Regional Overview of Coded Wire Tagging of Anadromous Salmon and Steelhead in Northwest America

Paper updated from 1989 to current year 2004
(NOTE: Most figures have not been updated for lack of time)

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Abstract-Coded wire microtags (CWTs) were introduced in the Pacific Northwest in the late 1960s as an alternative to fin clipping and external tags for identification of anadromous salmonids in the region, particularly those of hatchery origin. Coastwide use of CWTs quickly followed, and fisheries agencies in Alaska, British Columbia, Washington, Oregon, and California established ocean sampling and recovery programs. Now, 54 federal, provincial, state, tribal, and private entities release over 50 million salmonids with CWTs yearly. Regional coordination of these tagging programs is provided by the Regional Mark Processing Center operated by the Pacific States Marine Fisheries Commission. The 'Mark Center' also maintains a centralized database for coastwide CWT releases and recoveries, as well as for associated catch and sample data. CWT data are provided to users via interactive on-line data retrieval.

The coastwide CWT system proved successful and quite robust despite its piecemeal growth and dependence on cooperative support by all agencies. Not surprisingly, it also has a number of problems that reduce the CWT's effectiveness as a marking tool. Even so, the CWT has proved invaluable as a stock identification tool in marking salmonid hatchery stocks and, to a lesser extent, wild stocks.

Most of the CWT's limitations have persisted from the beginning. These problems include the need for the establishment of standards for tagging levels, expanded use of replication, improved tag loss estimates, improved accuracy of counts of released fish, resolve under-sampling of fisheries and escapement, and the development of a sound statistical framework for computing the various CWT statistics and the uncertainty associated with those statistics.

There are also a few new problems, some which are major, that have arisen as a direct result of the advent of mass marking with the adipose clip and the subsequent introduction of mark selective fisheries. These new problems include lack of uniformity in electronic sampling, the need to estimate 'imputed mortalities' of unmarked DIT fish in mark selective fisheries, and the impact of blank wire on recovery agencies. All of these problems, both old and new, are reviewed, along with changes introduced by the Pacific Salmon Treaty.

The coded wire tag (CWT) is widely used by fisheries agencies on the west coast of North America to gather major information on stocks of salmon *Oncorhynchus* spp. and steelhead *Oncorhynchus mykiss.* Management of the resource is based on hatchery contribution studies, differential treatment studies, fishery contribution studies, and a variety of related studies.

The highly migratory nature of salmonid species necessitated the development of a cooperative coastwide exchange of tag data. This paper presents an overview of the system now in place, of its problems and of its future direction. It also briefly reviews the important role fin marking played as a precursor of the present system.

Fin Marking Era

Early Coordination Efforts

Fin clipping was the standard marking method for stock identification until the early 1970s, when CWTs became popular. To avoid conflicts among the limited number of possible fin clips, agencies voluntarily agreed to abide by mutually established rules for fin-mark studies. These regional agreements were formalized in the early 1950s through efforts of the Committee on Anadromous Fish Marking and Tagging, more commonly known as the Mark Committee.

Work of the Mark Committee was facilitated by the Pacific Marine Fisheries Commission (PMFC; now the Pacific States Marine Fisheries Commission, PSMFC), an interstate fisheries compact created by the U.S. Congress in 1947. Membership on the committee consisted of one representative from each of the major state and federal fisheries agencies engaged in marking. Canadian fisheries agencies also participated on an informal but active basis.

The Mark Committee met annually in January or February to review fin-mark programs of the prior year and to coordinate and approve mark requests for coming years. Regional agreements also were reviewed for possible revision. In addition, committee members served as focal points for the exchange of fin-mark recovery data on an as-needed basis.

Regional Fin Mark Recovery Efforts

In spite of the early coordination of fin-marking programs, sampling and mark-recovery efforts remained limited to in-state and in-province programs for many years. This changed in 1962 when the first large-scale marking program was initiated to evaluate the contribution of fall chinook salmon *Oncorhynchus tshawytscha* released from 13 production hatcheries in the Columbia River basin (Worlund et al. 1969; Wahle and Vreeland 1978). Coastwide sampling for the study's sequestered fin marks (adipose, left ventral, right ventral, and maxillary marks in various combinations) 'began in 1963. Areas sampled included the major ocean commercial and sport fisheries from southeast Alaska to central California, Columbia River fisheries, parent hatcheries, and certain natural spawning grounds.

In 1965, this study was expanded to include coho salmon *O. kisutch.* Twenty hatcheries distributed over much of the Columbia River mainstem participated by marking 10% of their 1965 and 1966 brood coho salmon (Wahle et al. 1974).

All data collected during the recovery phase of the study (1963-1969) were recorded on a standard form and forwarded to the Oregon Fish Commission (now Oregon Department of Fish and Wildlife) Mark Processing Center at Clackamas, Oregon. After appropriate coding, the data were keypunched onto computer cards and then tabulated. The tabulations were forwarded to the Bureau of Commercial Fisheries (now the National Marine Fisheries Service) in Seattle, where annual summary reports were produced (Worlund et al. 1969).

In 1970, Oregon's Mark Processing Center formally became the regional center when it was funded through the Anadromous Fish Act (Public Law 89-304) to establish and maintain a regional database for mark recoveries. From 1970 through 1976, the center published annual regional summaries for fin marking and tag releases and subsequent recoveries in the ocean and Columbia River fisheries. This effort promoted better cooperation and coordination among agencies.

Coded Wire Tagging Era

Introduction of Coded Wire Tags

The invention of minute CWTs (0.25 x 1.1 mm) that could be easily implanted in the tough nasal cartilage of juvenile salmonids (Figure 1) greatly changed marking studies because of this tag's numerous advantages over fin clipping. The first tags were developed in the 1960s (Jefferts et al. 1963; Bergman et al. 1968) and carried up to five longitudinal colored stripes. More than a dozen different colors provided approximately 5,000 different codes, compared to the 15-20 fin-mark codes normally used to identify groups of fish.

Binary coded tags were later introduced in 1971 by Northwest Marine Technology, Inc. The new tags quickly replaced color coded tags because of the greatly improved readability and the enormous number of available codes per agency (not using zero), for a total of 250,047 unique Standard length binary tags (1.1 mm, 6 bit word) for example, had 63 possible agency codes and 3,969 codes. This provided unique codes for many years, and additional tens of thousands of binary codes were possible with a slight format change on the wire.

The large number of available binary codes, low cost per tag, and ease of application opened the way to large scale experimentation (i.e., multiple experiments on given stocks) by tagging agencies because all experimental groups could be identified accurately regardless of recovery location or time.

Another major advantage was that all experimental groups could be treated the same during the tagging process, thus reducing the variability in survival and behavior imparted by clipping different fins.

Restriction of the Adipose Mark (1977-1996)

The widespread acceptance and use of the CWT made it imperative that a single fin mark be reserved as a flag for tagged salmon and steelhead. Therefore, in early 1977, the Mark Committee recommended that the adipose fin be sequestered for tagged chinook and coho salmon. This recommendation was subsequently approved by PMFC's Salmon and Steelhead Committee (composed of fisheries management leaders from each of PMFC's five member states) and implemented in the 1977 tagging season.

This restriction was expanded later to include chum *Oncorhynchus keta,* sockeye *O. nerka,* pink salmon *O. gorbuscha* and steelhead, *O. mykiss* with some exceptions made for geographic areas and use of multiple fin clips. Restrictions on use of the adipose clip during 1977 – 1996 are summarized in Table 1.

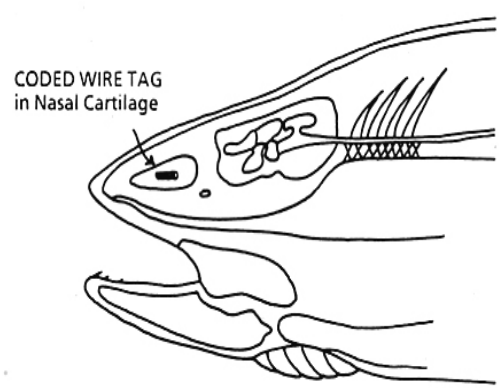


FIGURE 1.—Longitudinal section through the head of a juvenile salmonid showing the correct placement of a coded wire tag in the nasal cartilage. (After Koerner 1977.)

TABLE 1. **1977 – 1996:** Summary, by Pacific Northwest species, of fin marks that require a CWT. The adipose-fin-only mark was exclusively reserved as a CWT flag for all species except steelhead. (Ad = adipose fin; LV = left ventral fin; Max = maxillary.

			Fin Mark			
Species	Ad	Ad + Max	Ad + LV	Ad+other fin(s)	LV	LV+other fin(s)
Chinook salmon	Yes	Yes	Yes	Yes	No	No
Coho salmon	Yes	Yes	Yes	Yes	No	No
Chum salmon	Yes	Yes	No	No	No	No
Pink salmon	Yes	Yes	No	No	No	No
Sockeye salmon	Yes	Yes	No	No	No	No
Steelhead						
Coastal	No	No	No	No	No	No
Columbia basin	No	No	Yes	No	Yes	Yes

Concurrent with the restriction of the adipose clip, the Salmon and Steelhead Committee directed agencies to immediately phase out multiple fin marking of chinook and coho salmon for experiments that required recovery at sea or in major rivers. It was expected that regional sampling would continue for studies already in progress. However, 1976 was the last year in which coastwide sampling was conducted for multiple fin marks.

After serving nearly three decades as the rigorously protected flag for CWT marked salmonids, the adipose fin mark today is now primarily used as a flag for identifying hatchery fish for potential harvest in mark selective fisheries. This major transition commenced in 1996 when Oregon and Washington began to mass mark their hatchery coho production with the adipose clip. The impact of this transition on the coastwide CWT system will be discussed at a later point in this paper.

Changes in Regional Coordination

The dramatic upsurge in CWT use in the mid-1970s placed an increasing burden on the data processing facilities of individual recovery agencies and especially the Regional Mark Processing Center (Mark Center) at Clackamas. Therefore, in June 1976, PMFC's Salmon and Steelhead Committee upgraded the Mark Center operations by establishing a Regional Mark Coordinator position to facilitate interagency coordination and timely exchange of CWT release and recovery data. This was done in May 1977. The Mark Center was then transferred to PMFC in July 1977 to facilitate interagency coordination among the various state and federal agencies.

Functions and Duties of the Mark Center

The reorganization of the Mark Center in 1977 merged the previously separate but closely interrelated functions of regional coordination and data management into a single operation. Duties for each of these functions are summarized below, along with comments on how the tasks are carried out.

Regional coordination tasks.-The Mark Center provides coordination for marking programs by (1) establishing regional agreements for fin marking and use of CWTs with the assistance of agency coordinators; (2) recommending changes for upgrading the regional CWT database to meet expanding or changing user requirements; (3) assisting agencies to improve timeliness of reporting, with special emphasis on tag recovery data; and (4) developing recommendations for improving coordination and quality of CWT studies, with emphasis on experimental design, sampling design, estimation procedures, statistical problems, and documentation.

These tasks are achieved by several methods, including personal contacts by the Regional Mark Coordinator, use of meetings and workshops, and preparation of technical reports. In addition, the Mark Committee plays an invaluable role in facilitating regional coordination efforts of the Mark Center.

Data management tasks.-The Mark Center manages data by (1) maintaining and upgrading a regional database for all CWT releases and recoveries, plus release data for fish groups given other types of marks. (2) ensuring that reported data meet established format standards and pass validation procedures; (3) maintaining and upgrading the web-based Regional Mark Information System (RMIS) which provides users with on-line data retrieval capabilities; (4) providing electronic copies of data sets upon request; and (5) implementing recommended changes in the regional database exchange formats to meet expanding requirements for new information.

The primary focus of the Mark Center's data management activities since 1977 has been to serve as a clearinghouse for CWT release and recovery data, with special emphasis on timely reporting of data, standardization of data formats, and integrity of the data. Analysis of the politically sensitive recovery data, however, has remained the responsibility of the reporting agencies and other interested data users in order to maintain the Mark Center’s neutrality and the trust of all agencies submitting data.

Distribution of CWT data was originally achieved by hard copy reports and magnetic media. Among the regional data reports was the annual "Pacific Salmonid

Coded Wire Tag Release Report," which documented CWT applications for all Pacific coast salmonid studies that used the adipose fin clip. It included both the most recent year's releases plus all previous releases back to 1971. It also provided a complete summary of regional agreements on tagging and fin marks.

In addition, the Mark Center published an annual "Recovery Report" from 1970 through 1982. The reports provided summaries of observed and estimated recoveries and the associated catch and sample statistics, organized by agency-fishery-area strata in 2-week time periods.

The hard-copy data series reports ended in 1983 following the development of interactive online data retrieval capability for accessing both final and preliminary CWT recovery data. This afforded users the option of down-loading 'raw' release and recovery data for any given tag code. In addition, users were gradually given a wide range of reports to select from that provide summarized tag recovery information across all agencies, fisheries, areas, and years.

The Mark Center also distributed for many years an annual report known as the "Mark List". It provided a cumulative summary across years of all salmon and steelhead fin marks (other than the adipose and CWT) used for studies not requiring ocean recovery. The report was discontinued in 1987 because of the lack of regional interest at that time in reporting releases of most fin marks other than the adipose clip.

New CWT Data Formats

A Memorandum of Understanding to the Pacific Salmon Treaty (January 28, 1985) called for Canada and the USA "…to develop a coastwide stock assessment and data management system, including catch, effort, escapement, and coded wire tag data that will yield reliable management information in a timely manner ...."

Approximately one year later, the Pacific Salmon Commission's (PSC) Data Sharing Committee met and established a Working Group on Mark Recovery Databases. Assignments included documentation of existing CWT data files and recommendation of a preferred system that could be adopted coastwide.

The first task accomplished was a description of the existing CWT data sets and the associated limitations of each. Once this was done, the existing Mark Center formats for CWT release, recovery, and catch sample data were used as the starting point for defining the preferred data base. This second task required several meetings before a consensus was reached on data files, data fields, valid codes, and validation procedures.

Advantages of the new PSC coded wire tag data base over the "old" RMPC data base are discussed by Lapi et al. (1990). Benefits included the use of a hierarchical area coding scheme that standardized codes and provided links to other information (e.g., catch/ sample to recovery information). In addition, special attention was given to data control issues to ensure the validity of data coded into fields.

The new PSC data formats were presented to the Mark Committee in September 1987 and adopted for use coastwide by both non-PSC and PSC agencies.

Expanded Tasks of the Mark Center

PSC commissioners agreed in November 1987 that no single USA-Canada CWT database would be established under the auspices of the commission. Instead, it was agreed that the USA and Canada would each maintain a single database to expedite exchange of CWT data between the two nations. The U.S. commissioners subsequently considered the site issue for the U.S. database and selected the Mark Center. This position was supported by the Working Group on Mark Recovery Databases.

Advantages of the Mark Center cited by the working group included: long term experience in CWT data administration; coastwide representation of all fisheries agencies; well established coordination and reporting procedures; no start-up costs to PSC; reduced time for implementation of the new formats; and lack of vested interest in any data interpretation or applications. The Mark Center's primary role is to collect, validate, archive, and exchange U.S. data with Canada in the PSC data exchange formats.

Role of the Mark Committee

Membership.-All tagging and recovery agencies on the Pacific coast are represented by the 14 member Mark Committee. PSMFC's Regional Mark Coordinator serves as chair for the committee. Agency membership includes mark coordinators for the five member states of PSMFC (Alaska, Washington, Oregon, Idaho, and California), the National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), Canada Department of Fisheries and Oceans (CDFO), British Columbia – Freshwater Fisheries Society (BCFFS-newly created agency) and the Metlakatla Indian Community in Southeast Alaska. In addition, the Northwest Indian Fisheries Commission (NWIFC) coordinates the tagging and fin marking activities of 20 treaty tribes in western Washington. The Columbia River Intertribal Fish Commission (CRITFC) serves the same role for four tribes in the Columbia River basin. Private aquaculture,.

TABLE 2. Votes (total, 12) assigned to the 14 member Mark Committee in the event there is no consensus on an issue involving fin marking or CWT use. Private and other nongovernmental organizations are represented by state or provincial coordinators.

Jurisdiction	Committee Representatives (total)	Number of Votes
	USA	
Coordinating agency	Pacific States Marine Fisheries Commission (Chair – non voting)	0
State agencies		
Alaska	Alaska Department of Fish and Game (1)	1
Washington	Washington Departments of Fisheries and of Wildlife (1)	1
Oregon	Oregon Department of Fish and Wildlife (1)	1
California	California Department of Fish and Game (1)	1
Idaho	Idaho Department of Fish and Game (1)	1
Federal agencies		
U.S. Fish and Wildlife Service	Region-wide (1)	1
National Marine Fisheries Service	Alaska and Northwest regions and centers (2)	1
Tribal groups		
Annette Island (Southeast Alaska)	Metlakatla Indian Community, 1 tribe (1)	1
Western Washington	Northwest Indian Fisheries Commission, 20 tribes (1)	1
Columbia River basin	Columbia River Intertribal Fisheries Commission, 4 tribes (1)	1
Canada		
Federal level	Canada Department of Fisheries and Oceans (1)	1
Provincial level	British Columbia - Freshwater Fisheries Society (1)	1

universities, and other nongovernmental organizations are coordinated through the respective state or provincial coordinator.

Duties.-The Mark Committee provides oversight and guidance to the Regional Mark Coordinator in carrying out the operations of the Mark Center. In addition, the Mark Committee meets each year in the spring to expedite coastwide coordination of fin-marking and tagging activities. It is during this annual meeting that regional agreements are reviewed and updated if necessary.

Mode of decision making.-Regional agreements and restrictions on fin marking and CWT usage are reached by committee consensus after thorough discussion of the issues. A 30-day review period follows publication of the Mark Meeting minutes to allow for agency reversal on an issue if necessary. If no objections are raised, the agreement stands as recorded in the minutes.

In those situations where unanimity cannot be achieved, the decision is reached by a two thirds majority affirmative vote. All issues referred to a vote require a quorum of at least 75% of the committee members being present. Twelve votes are possible (Table 2). A single vote is assigned to the state level or federal agency level regardless of the respective number of coordinators serving on the committee. Canadian agencies are treated similarly in that the federal level (CDFO) and province level (BCFFS) are accorded separate votes

Compliance with regional agreements.-The Mark Committee does not have any legal authority to enforce the regional agreements. Therefore, cooperation and compliance are voluntary. This has not proven to be a serious weakness since all agencies mutually benefit from standardized tagging and sampling procedures. In addition, there exists tremendous peer pressure among the agencies to support the system because noncompliance can negatively affect studies of other agencies. The system has worked exceptionally well without having to resort to extreme measures to resolve problems, such as loss of funding support or embargoes on recovery data.

Changing Role of the Adipose Fin Mark (1997-2004)

Changes Imposed on the CWT System by External Factors

The 1990s proved to be a period of convergent factors that ultimately resulted in major changes for the coastwide CWT system. It was a time of declining survival rates for many chinook and coho stocks, resulting in reduced harvest and fewer CWT recoveries. It was also a time of growing pressure to protect threatened and endangered wild stocks, some of which were listed under the U.S. Endangered Species Act (ESA).

Weak stock management was introduced in order to reduce the harvest of threatened and endangered wild stocks. While this did help the wild stocks, it also limited the ability to harvest healthy surplus hatchery stocks in many mixed stock fisheries, including the highly valuable recreational fisheries. Further compounding the problem, excessive numbers of hatchery fish often returned to the hatchery to the dismay of both commercial and recreational fishers.

These circumstances led to a new paradigm of mass marking hatchery fish in order to conduct mark selective fisheries and thus achieve stock management objectives. Not surprisingly, the adipose clip was the only logical mark for the same reasons that it had been sequestered in 1977 as a flag for CWT marked salmonids. Fishers would be able to easily identify hatchery fish, and unmarked fish would be released alive.

The Mark Committee struggled greatly over several years to maintain the adipose clip as the CWT flag since visual sampling was the foundation for the coastwide tag recovery program. The alternative was to desequester the adipose clip and switch to electronic sampling to recover CWTs in the fisheries. Electronic sampling required either hand held wands to pass over the snout of the fish or larger tube detectors through which the entire fish is passed. In either case, electronic sampling was more expensive because of the necessary equipment and added labor costs since all fish would have to be sampled without an external flag for a CWT marked fish.

In the end, political pressures prevailed and agencies began mass marking without the formal approval of the Mark Committee. In 1996, Washington and Oregon were the first to make the policy decision to mass mark their hatchery coho stocks (1995 brood) with the purpose of future selective fisheries in mind. Canada followed suit soon thereafter and mass marked many of their hatchery coho stocks. More recently, some chinook hatchery stocks have been also mass marked in Oregon and Washington per federally mandated legislation (discussed later).

The political decision to shift to mass marking and selective fisheries also raised widespread concerns about the potential impact on the integrity of the coastwide CWT system. In particular, tagged hatchery stocks no longer can be assumed to represent the natural stocks since, by nature of the selective fishery, hatchery fish will have a higher mortality. In addition, some of the released fish die, and unlike harvested fish, they are not available for sampling. Thus the mortality due to the release of unmarked fish in a selective fishery is a new source of non-landed mortality that requires new indirect methods of estimation. At a minimum, this has introduced an undetermined impact on the accuracy and precision of the CWT recovery data.

To cope with these new challenges to the CWT system, the Pacific Salmon Commission (PSC) established a Selective Fisheries Evaluation Committee (SFEC). The committee is tasked with the technical aspects of reviewing mass marking and selective fishery proposals, and also the development of modeling tools that accommodate selective fisheries strategies.

