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Incidence of Thermally Marked Pink, Chum, and Sockeye Salmon in the Coastal Waters of the Gulf of Alaska

by

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ABSTRACT

North Pacific Ocean and eastern Bering Sea research cruises conducted by the Auke Bay Laboratory Ocean Carrying Capacity (OCC) program during July and August 1997 provided ocean recoveries of 180 pink (*Oncorhynchus gorbuscha*), 157 chum (*O. keta*), and 13 sockeye (*O. nerka*) salmon thermally marked during incubation at Alaskan (USA) and Canadian hatcheries. The 180 otolith thermal marks for juvenile pink salmon, 101 otolith thermal marks for juvenile chum salmon, and 8 otolith thermal marks for juvenile sockeye salmon represent 22.8%, 31.2%, and 2.5% of our samples, respectively. The 56 otolith thermal marks for immature chum and 5 otolith thermal marks for immature sockeye represent 3.7% and less than 1% of these samples, respectively. The marked juvenile (age .0) salmon migrated westerly along the coastal waters of the North Pacific Ocean. The marked immature (age .1+) chum salmon from southeastern Alaska and Canadian hatcheries were found in the coastal waters of the North Pacific Ocean from Prince William Sound to the eastern Aleutian Islands and also in the coastal waters of the eastern Bering Sea. The marked immature sockeye salmon from southeastern and central Alaska were found in the coastal waters of the North Pacific Ocean from the eastern Aleutian Islands to the central Aleutian Islands.

INTRODUCTION

Thermal marking of salmonid otoliths has become an important, cost-effective tool to identify hatchery salmon at sea. The large numbers of thermally marked salmon released into the North Pacific Ocean have greatly increased the probability of recovering marked salmon during high-seas sampling and have provided a unique opportunity to study the life history traits of hatchery salmonids (Ignell et al. 1997). In recent years, releases of thermally marked salmon into the North Pacific Ocean from hatcheries in Washington, British Columbia, and Alaska have numbered in the billions. Alaska hatcheries alone released over 800 million thermally marked salmon into the North Pacific Ocean in 1997 (Thermal Mark Database, Alaska Department of Fish and Game, Otolith Processing Lab, Juneau).

In 1996, the OCC program at the Auke Bay Laboratory, National Marine Fisheries Service initiated a comprehensive program to study the distribution, migration, origin, size, growth, and diet of juvenile, immature, and maturing salmonids in the Gulf of Alaska (Carlson et al. 1996). One objective of this ongoing program is to collect and analyze otoliths from juvenile and immature salmonids and then identify hatchery versus wild stocks and determine hatchery origins.

In this document we summarize information on recovery location and average lengths and weights at recovery for juvenile pink *Oncorhynchus gorbuscha*, chum *O. keta*, and sockeye (O. nerka) salmon and immature chum and sockeye salmon caught in the coastal waters of the Gulf of Alaska during July - August 1997 that contained thermally marked otoliths. Information from recoveries of thermally marked pink and

chum salmon from the previous research cruise during July - August 1996 was summarized and reported in Farley and Munk (1997).

CRUISE

During July and August 1997, the OCC program conducted a survey to describe the distribution of juvenile, immature, and maturing salmon in the North Pacific Ocean. The four week cruise began at Cape St. Elias near Prince William Sound and extended through the Gulf of Alaska and west to Attu Island. (Carlson et. al. 1997; Figure 1).

The fishing gear was a midwater rope trawl, model 400/580, made by Cantrawl Pacific Ltd.[1] of Richmond, B.C. The net is 198 m long, has hexagonal mesh in the wings and body, and has a 1.2-cm mesh liner in the codend. The net was fished with three 60 m, 1.9-cm bridles attached at a single point to steel alloy 5-m midwater trawl doors, each weighing 463 kg. The net was towed at 5 knots at or near surface, with floats on the headrope and 260 m of warp line on each door. The net was monitored using a Simrad 300 netsounder, which showed a typical spread of 41 m horizontally and 13 m vertically.

