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INCIDENCE OF THERMALLY-MARKED CHUM SALMON IN THE 1994-96 BERING SEA POLLOCK B-SEASON TRAWL FISHERY

by

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ABSTRACT

Otoliths from samples of chum salmon (*Oncorhynchus keta*) incidentally caught in the Bering Sea walleye pollock (*Theragra chalcogramma*) B-season trawl fishery during 1994, 1995, and 1996 were examined for thermal marks. The percentage of otoliths thermally marked was 0.0% (0/393) in 1994, 0.2% (1/612) in 1995, and 2.8% (82/2951) in 1996. Thermally marked chum salmon were either from the Douglas Island Pink and Chum hatchery located in Juneau, Alaska or the Nitinat hatchery located on the southwest coast of Vancouver Island, British Columbia. Thermal marks confirm the limited CWT data and recent genetic stock identification analyses suggesting that chum salmon migrate from the eastern Gulf of Alaska to the Bering Sea. Application of thermal mark technology to coastal and high seas salmon research issues is discussed and a recommendation made for all nations and agencies conducting research in the North Pacific Ocean to collect and examine salmon otoliths for thermal marks.

INTRODUCTION

The incidental harvest of salmon (*Oncorhynchus* spp.) in Alaskan groundfish fisheries has been a contentious issue since the late 1970s when U.S. observers were first placed on foreign fishing vessels under authority of the Magnuson Fishery Conservation and Management Act. At first, the bulk (about 90%) of the harvest was comprised of chinook salmon (*O. tshawytscha*), with smaller numbers (6-10%) of chum salmon (*O. keta*). Early interceptions were judged to have a moderate economic impact on domestic salmon fisheries, but not an immediate threat to the resource (NPFMC 1981). The incidental catch of over 100,000 chinook salmon in 1980 changed that perspective, bringing increased focus to the conduct of the fishery and its incidental harvests.

The bycatch issue gained new momentum in 1993 with the harvest of nearly 250,000 chum salmon (Fig. 1). A chum salmon savings area north of Unimak Island was created; trawling was prohibited in this area during August and during the walleye pollock (*Theragra chalcogramma*) B-season fishery after an incidental harvest of 42,000 non-chinook salmon. The Salmon Research Foundation (SRF) was also formed in response to the bycatch problem; their goals are to promote vessel-level accountability for bycatch, and to develop a better understanding of bycatch patterns and bycatch avoidance methods. Although the SRF originally focused on chinook salmon issues, recent projects have been directed towards chum salmon research needs[1]. In 1995 and 1996, SRF funds were used to increase collection of chum salmon tissues used in stock identification research at the Auke Bay Laboratory.

The inclusion of whole heads with the tissue samples have permitted the extraction and processing of otoliths to identify possible contributions of thermally marked hatchery stocks in this fishery. In this paper we report results of these examinations and compare the results with those of genetic stock identification analyses, and with data from coded wire tag (CWT) recoveries and high seas tagging studies. The paper closes with a discussion of the application of thermal mark technology to current and future coastal and high seas salmon research.

BERING SEA WALLEYE POLLOCK FISHERY

Walleye pollock are the most abundant groundfish species in the Bering Sea, comprising about 75% of the groundfish catch in recent years. They are found throughout the water column (0-500 m) and migrate seasonally from outer shelf/slope areas where they overwinter to shallow shelf waters (about 100 m) where they spawn in April. Most walleye pollock in the U.S. fishery are taken by trawl gear during two fishing seasons: a winter roe fishery (A-season) lasting from mid-January through February, and a fall non-roe fishery (B-season) lasting from mid-August to September.

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[1]S. Salveson, NMFS, Alaska Region, P.O. Box 21668, Juneau, AK 99802. Pers. Commun., February, 1997)

Fishing during the B-season primarily occurs in waters between Unimak Island and the Pribilof Islands (Fig. 2). The catch is divided between inshore and offshore processors, with 35% allocated to the inshore group. A special catcher vessel operational area (CVOA) near Unimak Island is designated during the B-season, restricting fishing to catcher vessels delivering to inshore processors. This area is bounded by longitudes 163°W and 168°W, and latitude 56°N (NPFMC 1993). The chum salmon saving area is located within the CVOA. The offshore fleet fishes north of the CVOA and east of the Pribilofs.