Double index tagging (DIT) is now being field tested and evaluated to see if it will provide a reliable estimate of post release mortality of unmarked fish in selective fisheries. In this scenario, one hatchery index group of fish is given a CWT and the adipose clip, while a second group is given only a CWT (adipose fin left intact).

In a selective fishery, the first group of fish (Ad+CWT) will provide a measure of contribution to the fishery as they will be landed and sampled, as well as returning fish sampled back at the hatchery. The second group (CWT only) will be released in the selective fishery as if wild, and survivors returning to the hatchery will be sampled. The difference in survival rates back to the hatchery for the two groups will provide an estimate of unmarked mortality in mark selective fisheries.

The introduction of DIT groups radically changed the thinking of fishery managers in terms of analyzing survival rates, exploitation rates and contribution rates. Data analysts quickly realized that it also was necessary to capture fin mark information on the presence or absence of the adipose fin while sampling landings for CWT marked fish.

Accordingly, PSC's Working Group on Data Standards developed a new series of data fields for the PSC Data Exchange Standards in order to capture the adipose mark incidence data. In addition, the data exchange formats were upgraded to allow capture of a wide variety of other mark combinations (i.e. other fin marks, elastomer marks, otoliths) given to groups of juvenile fish prior to release.

Current Status of Adipose Clips and CWT Sampling

A CWT is no longer universally required with an adipose fin clip on chinook and coho salmon (Table 3). Alaska and California are now the only exceptions in requiring a CWT with the adipose clip as their respective CWT sampling programs rely only on visual sampling. As such, DIT marked fish (intact adipose fin; CWT only) are not recovered by their sampling programs.

Canada uses electronic tag detection for chinook in its commercial fisheries, but takes the snouts from only from ad-clipped chinook as a cost saving measure. For recreational fisheries, Canada relies upon information from voluntary recoveries of heads of fish with a missing adipose fin coupled with the results of CDFO's limited direct sampling program.

As noted previously, there is no coastwide sampling for CWTs in steelhead, or in chum, sockeye, and pink salmon, Consequently, Table 3 can be confusing as to why Alaska (ADFG) requires a CWT with adipose clipped chum, sockeye, and pink salmon, and California (CDFG) requires the same for adipose clipped steelhead. The reason is that both Alaska and California continue to use CWTs and visual sampling to meet within-state management objectives for chum, sockeye and pink salmon, and steelhead, respectively. There are no expectations for out-of state tag recoveries for these tagging programs.

As a result of both political activism and legislation (state and federal), much of the hatchery production of chinook and coho in Oregon, Washington and Idaho, and hatchery coho in British Columbia is now mass marked with the adipose fin clip. The Washington State Legislature passed legislation in 1995 (SSSB 5157) that mandated WDFW to mark all appropriate hatchery coho

TABLE 3. **1997 – 2004:** CWT Required if Adipose Clip Applied

Region	Chinook	Coho	Steelhead	Sockeye	Chum	Pink
Alaska	**Yes**	**Yes**	No	**Yes**	**Yes**	**Yes**
Canada	**Yes**	No	No	No	No	No
Washington	No[2]	No	No	No	No	No
Oregon	No[2]	No	No	No	No	No
Idaho	No[2]	No	No	No	No	No
California	**Yes**	**Yes**	**Yes**	No	No	No

[1]These requirements also apply to adipose clips with one or more other fins).

[2]Use of a CWT with the adipose fin clip is presently required for all chinook from the Strait of Juan de Fuca and coastal Washington and for fall chinook from the Columbia Basin. (spring and summer chinook are being resolved).

beginning with the 1995 brood in order to pursue selective fishery opportunities. The 1995 Oregon legislation was less detailed but clearly specified the State's intent to also implement mass marking.

More recently, a 2003 Congressional Appropriations bill was passed that requires the mass marking of salmonids produced at federally funded or operated hatcheries, including but not limited to chinook, coho, and steelhead. Efforts under presently underway to fully fund and implement the federally mandated mass marking.

In concert with the tremendous expansion of mass marking hatchery stocks, electronic sampling is now the primary method used to recover CWTs in southern British Columbia, Washington, Oregon and Idaho waters. Fish tagged for stock recovery programs are generally not adipose clipped if they will be subjected to potential mark selective fisheries. Use of the adipose clip is currently being resolved for spring chinook from the mainstem Columbia River above Bonneville Dam. Adipose mass marking of Snake River spring chinook has been approved by majority vote of the Mark Committee.

Use of the adipose clip on summer chinook in the Columbia River remains unresolved. Adipose clipping of Snake River summer chinook has been approved by majority vote of the Mark Committee.

Current Tagging Program

Major Changes in CWT Technology

The CWT technology has undergone a number of significant improvements in the past decade, largely in response to the shift to mass marking hatchery stocks for the purpose of mark selective fisheries. These changes has discussed below:

New Decimal Coded Wire Tags.- In 2000, Northwest Marine Technology, Inc. (NMT) began to phase out the old work horse binary coded wire tags and started shipping decimal coded wire tags to tagging agencies. These new tags are identical in length and metallic composition. However instead of being a series of etched notches on the surface of the wire, the code now consists of laser etched decimal numerals that are 0.16 mm tall and very easy to read under low magnification. This advance greatly reduces the potential for error when reading the tag codes. Another benefit is that the new decimal coding format provides up to one million unique codes for the standard tag format, with millions more possible with slight changes in the coding scheme.

Electronic Detection Capabilities. – NMT recognized the need for higher quality tags with the growing need for electronic detection of tagged salmon. With the help of their vendor of stainless steel wire, they were able to introduce new wire in 1994 that had a higher magnetic moment, and thus detection at a greater depth in the snout of a fish.

A number of field tests by NWIFC, USFWS, WDFW, CDFO, and ODFW demonstrated that the hand held wand was able to detect approximately 98% of all standard length tags (1.1 mm) in coho and greater than 90 % in the larger chinook (e.g., PSC 1999B). The tube detector had approximately a 99.9% success rate in tag detection.

The detection depth for 'new wire' standard length tags (1.1 mm) is approximately 20 mm and deeper than that for the 'old wire'. NMT also markets so-called 'length and a half' tags (1.6 mm) and double length tags (2.1 mm) tags. Because of the greater mass, the longer tags have a greater magnetic moment and thus can be detected at much greater depths. The length and a half tags are effectively detected at a minimum of 30 mm depth. In addition, there was no difference found in tag retention between 1.1 mm and 1.6 mm wire. Given these results, tagging agencies are encouraged to use length and a half wire whenever possible to maximize tag detection by electronic sampling.

Mass Marking and Tagging Trailers. – The necessity to mass mark literally millions of hatchery fish each year in a relatively narrow window of time has led to the development of a quite amazing automated mass marking and tagging machine. The initial development began in 1993 with BPA funding provided to WDFW and then subcontracted to NMT. The first prototype system came on line in 1997 and was known as MATS (Marking and Tagging System). It has since evolved through several generations of development and improvements, and is now known as the AutoFish System.

In brief, the highly complex AutoFish System is housed in a normal sized tagging trailer and consists of 4-5 automatic fin clipping and CWT tagging lines that can process large numbers of juvenile salmonids without the use of anesthetic or handling. The system is designed to sort the fish by size, clip the adipose fin, and then inject a CWT into the snout, with the overall output rate of approximately one fish/second. Typical marking rates are on the order of 4,500 fish per hour or 36,000 fish per shift.

Costs are somewhat comparable to manual trailer operations. However, only two staff are required to run the AutoFish System trailers. Hence there is a trade off in savings in personnel costs that is counter balanced by the higher costs for the advanced technology.

The next generation of AutoFish System trailers, now under development, will also have a section at the rear of the trailer for several workers to manually clip and tag smolts that fall outside an optimal size range needed to allow continuous automated operations. Experience to date has shown that the new hybrid auto/manual trailers will be able to mark approximately 60,000 fish per eight hour shift.

Lastly, the AutoFish System uses state-of-the-art optical and computer control systems to fin clip and tag the fish. Tag placement is very precise, and the fin clips are superior to that seen in manual clipping. These technologies are also being modified to allow automated vaccination. In short, the AutoFish System is an amazing technological advance and will play an essential role in mass marking hatchery coho and chinook production.

Scale of Tagging Effort and Cost

Some 54 state, federal, tribal, and private entities in the USA and Canada (Table 4) presently participate in a massive coastwide CWT marking effort to provide essential data for effective conservation and management of Pacific salmonid stocks. This information forms the basis for monitoring the fisheries, allocating harvest rights among competing domestic users, improvements in productivity of hatchery stocks, establishment of escapement goals, and satisfaction of tribal treaty obligations. These data also play a key role in the Pacific Salmon Treaty allocations and management of transboundary stocks.

Over 50 million juvenile salmon and steelhead are now tagged annually. Chinook salmon tagging levels are the highest (circa 39 million), followed by coho salmon (9-10 million). Tagging of steelhead, and of chum and pink salmon is of minor importance at about 2 million, 1 million, and 400,000 fish, respectively. (Note: Sockeye salmon were formerly tagged at levels comparable to pink salmon but aren't being tagged in any significant numbers at the present time).

This massive tagging effort requires approximately 1,200 new tag codes each year. Hundreds of separate studies are involved, many of which include replication groups as part of the basic design. Total cost exceeds U.S.$7.5 million annually. The cost per individual fish (tag + application) ranges between 12 and 18 cents, depending on local labor costs, logistics of tagging, and number of tags purchased for a given code. Small tagging programs in more isolated areas often have much higher application costs. (Individual tags range between 6.9 and 13.8 cents each, with price determined by order size and delivery time).

An additional U.S.$12-13 million is expended annually coastwide for tag recovery programs in U.S. and Canadian commercial and recreational fisheries. (This estimate does not include the increased labor and equipment costs associated with the current use of electronic tag detection.) Tag recoveries from returning adult fish are on the order of 275,000 per year, with a range of 150,000 to 310,000, depending on fisheries and survival conditions.

Salmon and steelhead feed in the ocean from one to five or more years, depending on the species, before returning to spawn in their natal streams. Consequently, many millions of tagged fish from several brood years are present in the Pacific Ocean at any given time. The multiplicity of tagging studies today represents a long-term, multimillion-dollar investment by state, federal, tribal, and private sector entities.

Types of Tagging Studies

Although there are many kinds of tagging studies, they can be divided into three basic types (PMFC 1982a): experimental (e.g., multiple comparison); stock assessment (from the hatchery viewpoint); and stock contribution, (from the fishery viewpoint). Contribution is defined as the number of fish of a defined group occurring in a specific fishery. Fishery, as used here, is defined in a broad sense to include harvest and escapement (fish that return to natal streams to spawn.

Experimental tagging studies are designed to compare the relative survival or contribution of two or more experimental groups to the fisheries. Studies in this category deal with diet comparisons, time or site of release, pond density factors, disease control, and genetics. During the 1970s and 1980s, tagging studies were mainly experimental. However, the focus has now shifted to stock assessment and stock contribution.

TABLE 4. Federal, State, Tribal, and private entities and associated acronyms in the Pacific northwestern North America that have formerly used or continue to use CWTs with salmonid fishes. **Bolded acronyms identify entities currently releasing CWT marked salmonids**.

AAC	American Aquaculture Corporation (AK)	**AAI**	Alaska Aquaculture, Inc. (AK)

ADFG	Alaska Department of Fish and Game
AFSP	Aboriginal Fishery Strategy Program (BC)
AKI	Armstrong Keta, Inc. (AK)
ANAD	Anadromous, Inc. (OR)
BCFW	British Columbia Fish and Wildlife
BHSR	Burnt Hill Salmon Ranch (now OPSR) (OR)
BURR	Burro Creek Hatchery (AK) (Private non-profit organization)
CDFG	California Department of Fish and Game
CDFO	Canada Department of Fisheries and Oceans - Operations
CDFR	Canada Department of Fisheries and Oceans - Research
CDWR	California Department of Water Resources
CEDC	Clatsop Economic Development Committee (OR)
CIAA	Cook Inlet Aquaculture Association (AK)
COOP	Washington Department of Fisheries -Cooperative
CRITFC	Columbia River Inter-Tribal Fish Commission (OR)
CTWS	Confederated Tribes of the Warm Springs of Oregon
DIPC	Douglas Island Pink and Chum, Inc. (AK)
DOMS	Domsea Farms, Inc. (OR)
EBMD	East Bay Municipal Utilities District (CA)
ELWA	Elwha Tribe (WA)
FWS	U.S. Fish and Wildlife Service
HOH	Hoh Tribe (WA)
HSU	Humboldt State University (CA)
HVT	Hoopa Valley Tribe (CA)
IDFG	Idaho Department of Fish and Game
KAKE	Kake Non-Profit Fisheries Corp. (AK)
KRHI	Klawock River Hatchery, Inc. (AK)
KRUK	Karuk Tribe (CA)
KTHC	Ketchikan Tribal Hatchery Corporation (AK)
LUMM	Lummi Tribe (WA)
MAKA	Makah Tribe (WA)
MIC	Metlakatla Indian Community (AK)
MTSG	Mattole Salmon Group (CA)
MUCK	Muckleshoot Tribe (WA)
NBS	National Biological Survey
NEZP	Nez Perce Tribe (ID)
NISQ	Nisqually Tribe (WA)
NMFS	National Marine Fisheries Service
NOOK	Nooksack Tribe (WA)
NSRAA	Northern Southeast Regional Aquaculture Association (AK)
OAF	Oregon Aquafood, Inc.
ODFW	Oregon Department of Fish and Wildlife
OPSR	Oregon Pacific Salmon Ranch (formerly BHSR)
OSU	Oregon State University
PGAM	Port Gamble S'Klallam Tribe (WA)
PGHC	Port Graham Hatchery Corporation (AK)
PNPT	Point No Point Treaty Council (WA)
PSE	Puget Sound Energy (WA)
PUYA	Puyallup Tribe (WA)
PWHA	Prince of Wales Hatchery Association (AK)
PWSAA	Prince William Sound Aquaculture Association (AK)
QDNR	Quinault Department of Natural Resources (WA)
QUIL	Quileute Tribe (WA)
SJ	Sheldon Jackson College (AK)
SJRG	San Joaquin River Group (CA)
SKOK	Skokomish Tribe (WA)
SOF	Silverking Oceanic Farms (CA)
SPOK	Spokane Tribe (WA)
SQAX	Squaxin Tribe (WA)
SSC	Skagit System Cooperative (WA)
SSRAA	Southern Southeast Regional Aquaculture Association (AK)
STIL	Stillaguamish Tribe (WA)
SUQ	Suquamish Tribe (WA)
TULA	Tulalip Tribe (WA)
TYEE	Tyee Foundation (CA)
UAJ	University of Alaska - Juneau
UI	University of Idaho
USFS	U.S. Forest Service
UW	University of Washington College of Fisheries
VFDA	Valdez Fisheries Development Association (AK)
WDF	Washington Department of Fisheries
WDW	Washington Department of Wildlife
WDFW	Washington Department of Fish and Wildlife
WREG	Washington Regional Enhancement Groups (WA)
YAKA	Yakama Tribe (WA)

Stock assessment studies (hatchery viewpoint) have localized objectives and are designed to measure contributions and distributions of particular stocks among various fisheries, as well as escapement of those stocks. With this information, the success of a hatchery's production or of natural production can be evaluated. *The data may also have value to fishery management if adequate numbers of fish are tagged.*

Stock contribution studies (fishery management viewpoint) also are done for stock assessment purposes. In this case, fishery managers seek information on the contribution rates of key stocks in a given fishery (by time and area strata) in order to better manage harvest rates for conservation of the resource.

The major difference between the hatchery viewpoint and fishery viewpoint types of studies lies in the number of fish tagged. Stock contribution studies require far more tagged fish to generate meaningful recovery rates on a regional basis.

Principal Tagging Facilities

Tagging programs are carried out at over 330 federal, state, tribal, and private hatcheries and rearing facilities on the west coast. In addition, wild stocks are trapped and tagged at numerous sites. The principal tagging facilities are presented by state and province in Figures 2-8. Unless otherwise noted in the legend, the facilities are operated by the state (USA) or federal agency (Canada). Sites for tagging naturally produced fish in streams are not plotted because of the large number involved.

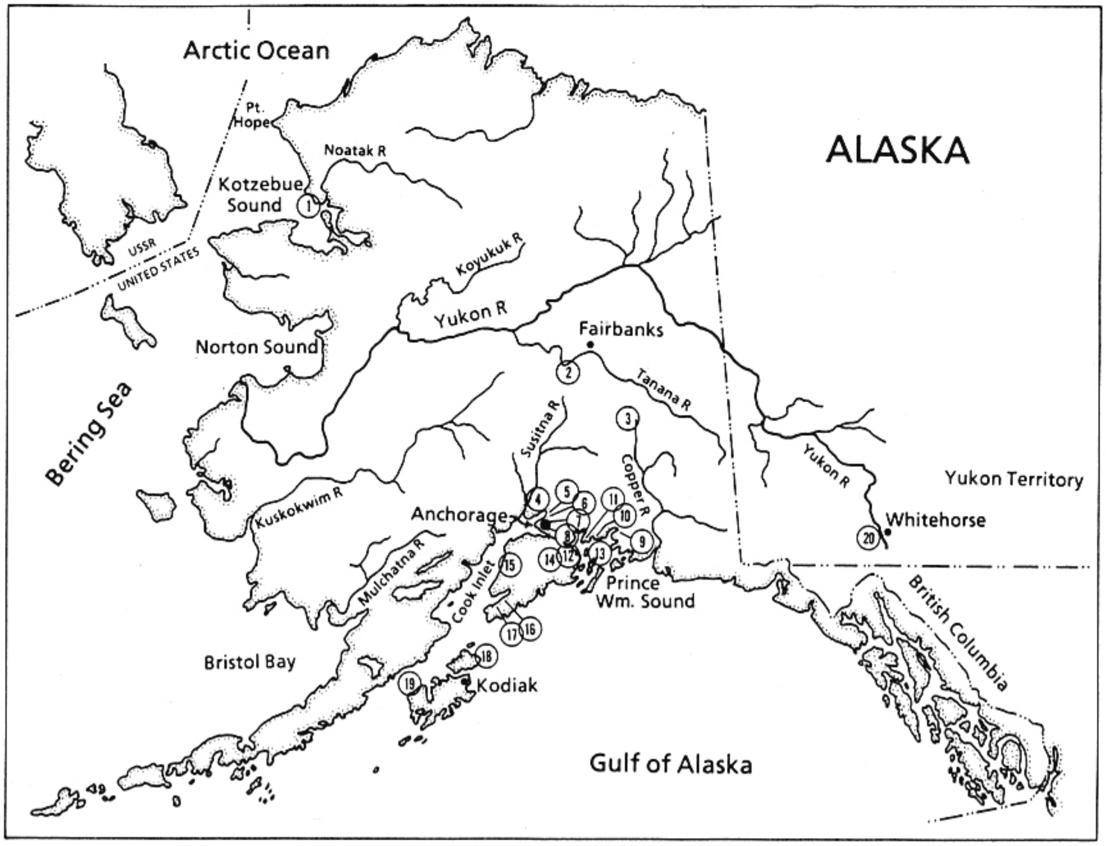


FIGURE 2.—Hatcheries and rearing facilities in Alaska (exclusive of the southeast region; see Figure 3) and the Yukon that release salmonids with coded wire tags.

1 Sikusuilaq
2 Clear
3 Gulkana
4 Big Lake
5 Eklutna
6 Fire Lake (closed)
7 Fort Richardson
8 Elmendorf
9 Solomon Gulch (VFDA)
10 Cannery Creek (ADFG, PWSA)
11 Esther Lake (PWSA)
12 Main Bay
13 Armin F. Koernig (PWSA)
14 Trail Lakes
15 Crooked Creek (formerly Kasilof)
16 Halibut Cove
17 Tutka Bay
18 Kitoi Bay
19 Karluk
20 Whitehorse (CDFO)

ADFG = Alaska Department of Fish and Game
CDFO = Canada Department of Fisheries and Oceans
PWSA = Prince William Sound Aquaculture Association
VFDA = Valdez Fisheries Development Association

Alaska: south-central region.-.Alaskan hatcheries north of the panhandle are limited to the Cook Inlet and Prince William Sound areas of the south-central region (Figure 2). Clear Hatchery on the Tanana River, a tributary of the extensive Yukon River system, and Sikusuilaq Hatchery, far to the northwest above the Arctic Circle in Kotzebue Sound were closed in the 1990s. (CDFO also maintains a hatchery far upstream on the Yukon River at Whitehorse in the Yukon Territory where tagged fish are released).

Recent tagging levels for this region have varied between 650,000 and 960,000 fish per year. Chinook, salmon have received the most emphasis at levels ranging from 400,000-600,000 fish, with coho salmon tagging at substantially lower levels (150,000-300,000). Pink salmon were tagged in the past (200,000-300,000 range) but most of the hatchery production is now marked with thermal marks. There is not any CWT marking of pink, sockeye or chum salmon at this time

Alaska: southeast region. - Eighteen hatcheries presently release tagged fish in southeast Alaska (Figure 3). Of these, 14 are operated by regional aquaculture associations (e.g., NSRAA, SSRAA) and private nonprofit groups (e.g., AKI, DIPC). In addition, the Metlakatla Indian Community operates a large hatchery (Tamgas Creek) on Annette Island in the southernmost part of the state.

Overall tagging levels range between 1.6 and 1.8 million fish per year. Chinook, coho, and chum salmon tagging levels are on the order of 750,000, 700,000, and 215,000 fish, respectively. And similar to Alaska's south-central region, pink, sockeye, and chum salmon production releases are not being tagged at this time.