Transects sampled for salmon were 60-120 nautical miles apart and roughly perpendicular to shore. Most transects ran from prominent points of land to 60 nautical miles offshore, but in areas with a broad continental shelf they extended up to 120 nautical miles offshore (Figure 1). Sampling began nearshore, and continued seaward over the shelf, and beyond to oceanic depths. Most tows lasted 1 hour and usually covered 5 nautical miles. Catches were brought aboard, and the codend was emptied onto a sorting table. Adult salmon and other fishes were identified to species and counted. Juvenile (first ocean year; ocean age .0) and immature (second or third ocean year; ocean age .1 or older) salmon were identified and sorted by species, and fork length and weight were recorded for each fish. A scale was taken from the preferred area (when possible) to determine age and brood year. Whole juvenile salmon and heads taken from immature salmon were frozen for further laboratory analyses.

LABORATORY ANALYSES

In the laboratory, juvenile salmon and heads of immature salmon were thawed and standard length (measured from tip of snout to posterior end of caudal peduncle) and weight were recorded for subsamples of juvenile pink, chum, and sockeye salmon. Left and right sagittal otoliths were removed, and the left sagittal otoliths mounted, using thermal resin, on petrographic slides and then ground to expose the primordia. If left sagittal otoliths were not available or were overground, then the right sagittal otoliths were used. Otolith microstructure was examined under a compound microscope, and the microstructure patterns were compared to thermal mark patterns from voucher specimens collected from the hatcheries before release. All otoliths were read independently by a second reader to assure accuracy and confidence in the readings (Hagen et al. 1995).

[1] Reference to trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

When disagreements between otolith readers occurred, they were resolved by the most experienced otolith reader.

Scales and otoliths from immature salmon were jointly examined to determine age and brood year. If discrepancies in age or brood year occurred between the otolith and scale readings, then we referred to the age and brood year from the salmon scale.

PRELIMINARY FINDINGS

Thermal Marks

A total of 788 juvenile pink, 324 juvenile and 1,803 immature chum, and 322 juvenile and 698 immature sockeye salmon were caught in the coastal waters of the Gulf of Alaska during July and August 1997. A subsample of 1,500 immature chum and all samples of other salmon were analyzed for hatchery marks. Otolith thermal mark patterns were found from seventeen discrete hatchery locations (Figure 2). The 180 otolith thermal marks for juvenile pink salmon, 101 otolith thermal marks for juvenile chum salmon, and 8 otolith thermal marks for juvenile sockeye salmon represent 22.8%, 31.2%, and 2.5% of our samples, respectively. The 56 otolith thermal marks for immature chum and 5 otolith thermal marks for immature sockeye represent 3.7% and less than 1% of these samples, respectively.

Fish Distribution

Juvenile hatchery origin salmon were released in the spring of 1997 and recovered between 24 July and 27 July 1997 (Figures 3 - 5). Pink salmon from the Gastineau Hatchery in southeastern Alaska were distributed northwest along the continental shelf from Cape St. Elias to Gore Point. Most pink salmon from Prince William Sound hatcheries were distributed southwest along the continental shelf from Cape Puget to Gore Point; however, one pink salmon from Solomon Gulch Hatchery was found east of Prince William Sound in the nearshore area at Cape St. Elias. Chum salmon from southeastern Alaska were distributed northwest along the continental shelf from Cape St. Elias to Gore Point. Chum salmon from Prince William Sound hatcheries were distributed southwest along the continental shelf from Cape Puget to Gore Point.

Three distinct brood years (1993 - 1995) of immature hatchery origin chum salmon released in the spring of 1994, 1995, and 1996 and one distinct brood year (1994) of immature hatchery sockeye salmon were recovered between 23 July and 17 August 1997 (Figures 6 and 7). Chum salmon from Gastineau and Hidden Falls hatcheries in southeastern Alaska and Nitinat Hatchery on the southwestern corner of Vancouver Island, British Columbia were found along the continental shelf and oceanic waters from Cape St. Elias to Samalga Island and also in the southeastern Bering Sea. Sockeye salmon from Trapper, Chilkat, and Tahltan hatcheries near southeastern Alaska and Packers Hatchery in Cook Inlet, Alaska were found along the continental shelf and oceanic waters from Scotch Cap to Adak Island.

Size

Sizes of juvenile pink, chum, and sockeye salmon recoveries varied widely among hatcheries, and in some instances, large standard deviations for lengths and weights were found for a given hatchery, even among fish captured in the same area (Table 1). This variation in length and weight may have been influenced by varied feeding and release dates, growth rates, migration rates, diet, or condition. The variation in the size of sockeye salmon may also indicate differences in residence times of sockeye salmon in freshwater lakes. In general, mean lengths and weights of hatchery juvenile pink and chum salmon increased with distance offshore and as fish migrated westward. These results are consistent with earlier findings characterizing juvenile salmon size with distance from shore and their location in the Gulf of Alaska (Hartt and Dell 1986; Jaenicke and Celewycz 1994; Farley and Munk 1997).