METHODS

Samples of chum salmon incidentally caught during the walleye pollock B-season were collected in 1994, 1995, and 1996 by NMFS observers either stationed aboard fishing vessels or at shoreside plants. In 1994, 457 chum salmon were sampled from vessels operating in five statistical areas (509, 513, 517, 521, and 541) between August 29 and October 8. In 1995, 1,853 chum salmon (11% of the total bycatch) were sampled from vessels operating in areas 509, 517, 518, and 519 between August 14 to October 1 (Fig. 3). In 1996, about 3100 salmon were collected by observers stationed at shoreside plants on Unimak Island; all samples were taken from vessels delivering to inshore processors and thus only represent chum salmon catches within the CVOA. Otoliths were taken from a subsample of the chum salmon collected in 1994 and 1995 and from nearly all of the chum salmon collected in 1996: number of otoliths processed the three years of our study were 393, 612, and 2951.

Fish heads were cut between the eyes and the left and right sagittal otoliths removed. Left otoliths were mounted on labeled petrographic glass slides using thermal resin. Otoliths were ground to expose a central plane bisecting the primordia and the microstructure examined under a compound microscope. Presence or absence of thermal marks was determined for each otolith, by comparing its microstructure pattern with the thermal mark patterns from voucher specimens that were collected from the hatcheries prior to release. All otoliths were read independently by a second reader to provide an estimate of precision and to verify marks identified by the initial reader (Hagen et al., 1995).

RESULTS

Results of the otolith processing were as follows:

Year	Otoliths Processed	Number Marked
1994	393	0
1995	612	1
1996	2951	82

The one thermally marked chum salmon otolith recovered in 1995 was from the Douglas Island Pink and Chum (DIPAC) hatchery, 1992 brood. Five discrete hatchery otolith thermal mark patterns were identified in the 1996 sample: DIPAC hatchery, 1992 brood (32 marks); DIPAC hatchery, 1993 brood (12 marks); Nitinat hatchery, early releases from 1993 brood (17 marks); Nitinat hatchery, late releases from 1993 brood (20 marks); and Nitinat hatchery, 1994 brood (1 mark). Seven otoliths in 1996 were classified as "questionable"; these had an apparent thermal-type pattern, but did not match any voucher specimens from Canada, Alaska, or Russia. The 82 marks in 1996 represents a mark rate of 2.78% for the 2951 fish sampled.

DISCUSSION

The identification of thermally marked chum salmon provide direct evidence of long-distance migration of chum salmon from the eastern Gulf of Alaska to the Bering Sea. The substantial geographical separation between the two thermally marked stocks identified in the analysis--the DIPAC hatchery is located in Juneau, Alaska and the Nitinat hatchery on the south west coast of Vancouver Island, British Columbia--suggest that this migration may be widespread.

These results are consistent with data from coded wire tag (CWT) releases. Since 1980, ten CWTs from chum salmon originating in southeast Alaska, British Columbia, or Washington have been recovered in the Bering Sea (Fig. 4; Table 2). A simple expansion of these recoveries using marked/total release ratios yields 350 chum salmon as a minimal estimate of the total number of fish from these tag lots incidentally caught in the fishery. Release locations of the ten CWT salmon are diverse in geographical location, but a small subsample of all the release sites of CWT chum salmon since 1980 (compare Fig. 4 with Fig. 5). Recovery dates are clustered with multiple CWT recoveries in some years (Table 2). The persistent recovery of CWTs from Stave River, British Columbia (Fig. 4) is unusual and likely represents an increased probability of migration to the Bering Sea for this stock.

The thermal mark data also support genetic stock identification (GSI) results showing a substantial contribution of eastern Gulf of Alaska (southeastern Alaska, British Columbia, and

Washington) chum salmon stocks to the chum salmon bycatch in the walleye pollock B-season fishery (Wilmot et al., 1996). Stock composition estimates for this stock group ranged from 21 to 29% in 1994 and 9 to 46% in 1995.

These composition estimates along with the high incidence of two eastern Gulf of Alaska hatchery stocks differ, however, from results of high seas tagging studies conducted several decades ago. Of the 312 recoveries from 9,912 chum salmon tagged since the 1950s within an area bounded by 50-56°N and 160-170°W, only three tags have been recovered in southeastern Alaska, British Columbia, or Washington[2], representing a contribution rate of 0.96%. This contribution rate is difficult to evaluate because of differences in tag recovery rates among fisheries and spawning grounds. Moreover, there are differences in sampling area and time between data sets; the B-season samples came from fishing operations occurring farther north and later in the year than the bulk of the high seas tagging operations. A more definitive analysis is beyond the scope of this paper, but still worthwhile as a change in the incidence of eastern Gulf of Alaska chum salmon stocks in the Bering Sea could indicate a response to decadal changes in coastal environmental conditions or an expansion of chum salmon ocean feeding areas due to increased population density (Helle and Hoffman 1995; Bigler et al., 1996).

