower than for the three upper Columbia River basin spring Chinook-producing hatcheries in Washington. Fish released at Dworshak NFH are recovered in that part of the Columbia River basin, however, often enough to be 7.3% of total recoveries. This is in marked contrast to the fact that there have been no recoveries of spring Chinook released at the three national fish hatcheries in the upper Columbia River basin: Leavenworth, Entiat, and Winthrop, in the Snake River basin. A total of 21% of recoveries were off route below the mouth of the Snake River, although 3.8% had barely left their route and were intercepted at locations such as Little White Salmon NFH, only 0.9 mi from the Columbia River. The Deschutes River seems especially attractive to Dworshak spring Chinook. Recoveries in this basin account for 15.2% of all recoveries. There are an estimated 11 recoveries of Dworshak NFH spring Chinook in dead fish and spawning ground surveys in the upper Columbia River basin. Nine observed recoveries in the Snake River basin lack estimated numbers and are expanded to one estimated.

### *Kooskia NFH Spring Chinook*

Kooskia NFH is situated along Clear Creek, just upstream of the confluence with the Middle Fork Clearwater River, approximately 75 mi southeast of Lewiston, Idaho, at an altitude of 1,295 ft. The route to Kooskia NFH is the same as to Dworshak NFH, but fish must continue past Dworshak NFH in the Middle Fork of the Clearwater River and swim an additional 55 km to Clear Creek and 0.64 km to the hatchery. Kooskia NFH has released spring Chinook from a variety of sources: Carson NFH, Little White Salmon NFH, Leavenworth NFH, Rapid River, and the Santiam River South Fork. Coded-wire tagged fish released in brood years 1988 and 1990 through 1993 totaled 1,239,495 among 2,834,962 fish.

On route and at the hatchery, recoveries equaled 88.6% of total recoveries. Recoveries in the Deschutes River basin account for 5.3% of the total, and 4.3% of all recoveries were in Columbia River (specifically Wells Dam) and tributaries above the confluence with the Snake River. Only 0.4% of the total recoveries were from locations that were a significant distance from the Columbia River: one each from Washougal and Lewis River hatcheries. A query for recoveries in dead fish and spawning ground surveys found one observed recovery with an estimated number of three in Nason Creek outside the Snake River basin.

### *Eagle Creek NFH Spring Chinook*

The location and route for these fish was described in the Eagle Creek NFH Coho section. The production and release of spring Chinook at Eagle Creek NFH ended with brood year 1990. This stock of fish was created from various sources over the 30 some years it was in existence. Yearling fish were coded-wire tagged in brood years 1983 and 1984. Only 95,480 of the total 352,000 coded-wire tagged fish released with brood year 1984 were Eagle Creek stock. The remainder were from other sources in the Willamette River basin. A total of 97.4% of all recoveries were on route. An additional 2% of all recoveries were at the Clackamas Hatchery, which returning fish must pass on their way to Eagle Creek. The Willamette Falls Ladder, 6.6 mi up the Willamette River above the mouth of the Clackamas River, was responsible for 0.5% of recoveries. Less than 1% of recoveries were reported outside the Willamette River basin. One was at Little White Salmon NFH above Bonneville dam, and three were in the Snake River basin. It should be noted that the tag codes used were agency "10" wire

used by Idaho Fish and Game, making it possible that these recoveries, which are hundreds of miles off route, are the result of erroneous reporting.

## Discussion

### *A Fish that has Strayed is Not Necessarily a Stray*

The terms "homing" and "straying" are often used in discussions of salmonid migratory and spawning behavior. The definition of a stray is, however, relative. Quinn (1997) notes a dependence "on the spatial scale of interest," and qualified the term when referring to fish which swim into, and are spawned at, a hatchery different than the releasing hatchery by using the phrase "functional stray." Although the exploratory behavior of migrating salmonids has been acknowledged, fish intercepted at dams or traps in the main stem of major rivers or in nonnatal streams have been considered to be strays (Hayes and Carmichael 2002). Although these fish have "strayed" from their route, we cannot know where they may have gone to spawn and die had they not been intercepted. Indeed, Heard (1991) wrote "Only when a fish has spawned can a judgment be made as to whether it has homed or strayed. Otherwise there is still the possibility for the fish to migrate elsewhere."