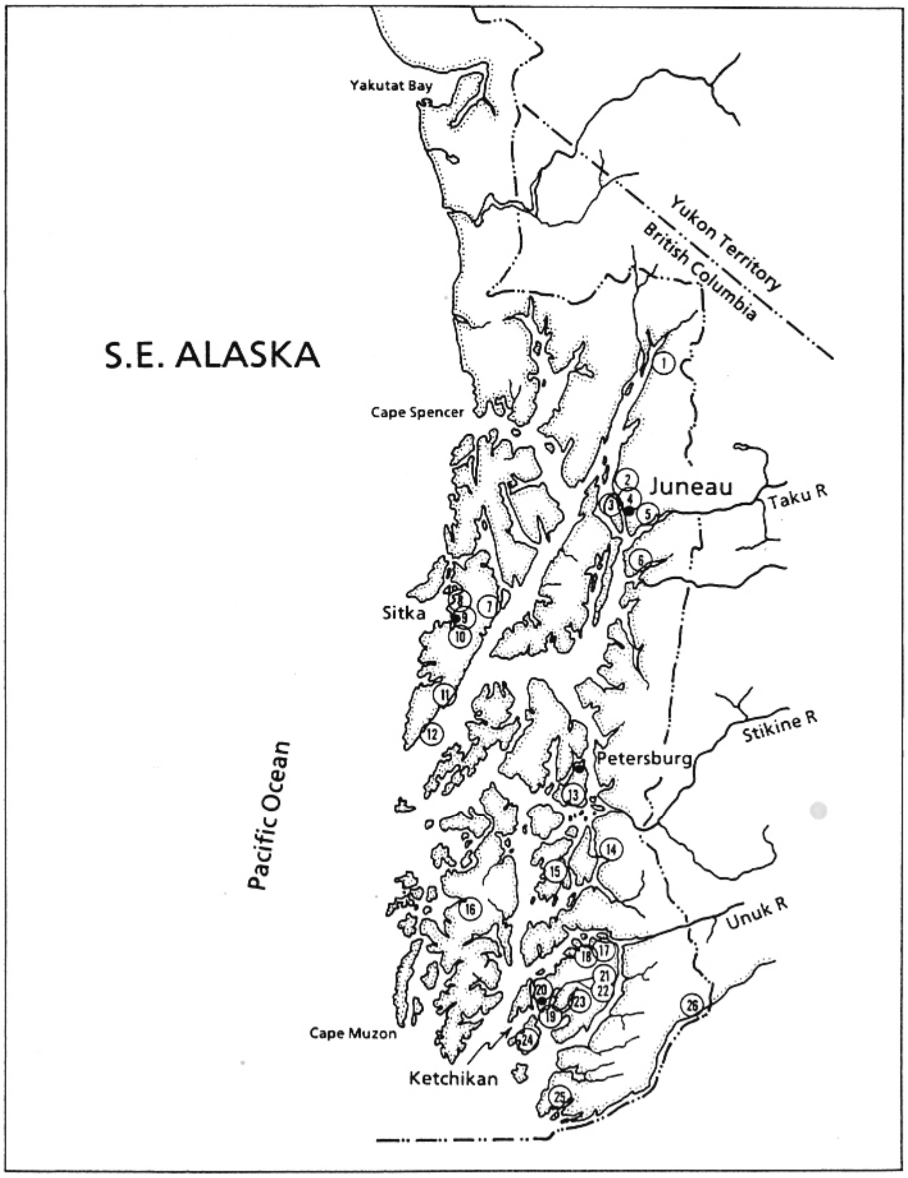


FIGURE 3.—Hatcheries and rearing facilities in southeast Alaska that release salmonids with coded wire tags.

1 Pullen Creek
2 Auke Creek (NMFS, UAJ)
3 Fish Creek
4 Salmon Creek (NSRA, ADFG)
5 Sheep Creek (DIPC)
6 Snettisham
7 Hidden Falls
8 Starrigavan (closed)
9 Sheldon Jackson (SJ)
10 Medvejie CIF (NSRA)
11 Little Port Walter (NMFS)
12 Port Armstrong (AKI)
13 Crystal Lake
14 Earl West Cove (SSRA, ADFG)
15 Burnett Inlet (AKAF)
16 Klawock
17 Shrimp Creek (SSRA)
18 Neets Bay (SSRA)
19 Whitman Lake (SSRA)
20 Deer Mountain
21 Beaver Falls
22 George Inlet (SSRA)
23 Carroll Inlet (SSRA)
24 Tamgas Creek (MIC)
25 Nakat Inlet (SSRA)
26 Marx Creek

AKAF = Alaska Aquaculture Foundation, Inc.
AKI = Armstrong Keta, Inc.
DIPC = Douglas Island Pink and Chum, Inc.
MIC = Metlakatla Indian Community
NMFS = National Marine Fisheries Service
NSRA = Northern Southeast Regional Aquaculture Association
SJ = Sheldon Jackson College
SSRA = Southern Southeast Regional Aquaculture Association
UAJ = University of Alaska, Juneau

British Columbia.- Management of salmon species in British Columbia falls under the jurisdiction of Canada's federal agency, Department of Fisheries and Oceans, Canada (CDFO). The Salmonid Enhancement Program (SEP) in British Columbia was undertaken in 1977 primarily to rebuild stocks and increase catch through the expanded use of enhancement technology. The program is now comprised of nearly 300 projects and produces chinook, coho, chum, pink, and sockeye salmon, as well as small numbers of steelhead and cutthroat trout.

Projects include hatcheries, fishways, spawning and rearing channels, and small classroom incubators, ranging in size from spawning channels producing nearly 100 million juvenile salmon annually to school classroom incubators releasing fewer than one thousand juveniles.

Projects are operated by CDFO staff (24 projects) or contracted to community and native groups (22 projects), as well as by volunteers with some CDFO support. Of these, 31 hatcheries and facilities released CWT marked salmon in 2003 (Figure 4).
Up to 10,000 volunteers participate in the program annually. The focus is also on restoring and improving fish habitat, working with First Nations (tribal), industry, community groups and other government agencies to design and implement habitat restoration projects.

It is not possible to assess each enhancement project and release strategy. Consequently, certain stocks are used as indicators, their production is marked annually, and rigorous escapement sampling and estimation programsare normally carried out. Other stocks may be marked to assess hatchery strategies or resolve stock specific issues.

Coded wire tagging of chinook and coho from British Columbia facilities peaked in the mid to late 1980s, when 2.7 million CWT coho and 7.8 million CWT chinook were released. From 1997 to 2002, approximately 1.2-1.7 million tagged coho and 3.8-4.5 million chinook were released annually. In 2003, 0.9 million tagged coho and 3.7 million tagged chinook were released.

Chum salmon are generally marked with a multiple fin clip. Tagging programs were undertaken only where more codes were needed than possible through fin clip combinations. There are currently no chum stocks being marked with a CWT. Pink salmon marking programs were discontinued after 1993 release year.

Overall tagging and/or multiple fin clip marking levels will decline in the next few years. The reason for the decline is reduced budgets combined with increasing costs for marking and recovery projects. In 2003, 23 coho and 31 chinook stocks were CWT marked, and 6 chum stocks were marked with a multiple fin clip. In comparison, 46 coho stocks and 57 chinook stocks were CWT marked and released in 1986, during the peak marking period.

Steelhead fall under the jurisdiction of British Columbia's provincial government. In the 1970s and 1980s, CWT marked steelhead were released in modest numbers. While hatchery production of steelhead continues, no CWT marked steelhead have been released for many years.

Washington.- Over *120* hatcheries and rearing facilities in Washington participate in tagging salmonids, many of which are in the southern half of Puget Sound (Figure 5). The majority are state hatcheries operated by WDFW. However, the tribes also play a prominent role and release tagged salmonids at 24 tribal facilities, mostly in coastal Washington and Puget Sound. Another 17 federal facilities (USFWS and NMFS) also release large numbers of tagged salmonids. Overall, approximately 16 million CWT marked salmonid fish are released yearly in Washington.

As in British Columbia and southeast Alaska, chinook salmon are tagged at the highest rates, followed by coho salmon. WDFW is the primary tagging agency and tags approximately 12 million chinook annually. The Columbia River (3 million) receives the most emphasis, followed by Puget Sound (2.5 million). Chinook tagging levels for coastal Washington were on the order of 200,000 in the late 1990s. However WDFW has not tagged coastal chinook stocks on the coast for the past three years.

WDFW also releases approximately 2.5 million tagged coho salmon annually, with somewhat comparable levels of tagging for the Columbia River (525,000), coast (700,000), and Puget Sound (850,000). Much of the tagging is done for Pacific Salmon Treaty requirements.

The western Washington tribes release approximately 2.5 million tagged chinook and 1.1 million tagged coho salmon. Approximately 60% of the tagging is associated with the Pacific Salmon Treaty assessment efforts for indicator stocks.

Federal tagging programs primarily focus on marking chinook salmon in the Columbia Basin. USFWS tags approximately 2.5 million chinook salmon in Washington, of which two million are released from Columbia River hatcheries. Tagging in this case is done primarily for hatchery evaluations.

Tagging of steelhead is relatively limited. WDFW tags approximately 500,000 steelhead each year. In addition, approximately 120,000 steelhead are marked and/or tagged by the Quinault Nation, the Hoh Tribe, and USFWS in cooperative programs

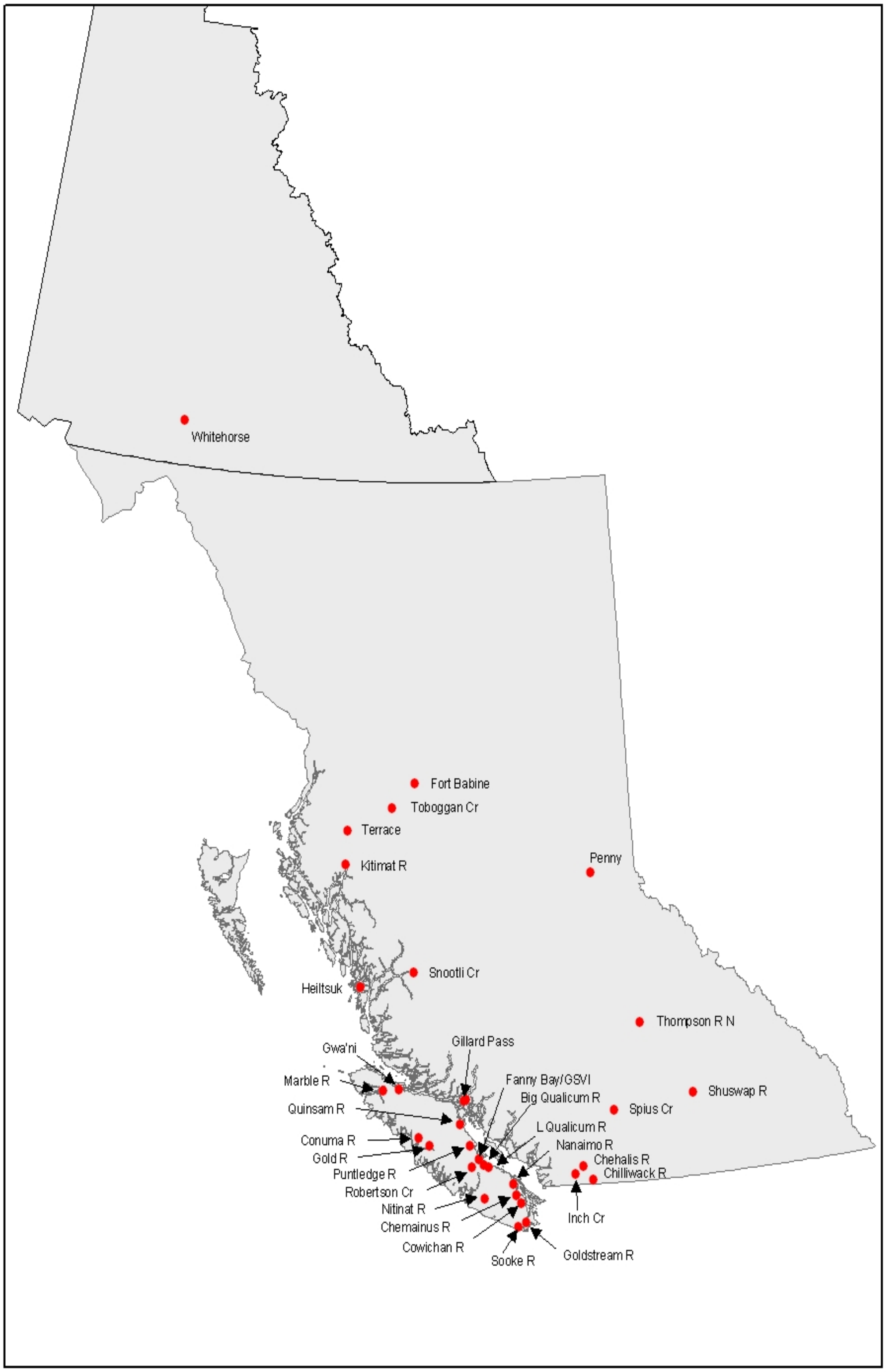


Figure 4. *(Updated figure*) Hatcheries and rearing facilities in British Columbia and the Yukon Territory that released salmonids with CWTs in 2003.

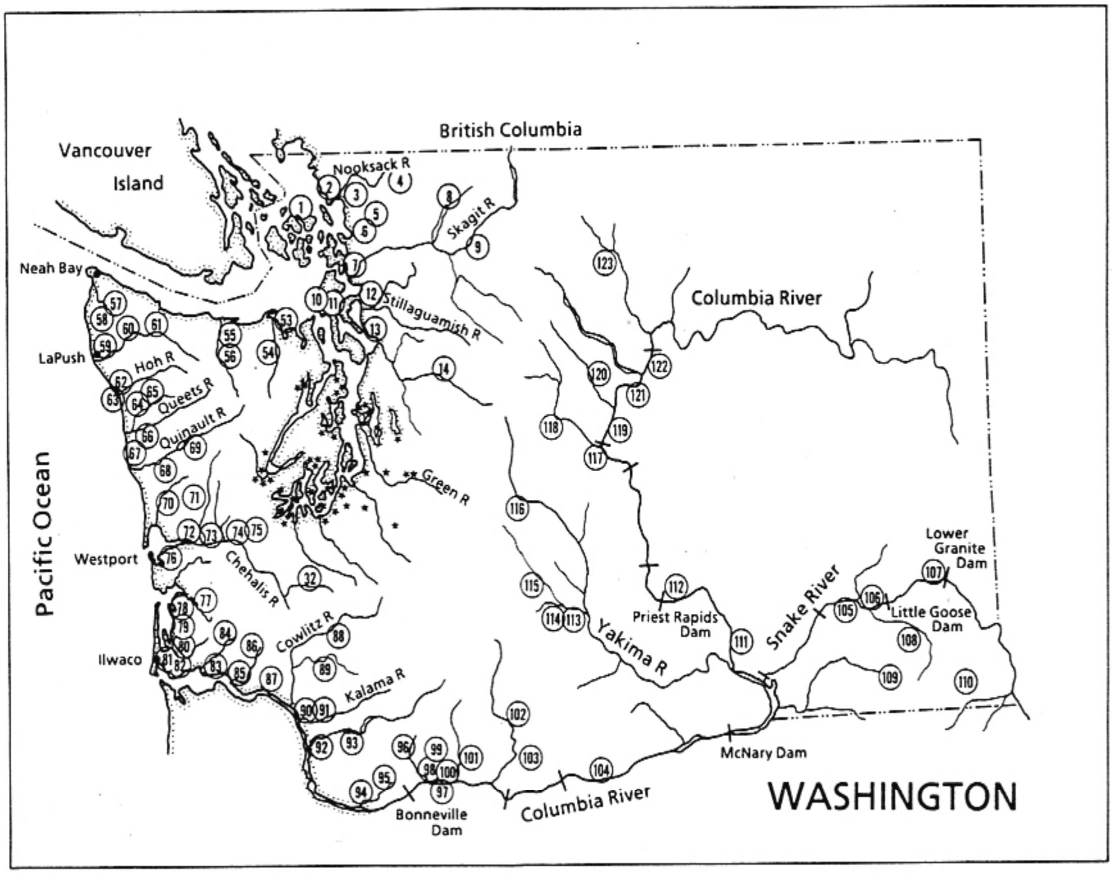


FIGURE 5.—Hatcheries and rearing facilities in Washington that release salmonids with coded wire tags. Sites marked with stars in the left panel are numbered in the right panel.

1 Glenwood Springs
2 Lummi Sea Pens (T)
3 Bellingham
4 Nooksack River
5 Skookum Creek (T)
6 Samish River
7 Swinomish Raceways (T)
8 Puget Power (U)
9 Skagit River
10 Oak Harbor Pen
11 Whidbey Island Pens
12 Stillaguamish Tribal (T) (formerly Armstrong Creek)
13 Tulalip Creek (T)
14 Skykomish River
15 Montlake (F)
16 University of Washington (CF)
17 Seattle Aquarium
18 Elliott Bay Pens
19 Issaquah Creek
20 Northwest Steelheaders (S)
21 Green River
22 Crisp Creek
23 Keta Creek (T)
24 Totem Marina Pens
25 Puyallup Tribal (T)
26 Puyallup River
27 Narrows Pens
28 Chambers Creek
29 Garrison Springs
30 Kalama Creek (T)
31 Deschutes River
32 Skookumchuck River
33 Allison Springs
34 Squaxin Island Pens (and South Sound Pens)
35 Filucy Bay Pens
36 Shaws Cove Pens
37 Fox Island Pens
38 Gig Harbor Pens
39 Minter Creek
40 Hupp Springs
41 Coulter Creek
42 George Adams
43 McKernan
44 Shelton
45 Enetai (T)
46 Hood Canal
47 Gorst Creek
48 Manchester (F)
49 Grovers Creek (T)
50 Suquamish Pens (T)
51 Port Gamble Pens (T)
52 Quilcene River (NFH)
53 Hurd Creek
54 Dungeness River
55 Lower Elwha (T)
56 Elwha Channel
57 Hoko Ponds
58 Makah (NFH)
59 Lonesome Creek (T)
60 Soleduck River
61 Bear Springs
62 Chalaat Creek (T)
63 Reservation Slough (T)
64 Mule Pasture Pond (T)
65 Shale Creek

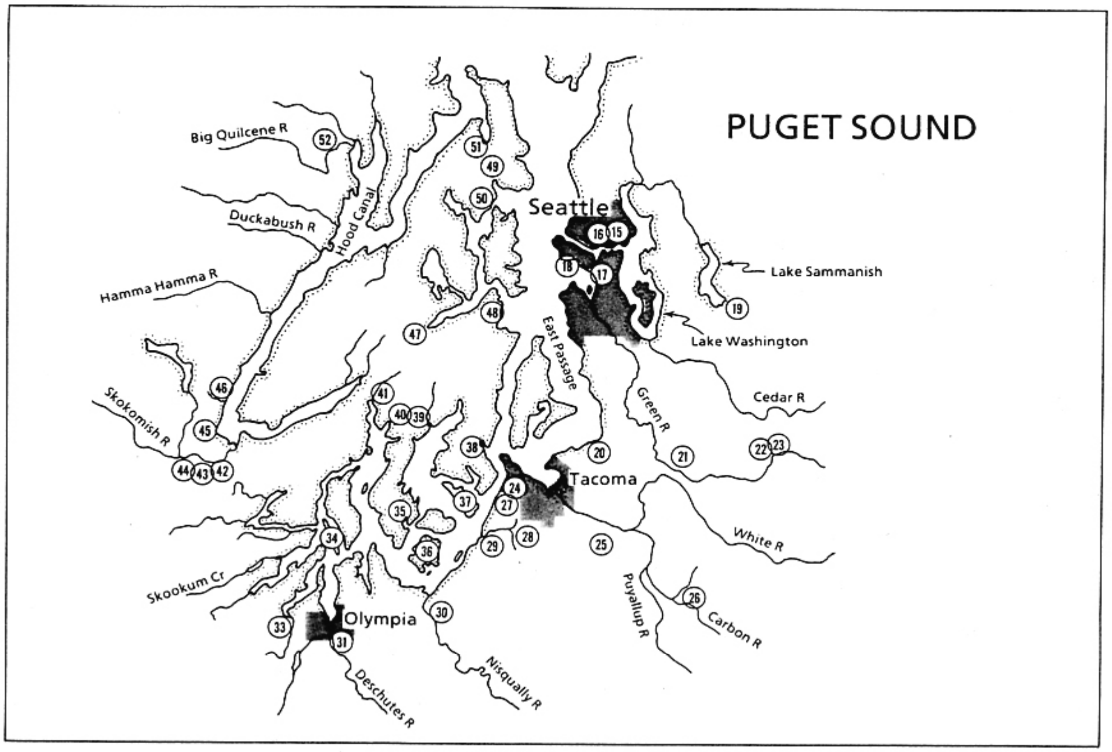


FIGURE 5.—Continued.