The large difference in thermal mark incidence between 1995 and 1996 is likely due to a change in mark incidence for the Nitinat hatchery (thermal marking was re-instituted in 1993), but not for the DIPAC hatchery (marked releases date back to 1991). Neither can this difference be explained by a change in the level and distribution of sampling effort between the two years. Sampling in 1994 and 1995 occurred throughout the fishery, including vessel operations in shelf and slope waters near the Pribilof Islands and beyond where recovery rates of CWT chum salmon from the eastern Gulf of Alaska are reduced (see Fig. 3). About one-half of the pollock catch occurs in the southeastern portion of the fishery, near the CVOA where the 1996 samples originated. Even if we account for this by reducing the effective sampling size to 306 (one-half of 612), the mark incidence rate in 1995 is .33%, or about 10 times less than the rate in 1996.

The lack of thermally marked chum salmon from the Hidden Falls hatchery in our samples probably reflects the low quality of initial thermal marks at that facility for the 1991 and 1992 broods. This hatchery stock is known to migrate to the Bering Sea; a CWT chum salmon from that hatchery was recovered in the Bering Sea in 1986 (Table 2). Previous efforts to identify thermal marks from these broods in commercial fishery samples, however, have proved difficult and it is possible that marked otoliths from the 1991 and 1992 broods could have been processed and the marks not detected.

Thermal Marking as a Research Tool

The advent of large-scale, but low-cost, thermal mark technology offers a new dimension to our efforts to identify the origin of individual fish in mixed-stock fisheries and ocean environments

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[2]K. Myers, Fisheries Research Institute, University of Washington, Seattle, WA. Pers. Commun., February, 1997)

and to refine forecasts of returning stocks for fishery managers. In particular, this development has proved to be a timely and cost-effective tool for managing mixed stock fisheries in southeastern Alaska and shows promise for addressing issues related to wild and enhanced components of salmon fisheries (Hagen et al., 1996). It is particularly effective when fishery sampling rates are low and/or stock contribution rates small--which was the case in our data and is common in the collection of bycatch data.

Our results also suggest that thermal marking will provide new research opportunities for salmon life-history studies in coastal and offshore waters. The availability of potential large numbers of marked fish through application of thermal marks in hatcheries means that a modest research sampling program can collect sufficient numbers of marked fish for detailed studies of the growth and development of individual salmon stocks as they migrate through coastal waters to offshore oceanic waters.

For example, the Auke Bay Laboratory is initiating in 1997 a comprehensive monitoring program designed to provide repeated measurements of the habitat, biological, and population characteristics of salmon from their early marine residence period to their later migration through the coastal waters of the Gulf of Alaska. Particular focus is placed on monitoring the northern southeastern Alaskan thermally-marked hatchery fish: over 126 million thermally-marked chum salmon from two hatcheries and a remote incubation site are scheduled to be released in the spring of 1997.

These research opportunities will be more fully realized through a commitment by all nations and agencies conducting research in the North Pacific Ocean to collect and examine salmon otoliths for thermal marks. Pooled data from coastal programs such as the OCC monitoring program, bycatch sampling in groundfish fisheries, and high seas research cruises such as those conducted by NPAFC member countries will yield new understanding of salmon on the high seas, particularly if the use of thermal marking spreads to additional hatcheries and other Pacific Rim regions.

Since the effectiveness of this tool is greatly diminished when undocumented or poor quality thermal mark patterns are present, a commitment by all nations and agencies must include setting standards for thermal marking and outlining guidelines for maintaining high quality of thermal marks. Presence of undocumented thermal mark patterns add to the difficulty in distinguishing them from noisy wild stock patterns. A single poor quality mark which lacks discrete definition may compromise classification, and therefore estimates of stock contribution, of other discrete hatchery marks. This effort may best be coordinated through one entity identified through consensus of participating nations and agencies.