Another source of uncertainty when considering recovery location and labeling fish as strays is the fact that fish may be intercepted a short distance from the direct route to the releasing hatchery. The Drano Lake, Little White Salmon River, and Little White Salmon NFH recovery locations are an excellent example of this uncertainty. Drano Lake at the mouth of the Little White Salmon River exists because of Bonneville Dam, but is certainly not in the middle of the Columbia River, which could be considered the "direct route" to a hatchery further up the Columbia River. The free-flowing section of the Little White Salmon River is less than a mile long, and Little White Salmon NFH is 0.9 mi from the Columbia River. Although we may decide that at a certain distance from the "direct route" to the hatchery, a fish is straying, that distance and the term "stray" would be arbitrary.

It would seem possible to assign numeric values on the basis of the distance from the direct route a fish was recovered. Unfortunately, although recovery site codes can be very precise, at a hatchery for instance, they can also be very imprecise. An example of an imprecise code would be "Columbia River - Bonneville Dam to Chief Joseph Dam," a distance of 399 mi.

There are many instances where all of the recoveries in a river have one code. I have concluded that, with the limitations of the current data, the assigning of numeric values would be much too subjective, and statistical analysis of these data would, therefore, be inappropriate.

Recent publications are often concerned with the ecological risk of the straying of hatchery fish (Ham and Pearsons 2001; Hayes and Carmichael 2002). Fish spawned in hatcheries have no influence on the genetic makeup of wild fish produced by spawning, which occurs in the same year. Fish spawned or killed in hatcheries are fish that also will not influence the behavior of wild fish on spawning grounds. Fish that are recovered at other hatcheries, and are spawned there, will influence the gene pool of those hatchery populations and are functional in that sense. These fish from other hatcheries may be a concern to the hatchery broodstock managers, as they are at the Warm Springs NFH, or not, as at Little White Salmon NFH.

A rigorous definition of a stray would include only recoveries that occurred in spawning ground or dead fish surveys. Quinn (1991) wrote of spawning ground recoveries as "straying in the truest sense of the word."

### *Frequency of On Route Recoveries and Possible Influences*

Except for upriver bright fall Chinook at Little White Salmon NFH, well over 90% of recoveries from the hatcheries not located in the Snake River basin were at, or on the route to, the releasing hatchery. Carson NFH has the lowest percentage of at or on route recoveries at 92.5% (Table 1). The major nonroute re-

covery site for Carson NFH spring Chinook is the Little White Salmon River with the associated Drano Lake and Little White Salmon NFH. 7.2% of Carson NFH recoveries are at this complex of sites. A major sport fishery is located on Drano Lake, and fish entering the hatchery do not always have the option of leaving. It should also be noted that fish passage above Little White Salmon NFH is blocked by a waterfall and that the hatchery is less than a mile from the Columbia River. Adults with opercular punches returned to the Little White Salmon River from the hatchery have been recovered at Carson NFH. This supports the hypothesis that Carson fish recovered in Drano Lake, the Little White Salmon River, and Little White Salmon NFH are interceptions. Carson NFH fish spawned at Little White Salmon NFH are "functional" in that they represent a one-way gene flow from the Carson NFH population to the Little White Salmon NFH population, which is already considered to be a Carson stock. There have been no spawning ground or dead fish survey recoveries in the Little White Salmon River of fish released at Carson NFH. No fish from Little White Salmon NFH has ever been recovered at Carson NFH. I conclude that the high rate of off-route recoveries from Carson is due to the relative locations of the recovery sites rather than any inherent lack of homing ability by Carson fish.

Entiat NFH spring Chinook have the next lower percentage of on route recoveries for hatcheries not in the Snake River basin. Wells Dam is 31.4 mi up the Columbia River from the mouth of the Entiat River, but accounts for 4.9% of all estimated recoveries of spring Chinook from Entiat NFH. Only 0.2% of fish from Leavenworth NFH are recovered at Wells Dam. Leavenworth NFH is on a tributary of the Wenatchee River which flows into the Columbia River 15 mi further down stream than the Entiat River. But, Leavenworth fish swimming up the Columbia River would also have to negotiate Rock Reach Dam. It seems reasonable that the combination of a dam and an additional 15 mi would discourage Leavenworth NFH fish from proceeding to Wells Dam, unlike the Entiat fish.