66 Salmon River Pond (T)
67 Raft River Pond (T)
68 Quinault River (NFH)
69 Quinault Lake (T)
70 Humptulips River
71 Mayr Brothers Ponds
72 Aberdeen
73 Wynoochee River Pens
74 Satsop Springs
75 Simpson
76 Westport Pens
77 Willapa River
78 Bay Center Springs
79 Nemah River
80 Naselle River
81 Fisher Slough
82 Sea Resources
83 Grays River
84 Weyco Pond
85 Beaver Creek
86 Elokomin River
87 Abernathy Salmon Culture Development Center (F)
88 Cowlitz River
89 Toutle River
90 Lower Kalama
91 Kalama Falls
92 Lewis River
93 Speelyai
94 Skamania
95 Washougal River
96 Carson River (NFH)
97 Drano Lake Pens (F)
98 Little White Salmon (NFH)
99 Willard (NFH)
100 Spring Creek (NFH)
101 Big White Salmon (F)
102 Klickitat River
103 Goldendale
104 Rock Creek Ponds (F)
105 Lyons Ferry
106 Little Goose Dam (F)
107 Lower Granite Dam (F)
108 Tucannon River
109 Curl Lake
110 Cottonwood Pond
111 Ringold
112 Priest Rapids
113 Nelson Springs (S)
114 Naches
115 Nile Spring (T)
116 Cle Elum Ponds (T)
117 Rocky Reach
118 Leavenworth (NFH)
119 Turtle Rock
120 Entiat River (NFH)
121 Chelan
122 Wells Channel
123 Winthrop (NFH)

CF = College of Fisheries, Fisheries Research Institute
NFH = National Fish Hatchery
F = other federal facilities
S = sportsmen's project
U = public utility

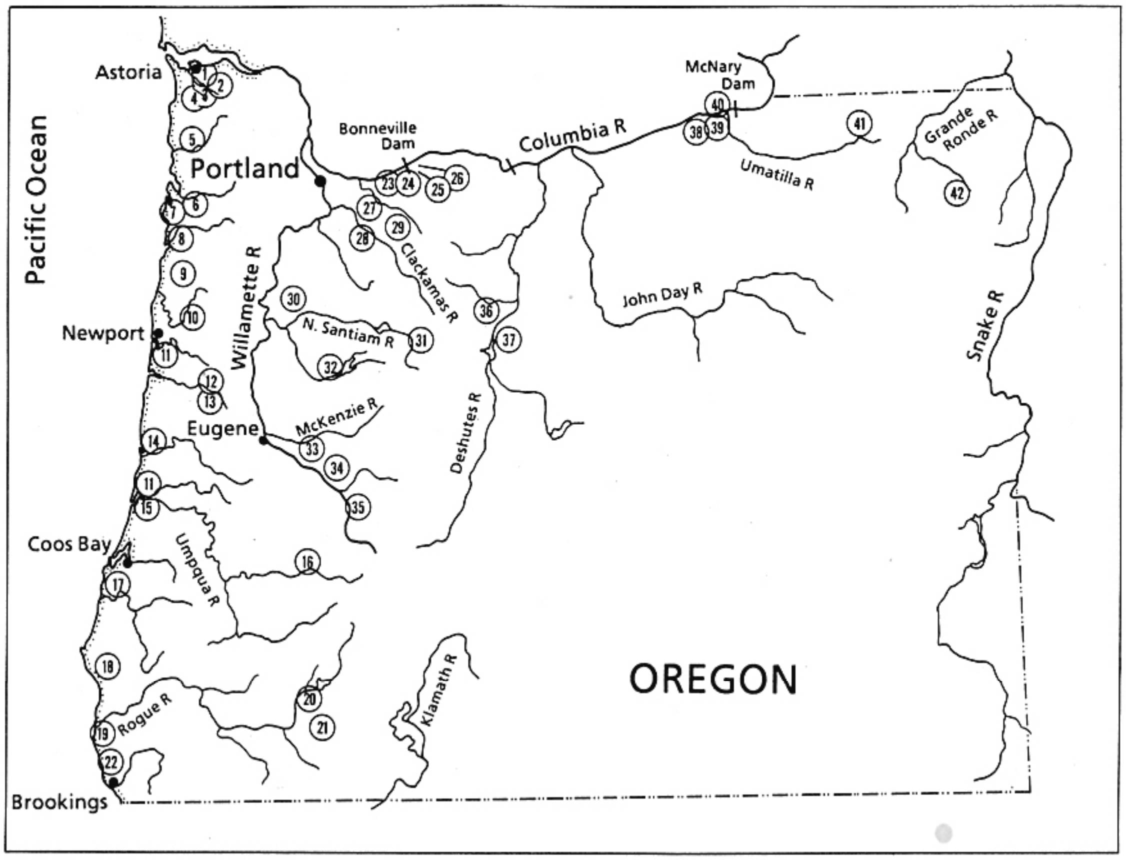


FIGURE 6.—Hatcheries and facilities in Oregon that release salmonids with coded wire tags.

1 Big Creek
2 Klaskanine River
3 Klaskanine River Ponds, South Fork
4 Vanderveldt Ponds
5 Nehalem River
6 Trask River
7 Whiskey Creek (OSU)
8 Cedar Creek
9 Salmon River
10 Siletz River
11 Oregon Aqua-Foods (P) (Coos Bay, Yaquina Bay)
12 Fall Creek
13 Alsea
14 Domsea Farms (P)
15 Anadromous, Inc. (P)
16 Rock Creek
17 Bandon
18 Elk River
19 Indian Creek Pond
20 Cole Rivers
21 Butte Falls
22 Oregon Pacific Salmon (P) (formerly Burnt Hill Salmon)
23 Wahkeena Pond
24 Bonneville
25 Cascade
26 Oxbow
27 Sandy River
28 Clackamas
29 Eagle Creek (NFH)
30 Stayton-Aumsville Ponds
31 Marion Forks
32 South Santiam
33 McKenzie River
34 Dexter Ponds
35 Willamette River
36 Warm Springs (NFH)
37 Round Butte
38 Irrigon
39 Bonifer Pond
40 Social Security Pens (F)
41 Lookingglass
42 Wallowa River

NFH = National Fish Hatchery
F = other federal facility
P = private aquaculture
OSU = Oregon State University

Oregon.-Oregon has 47 hatcheries and rearing facilities that release tagged salmon and steelhead. Of these, 42 are shown in Figure 6. Most are located on the coast, the lower Columbia River, or Willamette River. In addition, nearly all are state facilities operated by ODFW.

The Warm Springs and Eagle Creek national fish hatcheries are the only federal hatcheries in Oregon. Warm Springs NFH produces 650,000 spring chinook, all of which are given a CWT plus the adipose clip. Eagle Creek NFH produces 1.1 million coho, with representative tagging of release groups.

Chinook salmon tagging levels for ODFW and private agencies are 4.0 million and 1.3 million respectively, while coho salmon tagging levels at ODFW facilities are 1.3 million with no private hatchery production.

ODFW also manages steelhead and releases some 385,000 tagged smolts annually.

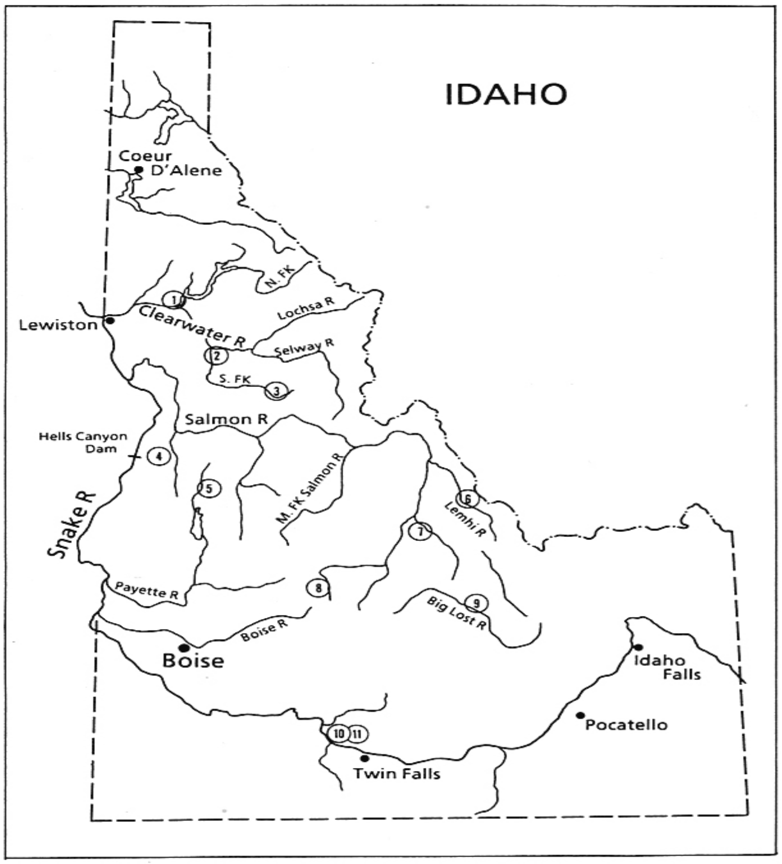


FIGURE 7.—Hatcheries and rearing facilities in Idaho that release salmonids with coded wire tags.

1 Dworshak (NFH)
2 Kooskia (NFH)
3 Red River Pond
4 Rapid River
5 McCall
6 Hayden Creek
7 Pahsimeroi
8 Sawtooth
9 Mackay
10 Hagerman (NFH)
11 Niagara Springs

NFH = National Fish Hatchery

Idaho.-In spite of their great distance from the ocean, Idaho's 17 anadromous fish hatcheries are major contributors in terms of both production and numbers of tagged chinook salmon (circa 1.5 million tags). Millions of steelhead are also released, with tagging levels on the order of 1.0 million. Many of the released fish groups are also marked with PIT tags to evaluate downstream migration, dam passage, and eventual return upstream.

The Clearwater and Salmon rivers and the Snake River below Hells Canyon Dam are the only chinook and steelhead producing waters in Idaho now that Hells Canyon Dam has blocked off the upper Snake River (Figure 7). However, several of the hatcheries (McCall, Niagara Springs, Hagerman NFH, and Magic Valley) are located upstream of Hells Canyon Dam because of superior water quality and other factors. Fish produced by these facilities are trucked to the Salmon River for release.

Coho salmon are being reared at Dworshak NFH by the Nez Perce Tribe in an attempt to restore coho runs back to the Clearwater River system. Tagging levels for coho salmon are presently at 110,000 fish yearly. In addition, the tribe is now producing spring and fall chinook at the new Nez Perce Tribal Hatchery. At full production, 1.4 million fall chinook and 600,000 spring chinook will be reared. All of the Nez Perce fish will be CWT marked.

Figure 7 is no longer current for many of Idaho's anadromous salmonid hatcheries:

Clearwater Hatchery (not shown)	Chinook, Steelhead
+ Crooked River (not shown)	Chinook, Steelhead
+ Red River	Chinook, Steelhead
+ Powell (not shown)	Chinook, Steelhead
Dworshak NFH	Chinook, Steelhead
Kooskia NFH	Chinook
Rapid River	Chinook
Oxbow (not shown)	Chinook
McCall	Chinook
Sawtooth	Chinook
Pahsimeroi	Chinook
Nez Perce Tribal Hat. (not shown)	Chinook, Coho
+ Pittsburg Facility	Chinook
Johnson Creek (not shown)	Steelhead
Hagerman NFH	Steelhead
Magic Valley (not shown)	Steelhead
Niagara Springs	Steelhead

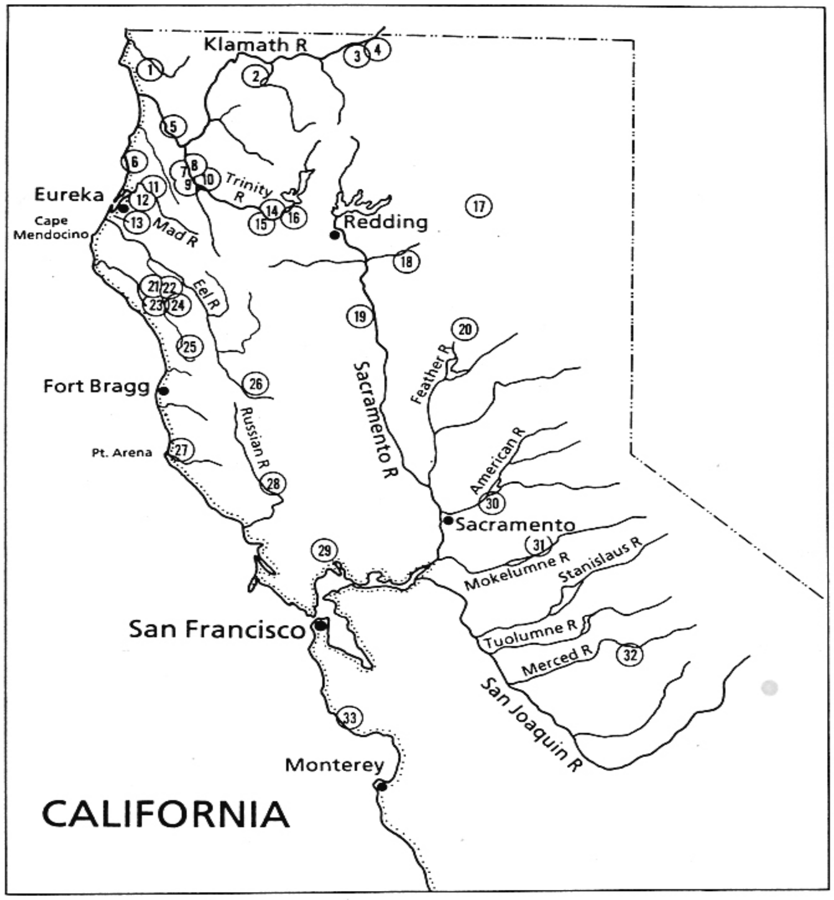


FIGURE 8.—Hatcheries and facilities in California that release salmonids with coded wire tags.

1 Rowdy Creek
2 Kelsey Creek Channel
3 Fall Creek Ponds
4 Iron Gate
5 Chappel (F)
6 Little River Ponds
7 Mill Creek Ponds (T)
8 Supply Creek Ponds (T)
9 Tish Tang Creek Ponds (T)
10 Horse Linto Creek Ponds
11 Mad River
12 Arcata
13 Cochran Ponds
14 Sawmill Pond
15 Ambrose Pond
16 Trinity River
17 Crystal Lake
18 Coleman (NFH)
19 Tehama Colusa Fish Facility (F)
20 Feather River
21 Redwood Creek Ponds
22 Dinner Creek Ponds
23 Marshall Creek Ponds
24 Sprowel Creek
25 Hollow Tree Creek Ponds
26 Van Arsdale
27 Garcia River Ponds
28 Warm Springs
29 Silverado Planting Base
30 Nimbus
31 Mokelumne River
32 Merced River
33 Silverking Oceanic Farms (P)

NFH = National Fish Hatchery
F = other federal facilities
P = private aquaculture
T = Tribal facility

California.-Nine hatcheries, operated by CDFG or USFWS in northern California, currently release CWT + adipose fin clipped chinook and coho salmon and steelhead (Figure 8). The six hatcheries located in the Sacramento-San Joaquin river system of the Central Valley (Coleman NFH, Livingston Stone NFH, Feather River, Nimbus, Mokelumne River, and Merced River), account for about 85% of the total tagged releases, with the remainder from the Klamath-Trinity and coastal river systems (Iron Gate, Warm Springs, and Trinity River hatcheries). With minor exceptions, the scattered satellite ponds have not released tagged salmon for many years.

The Livingston Stone NFH (USFWS) is relatively new (1998) and not shown in Figure 8. It is located on the upper Sacramento River just below the Keswick Dam (near Shasta Dam) and serves as a brood stock facility for the recovery of winter chinook.

Chinook salmon constitute the majority of the tagged fish released, with an average of 5.5 million salmon tagged annually during 1999-2003. About 15% of the approximately 30 million fall-run Chinook produced in Central Valley hatcheries, and 10% of the 9 million Klamath-Trinity fall run, are tagged. Tagging rates at individual hatcheries vary from about 5% to 95%, but plans for implementation of a constant fractional tagging program are being developed.

Tagging of coho salmon is limited (about 10,000 of the State’s 550,000 fish production) and is presently focused on the coastal Russian River stock.

Tag Recovery and Estimation Procedures

Regional Sampling Effort

Many agencies release tagged salmonids, but the burden of ocean tag recoveries largely falls on five agencies: ADFG, CDFO, WDFW, ODFW, and CDFG.

In addition, the 20 western Washington treaty tribes jointly carry out a sizable and important component of the coastwide sampling effort. Their tribal fishery recovery information is combined with non-treaty recoveries and processed by WDFW. However the coastal Washington Quinault Nation and the Quileute Tribe maintain their own recovery and reporting programs.

In the lower Columbia River, ODFW and WDFW jointly share the primary responsibility for sampling the commercial, tribal, and recreational fisheries. In the upper Columbia River (Washington), the Yakama Tribe maintains a CWT sampling program.

In the Snake River basin, IDFG samples its freshwater fisheries and hatchery returns for CWT marked fish. The Nez Perce Tribe (Idaho) has also developed a sampling program. Their respective CWT recovery data sets are submitted to the Mark Center through the Columbia River Intertribal Fish Commission (CRITFC).

Limited sampling is done by a few other agencies. In Alaska, NMFS and the Metlakatla Indian Community maintain sampling programs for their respective fisheries and escapement. Lastly, USFWS maintains a sampling program on the Klamath-Trinity River system in northern California, as well as sampling programs at its various hatcheries in Washington, Oregon, Idaho, and California.

Sampling Design

The sampling programs of the participating agencies are comparable in overall design but differ in many specifics because of constraints imposed by local conditions and differing approaches to mark recovery. There are, however, five common elements of the major recovery programs, discussed below.

Sampling of commercial fisheries.-All of the major recovery programs sample landings of commercial marine and mainstem river fisheries for CWT marked chinook and coho salmon. In California and Alaska, visual sampling for adipose clips is the only method used to retrieve CWTs.

Electronic tag detection equipment is used by Oregon, Idaho, and Washington to sample the chinook and coho salmon landings.

In British Columbia, electronic sampling is limited to coho landings in general. However, at the present time, chinook landings are also being electronically sampled because of the restricted fisheries. If there is an improvement in commercial fisheries (either coho or chinook), the equipment and infrastructure currently in place will be inadequate to support electronic sampling.

Representative samples are randomly taken at ports throughout the state or province at appropriate time intervals to track changes in stock composition in the harvest and to also estimate survival rates for the intercepted stocks of interest.

Sampling of recreational fisheries.- A second major component is the sampling of the recreational fishery. The emphasis typically is focused on sampling day boats and charter boats in marine waters. Creel sampling is also carried out in some inland fisheries.

The chinook and coho salmon recreational fisheries in Washington's Puget Sound and British Columbia's Strait of Georgia pose a special problem because both are geographically widespread and typically open much or all of the year. In addition, there are hundreds of marinas and private and public launch ramps where anglers land their catch, thus representative sampling of recreational fisheries can be costly. CDFO also carries out recreational fishery sampling on the major ports along the west coast of Vancouver Island, and during some years, in other areas

Prior to the desequestering of the adipose clip, CDFO and WDFW each maintained voluntary return programs in which anglers were encouraged to turn in heads of adipose clipped salmonids at any of the many "head depots" located throughout the region. In addition, WDFW conducted interviews of anglers to determine public awareness of the CWT program. That “awareness factor” was then used in the estimation of total sport recoveries.

With the advent of mass marking, WDFW’s voluntary snout return program for anglers was gradually phased out from 1998 to 2000. In its place, WDFW increased direct sampling levels to compensate for the loss of volunteer recovery information.

During that same period, CDFO had continued its voluntary snout return program along with an expansion of creel surveys that have been in progress since 1977. The creel census design is structured to record regional mark incidence and compute the awareness or compliance of anglers, based on voluntary submissions to the head depots. In 1998, creel surveyors also began electronically sampling for CWT. This was discontinued in 2004 due to high costs and low CWT sample rates obtained.

The Voluntary Head Recovery Program in B.C. has been found to be more cost effective and provide more recoveries than the Creel Survey program. Creel Samplers will concentrate on obtaining effort and mark rate data and will not be collecting heads. CWTs will be obtained via the Voluntary Head Recovery program. Sport Awareness factors will be used to expand CWTs turned in to estimated recoveries in the recreational catch.

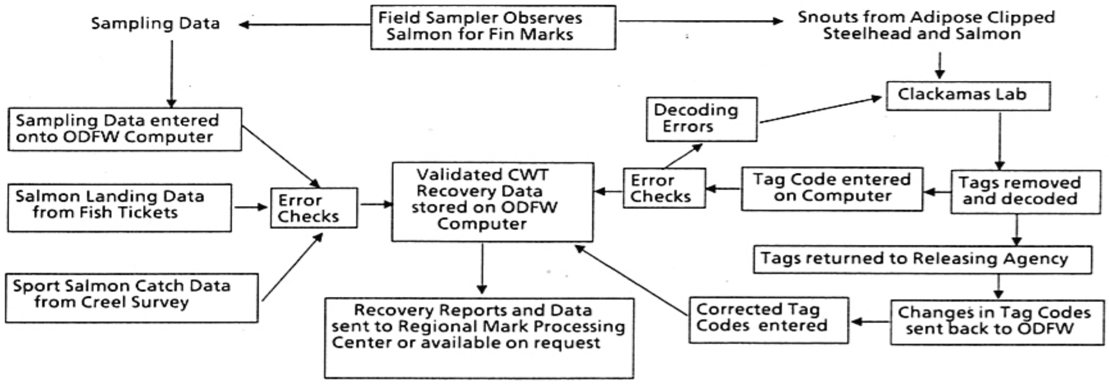


FIGURE 9.—Flowchart for the Oregon Department of Fish and Wildlife (ODFW) coded wire tag (CWT) recovery system. Other recovery agencies follow similar procedures for tag recovery and data management.

This sport 'indirect mark incidence' program will be described later in the subsection describing British Columbia's recovery programs.

Sampling of escapement.-A third common element is the sampling of escapement. This includes returns to the hatchery and spawning ground surveys. Historically, this has been the weakest component of the sampling coverage by nearly all recovery agencies. However, it has received ever increasing attention and importance with the implementation of the Pacific Salmon Treaty.