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Table 1.--Number of thermally marked chum salmon from the DIPAC and Hidden Falls hatcheries in Southeast Alaska, and from the Nitinat Hatchery in British Columbia. (Sources: R. Focht, DIPAC, 2697 Channel Dr., Juneau, Alaska 99801; B. Bachen, NSRAA, 1305 Sawmill Creek Rd, Sitka, AK 99835; D. Bailey, Department of Fisheries and Oceans, Stock Enhancement Program (SEP), 555 W. Hastings, Suite 323, Vancouver, British Columbia V6B 5G3).

Brood Year	Numbers of Thermally Marked Chum Salmon Released (in millions of fish)			
	DIPAC	Hidden Falls	Nitinat early	Nitinat late
1987			2.24	
1988			7.65	
1991	56.4	25.4		
1992	67.6	36.5		
1993	67.6	33.1	13.05	15.32
1994	82.3	37.3	17.25	13.58
1995	90.0	49.7	6.58	18.10
1996 (est.)	88.0	37.2		

Table 2.--Hatchery of origin and brood year of CWT chum salmon recovered in Bering Sea groundfish fisheries. The middle column gives, by brood year, the total number of chum salmon given CWT for the combined area of southeastern Alaska, British Columbia, Washington and Oregon (Sources: Pacific States Marine Fisheries Commission, Dahlberg et al. (1986, 1987, 1991, 1994, 1995), and S. Fowler, Alaska Fisheries Science Center, Auke Bay Laboratory, 11305 Glacier Hwy, Juneau, Alaska, 99801).

Brood Year	Tagged	Year of Recovery in Bering Sea and Hatchery of Origin
1980	1,143,216	
1981	1,256,264	Finch Creek, Washington (1984); Kasnyku Bay, Alaska (1985)
1982	1,164,155	Deep Inlet, Alaska (1986); Stave River, BC (1985)
1983	1,186,350	
1984	1,619,331	
1985	992,361	
1986	783,306	Puntledge River, BC (1990)
1987	1,062,659	
1988	1,309,604	Stave River, BC (1993)
1989	1,550,441	
1990	1,545,411	Nimpkish River, BC (1994); Chehalis River, BC (1993)
1991	911,320	
1992	1,137,684	
1993	740,662	Stave River, BC (1996); Stave River, BC (1996)