Sizes of immature chum and sockeye salmon by hatchery, brood year, and date recovered are given in Tables 2 and 3. Immature chum salmon from Hidden Falls Hatchery brood year 1994 recovered at Cape Prominence contained large standard deviations for length and weight. This is indicative of the variation in growth of chum salmon where standard deviation of length and weight increases as ocean age increases (Table 4).

DISCUSION

This was the second year of ocean sampling of salmon in the Gulf of Alaska and southeastern Bering Sea by the OCC program. Results of the 1996 survey (Farley and Munk 1997) indicated a large proportion of thermally marked juvenile pink (29.7%) and chum (20.6%) salmon in the juvenile salmon samples. Our results suggest a lower proportion of thermally marked pink salmon (22.8%) and a higher proportion of thermally marked chum salmon (31.2%) during 1997 in our juvenile salmon samples. The larger proportion of thermally marked chum salmon in 1997 may be due to the inclusion of hatcheries releasing thermally marked chum salmon from Prince William Sound during 1997 that were not actively marking chum salmon during 1996.

The largest catches of immature chum salmon during July and August occurred from Cape St. Elias past Samalga Island whereas the largest catches of immature sockeye salmon occurred from Scotch Cap past Adak Island (Carlson et. al 1997). Coincidentally, immature hatchery chum and sockeye salmon recovered during our survey were located in these areas of highest relative abundance. The highest concentrations of immature hatchery chum salmon were located south of the Alaska Peninsula and eastern Aleutian Islands. The lower proportion of immature hatchery chum salmon in the Bering Sea (particularly from British Columbia) is consistent with coded-wire tagged recoveries of chum salmon from British Columbia (Dahlberg et al. 1997).

Our results indicate that thermal marking will provide new research opportunities for salmon life history studies in coastal and offshore waters of the Gulf of Alaska. The availability of large numbers of thermally marked salmon from hatcheries in Washington, British Columbia, and Alaska means that sufficient numbers of marked fish can now be collected in the North Pacific Ocean to determine the migration, distribution, growth, and development of individual hatchery stocks.

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Table 1. Mean lengths and weights and standard deviations (in parenthesis) of 180 hatchery pink, 101 hatchery chum, and 8 hatchery sockeye salmon juveniles recovered in the Gulf of Alaska during July and August 1997.

Species	Date recovered	Lat. north	Long. west	Gastineau					Armin F. Koernig					Cannery Creek					Wally Noerenberg					Solomon Gulch				
					Mean length		Mean weight			Mean length		Mean weight			Mean length		Mean weight			Mean length		Mean weight			Mean length		Mean weight	
				n	(mm)	SD	(g)	SD	*n*	(mm)	SD	(g)	SD	*n*	(mm)	SD	(g)	SD	*n*	(mm)	SD	(g)	SD	*n*	(mm)	SD	(g)	SD
Pink	7/24/97	59° 44'	144° 38'	1	114	(0.0)	14	(0.0)																1	105	(0.0)	11	(0.0)
	7/25/97	59° 52'	148° 25'						8	137	(13.1)	26	(6.9)	7	119	(17.2)	17	(8.6)	10	131	(7.3)	21	(5.9)	22	138	(17.4)	27	(9.2)
	7/25/97	59° 43'	148° 19'						1	136	(0.0)	22	(0.0)	2	112	(16.3)	14	(4.1)	2	119	(4.2)	18	(4.1)	8	156	(6.1)	39	(4.7)
	7/25/97	59° 34'	148° 16'																1	146	(0.0)	31	(0.0)	11	161	(4.0)	41	(6.6)
	7/25/97	59° 26'	148° 11'						1	122	(0.0)	19	(0.0)	1	113	(0.0)	13	(0.0)						1	156	(0.0)	34	(0.0)
	7/27/97	59° 07'	150° 49'						8	109	(12.6)	11	(4.8)	1	109	(0.0)	14	(0.0)	4	133	(4.2)	23	(3.6)	3	130	(10.6)	20	(5.6)
	7/27/97	58° 42'	150° 12'						9	134	(10.2)	23	(6.1)	7	128	(11.6)	20	(6.8)	26	143	(6.7)	28	(3.9)	20	148	(10.4)	30	(6.6)
	7/27/97	58° 16'	149° 22'	1	140	(0.0)	24	(0.0)	8	126	(12.4)	20	(6.1)	2	120	(16.3)	17	(7.4)	5	135	(8.6)	24	(5.5)	9	159	(14.0)	42	(10.3)