Minimum of 20% sampling rate.-All recovery agencies strive to randomly sample at least 20% of commercial and sport landings to have a statistically acceptable estimate of total tag recoveries for a given area-time stratum. In many cases, sampling coverage may exceed 50% if port coverage by samplers is high. However, inland sport fisheries may be sampled at less than 20% because of inherent sampling difficulties, coupled with limited staffing. This can be true at times for the lower Columbia River and Willamette River sport fisheries, for example.

Coastwide CWT sampling coverage limited.- Lastly, chinook and coho salmon are the only species sampled in commercial and sport fisheries, both marine and freshwater, on a coastwide basis.

Some sampling does occur for chum, sockeye, and pink salmon and steelhead. In such cases, it typically involves agency only management objectives in marine terminal areas or limited freshwater areas.

Sampling Procedures

Field samplers typically work on the docks and sample commercial landings at buying stations. Recreational vessels also are sampled as they return to port. The basic sampling unit is the boatload of fish, not the individual fish. Samplers attempt to randomly sample vessels, whether they are day boats or trip boats. In the latter case, some of the larger vessels must be sub-sampled because of the size of the catch. Bins of fish then become the sampling units.

Sampled fish testing positive for the presence of a CWT (electronic sampling) or missing the adipose fin (visual sampling) are set aside for removal of the head or snout. The sampler then may collect species, sex, and fork length of the fish and record these data on a small waterproof label and encloses it with the head in a small plastic bag for later processing. Scale samples and weight information also may be collected.

Information on the sampled unit (boat load, or bin) is recorded on a sample form. This typically includes catch location, catch period, gear type, processor, species, total fish sampled, total marks recovered, and sample date.

CWT Processing Procedures

A simplified flowchart of CWT processing procedures is shown above in Figure 9, which uses ODFW's system as the example. Heads removed from adipose clipped salmonids are transported frozen or preserved to the agency's head lab for tag removal and decoding. The tiny tags are recovered by dissection, aided by an electronic metal detector that indicates which portion of the snout the tag is in after each successive sectioning of the sample. If no tag is found, the sample is passed through a magnetic field to re-magnetize the tag (if present). The sample is then passed through a highly sensitive tubular tag detector to confirm the absence of a tag.

Following tag extraction, the tag is decoded under a low power microscope. After the initial reading, a second tag reader makes an independent reading for verification. Several agencies now use a small television camera to project the tag image on a small screen, thereby making it easier to read the code.

Once decoded, the tag code and associated sampling data are entered on the computer for further processing. Several error checks are run, including verification that the tag code is legitimate (i.e., was previously released) and that the species is correct. Questionable tag codes are re-read by dissection laboratory personnel, and pertinent supplementary data are checked to resolve other errors.

Upon validation, the "observed recoveries" are made available for use in preliminary reports. This includes expansion of the observed recoveries into "estimated recoveries" for the given area-time stratum once the catch-sample data are available.

Catch Data

Total landings are required for a given sampled time-area stratum to estimate total tags recovered. These data for commercial fisheries usually are obtained from fish tickets provided by the buyers. Fish tickets often are not finalized and error checked until months after the catch was landed and sampled. Estimates of recreational catch, are often less timely than for commercial fisheries due to the time required to process data from punch cards and angler surveys.

Recovery Estimation Equations

The total number of fish from a particular release group that are caught in a particular area (or landed at a particular port) during a particular time period can be estimated in a two-step, process. The first step is to estimate the number of tagged fish in the fishery sample for that area (or port) and time:

$$R_T = aR_O;$$

R_T = the estimated total recoveries of tags bearing the release group's code;
R_O = the observed number of tags of the appropriate code;
a = a sampling expansion factor: (total catch)/(sampled catch).

The second step is to account for the fraction of the release group that was tagged:

$$C = bR_T;$$

C = the total estimated contribution of the release group to the fishery in that area at that time;
b = a marking expansion factor: (total fish released)/(total fish marked).

These are the simplest forms of the recovery expansion equations. Typically, the sampling expansion factor is adjusted to account for biases introduced by snouts with no tags, snouts sampled but not taken, lost snouts, and lost tags. In addition, WDFW and CDFO commonly include an adjustment for angler awareness in recreational fisheries because of the large number of voluntary (out-of-sample) recoveries present.

Reporting

Upon completion of this process, the recovery agency forwards the observed and estimated tag recovery data and. associated catch and sample data on magnetic tape to the Mark Center (Figure 9). The Mark Center checks the data for errors and works with the recovery agency to resolve discrepancies. Once validated, the CWT data (preliminary or final) are combined with those of other recovery agencies in the online CWT database.

Overview of Major Recovery Programs

As noted above, sampling programs of the major recovery agencies have general similarities. However, important differences also exist that must be understood in order to compare approaches. Therefore, the following provides a closer look at the recovery programs operated by ADFG, CDFO, WDFW, ODFW, IDFG, and CDFG. Stratifications used for fisheries, statistical areas, time, and expansion of recovery data also are summarized.

Alaska: South-Central Region

The CWT recovery program in south-central Alaska is unusual in that there are no regional troll fisheries to deal with; instead, terminal net fisheries are the rule. Consequently, the sampling programs are designed to meet localized objectives for the various management units involved in tagging chinook and coho salmon stocks.

Prince William Sound is no longer sampled for CWTs. Their hatcheries now use otolith thermal marking to evaluate stock composition.

Alaska: Southeast Region

Southeast Alaska's CWT recovery program is designed to sample at least 20% of the chinook, and coho salmon caught in the commercial troll and net fisheries. Sampling of sockeye and chum salmon caught in net fisheries in southeast Alaska has been significantly scaled back for budgetary reasons and as a consequence of reduced coded wire tagging of those species.

Samplers are deployed to approximately 12 ports in southeast Alaska each year, based on expected landings. At each port, samplers allocate their time to processor facilities according to the observed level of activity.

Sampling of tenders with catch from more than one area or more than 1 week is avoided when possible. Depending on the sampling rate, tenders often are the only practical source for sampling. When tender loads or landings are processed faster than samplers can properly observe and handle fish, only a portion of the landing is sampled. In all cases, an effort is made to achieve a random sub-sample of the tender or individual landings.

Sampling of sport anglers is done at popular landing locations. Aside from temporal and spatial stratification, interviewers also record sportfish specific strata that segregate marine, freshwater, and derby recoveries. Catch is similarly stratified. Catch figures are estimated during the season for expansions. More comprehensive modeled catch values are employed post-season.

Area and time stratifications.- The troll fishery sampling is stratified by 4 geographic areas: NE, NW, SE, and SW. These are pooled from traditional statistical areas because of the large number of tags recovered from catches taken in more than one area and because sampling effort is small in some statistical areas.

These areas are not directly related to the old fishing areas (Table 4, Figure 10), but the larger units fit closer to fishing patterns, and delivery locations. An approximate assignment of the old areas is as follows:

AREA	‘Old’ PSMFC Statistical Areas
NE	~(LYNN, STEP, CNTR, SNTR)
NW	~(NOUT, COUT, CNTR)
SE	~(CIN, SNTR, SIN)
SW	~(SOUT, SIN)

Temporal stratification for troll corresponds to discrete opening periods. The gill-net and seine fisheries area stratified by statistical areas named 101-116, (Figure 10). Time is stratified by statistical week. Statistical weeks are standard calendar weeks beginning at 12:01 am Sunday.

Sport fish catch are stratified by location, bi-week (2), and sport harvest code:

Sport Harvest Code	Description
MB	Marine boat
MR	Marine roadside
DE	Derby entered
DT	Derby takehome
TF	Terminal fishery
FF	Freshwater fishery
MS	Mixed sport

Table 4. Southeast Alaska’s nine catch regions used for reporting catch and coded wire tag recovery data to the Regional Mark Processing Center (see Figure 10).

Code	Catch region	Commercial statistical areas
SIN	Southern inside	101, 102, 150
SOUT	Southern outside	103, 104, 152
SNTR	Southern intermediate	105, 109, 110
CIN	Central inside	106, 107, 108
COUT	Central outside	113, 154
CNTR	Central intermediate	112, 114
STEP	Stephens Passage	111
LYNN	Lynn Canal	115
NOUT	Northern outside	116, 157, 181, 183[a], 186[a], 189

[a]Areas 183 (Yakutat Bay) and 186 (Icy Bay) are not shown in Figure 10, but are between Cape Fairweather and Cape Suckling.

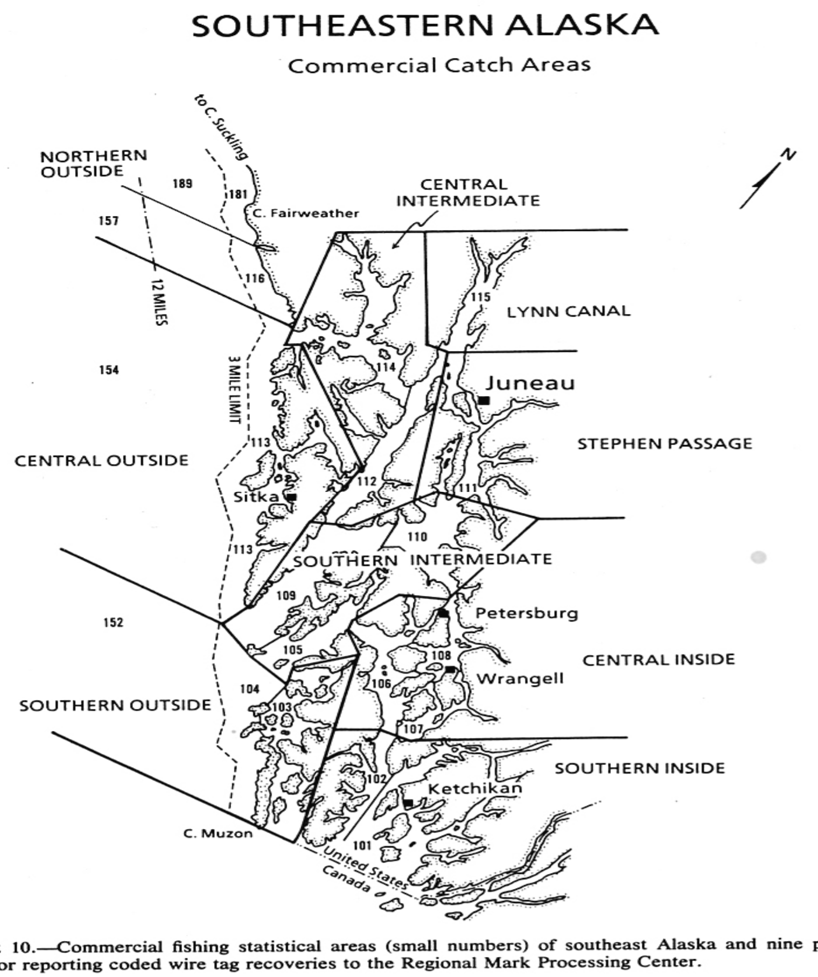


Figure 10.—Commercial fishing statistical areas (small numbers) of southeast Alaska and nine pooled area (names) for reporting coded wire tag recoveries to the Regional Mark Processing Center.

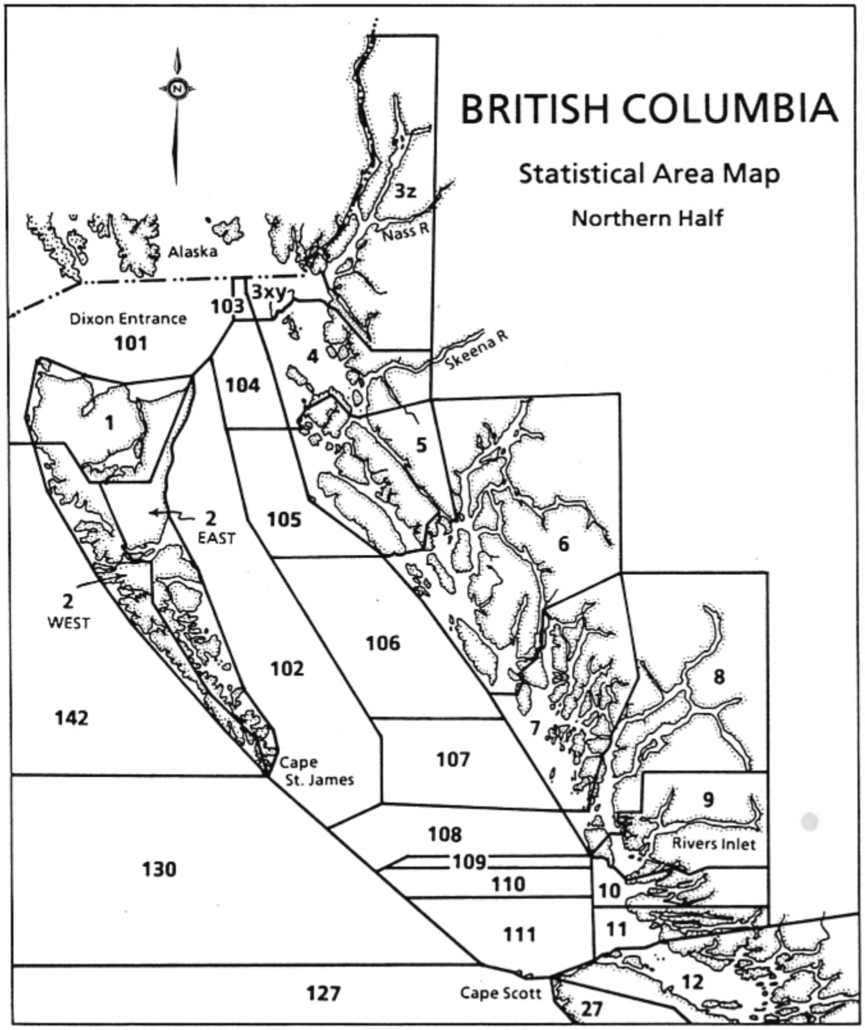


FIGURE 11.—Statistical catch areas for northern British Columbia waters.

British Columbia

Commercial fisheries.-The goal of the commercial CWT recovery program in British Columbia is to randomly sample 20% of the chinook and coho salmon caught in all fisheries throughout the season. Sampling is no longer done for either chum or steelhead as neither species is now tagged. Sampling of chum for mark selective fisheries occurs in specific target fisheries. Retention of steelhead is prohibited in marine commercial fisheries.

A commercial fishery is defined by its operating gear and by a specific catch area. The troll fisheries are an aggregate of freezer troll, day boat, and ice boat catch and sample from the catch area. Net fisheries, except for two in Fraser area, (Fraser Gillnet and Fraser Seine), are an aggregate of gill net and seine.

These aggregations reflect the nature of the fishery. For example, some net fisheries will see both gill and seine fishing in the same area. Often the vessels will deliver to a packer boat rather than deliver the catch to a plant. As such, the packer boat must be sampled. Based on the packer boat's records, samplers can determine how much of his cargo is from gill, how much from seine. However, since the fish are mixed in the hold, sampling cannot be done by gear. This was very common historically. In recent years, many net fisheries are specific to one gear. They are still called "net", but the type of net is reported in the cwt recovery records.

Ten major coastal ports or port areas are sampled on the basis of their spatial and temporal fisheries. These are listed in Table 5, along with associated regions represented in the catch landings.

CDFO electronically samples all commercial chinook and coho fisheries. This is typically done with tube detectors. Wands are used on large chinook that don't pass through the tube, and when a tube is not available.

A significant change this year is that CDFO will cease electronic sampling for DIT tags in non adipose clipped

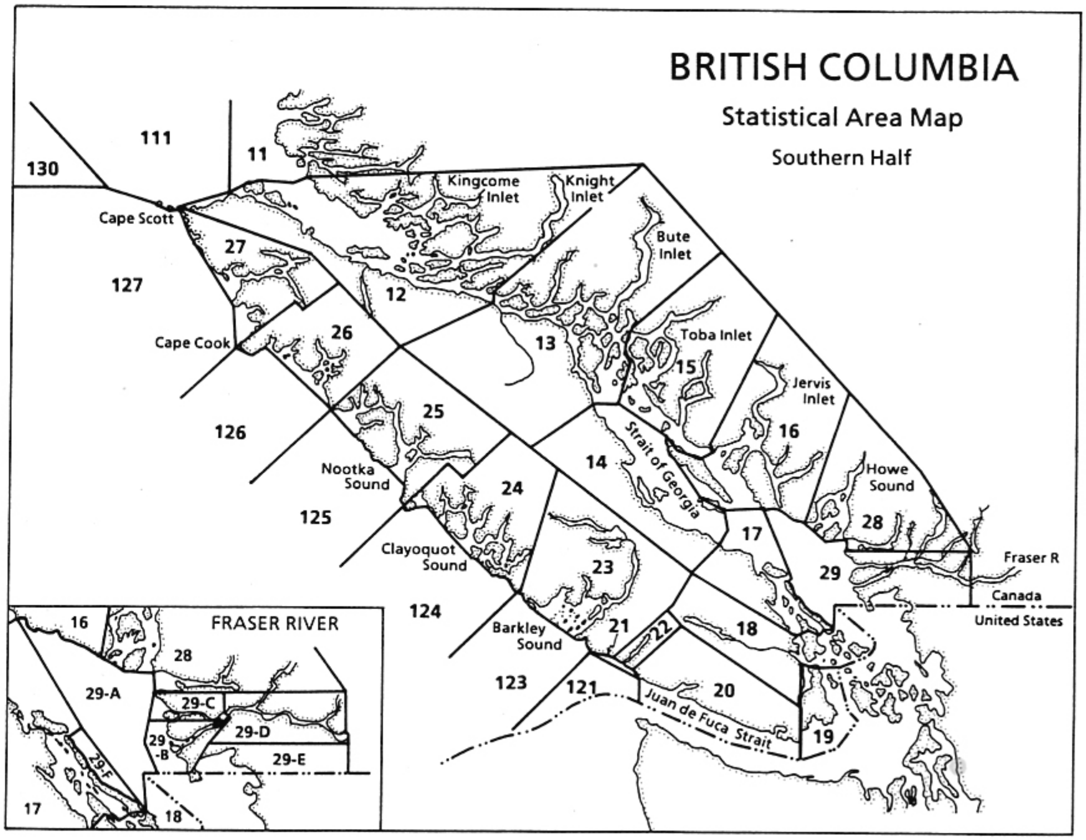


FIGURE 12.—Statistical catch areas for southern British Columbia waters.

TABLE 5. Major coastal sampling locations in British Columbia and associated catch regions represented in the landings.

Port	Catch region
Masset	Queen Charlotte Islands
Prince Rupert	Nass, Skeena River area, central coast, Queen Charlotte Islands
Namu	Central coast
Port Hardy	Northwest Vancouver Island
Winter Harbour	Northwest Vancouver Island
Tofino	Southwest Vancouver Island
Ucluelet	Southwest Vancouver Island
Georgia Strait (minor ports)	Southeast Vancouver Island
Steveston	Georgia Strait mainland, central coast, Johnstone Straits
Vancouver	Georgia Strait mainland, southeast Vancouver Island, Johnstone Straits

chinook in both commercial and sport fisheries as a cost saving measure. Said another way, ‘CWT positive beep’ chinook with an intact adipose fin will not have the head removed for lab recovery of the CWT.

This will also eliminate needless processing of blank CWT wire in chinook with an intact adipose clip. No decision has been made yet for processing ‘CWT positive beep’ coho.

Another significant change since 1989, also related to mass marking, is that CDFO is now able to sample the freezer troll boats for tagged fish. Freezer boats dress fish at sea and freeze them with heads off, making visual sampling impossible. Now the freezer boat fleet is required to retain all of the heads. Upon landing, the heads are retrieved and sampled by electronic tube. The frozen fish carcasses are sampled independently for the purpose of monitoring the overall adipose mark rate for the population.

Recreational fisheries.- CDFO’s sport fishery sampling program is totally voluntary and visual based. Anglers are requested to turn in heads from adipose clipped salmon. Voluntary recoveries are solicited by a variety of advertising mechanisms, including radio, fishery publications, and posters displayed at boat ramps and marinas. A network of over 270 head depots blankets areas supporting ocean sport fisheries and terminal freshwater areas.

CDFO’s ‘indirect mark incidence’ sampling program provides managers with an ‘awareness factor’ which represents public awareness of the adipose clip as a CWT flag. This awareness factor is then used to compute estimated numbers of CWTs recovered in the sport fisheries.

Table 6. British Columbia’s catch regions, defined by gear types, and their respective statistical areas (see Figures 11,12).

Code	Catch Region	Gear	Statistical Areas
NWTR	Northwest Vancouver Island	Troll	25-27
SWTR	Southwest Vancouver Island	Troll	21, 23, 24
GSTR	Georgia Strait	Troll	13-18, 29
NCTR	North Central	Troll	6-9
SCTR	South Central	Troll	10-12
NTR	Northern	Troll	1-5
JFTR	Juan de Fuca Strait	Troll	20
FGN	Fraser	Gill net	29
FSN	Fraser	Seine	29
NN	Northern	Net	1-5
GSN	Georgia Strait	Net	14-18
JSN	Johnstone Strait	Net	12-13
CN	Central	Net	6-11
JFN	Juan de Fuca Strait	Net	20
NWVN	Northwest Vancouver Island	Net	25-27
SWVN	Southwest Vancouver Island	Net	21-24
NSPT	North	Sport	1-5
CSPT	Central	Sport	6-12
GSPTN	Georgia Strait North	Sport	13-16
GSPTS	Georgia Strait South	Sport	17-18, 19A, 28-29
JFS	Juan de Fuca Strait	Sport	19B, 20
WSPT	West Coast Vancouver Island	Sport	21-23, 23B, 24-27
ACSPT	Alberni Canal	Sport	23A
FWS	Freshwater	Sport	Province wide

The indirect mark incidence sampling program involves several steps. Samplers first observe boats landing at marinas, boat ramps, etc, and ask where they were fishing to determine time and area. The boat's catch is also recorded (number landed, species, and incidence of adipose clips). Concurrently, aircraft overfly the catch area stratum and provide a count of all boats that are sport fishing. The average catch per sport boat sampled times the total sport boats fishing provides a total catch estimate for the stratum.