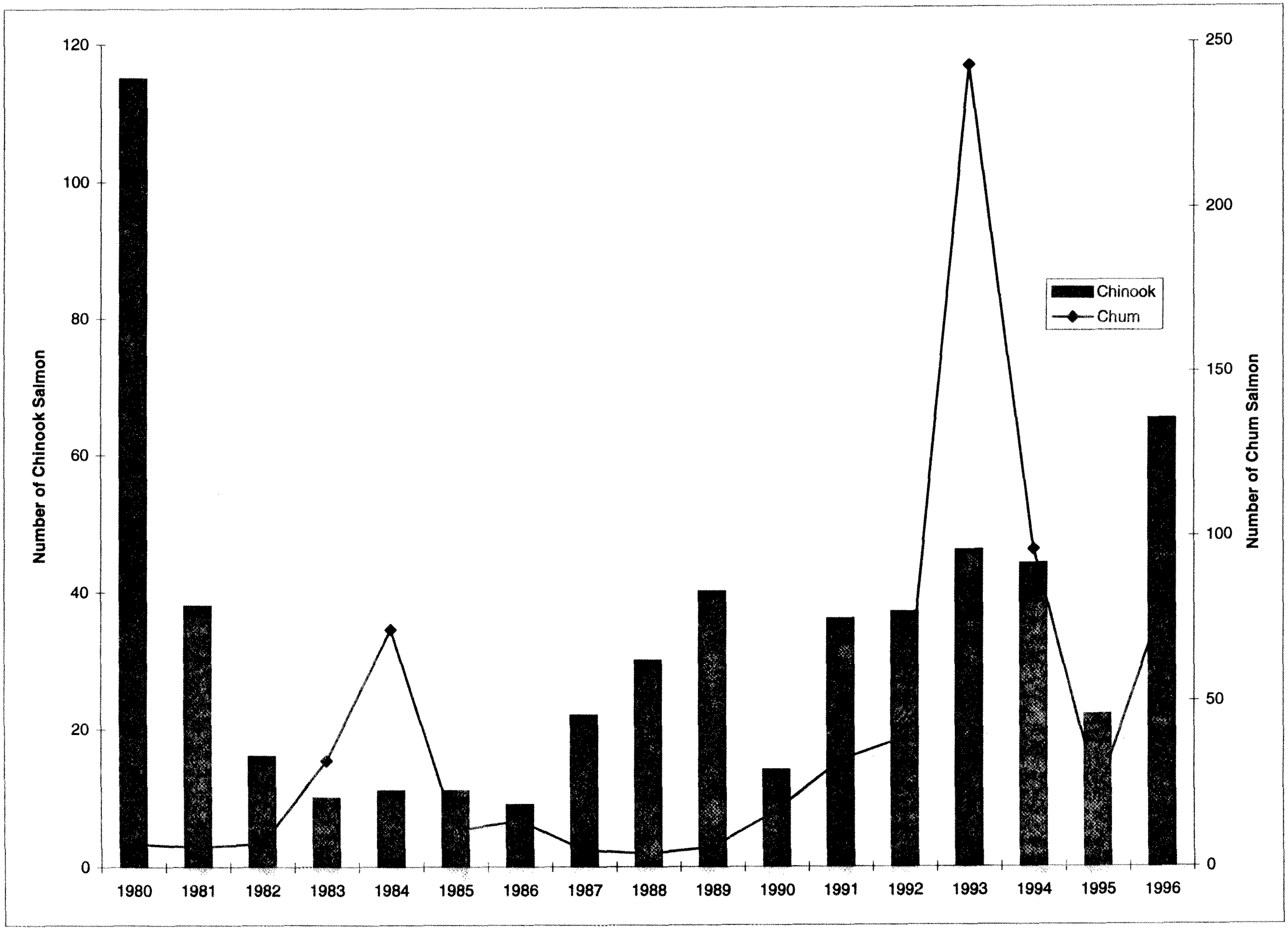

Fig. 1--Bycatch of chinook and chum salmon in the Bering Sea, 1980-1996. (Source: NMFS observer program, Alaska Fisheries Science Center).