Chum				Gastineau					Hidden Falls					Armin F. Koernig					Cannery Creek					Wally Noerenberg					Port Chalmers				
					Mean length		Mean weight			Mean length		Mean weight			Mean length		Mean weight			Mean length		Mean weight			Mean length		Mean weight			Mean length		Mean weight	
				n	(mm)	SD	(g)	SD	*n*	(mm)	SD	(g)	SD	*n*	(mm)	SD	(g)	SD	*n*	(mm)	SD	(g)	SD	*n*	(mm)	SD	(g)	SD	*n*	(mm)	SD	(g)	SD
	7/24/97	59° 44'	144° 38'	16	131	(9.6)	21	(4.4)	11	134	(8.1)	23	(4.5)																				
	7/25/97	59° 52'	148° 25'											2	131	(3.5)	18	(0.1)						12	151	(11.8)	35	(9.2)	1	129	(0.0)	-	-
	7/25/97	59° 43'	148° 19'	1	142	(0.0)	27	(0.0)	1	137	(0.0)	24	(0.0)																				
	7/25/97	59° 34'	148° 16'	2	139	(4.2)	26	(1.2)																									
	7/25/97	59° 26'	148° 11'	1	132	(0.0)	24	(0.0)																									
	7/27/97	59° 07'	150° 49'						2	148	(0.0)	34	(0.7)	5	133	(19.0)	23	(7.3)						17	137	(9.6)	26	(5.6)	8	139	(13.4)	29	(10.8)
	7/27/97	58° 42'	150° 12'											4	149	(9.1)	34	(4.9)	1	152	(0.0)	33	(0.0)	12	144	(8.2)	29	(4.7)	5	153	(9.1)	35	(6.8)

Sockeye				Sweetheart					Chilkat					Tuya					Bear Lake					Hugh Smith				
					Mean length		Mean weight			Mean length		Mean weight			Mean length		Mean weight			Mean length		Mean weight			Mean length		Mean weight	
				n	(mm)	SD	(g)	SD	*n*	(mm)	SD	(g)	SD	*n*	(mm)	SD	(g)	SD	*n*	(mm)	SD	(g)	SD	*n*	(mm)	SD	(g)	SD
	7/24/97	59° 44'	144° 38'	1	143	(0.0)	37	(0.0)																1	150	(0.0)	37	(0.0)
	7/25/97	59° 43'	148° 19'	1	194	(0.0)	82	(0.0)	1	160	(0.0)	42	(0.0)															
	7/25/97	59° 34'	148° 16'						1	162	(0.0)	44	(0.0)	1	191	(0.0)	74	(0.0)										
	7/25/97	59° 26'	148° 11'	1	190	(0.0)	81	(0.0)																				
	7/27/98	58° 16'	149° 22'																1	136	(0.0)	24	(0.0)					

Table 2. Mean lengths and weights and standard deviations (in parenthesis) of 56 hatchery chum salmon immatures (brood year (BY) 1993-1995) recovered in the Gulf of Alaska during July and August 1997. Dash indicates no measurement taken.