The number of adipose clipped fish observed by the samplers is used to estimate the number of adipose clipped fish that were in the total estimated catch for the stratum (i.e. Catch/Sample x adipose clip count). That gives the number of voluntary heads expected to be turned in by the anglers if they were 100% aware of adipose clips and were compliant with the voluntary program.

Lastly, a comparison is made between the number of heads that showed up at the various head depots and the projected number of voluntary heads submitted had there been 100% awareness and compliance. This then gives an 'awareness factor' estimate for expanding observed CWT recoveries in the sport fishery.

Area and time stratifications.-The British Columbia coast is divided into 32 statistical areas (Figures 11, 12). Each statistical area is partitioned into a variety of subareas (80 for the coast) that represent localized fishing areas. Subareas are uniquely coded to reflect the type of fishing activity they support inside and outside the surf line; nets are not permitted seaward of the surf line.

[*Note: Figures 11 and 12 have not been updated from 1989. Although it is true that CDFO still reports data using statistical areas as described, in recent years the federal Fisheries Act was modified. The coast is now legally described using the term Pacific Fisheries Management Area (PFMA). The areas are further stratified into management subareas. CDFO's data system maps these new areas into the traditional statistical areas. But the fisheries (openings, closings, and assorted regulations) are managed using PFMA. Maps of these areas are on the internet*: http://www.pac.dfo-mpo.gc.ca].

Commercial fisheries are stratified by statistical week (beginning on Sundays). Estimation factors for some troll fisheries, although reported by week, are computed using catch and sample that is pooled across weeks (e.g., a troll fishery may be open 7 days a week for 3 or more weeks. This makes it difficult to attribute a landing to a specific week. Sport fisheries are stratified by calendar month.

Stratification for expansion factor calculations.-Statistical areas are aggregated to form 15 commercial and 6 sport-catch regions (Table 6). In most cases, the catch region is defined with respect to the operating gear. Hence, some catch regions differ for the troll and net fisheries. For example, North Central Troll and South Central Troll together include statistical areas 6-12, and Central Net is defined as statistical areas 6-11.

British Columbia is unique in defining its catch regions on the basis of gear type. Other recovery agencies maintain fixed boundaries for their respective catch regions, regardless of the fishery. CDFO considers its catch data accurate only at the catch-region level and computes expansion factors only at that level.

Washington

The majority of the ocean sport catch is landed at Ilwaco and Westport, where the fleet is divided between kicker (private) and charter vessels (Figure 13). This concentration of effort to the south is most likely due to the proximity to Washington and Oregon population centers. Northern recreational effort is much less intense and consists almost exclusively of kicker vessels.

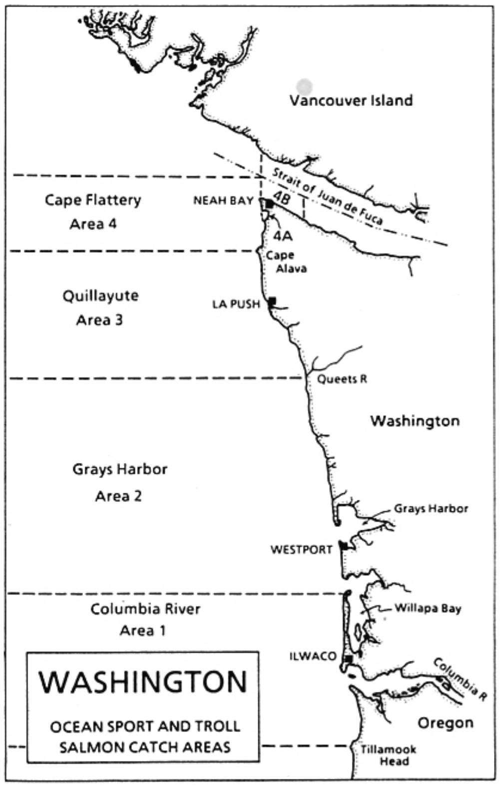


FIGURE 13.—Reporting areas for Washington's coastal sport and commercial troll fisheries for salmon.

Sampling in Puget Sound is oriented to management area and gear type (Figure 14). Commercial net fisheries typically include eight gear types: tribal and non-tribal purse seine, tribal and non-tribal drift gill nets, tribal set gill nets, tribal beach seines, tribal traps, and reef nets. Whenever possible, samples are taken by area and by gear. However, mixed gear types occur and must be sampled as such.

Area and time stratifications.-The Washington coast is stratified into four catch areas (Figure 13): Columbia River (1), Grays Harbor (2), Quillayute (3), and Cape Flattery (4). Sampling is largely limited to Ilwaco (Chinook), Westport, La Push, and Neah Bay, the four major ports on the coast. Sampling at Ilwaco also includes catch from the "Buoy 10" sport fishery at the mouth of the Columbia River.

Puget Sound is divided into more than 35 statistical areas because of the complexity of managing local fisheries. Figure 14 shows the management and catch areas currently in use.

Time is stratified by statistical week, as in Alaska and British Columbia. However, Washington differs in that its 7-day statistical week starts on Monday and ends on Sunday rather than running from Sunday to Saturday.

Stratification for expansion factor calculations.- Sampling rates and stock composition of the ocean sport and troll catches vary somewhat over the season. Therefore, WDFW computes expansion factors on the basis of a statistical week. Ocean and Buoy 10 sport fisheries are further stratified by boat type because charter boats may fish different areas from kicker boats. Sport catches and samples for each statistical week are summed by area, species, and boat type and are then used in finding the basic expansion factor for recoveries made in that fishery during that week.

There are over 100 active salmon buyers in Puget Sound, which makes total coverage impractical. Therefore, all major ports and major buyers are sampled, along with as many small dealers as possible.

The sport fishery in Puget Sound is even more complex, with hundreds of public and private sites where landings occur. With the advent of mass marking, the voluntary return of snouts by anglers from adipose-clipped coho and chinook was phased out between 1998-2000, and sampling levels were increased. The target sampling rate for this fishery is 20%.

Tag recoveries in non-treaty coastal gillnet fisheries (e.g., Willapa Bay and Grays Harbor) are estimated separately. In this case, the expansion factor is calculated on the basis of weekly catch and sampling data from each of the sub-areas (2A-2D in Grays Harbor, 2G-2M in Willapa Bay).

Estimated recoveries from the Puget Sound sport fishery are calculated from samples of time strata for statistical months.

Recoveries in Puget Sound net fisheries are expanded by statistical weeks because of more reliable sampling data. However, some pooling across weeks is necessary when samples are inadequate or week boundaries split catch from its associated sample. In addition, some pooling of reported areas is done when sampling across more than one area occurs.

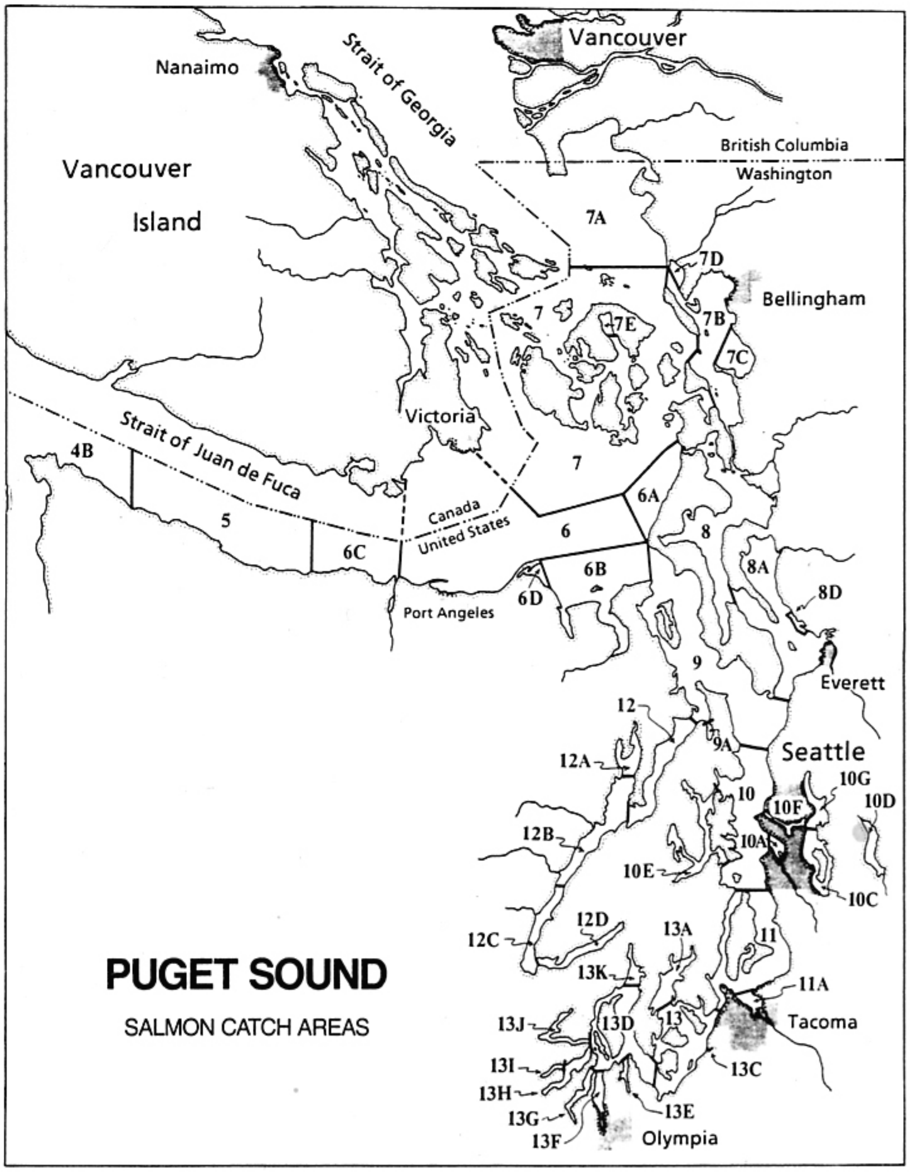


FIGURE 14.—Management and catch-reporting areas for commercial and recreational salmon fisheries in the Puget Sound area of Washington.

4B Neah Bay
5 Clallam Bay
6 Port Angeles
6A West Beach
6B Discovery Bay
6C Crescent Bay
6D Dungeness Bay
7 San Juan Islands
7A Point Roberts
7B Nooksack Bay
7C Samish Bay
7D Lummi Bay
7E East Sound
8 Skagit Bay
8A Saratoga Passage
8D Tulalip Bay
9 Admiralty Inlet
9A Possession Sound
10 Seattle
10A Elliott, Shilshole Bay
10C South Lake Washington
10D Lake Sammamish
10E East Kitsap
10F Ship Canal
10G North Lake Washington
11 East Pass, West Pass
11A Commencement Bay
12 North Hood Canal
12A Quilcene Bay
12B Dabob Bay
12C Central Hood Canal
12D South Hood Canal
13 Nisqually
13A Carr Inlet
13C Chambers Bay
13D South Sound Passages
13E Henderson Inlet
13F Budd Inlet
13G Eld Inlet
13H Totten Inlet
13I Skookum Inlet
13J Hammersley Inlet
13K Case Inlet

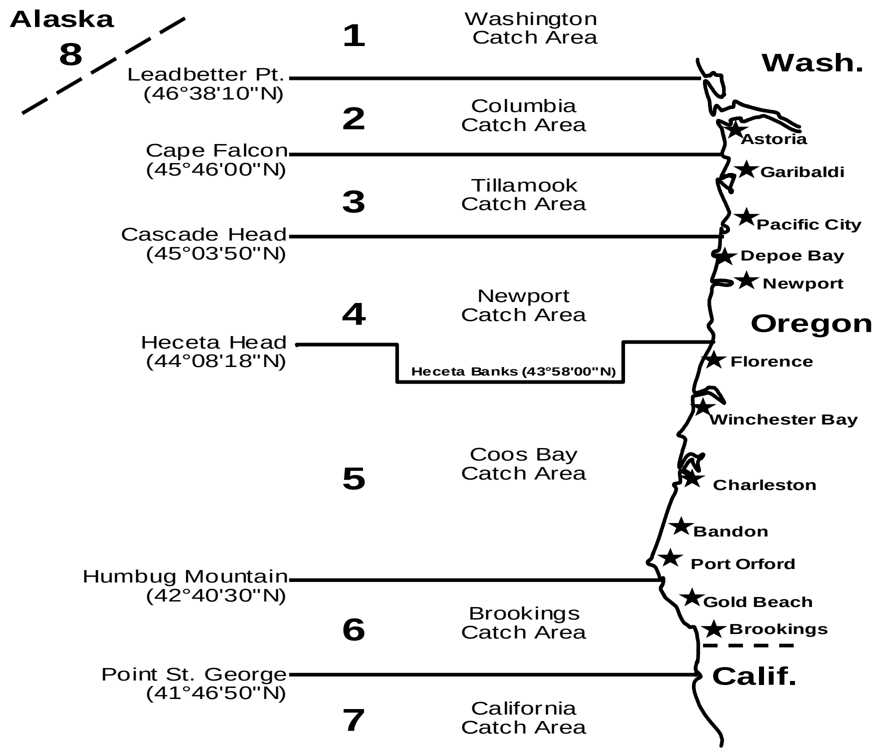


Figure 15. Oregon salmon catch areas and major ports.

Oregon

Ocean Fisheries: Oregon's ocean CWT sampling program is designed to sample 20% or more of the chinook and coho salmon caught in the ocean troll and ocean sport fisheries. These fisheries target a multitude of regional and West Coast chinook and coho salmon stocks along the approximately 310 miles of the Oregon Coast and in both state and federal offshore waters. Oregon uses electronic tag detection equipment to identify coho containing CWTs, but does not electronically sample chinook taken in the ocean fisheries.

Area and time stratification: Commercial fisheries.- Sampling of the commercial troll fishery is stratified by port of landing, area of catch, statistical week, and by fishery (Figure 15). Sampling is conducted at the six major ports where most troll salmon are landed. These ports include Astoria, Garibaldi, Newport, Charleston, Port Orford, and Brookings (Table 7).

The sampling period varies somewhat by port. However, as a general rule, the entire troll season from mid-March through October is sampled in the two primary salmon ports of Newport and Charleston. The remaining ports are usually sampled from early May through September.

Sampling coverage usually covers at least 4 days out of the week, but can be tailored to the pattern of landings as dictated by weather or other factors.

Area and time stratification: Recreational fisheries.- Sampling of the recreational ocean fishery is carried out at 11 ports at which approximately 98% of the total catch is landed. These ports are Astoria (including Warrenton and Hammond), Garibaldi, Pacific City, Depoe Bay, Newport, Florence, Winchester Bay, Charleston, Bandon, Gold Beach, and Brookings (Figure 15). Salmon sampling begins in March in Garibaldi, Depoe Bay, Newport, and Charleston. Sampling at Winchester Bay begins in May. In the remaining ports, sampling usually begins in mid-June just prior to the opening of the coho season.

All commercial and recreational fisheries sampling and recovery data are collected and analyzed on the basis of statistical weeks, beginning on Monday and ending on Sunday. The first statistical week of the year ends on the first Sunday of the calendar year, and the weeks are numbered sequentially thereafter. This system is identical to that used by WDFW.

Stratification for expansion-factor calculations.-Catch estimates for the commercial troll fishery are based on total weight landed (using fish tickets) and average weight information (determined from sampling). This information is obtained by port for each species and grade. The weight landed is divided by average weight to determine number of fish landed. For ports and time periods not sampled, average weight data are generated from numbers and weights, reported on fish tickets or from average weights reported for adjacent ports or time periods.

Catch and effort estimates are reported by both port of landing and catch area. The CWT data are also expanded and reported by port of landing and area of catch. ODFW's harvest management staff has always regarded tag recovery data, when expanded to area of catch, as necessary in managing shifting ocean fisheries.

Ocean recreational catch is estimated weekly by expanding catch per boat by total effort for each port. Sampling is stratified by boat type (charter boats and pleasure boats), and by trip type (salmon, bottomfish, halibut, tuna, spear fishing, combination (salmon and other species), and non-fishing). Effort counts are conducted for pleasure boats using either bar crossing counts or a trailer and moorage slip count. Charter boat effort is generally collected by contacting each charter office to get a count of the trips by trip type each day. The sampling period varies by port (Table 7).

The major ports of Astoria, Newport, Florence, Winchester Bay, Charleston, Gold Beach, and Brookings are sampled throughout the troll season. Coverage for the remaining ports is limited to the coho season, which accounts for the bulk of Oregon's troll landings. In recent years, efforts have been made to extend sampling coverage on the south coast later in the year because the majority of Oregon's chinook salmon landings are made in this area, particularly after August 1. Sampling is conducted at least 5 days/week or is tailored to the pattern of landings dictated by weather or other factors.

Sampling of the recreational ocean fishery is carried out at 10 ports at which approximately 98% of the total catch is landed. These ports are Astoria (including Warrenton and Hammond), Garibaldi, Pacific City, Depoe Bay, Newport, Florence, Winchester Bay, Charleston, Gold Beach, and Brookings (Figure 15). Sampling is done throughout the season at all ports except Gold Beach (Table 7).

All data are collected and analyzed on the basis of statistical weeks, beginning on Monday and ending on Sunday. The first statistical week of the year ends on the first Sunday of the calendar year, and the weeks are numbered sequentially thereafter. This system is identical to that used by WDFW.

Stratification for expansion-factor calculations.-Catch estimates for the commercial troll fishery are based on total weight landed (determined from fish tickets) and average weight information (determined from sampling). This information is obtained by port for each species and grade. The weight landed is divided by average weight to determine number of fish landed. For ports and time periods not sampled, average weight data are generated from numbers and weights, reported on fish tickets or from average weights reported for adjacent ports or time periods.

Table 7. Oregon's major ports and sampling coverage for troll and sport fisheries (see Figures 15, 16).

Port of landing	Sampling in time periods for: Troll	Sport
Astoria	All	All
Garibaldi	Most	All
Pacific City	Most	All
Depoe Bay	Most	All
Newport	All	All
Florence	All	All
Winchester Bay	All	All
Charleston (Coos Bay)	All	All
Port Oxford	Most	None
Gold Beach	All	Most
Brookings	All	All

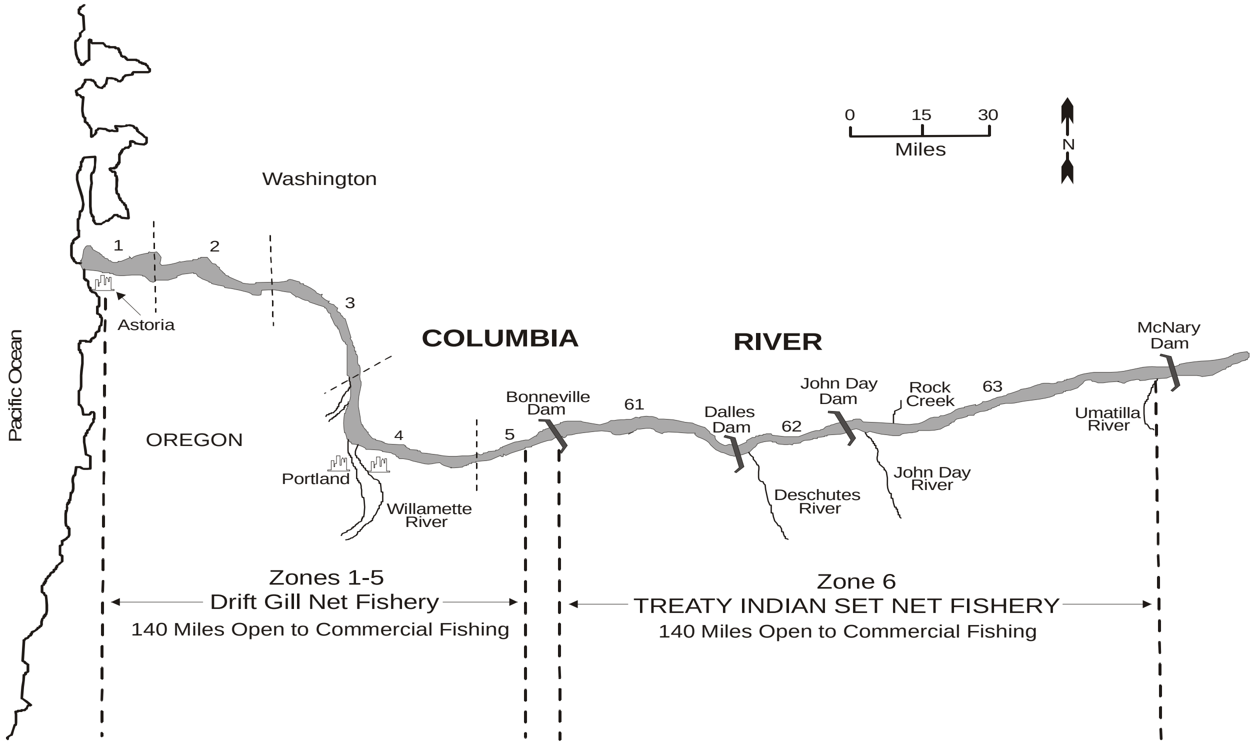
ODFW reports ocean catch and effort estimates by both port of landing and catch area. However, CWT data are expanded and reported only by port of landing for sampled ports. This approach, used also by California, was adopted by ODFW's Biometrics Section because of concerns about the accuracy of catch areas reported on fish tickets. In addition, approximately 10% of the fish tickets lacked any catch area information.