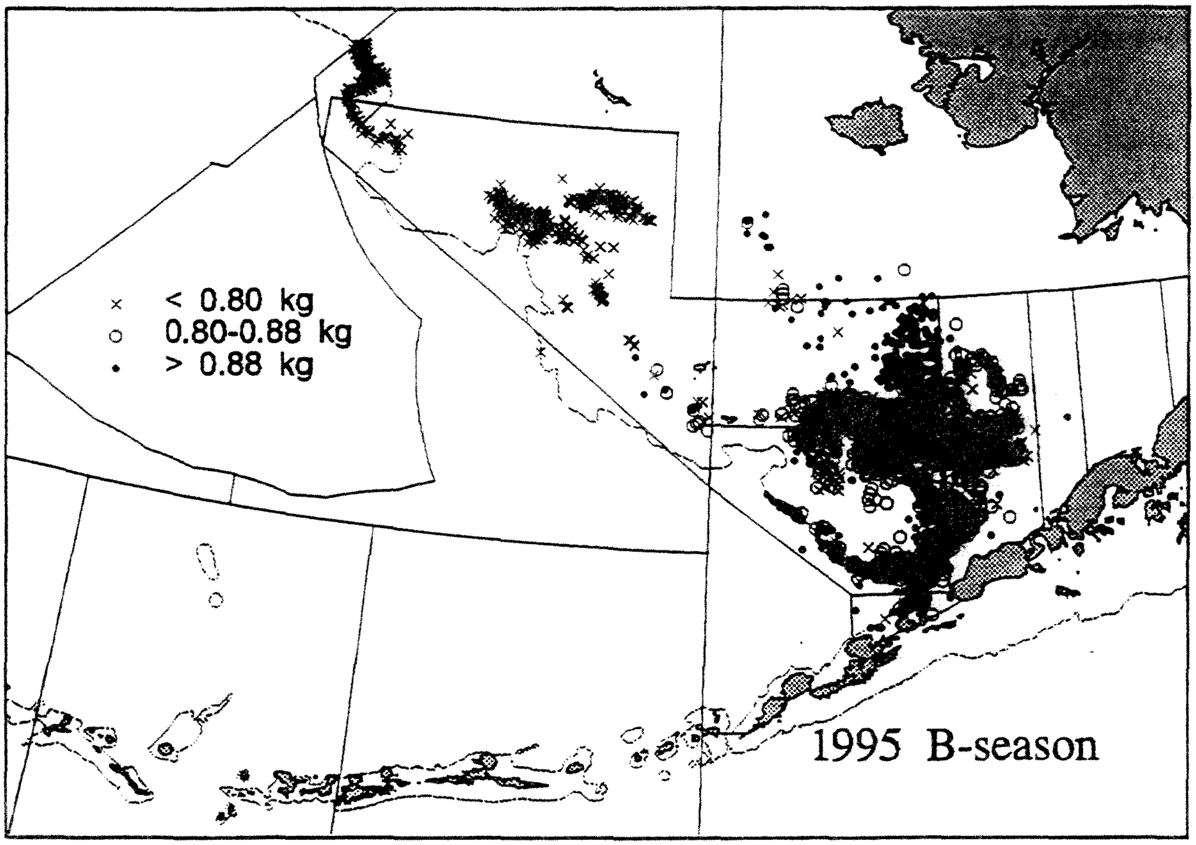

Fig. 2--Trawl locations in the 1995 pollock B-fishery. Symbols indicate mean pollock weight in the trawl: < 0.80 kg (x); 0.80-0.88 kg (◦); and > 0.88 kg (•). (Source: M. Sigler Alaska Fisheries Science Center, Auke Bay Laboratory, 11305 Glacier Hwy, Juneau, Alaska, 99801).

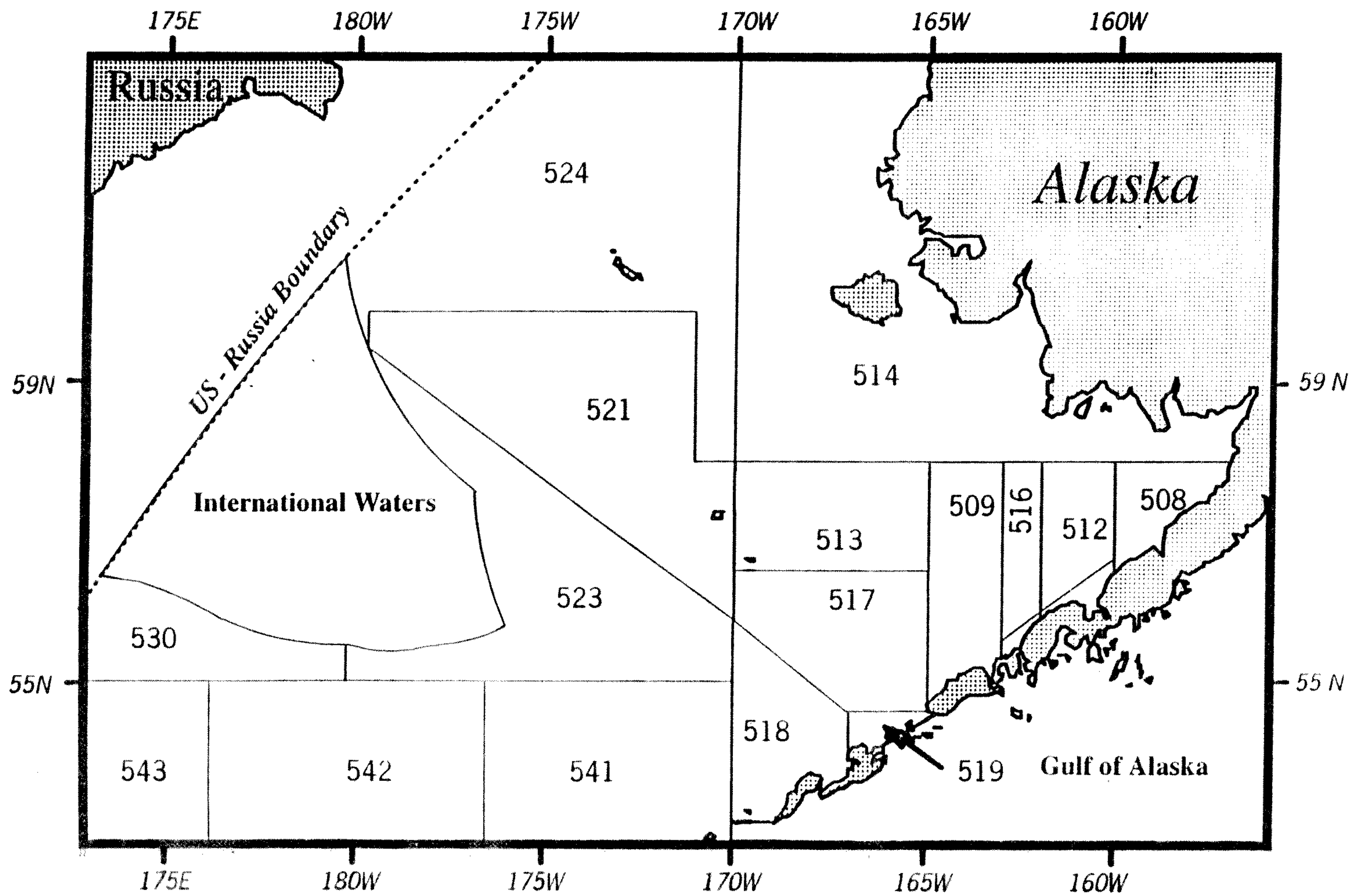

Fig. 3--Statistical areas for the Bering Sea trawl fishery.