Little White Salmon NFH upriver bright Chinook have the highest percentage of recoveries off the route to the hatchery. Ten percent of the total estimated recoveries were further up the Columbia River than the releasing hatchery. Nearly 80% of those recoveries are, however, in Big White Salmon River, which is 6.3 mi from the Little White Salmon River. 0.3% of total recoveries were 183 mi upstream in the Hanford Reach. An estimated four recoveries occurred in the Snake River basin, the only Snake River basin recoveries from re-

Table 1. Percent of estimated recoveries on the route to or at the releasing hatchery

National fish hatchery	Percent
Carson NFH spring Chinook	92.5
Little White Salmon NFH spring Chinook	98.9
Warm Springs NFH spring Chinook	97.8
Leavenworth NFH spring Chinook	99.2
Entiat NFH spring Chinook	94.0
Winthrop NFH spring Chinook	98.5
Dworshak NFH spring Chinook	71.0
Kooskia NFH spring Chinook	88.6
Eagle Creek Coho	99.9
Spring Creek NFH tule fall Chinook	98.0
Little White Salmon NFH upriver bright fall Chinook	88.2

leases occurring outside of this basin in this entire data set. The Carson stock of spring Chinook raised at most national fish hatcheries in the basin, and the upriver bright fall Chinook stock were both initiated by trapping fish migrating over Bonneville Dam. With the exception of brood year 1997, Little White did not receive upriver bright fall Chinook from other hatcheries. In contrast, many other sources of spring Chinook were added to the Carson stock to create the Little White spring Chinook population. Nevertheless, Little White Salmon NFH spring Chinook stay on route at a much higher rate than the upriver bright fall Chinook raised and released at Little White.

Hatcheries on or near the Columbia, and mainstem dams with active collection facilities, provide an opportunity to collect returning fish that are off the route to the releasing hatchery. Wells Dam is a good

example of this, as is Little White Salmon NFH. Table 2 shows information for three of these instances. Linear regression analysis of percent as a function of either miles or miles divided by Columbia river miles shows a negative relationship between the percent of total recoveries recovered further up the Columbia River than the tributary the fish were released in and distance from the tributary where the fish were raised and released, when distance is expressed as a percentage of main stem distance to the tributary ( $r^2 = 0.9992$ ).

### *“Strays in the Truest Sense of the Word”*

The numbers of fish recovered in dead fish and spawning ground surveys are quite small (Table 3), as they are as percentages of all tagged fish recovered. Upriver bright fall Chinook from Little White Salmon NFH account

Table 2. Relationship of total estimated recoveries recovered further up the Columbia River than the tributary where the fish were released, and the distances involved for spring Chinook released as yearlings

Rearing and release location/ tributary/recovery location	% of total recoveries	Miles <sup>a</sup>	Miles/river miles <sup>b</sup> *100
Carson NFH/Wind River/L White Salmon NFH	7.2	7.5	4.63
Entiat NFH/Entiat River/Wells Dam	4.9	31.4	6.2
Leavenworth NFH/Wenatchee River/Wells Dam	0.2	46.7	9.07

<sup>a</sup>Distance from the tributary to the recovery location.

<sup>b</sup>Distance from the tributary to the recovery location divided by distance from the mouth of the Columbia River to the tributary on which the hatchery is located.

Table 3. Estimated number of dead fish and spawning ground survey recoveries.

Fish strain	On route	Other	Location
Carson spring Chinook	136	0	
L White Salmon spring Chinook	30	10	Big White Salmon
Warm Springs spring Chinook	1	0	
Leavenworth spring Chinook	61	19	Wenatchee basin
Entiat spring Chinook	0	7	Wenatchee basin
Winthrop spring Chinook	0	0	
Dworshak spring Chinook	0	11	Upper Columbia
		1	Snake River basin
Kooskia spring Chinook	0	1	Upper Columbia
Eagle Creek Coho	0	0	
Willard Coho	1	1	Big White Salmon
		1	Dog Creek
Spring Creek tule fall Chinook	0	25	Wind River
		26	Big White Salmon
		15	Washougal River
		6	Drano Lake
		3	Plympton Creek
			Kalama River
L White Salmon upriver bright fall Chinook	158	591	Big White Salmon
		42	Wind River

for the largest portion of these recoveries, mostly in the Big White Salmon River 6.3 mi upstream from the Little White Salmon River and in the Wind River 7.5 mi below. Spring Creek NFH is 5.2 mi from the Little White Salmon River, and tule fall Chinook from this hatchery are recovered in these same rivers. Dead fish and spawning ground survey recoveries for Carson NFH and Leavenworth NFH spring Chinook, and Little White Salmon NFH upriver bright fall Chinook are mostly in the streams on which the hatcheries are located. Since Warm Springs NFH spring Chinook production is the only program where 100% of the fish released were coded-wire tagged; these listed recoveries indicate that untagged fish were in all likelihood also present during the surveys.