Ocean recreational catch is estimated weekly by expanding catch per boat by total effort for each port. Effort counts are made for three vessel categories: salmon charter, bottomfish charter, and pleasure craft. Catch is calculated separately for weekends and weekdays, and the results are summed to derive estimates for each week and port.

Lower Columbia River

ODFW and WDFW jointly share the task of sampling the lower Columbia River sport and commercial fisheries for CWT marked salmonids.

The sport and commercial fisheries target salmon and steelhead stocks throughout the lower 395 miles of the Columbia River stretching from the mouth at Buoy 10 to the Priest Rapids Dam. The Treaty Indian commercial fisheries operate between Bonneville and McNary dams while the non-Indian commercial fishery is limited to the area from Bonneville Dam downstream (Figure 16). The primary mainstem sport fisheries occur from Bonneville Dam downstream (including Buoy 10) and at Hanford Reach on the upper Columbia. Tributary sport fisheries primarily occur from The Dalles Dam downstream. Additional sampling occurs for fish returning to hatcheries and natural escapement areas.



Commercial Fishing Zones on the Columbia River Below McNary Dam.

Figure 16

All fish encountered are examined for the presence of a CWT. Fish containing a CWT have their snout removed and are sampled for pertinent biological data. Pertinent biological data vary from project to project and may include length, weight, sex, skin color, other marks, and a scale sample. Catches received by commercial fish processors at their plants are sampled for CWTs at the minimum 20% level. All snouts recovered from these fisheries are delivered to the ODFW tag recovery lab.

In conjunction with CWT sampling, a random portion of the catch is sampled for average weight and pertinent biological data. These data are used to determine species specific average weights that are applied to poundages recorded on fish tickets to estimate the total salmonid catch by species in Columbia River Treaty Indian and non-Indian commercial fisheries.

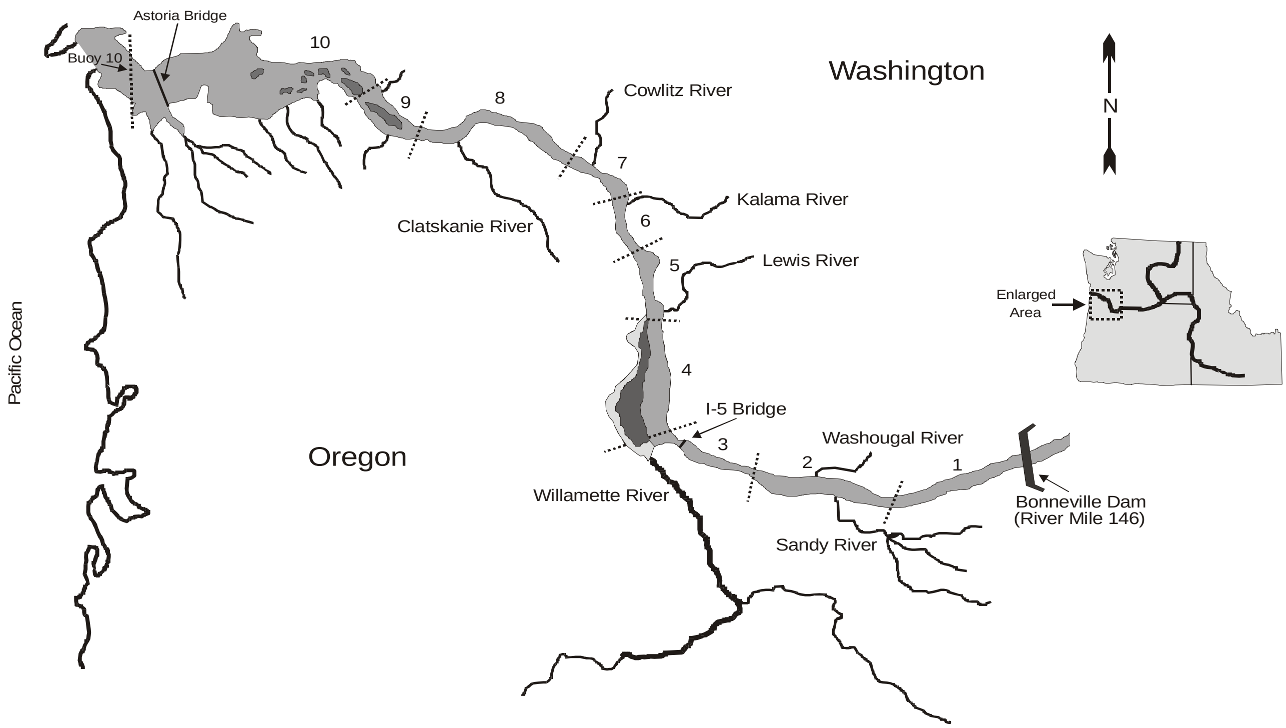
Columbia River commercial fisheries.- Non-Indian commercial fisheries occur in the lower 140 miles of the Columbia River from the mouth at Buoy 10 upstream to Bonneville Dam, while treaty Indian fisheries occur in the 140 miles of the Columbia River between Bonneville and McNary Dams.

Columbia River non-Indian and Treaty Indian commercial salmon and steelhead fisheries may occur during February through October with the majority of the landings occurring during the mid-August through October time frame. Seasons are set during the year based on expected run strength of salmon and steelhead stocks.

In recent years, the ESA has imposed severe constraints on mainstem non-Indian commercial fisheries and has greatly increased the need for precise stock accounting in fisheries. The advent of mass marking spring chinook has provided additional fishing opportunity in the spring, primarily during the last half of March. In addition, the BPA funded Select Area Fishery Enhancement (SAFE) Project has increased the time and area in which Columbia River non-Indian commercial fisheries occur in select areas. Select Area fisheries occur from late February through October with the majority of the fisheries occurring during the late April though early June and early September through October time frames.

Salmonids landed in these commercial fisheries are generally sold to commercial fish buyers with the exception that some fish are sold directly to the general public. Sampling of fish occurs only at commercial fish buying stations or processing plants because sampling of fish sold directly to the general public is unfeasible at this time. Salmon and steelhead landed in commercial fisheries are sampled at fish processing plants and buying locations upon delivery to the commercial buyer.

The goal for CWT recovery purposes is to sample a minimum 20% of the commercially landed catch. Attainment of the 20% sampling goal is achieved in most



Recreational Sampling Sections on the Columbia River Below Bonneville Dam

Figure 17

commercial fisheries because sampling occurs at fish buying stations or processing plants where large numbers of fish are delivered in a relatively short amount of time. However, recent funding restrictions have reduced the agencies' ability to accomplish this goal for commercial fisheries.

Area and time stratifications.-The nontreaty drift gillnet fishery below Bonneville Dam is stratified into five management and catch reporting zones (Figure 16). Most of the fish are taken in zones 1-3.

The treaty set-net fishery between Bonneville and McNary dams is stratified into three zones (61, 62, 63) delimited by Bonneville, The Dalles, and McNary dams. The set-net fishery is conducted by the Yakima, Warm Springs, Nez Perce, and Umatilla treaty tribes. Most of the effort and catch occurs in the Bonneville Pool (zone 6, area 61).

The commercial fisheries are stratified by statistical weeks, which begin on Monday and end on Sunday. The Columbia River sport fishery, however, is stratified by calendar month.

Stratification for expansion factor calculations. -Tag recoveries in zones 1-5 are expanded after aggregation of catch and recoveries for all five zones. Consequently, recovery data reported to the Mark Center are defined as being either below Bonneville or above Bonneville.

Columbia River sport fisheries

Area and time stratifications.-The Columbia River sport fishery is stratified into 10 management and catch reporting sections (Figure 17). Section 1 commences below Bonneville Dam, and Section 10 extends just past the Astoria Bridge at the river's mouth.

The Buoy 10 sport fishery, located at the Columbia River mouth, occurs during early August through mid-October. Nearly all of the Buoy 10 catch is fall chinook and coho with a few steelhead being landed. The fishery has been sampled since its resurgence in 1982. Effort and catch is estimated on a weekly basis but is not part of the statistical creel program. Effort is indexed by on ground trailer and rod counts at popular launch sites and bank angling locations. Anglers are queried for success at boat ramps and bank fishing locations, but no on-water sampling occurs.

The sport fishery on the lower Columbia River occurs year round and targets different species or races throughout the year. The fishery targets spring chinook during mid-February through mid-May, summer chinook during mid-May through July, fall chinook and coho during August through October, summer steelhead during mid-May through September, and winter steelhead during December through February. Mass marking of spring and summer chinook has provided additional fishing opportunity during the April through July time frame.

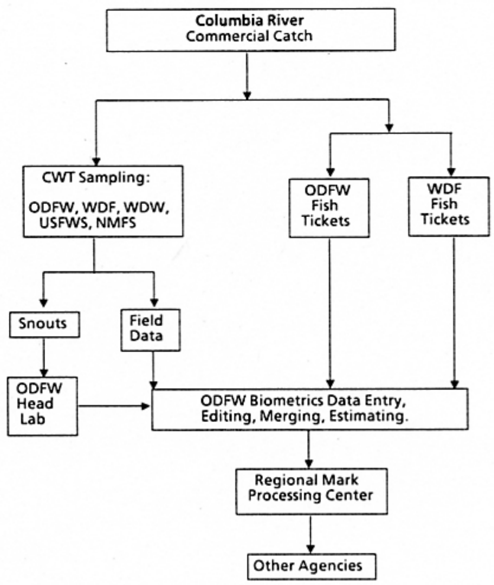


FIGURE 18.—Flowchart for multiagency management of commercial catch, sample, and coded wire tag (CWT) recovery data for the lower Columbia River. ODFW = Oregon Department of Fish and Wildlife; WDF = Washington Department of Fisheries; WDW = Washington Department of Wildlife; USFWS = U.S. Fish and Wildlife Service; NMFS = National Marine Fisheries Service.

Sampling of the sport fishery in the mainstem occurs at popular bank fishing and boat launch locations throughout the lower 146 miles of the Columbia River. The goal is to sample a minimum 20% of the sport harvest. However, achieving the 20% sample rate goal on the lower Columbia River is a difficult task because the distances involved and the fact that fish are landed throughout the day.

Boat and bank effort are estimated by aerial ‘fly over’ counts conducted over the lower Columbia River twice a week during February through October. These data are used as part of a statistical creel program to estimate monthly effort and catch for lower Columbia River salmonid fisheries. This fishery has been sampled as part of a statistical creel program since 1969.

There are also some localized fisheries occurring between Bonneville and McNary dams just below mainstem dams and at river mouths. Limited creel sampling of the salmonid sport fisheries in the mainstem Columbia River between Bonneville and McNary dams began in 1994. Ancillary sampling occurs in mainstem sport fisheries from Bonneville to McNary Dam and sampling rates seldom achieve the 20% sampling rate.

The Hanford Reach fall chinook fishery occurs from mid-August through October. Anglers are interviewed at boat ramps or bank fishing locations. Trailer counts are made to estimate total effort. Angler success data are used to estimate total catch. The 20% sampling rate goal is achieved sometimes, but not consistently, for this fishery.

Washington tributary spring chinook fisheries typically occur between April and June, and fall salmon fisheries primarily occur in September and October recoveries. The fisheries occur on lower Columbia and Bonneville Pool tributaries and are sampled for CWTs. Anglers are queried for success at boat ramps and bank fishing locations. Sample rates generally do not exceed 20% except in the largest fisheries. Bonneville Pool tributaries spring chinook fisheries are managed jointly between WDFW and Yakama Indian Nation (YIN) to meet hatchery escapement goals in addition to harvest sharing

Sampling data gathered by WDFW are forwarded by ODFW, where they are verified and then merged with the Oregon data before tag expansions are done. Following this, the pooled data are reported to the Mark Center. Figure 18 summarizes the flow of recovery data for Columbia River commercial fisheries.

By a similar process, WDFW's and ODFW's sampling data are combined for the recreational fisheries in the lower Columbia River.

Idaho

Idaho's tag recovery programs historically have received little interest from most other recovery agencies because sampling typically encounters only upper Snake River stocks. However, Idaho's contribution of fall chinook salmon to the ocean fisheries has become important with the implementation of the Pacific Salmon Treaty. Consequently, all escapement and freshwater sport recoveries are important for evaluating the contribution of Idaho stocks designated as index stocks.

Electronic sampling is widely used in Idaho because most if not all salmon and steelhead stocks are now mass marked with the adipose clip. In addition, various other marks are often applied to provide additional stock separation capacity at Lower Granite Dam (trap) or upstream passage or brood stock selection at the hatcheries.

Tag recovery programs rely on sampling the sport fisheries at major fishing sites. This includes a cooperative sampling effort with WDFW to sample steelhead harvested on the Snake River where it forms the boundary between Washington and Idaho. Extensive spawning ground surveys also are taken on a regular basis. Hatchery returns are also sampled, along with the use of off-site traps.

In addition, USFWS maintains a significant sampling program at both Dworshak NFH and Kooskia NFH. Likewise, the Nez Perce Tribe has become very involved in sampling its returning CWT marked hatchery stocks in the escapement and at the rack.

Sampling and expansions are stratified by calendar month.

California

California's CWT sampling programs are designed to sample at least 20% of the chinook landed in ocean commercial (troll) and recreational (charter boat and private skiff) fisheries. Retention of coho salmon is prohibited in all California ocean fisheries.

Sampling of California inland salmon fisheries has been limited to a systematic creel surveys on the Klamath-Trinity rivers and sporatic sampling of fisheries in the Sacramento and San Joaquin basin. Additional inland recoveries are obtained from hatchery returns and spawning ground surveys. These inland CWT recoveries have been uploaded with all ocean CWTs to the Mark Center's RMIS server since 2000.

Fishery sectors- CDFG's Ocean Salmon Project (OSP) makes separate estimates for commercial passenger fishing vessels (CPFV) and private skiffs. However these data are pooled before being reported to the Mark Center since the two fisheries are managed as one by the Pacific Fisheries Management Council.

Area and time stratifications.- California produces salmon catch and effort estimates for five major port areas (Figure 19):

1) Crescent City (Oregon border to Big Lagoon)
2) Eureka (Big Lagoon to Horse Mountain near Shelter Cove)
3) Fort Bragg (Horse Mountain to Point Arena)
4) San Francisco (Point Arena to Pigeon Point)
5) Monterey (Pigeon Point to the U.S.-Mexico border).

Sampling normally extends from Crescent City Harbor to Avila Beach. In some years when there is a southern shift in the distribution of salmon, sampling may be extended south to include Santa Barbara, Ventura and Oxnard ports. The estimates normally are based on area of landing rather than area of catch. Each major port area consists of several minor ports where sampling occurs (Table 8). In addition, the Monterey major port area is broken into two submajor port areas: Monterey Bay area and Morro Bay area.

The estimates are generated by half-month period; i.e., 1-15 and 16-end of month. Private skiff sampling is further stratified by day type: 1) regular week days and 2) weekend and holiday days.

The basic sampling unit is a sample area-day and samplers are responsible for sampling as close to 100% of the salmon fishing effort and catch made on each sample area-day.

A salmon trip is defined as those trips in which salmon was the target species for all or part of the day. A combination trip, on which several species including salmon were targeted, is also considered a salmon trip.

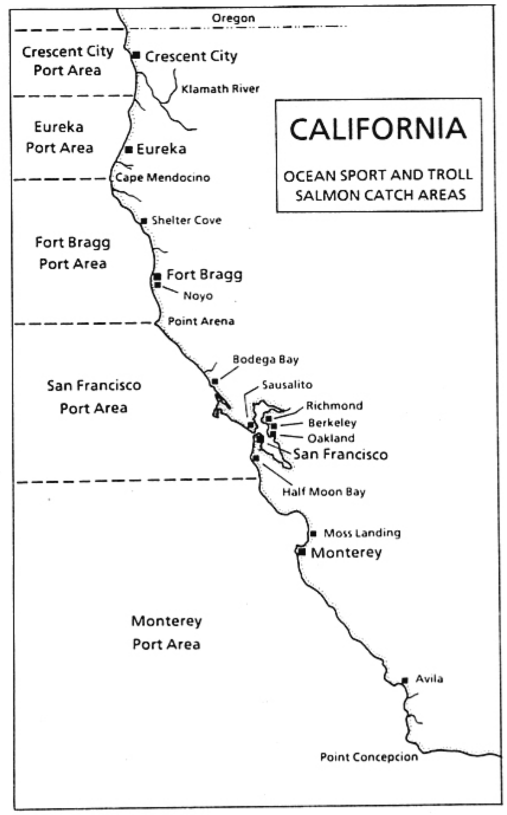


Figure 19.—Port management and catch-reporting areas for California's commercial troll and ocean sport fisheries.

Stratification for expansion factor calculations.-A two-stage program is used to estimate effort and landings by CPFVs (i.e., charter boat). Total effort is determined by counting the actual number of CPFVs that targeted salmon each day of the season by port and area. Field samplers visit the landing areas or make phone calls to get these counts, which are usually made on the same day the fishing trip was conducted. Post season, CDFG staff compare the counts to the submitted logbooks (which are required by law) and may adjust the counts upwards if more logs are returned for a given port-day than the number of boats counted during the season.

CDFG does not depend on log returns only to estimate total salmon fishing effort (or catch) because of the highly variable return rate of these documents by individual skippers. The average return rate has been about 75% in recent years, which is up from an average return rate of about 54% in the mid 1990s. However, over the years, there has been close agreement between the salmon landings and angler effort observed by samplers in the field and the salmon landings and angler effort reported on submitted logs.

TABLE 8. Primary CDFG sampling sites north of Pt Conception by major port area and fishery.			
Major Port	Skiff	Charter	Troll
Crescent City			
Crescent City launchramp	X		
Crescent City dock	X	X	X
Eureka			
Trinidad Hoist	X		
Trinidad docks	X	X	X
Eureka	X	X	X
Field's Landing	X		
Fort Bragg			
Shelter Cove	X	X	X
Fort Bragg/Noyo	X	X	X
San Francisco			
Bodega Bay/Westside	X	X	X
Sausalito	X	X	X
Berkeley/Emeryville	X	X	
San Francisco Wharf		X	X
Princeton	X	X	X
Monterey			
Santa Cruz	X	X	X
Moss Landing	X	X	X
Monterey	X	X	X
Morro Bay	X	X	X
Avila Beach	X	X	X
Total Sites	17	15	14

Sampling of completed CPFV (charter) salmon trips dockside is conducted to estimate the salmon catch and effort and to recover CWT marked salmon. Samplers must sample at least 20% of the CPFV landings in each statistical area during each half-month time period. (Note: CDFG only samples completed trips dockside and does not use at-sea sampling to estimate the total salmon catch, including released fish.)

CDFG samplers also sample at least 20% of all salmon (by weight) landed in California's commercial troll fishery in each major port area and half-month period. Samplers keep a tally of all commercial landings in their respective minor port area to ensure that all sampling goals are being met.

During sampling in all fisheries, each salmon must be visually checked for a missing adipose fin and the head removed. All ad-clipped salmon recovered are measured in the field for fork length (to the nearest mm) and their heads removed for later CWT extraction and decoding in the lab.

The recent mass marking (i.e., de-sequestering the use of ad-clipping to flag only CWT fish only) of hatchery chinook in Oregon and Washington has increased the proportion of heads collected by CDFG not containing CWTs. In the northern ports, there have been sample periods where almost 50% of the heads collected did not contain CWTs. This has increased costs both in the field and at CDFG's CWT processing lab.

CWT Program: Some Issues of Concern

The current coastwide CWT program is a composite of individual agency programs that have co-evolved over the past three+ decades. It proved to be effective and robust, but it wasn't without flaws and challenges, some of which were recently exacerbated by the impact of mass marking and mark selective fisheries. Consequently, it is important to look for ways to improve the accuracy and precision of its estimates of contribution and survival, and also determine whether existing tagging and sampling rates continue to be appropriate.

In 1982, PMFC sponsored two technical workshops to review all aspects of tagging, to identify problem areas, and to make recommendations. The first workshop dealt with experimental design, and the second focused on tag recovery and estimation procedures (PMFC 1982a, 1982b). Results of the workshops demonstrated that several problem areas were common to all agencies. Most of those areas still persist today and are reviewed below. Some problems are much more serious than others but they are not discussed in any particular ascending or descending order.

Lack of Standards for Tagging Levels

Regardless of the type of tagging study, few guidelines exist for determining the minimum number of juvenile fish to tag in a given release to assure scientific validity of recovery results. Similarly, guidelines are needed for determining maximum tagging levels to prevent unnecessary recovery costs. The basic problem encountered is that the number of tagged fish required for a given study depends upon too many variables to be accommodated by a few well defined guidelines. Some of the variables involved include specific objectives of the research study, biology of the stock, expected tag loss, in-river predation rates, and sampling rates expected in the future for specific fisheries. The biggest issue could well be marine survival. Tagging levels haven't increased much even though survival rates are a fraction of what they were in the 1980s.

Several models have been developed, however, and they provide some guidance to the researcher in determining numbers of fish to tag. Most work to date, however, is contained in unpublished draft reports, and is largely unavailable. Published work includes models by Reisenbichler and Hartmann (1980) and Vreeland (1987). Further work is needed to simplify decisions on correct tagging levels which are vital to the success of CWT studies.

Need for Expanded Use of Replication

The majority of tagged release studies over the years have not had replicate tag groups (Pascual 1993) and methods to obtain confidence limits on the estimates of contributions have not been developed until recently.