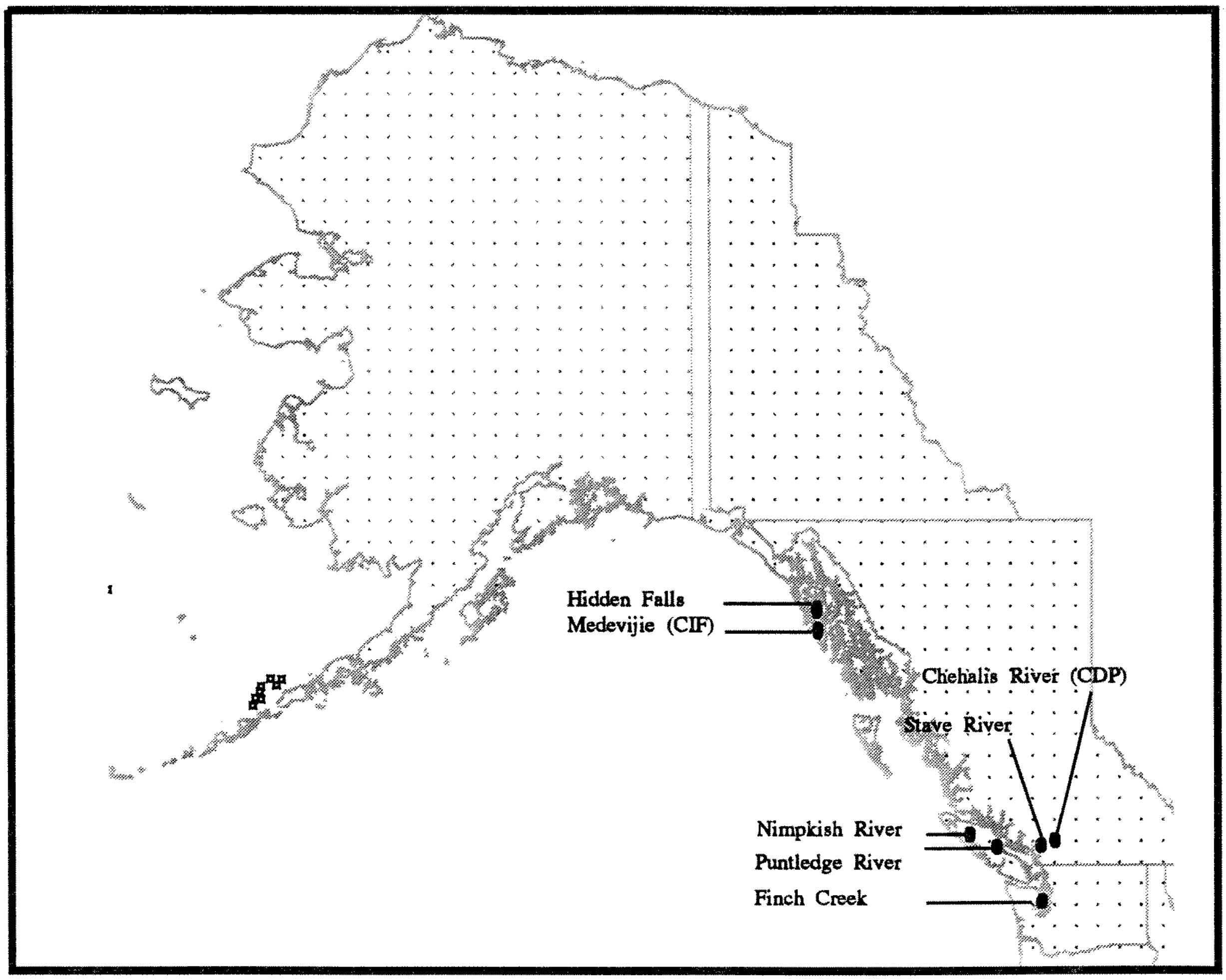

Fig. 4--Hatcheries from Southeast Alaska, British Columbia, and Washington with CWT recoveries in Bering Sea groundfish fisheries (Source: S. Fowler, Alaska Fisheries Science Center, Auke Bay Laboratory, 11305 Glacier Hwy, Juneau, Alaska, 99801).