Quinn (1991) found the Lewis and Kalama Rivers to be "very attractive" to lower river tule fall Chinook from brood years 1977, 1978, and 1979. Spring Creek NFH is 21.1 mi above Bonneville Dam, and was not discussed in that paper, but I note that the Kalama River attracted only 0.017% of Spring Creek recoveries, and there were not any in the Lewis River.

### *Differences between Snake River and Upper Columbia River Basin Recovery Patterns*

The difference in recovery patterns of spring Chinook between the two hatcheries located in the Snake River basin: Dworshak NFH and Kooskia NFH in the state of Idaho, and the three hatcheries located on tributaries to the Columbia River above the confluence with the Snake River in the state of Washington: Leavenworth NFH, Entiat NFH, and Winthrop NFH is striking. Although there have been no recoveries of Leavenworth NFH, Entiat NFH, or Winthrop NFH spring Chinook in the Snake River basin, more than 4% of recoveries from Dworshak NFH and Kooskia NFH have been further up the Columbia River basin than the mouth of the Snake River. The attractiveness of the Deschutes River basin also differs greatly. Less than 1% of recoveries for the Washington hatcheries were in that basin, while more than 5% of Dworshak NFH and Kooskia NFH recoveries were in the Deschutes River basin.

Spring Chinook programs at all five hatcheries were started with Carson stock, which are of mixed, upriver ancestry: both Snake River and upper basin Columbia River, as described in the Carson NFH spring Chinook section of this paper. Rapid River stock from within the Snake River basin became the predominant stock at Dworshak in the late 1980s. It there-

fore seems unlikely that genetic differences among the hatchery populations accounts for the observed differences in recovery patterns.

The low rate of on route recoveries for Dworshak NFH spring Chinook (71%) when compared to that of 88.6% for Kooskia NFH spring Chinook should also be noted. This difference was intriguing enough that Dworshak NFH spring Chinook recovery data were processed a second time using only the same brood years that were used for Kooskia NFH: 1988, and 1990 through 1993. The percent of recoveries in the Columbia River and tributaries above the mouth of the Snake River rose from 7.3% to 11.2%. Likewise, eliminating brood years 1986 and 1987 from the summation increased the percentage of recoveries in the Deschutes River basin from 15.2 to 19.6. Differences between brood years used does not appear to account for the high rate of off route recoveries observed for Dworshak NFH. Kooskia fish must traverse 34 mi before joining the route Dworshak fish must swim. The only readily apparent difference is that extra distance.

When comparing the two sets of hatcheries, we note similar distances and numbers of dams involved. Fish migrating down the Columbia River above the mouth of the Snake River must swim the entire distance. Those migrating down the Snake River may be trapped and barged or trucked. The volitional downstream migration of fish from both Dworshak NFH and Kooskia NFH are equally likely to be interrupted. The homing ability of fish from Kooskia NFH apparently benefit from the additional time and distance spent in the Middle Fork of the Clearwater River.

### **Acknowledgments**

The creation and maintenance of databases is a cooperative endeavor. Perhaps thousands of individuals have contributed to the RMIS coded-wire tag database. Without their efforts, this paper would not have been possible.

### **References**

- Ham, D. H., and T. N. Pearsons. 2001. A practical approach for containing ecological risks associated with fish stocking programs. *Fisheries* 26(4):15–23.
- Hayes, M. C., and R. W. Carmichael. 2002. Salmon restoration in the Umatilla River: a study of straying and risk containment. *Fisheries* 27(10):10–19.

- Heard, W. R. 1991. Life history of pink salmon. Pages 201–204 *in* C. Groot and L. Margolis, editors. Pacific salmon life histories. UBC Press, Vancouver.
- Quinn, T. P. 1991. Homing and straying patterns of fall chinook salmon in the lower Columbia River. *Transactions of the American Fisheries Society* 120:150–156.
- Quinn, T. P. 1997. Homing, straying, and colonization. Pages 73–84 *in* W.S. Grant, editor. Genetic effects of straying of non-native hatchery fish into natural populations: proceedings of the workshop. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS-NWFSC-30, Springfield, Virginia.