A number of statistical studies in the past fifteen years have strongly emphasized the importance of replication when designing and carrying out CWT studies. Reisenbichler and Hartmann (1980) stressed the need for replication within the release group (i.e. within brood variation) and across three to four years (between brood variation). The Workshop on CWT Experiment Design (PMFC 1982a) recommended replication for all tagging studies and also stressed the need for replication within-year and among-years to provide measures of standard error and variability in production and contribution over time. de Libero (1986) recommended a minimum of three replicates to indicate if the estimates were internally consistent. Vreeland (1987) and Pascual (1993) likewise stressed the power of replication for CWT studies. Lastly, the Hatchery CWT Methodology workshop in 1995 recommended using four replicates (PSC 1995).

CWT studies today are trending towards increased use of replicates. However, replication remains in the minority of studies in spite of the strong statistical endorsements to do so. There is need to address the reasons why and find practical solutions to improve the statistical quality of tag studies.

Need to Improve Accuracy of Tag Loss Estimates

The tagged to untagged ratio in a release group is a key parameter used in applying the total number of tag recoveries to the total contribution of a hatchery. As such, accurate estimates of tag loss are very important to hatchery staff that want to estimate expanded recoveries for their hatchery stocks. For fishery managers, the more important point is that tag loss results in an apparent lower survival. If high enough, it could also result in fewer recoveries in specific fisheries, even though the stock is present.

Current problem areas include inadequate sample sizes and short term retention before release. Vreeland (1987) pointed out that a 1% post release tag loss can translate into a 10% underestimate of the contribution if tag loss is not accounted for. He recommended that approximately 2,000 tagged fish be sampled for tag loss to get the necessary precision to within 1%. In practice, however, sample sizes for tag loss estimation are typically much lower.

Regarding short term retention, roughly half of the tagged coho and over a quarter of the tagged chinook groups are released within the first five days of tagging (PSC 1999A). This is the period of greatest tag loss (Blankenship 1990). Hence more effort is needed to extend the retention period to 30 days at which time tag loss has essential ceased.

Unstable Funding for Tag Recovery Programs

Stable, long term funding is essential to guarantee that tags released in a given year will be recovered at an adequate sampling rate when the fish return two, three, or more years later. Yet funding for these programs continues to be at risk as most tag recovery agencies continue to experience ever growing budget constraints.

Furthermore, most recovery agencies can not closely link their release and recovery programs under a single coordinated budget and administrative system. Consequently, an agency's recovery program typically has little control over within-agency tagging levels. WDFW is an exception in that its budget for tagging and tag recovery passes through the agency's tag coordinator. In CDFO's case, it has the budgets split amongst several branches of the agency.

Inequitable Cost Burden upon Recovery Agencies

Although 54 agencies release tagged fish, the cost of tag recovery in the marine and freshwater fisheries basically falls upon ADFG, CDFO, WDFW, ODFW, and CDFG. This responsibility has largely been borne by the recovery agencies to avoid the hassles of bookkeeping and billings. However, the number of tags released by non-recovery agencies is a sizable percentage of total releases and likely will continue to expand over the next decade. Given today's widespread budget shortfalls, a means is needed to distribute recovery costs more equitably across all tagging agencies.

Some progress has been made in recent years to ease the burden on recovery programs in Oregon and Washington. USFWS reimburses ODFW for recovering their tags. In addition, Bonneville Power Administration (BPA) provides funding annually to assist the Oregon and Washington recovery programs in the Columbia basin and the Oregon coast. These funds defray recovery costs for tags released by the many BPA-sponsored tagging programs.

The Mark Committee recommended in 1987 that the status quo be maintained rather than switching over to billing all agencies on a cost-recovery basis. However, they also recommended that non-recovery agencies with significant new tagging programs be charged an incremental fee for each tag recovered.

The advent of mass marking also poses the strong likelihood of increased sampling costs for recovery agencies due to requirements for electronic tag detection (labor and equipment), and direct sampling of recreational fisheries and escapements. Agencies that elect to continue to rely on visual detection methods will also experience some increased costs of handling and processing from adipose clipped fish, many of which may not have a CWT. Additionally, there is a possibility that taking heads from fish without CWTs will reduce the willingness of fishermen and processors to cooperate in CWT recovery efforts.

Sampled Harvest from Multiple Catch Areas

Nearly all agencies rely upon estimates of mark contribution by area of catch for management of fisheries. However, in many cases, a vessel will land fish harvested in two or more management areas or the sampling location (e.g., tenders) will have not separate catches by gear and area. This poses a major problem for those engaged in sampling and expanding tag recoveries because individual tags (or fish) cannot be assigned with certainty to a specific catch area or fishery. As a result, expansions cannot be made in most cases for the specific catch area but must be rolled up to a larger pooled area.

Unreported and Misreported Harvest Bias

Unreported catches occur in every fishery, and misreporting is a problem in some fisheries. These problems include fish taken home for personal use, some subsistence and ceremonial catches, and incidental catches of one species sold as the target species in a fishery. These non-reported and miss-reported catches result in a downward biasing of the estimated total number of tags recovered in a given fishery.

Need for a Solid Statistical Foundation

A sound theoretical framework is needed for computing various CWT statistics and the uncertainty associated with those statistics. Consequently, it is difficult to determine the reliability of the results for a given tagging study. Estimates of total recoveries, for example, may be misleading in strata of limited sampling effort or for releases where only a small proportion was tagged (Clark and Bernard 1987).

Considerable progress has been made in the past 5 years in developing the necessary statistical models and methodologies. Impetus was given to the work in 1984 with the establishment of a CWT Statistical Committee by PMFC and the Pacific Salmon Commission's Working Group on Mark Recovery Statistics.

Several statistical papers (published and unpublished) are now available for CWT applications. These include methods for calculating variances (Reisenbichler and Hartmann 1980; Neeley 1982; Webb 1985; Newman 1990), use of replication (de Libero 1986; Perry et al. 1990), determination of sample sizes (Palermo 1984), evaluation of awareness factor variability (Palermo 1990), contribution and variances (Clark and Bernard 1987; Geiger 1990), and statistical design of contribution studies (Vreeland 1987 and 1990). This work needs to accelerate, given the PSC's requirements for statistically sound fisheries information.

Are Hatchery Indicator Stocks Representatives of Wild Stocks?

Although the CWT represents a major technological advance in marking hatchery stocks, it has only limited value for coastwide identification of non-hatchery stocks. Constraints for marking non-hatchery stocks with CWTs include: inaccessibility of many chinook and coho salmon streams; difficulty in collecting statistically significant numbers of representative non-hatchery fish to tag; fragility of wild chinook smolts when handled and marked; a great number of non-hatchery stocks from Alaska to California; and the need for repeated marking on an annual basis.

For the most part, impacts of fisheries on wild stocks have been inferred from CWT studies on hatchery fish that are believed to be representative by virtue of brood stock, rearing and release practices. For coho, CWT experiments have determined that hatchery indicator stocks and associated wild stocks have similar patterns of exploitation when fisheries are not designed to selectively remove hatchery fish. For chinook, the degree to which hatchery indicator stocks are truly representative of associated wild stocks needs to be determined.

Other tools are now available or under development that hold promise for overcoming some or most of the above CWT limitations for identifying fish originating from natural spawning. These include the scale pattern analysis method (Conrad 1984; Marshall et al. 1984), and inducement of unique otolith banding patterns (Volk et al. 1990). These methods, used individually or in concert with CWTs, can provide valuable and timely data on fishery composition for in-season and post-season management. The electrophoretic method of genetic stock identification (Milner et al. 1985; Shaklee and Phelps 1990, can provide information regarding stock origin, but cannot distinguish between hatchery and wild fish from the same brood stock.

Error in Estimates of the Number of fish Released and Under-Sampling of Fisheries and Escapement

CWT release and recovery data are used to calculate survival rates, exploitation rates and fishery contribution rates on a stock specific basis. Accuracy and precision of stock specific parameter estimates are a direct function of the quality and integrity of the hatchery release data, the catch sample data and the recovery data (PSC 1999A).

One key finding of the 1982 CWT workshops was that a major source of error in estimating contribution involved the estimate of the number of both tagged and untagged fish released. Rigorous procedures must be followed to count the number of tagged and untagged fish released, and to determine if the tagged fish are representative of the total release (PMFC 1982a; Vreeland 1990).

It has been 22 years since the PMFC workshop participants voiced a strong concern about counts of tagged and untagged releases. However, a variety of counting methods continues to be used at the hatcheries to get release estimates. The least desirable method, the so-called 'book estimate', involves regular subtraction of the dead fish and is fraught with problems. More commonly, various weight-derived methods are used but these too can have sizeable inherent error.

The optimal method of estimating the number of fish released is to obtain actual physical counts. Vreeland (1987, 1990) and de Libero (1986) strongly stressed that mechanical or electronic counters are the only adequate method for getting accurate release numbers. Therefore, more attention must be given to moving away from the alternative types of counting and standardizing on actual counts of releases by either mechanical or electronic counters.

The lack of adequate sampling programs in some fisheries and in escapement can seriously compromise the quality of the catch and recovery data and bias estimates of key statistics like fishery exploitation rates. Sport catch is particularly difficult to sample because of the logistic challenges of sampling a broad region. In addition, the number of recoveries from sport fisheries is often quite small, expansions may be generated over time periods not sampled, and often the expansion values are not reported.

Recovery of CWTs from naturally spawning fish can be problematic, depending on location of release, the degree of straying, the physical characteristics of spawning areas, and design of escapement monitoring programs.

Additional problems with CWT recovery are emerging due to the declines in market prices. More and more of the catch is being marketed directly from harvesters to consumers rather than processors; this increases the difficulty of accurately accounting for and sampling catches for CWTs. In some instances, fish taken are not even available for sampling since only the eggs are sold while the body is discarded because of the lack of an adequate market price to cover the cost of handling the fish.

Variation and under-sampling across the fisheries is the most serious concern relating to uncertainty in CWT analyses (PSC 1999A). The coastwide sampling rate standard of 20% is often not met as a result of budget or logistic constraints. Similar problems exist for escapement, with many areas not sampled at all. Such sampling 'holes' seriously weaken any stock specific analyses

Lack of Uniformity in Electronic Sampling

By the same token, the switch to electronic sampling has not been fully implemented throughout the Pacific coast. Alaska and California continue to rely on visual sampling for the adipose clip to recovery CWTs. Washington, Oregon, and Idaho rely fully on electronic sampling (with the exception of Oregon's coastal fall chinook fishery which is visually sampled for adipose clipped fish).

British Columbia is a mixed bag with electronic sampling limited to commercial chinook and coho fisheries and hatchery returns. Sport fisheries rely on voluntary submission of head by anglers. In addition, CDFO will no longer remove snouts from fish that have an intact adipose clip but are 'beep positive' for the presence of a CWT.

This lack of uniformity with electronic sampling procedures continues to raise serious questions about the impact on the quality of the CWT data. And in particular, it brings into question the impact on DIT marked groups if a significant portion of the Pacific Coast is not sampled for DIT marked indicator stocks.

Impact of 'Blank Wire' Tags on Recovery Agencies

Tagging agencies may also opt to use so-called 'blank wire' tags to mark some hatchery stocks. In the past, blank tags literally were blank in that there was no code present. Northwest Marine Technology, Inc. has since replaced that product with 'agency only' blank wire. It differs in that the wire carries a single code for agency. As such, the tag carries limited information on the origin of the tagged fish based on the agency code. However, it is not a true tag code since it can't be used to separate various release groups from the same agency.

Blank wire is used by various agencies in situations where stocks need to be marked for basic identification and separation purposes only. For example, WDFW and NMFS operate a trap at Lower Granite Dam (lower Snake River) to selectively remove tagged stocks while untagged fish can pass upstream.

The incentive for using blank wire is simply reduced cost over full coded wire tags. The current price for blank wire is $30 per 1,000 tags as compared to $74 per 1,000 tags for coded wire tags.

Blank wire poses a problem for some recovery agencies in that the tags are detected with electronic sampling equipment. The tags will also be recovered with visual sampling since many of the 'tagged' fish will also be adipose clipped.

The extra time and labor required to extract blank tags can result in substantial expense with no benefits to the recovery agency processing the tags. At this point, it does not appear to be a 'show stopper' for the recovery agencies. However, there are concerns that the impact would become a serious problem if the use of blank wire tagging continues to grow.

Need to Estimate and Report 'Imputed Mortalities' in Mark Selective Fisheries

Mass marking of hatchery stocks with the adipose clip has meant that mark selective fisheries (MSF) can harvest the adipose clipped hatchery fish while unclipped fish are released. This desirable benefit is countered balanced to some extent in that the higher exploitation rates on marked hatchery fish jeopardize the long standing assumption that CWT marked hatchery stocks can be used to infer life history parameters of their natural origin counterpart stocks (PSC 2004).

As discussed earlier, double index tagging (DIT) was introduced to provide an estimate of the impact on natural stocks of coho salmon intercepted and released in MSFs. In practice, however, this has not proved as simple as hoped as some of the unmarked fish die of their injuries following their release. As there is no way to directly sample the post catch release mortality for these fish, it necessitates an indirect method with its attendant bias for estimating CWT mortalities or 'imputed' mortalities of unmarked DIT fish (CWT only, adipose intact) in MSFs.

There are different contexts in which imputed CWT recoveries are needed for coho salmon. (Separate estimates would also be needed for chinook if DIT marking is extended to chinook):

1) Imputed CWT mortalities are required for the unmarked pair of DIT release groups.
2) Imputed CWT mortalities are needed to estimate the impact of mark selective fisheries on CWT unmarked fish.
3) Lastly, imputed CWT mortalities recoveries are required for fisheries where there is no electronic tag detection (e.g. Alaska). In these cases, the unmarked pair of DIT fish are landed but not sampled.

The procedures for estimating, reporting and exchanging these new data elements have not been resolved yet but PSC's Working Group on Data Standards has been charged to work out the necessary procedures.

Summary

The CWT is the most important identification tool used on the west coast for salmonid research and management. This paper has attempted to give an overview of its historical development, current regional coordination procedures, agency tagging and recovery programs, major problems, and upcoming improvements. It is important to note, however, that the various agencies' release and recovery programs are considerably more complex than presented here. As such, additional information should be obtained either directly from the agency tag coordinators or from the Mark Center.

It is relatively easy to identify 'problems and shortcomings' of any marking tool. In the process, one must not lose sight of the tool's positive benefits. Such is the case for the CWT. Several old problems and a few new ones, some of which are major, reduce the CWT's effectiveness as a marking tool. Even so, the CWT has proved invaluable in marking salmonid hatchery stocks and, to a lesser extent, wild stocks. Its widespread and large-scale use on the west coast is ample evidence of this.

In addition, CWTs are now being used increasingly with other marking techniques (e.g., genetic markers, scale pattern, and otolith banding) to provide a better analysis of' salmonid population dynamics. Continual use and expanding research efforts (particularly in the areas of statistical applications) are certain to further strengthen its value as a stock identification tool in the researchers and fishery managers shared 'marking tool box'.

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References

Bergman, P. K., K. B. Jefferts, H. F. Fiscus, and R. C. Hager. 1968. A preliminary evaluation of an implanted coded wire fish tag. Washington Department of Fisheries, Fisheries Research Paper 3:63-84.

Clark, J. E., and D. R. Bernard. 1987. A compound multivariate binomial-hypergeometric distribution describing coded micro-wire tag recovery from commercial salmon catches in southeastern Alaska. Alaska Department of Fish and Game. Technical Report 202, Juneau.

Conrad, R. H. 1984. Scale pattern analysis as a method for identifying the origins of sockeye salmon (On*corhynchus nerka)* in the waters surrounding the Kodiak Archipelago. Alaska Department of Fish and Game, Information Leaflet 241, Juneau.

Dawley, E. M., R. D. Ledgerwood, and A. L. Jensen. 1985. Beach and purse seine sampling of salmonids in the Columbia River estuary and ocean plume, 1977-1983, volume 1. Procedures, sampling effort, and catch data. NOAA (National Oceanic and Atmospheric Administration) Technical Memorandum NMFS (National Marine Fisheries Service) FNWC-74, Seattle, Washington.

de Libero, F. E. 1986. A statistical assessment of the use of the coded wire tag for chinook *(Oncorhynchus tshawytscha)* and coho *(Oncorhynchus kisutch)* studies. Doctoral dissertation. University of Washington, Seattle.

Geiger, H. J. 1990. Parametric bootstrap confidence intervals for estimating contributions to fisheries from marked salmon populations. American Fisheries Society Symposium 7:667-676.

Jefferts, K. B., P. K. Bergman, and H. F. Fiscus. 1963. A coded wire identification system for micro-organisms. Nature (London) 198:460-462.

Koerner, J. F. 1977. The use of the coded wire tag injector under remote field conditions. Alaska Department of Fish and Game, Information Leaflet 172, Juneau.

Lapi, L., M. Hamer, and B. Johnson. 1990. Data organization and coding for a coastwide mark-recovery data system. American Fisheries Society Symposium 7:720-724.

Marshall, S. L., G. T. Oliver, D. R. Bernard, and S. A. McPherson. 1984. Accuracy of scale pattern analysis in separating major stocks of sockeye salmon *(Oncorhynchus nerka)* from southern southeastern Alaska and northern British Columbia. Alaska Department of Fish and Game, Information Leaflet 230, Juneau.

Milner, G. B., D. J. Teel, F. M. Utter, and G. A. Winans. 1985. A genetic method of stock identification in mixed populations of Pacific salmon *Oncorhyn*chus spp. U.S. National Marine Fisheries Service Marine Fisheries Review 47(l):1-8.

Neeley, D. 1982. Estimating variances of coded wire tagged salmonid ocean recovery statistics. Pages 176-218 in Workshop on coded wire tag recovery and estimation procedures for Pacific salmon and steelhead. Pacific States Marine Fisheries Commission, Portland, Oregon.

Newman, K. B. 1990. Variance estimation for stock contribution estimates based on sample recoveries of coded-wire-tagged fish. American Fisheries Society Symposium 7:677-683.

Palermo, R. V. 1984. Determination of sample size requirements to analyze the age structure of the B.C. chinook catch. Canadian Technical Report of Fisheries and Aquatic Sciences 1335.

Pascual, M.A. 1993. The estimation of salmon population parameters from coded wire tag data. Doctoral dissertation. University of Washington, Seattle. 153 pp.

Palermo, R. V. 1990. Jeopardized estimates of the contribution of marked Pacific salmon to the sport fishery of the Strait of Georgia, British Columbia, due to awareness factor variability. American Fisheries Society Symposium 7:631-646.

Perry, E. A., H. L. Blankenship, and R. V. Palermo. 1990. Comparison of two methods for replicating coded wire tag studies. American Fisheries Society Symposium 7:660-666.

Pascual, M.A. 1993. The estimation of salmon population parameters from coded wire tag data. Doctoral dissertation. University of Washington, Seattle. 153 pp.

PMFC (Pacific Marine Fisheries Commission). 1982a. Workshop on coded wire tagging experimental design: results and recommendations. Pacific State Marine Fisheries Commission, Portland, Oregon.

PMFC (Pacific Marine Fisheries Commission). 1982b. Workshop on coded wire tag recovery and estimation procedures for Pacific salmon and steelhead. Pacific State Marine Fisheries Commission, Portland, Oregon.

PSC (Pacific Salmon Commission). 1995. Workshop on hatchery CWT methodology. January 10-12, 1995. Seattle, WA. (unpublished report).

PSC (Pacific Salmon Commission). 1999A. Report on the 1994 status of the coastwide coded wire tag database. Technical Committee on Data Sharing. Report TCDS (99)-1.

PSC (Pacific Salmon Commission). 1999B. Selective Fishery Evaluation Committee. 1998 Annual Report. SFEC (99)-1.

PSC (Pacific Salmon Commission). 2004. Draft version: Mass marking and mark-selective fisheries for 2002.. Regional Coordination Working Group, Selective Fishery Evaluation Committee.

Reisenbichler, R. R., and N. A. Hartmann. 1980. Effect of number of marked fish and years of repetition on precision in studies on contribution to a fishery. Canadian Journal of Fisheries and Aquatic Sciences 37:576-582.

Shaklee, J. B. and S. R. Phelps. 1990. Operation of a large-scale, multiagency program for genetic stock identification. American Fisheries Society Symposium 7:817-830.

Volk, E. C., S. L. Schroder, and K. L. Fresh. 1990. Inducement of unique otolith banding patterns as a practical means to mass-mark juvenile Pacific salmon. 'American Fisheries Society Symposium 7:203-215.

Vreeland, R. R. 1987. An experimental design for studies of contribution to fisheries by salmonid hatcheries. Master's thesis. University of Washington, Seattle.

Vreeland, R. R. 1990. Random-sampling design to estimate hatchery contributions to fisheries. American Fisheries Society Symposium 7:691-707.

Wahle, R. J., and R. R. Vreeland. 1978. Bioeconomic contribution of Columbia River hatchery fall chinook salmon, 1961 through 1964 broods, to the Pacific salmon fisheries. U.S. National Marine Fisheries Service. Fishery Bulletin 76:179-208.

Wahle, R. J., R. R. Vreeland, and R. H. Lander. 1974. Bioeconomic contribution of Columbia River hatchery coho salmon, 1965 and 1966 broods, to the Pacific salmon fisheries. U.S. National Marine Fisheries Service Fishery Bulletin 72:139-169.

Webb, T. M. 1985. An analysis of some models of variance in the coded wire tagging program. Report to Canada Department of Fisheries and Oceans, Vancouver.

Worland, D. D., R. J. Wahle, and P. D. Zimmer. 1969. Contribution of Columbia River hatcheries to harvest of fall chinook salmon *(Oncorhynchus tshaw*ytscha). U.S. Fish and Wildlife Service Fishery Bulletin 67:361-391.