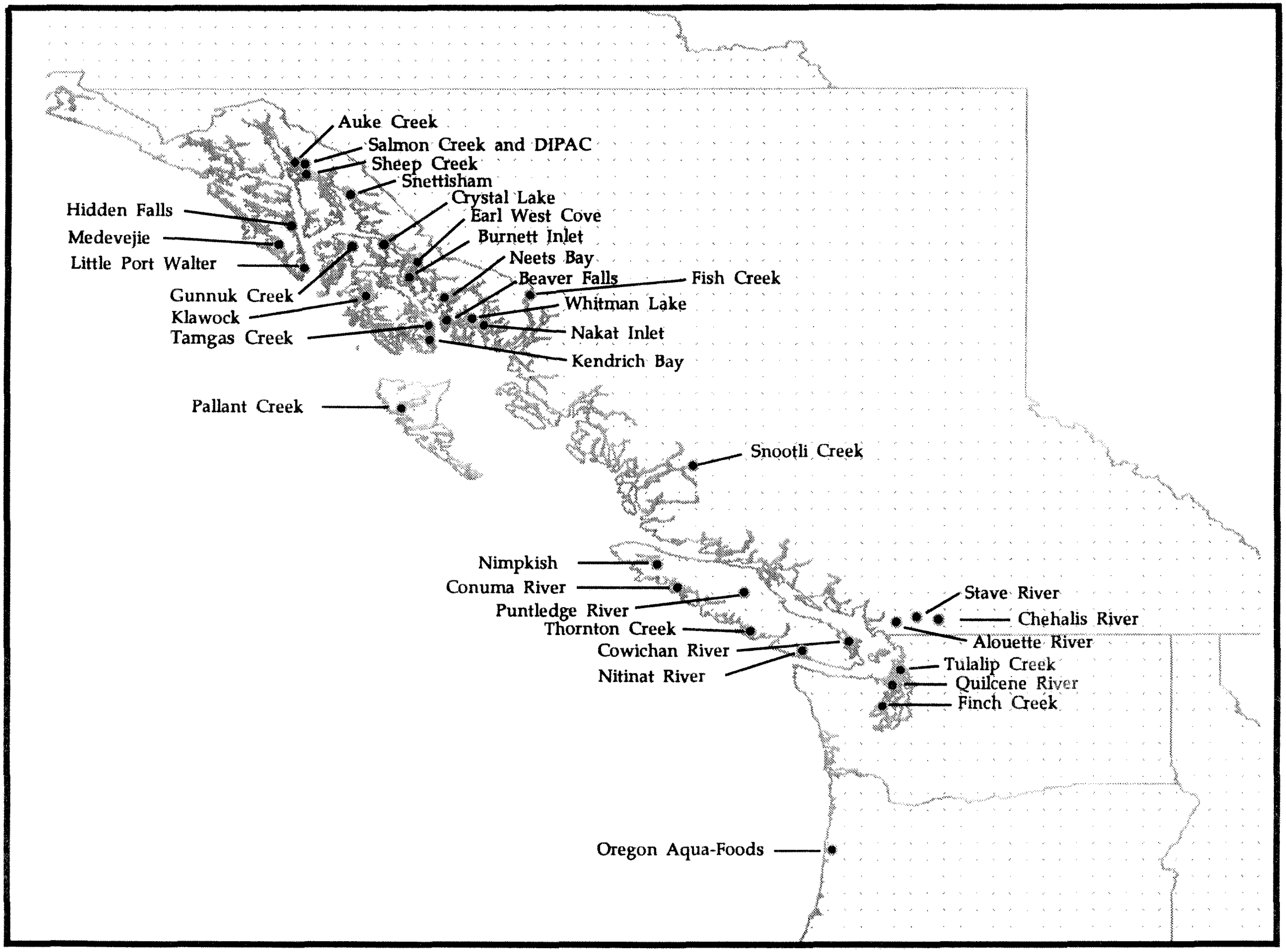

Fig. 5--Location of Southeast Alaska, British Columbia, and Washington hatcheries releasing CWT chum salmon from 1980 to 1993. (Source: Pacific States Marine Fisheries Commission).