Date recovered	Lat. north	Long. west	Gastineau						Hidden Falls						Nitinat					
				Mean length		Mean weight		BY		Mean length		Mean weight		BY		Mean length		Mean weight		BY
			n	(mm)	SD	(g)	SD		*n*	(mm)	SD	(g)	SD		*n*	(mm)	SD	(g)	SD	
7/23/97	58° 47'	144° 35'	1	575	(0.0)	-	-	93												
7/23/97	59° 10'	144° 36'													1	337	(0.0)	-	-	94
7/23/97	59° 21'	144° 35'													3	382	(15.1)	-	-	95
7/24/97	59° 30'	144° 32'													1	502	(0.0)	-	-	94
															1	364	(0.0)	-	-	95
7/25/97	59° 43'	148° 19'							1	476	(0.0)	-	-	94						
7/26/97	59° 14'	147° 58'	1	427	(0.0)	-	-	94												
7/27/97	59° 07'	150° 49'													1	565	(0.0)	-	-	95
7/27/97	58° 42'	150° 12'							1	484	(0.0)	-	-	94	1	401	(0.0)	-	-	94
7/27/97	57° 57'	149° 00'	1	520	(0.0)	-	-	94	1	527	(0.0)	-	-	94	1	499	(0.0)	-	-	94
7/29/97	57° 00'	151° 13'													1	499	(0.0)	-	-	94
7/30/97	55° 13'	156° 49'													1	545	(0.0)	-	-	94
8/1/97	53° 45'	164° 05'	1	493	(0.0)	1660	(0.0)	94	1	500	(0.0)	1461	(0.0)	94						
			1	348	(0.0)	452	(0.0)	95												
8/1/97	53° 34'	163° 54'	1	523	(0.0)	1616	(0.0)	94							2	515	(19.8)	1760	(80.6)	93
			2	370	(26.2)	614	(149)	95							1	468	(0.0)	1276	(0.0)	94
8/4/97	53° 21'	166° 39'	1	552	(0.0)	1855	(0.0)	94	1	343	(0.0)	448	(0.0)	95						
			1	304	(0.0)	272	(0.0)	95												
8/4/97	53° 15'	166° 34'	1	392	(0.0)	671	(0.0)	94	1	380	(0.0)	588	(0.0)	95						
8/4/97	52° 52'	166° 26'	1	523	(0.0)	1780	(0.0)	94	1	351	(0.0)	510	(0.0)	95	1	547	(0.0)	1820	(0.0)	93
									2	500	(52.3)	1503	(532.0)	94	6	516	(21.0)	1731	(199.0)	94
8/5/97	52° 42'	169° 15'	1	563	(0.0)	1920	(0.0)	94	2	518	(3.5)	1555	(21.2)	94	1	563	(0.0)	2270	(0.0)	93
			1	357	(0.0)	480	(0.0)	95							1	509	(0.0)	1590	(0.0)	94
8/15/97	53° 54'	164° 20'	1	377	(0.0)	582	(0.0)	95	1	377	(0.0)	602	(0.0)	95						
8/15/97	53° 38'	164° 02'	1	556	(0.0)	720	(0.0)	94	1	506	(0.0)	1416	(0.0)	94						
			1	392	(0.0)	706	(0.0)	95												
8/16/98	54° 49'	166° 23'	1	392	(0.0)	651	(0.0)	95												
8/17/97	54° 47'	166° 29'							1	533	(0.0)	1741	(0.0)	94	1	524	(0.0)	1700	(0.0)	94

Table 3. Mean lengths and weights and standard deviations (in parenthesis), brood year (BY), and age of 5 hatchery sockeye salmon immatures recovered in the Gulf of Alaska during July and August 1997. Dash indicates no measurement taken.

Date recovered	Lat. north	Long. west	Trapper							Chilkat							Packers							Tahltan						
			Mean length			Mean weight		BY	Age	Mean length			Mean weight		BY	Age	Mean length			Mean weight		BY	Age	Mean length			Mean weight		BY	Age
			n	(mm)	SD	(g)	SD			*n*	(mm)	SD	(g)	SD			*n*	(mm)	SD	(g)	SD			*n*	(mm)	SD	(g)	SD		
8/1/97	53° 45'	164° 05'	1	336	(0.0)	468	(0.0)	94	-																					
8/7/97	50° 53'	176° 30'								1	371	(0.0)	571	(0.0)	94	-														
8/15/97	53° 54'	164° 19'								1	337	(0.0)	447	(0.0)	94	1.1	1	401	(0.0)	-	-	94	-	1	367	(0.0)	-	-	94	-

Table 4. Mean lengths and weights and standard deviations (in parenthesis) by hatchery and brood year of immature chum salmon recovered in the Gulf of Alaska during July and August 1997.

Brood Year	Gastineau					Hidden Falls					Nitinat				
		Mean length		Mean weight			Mean length		Mean weight			Mean length		Mean weight	
	n	(mm)	SD	(g)	SD	n	(mm)	SD	(g)	SD	n	(mm)	SD	(g)	SD
93	1	575	(0.0)	-	-	-	-	-	-	-	4	535	(26.6)	1903	(250.0)
94	9	515	(59.3)	1460	(533.0)	10	495	(50.6)	1417	(397.0)	15	511	(23.4)	1661	(219.0)
95	8	364	(30.3)	546	(150.0)	4	363	(18.5)	537	(72.0)	5	415	(84.9)	-	-

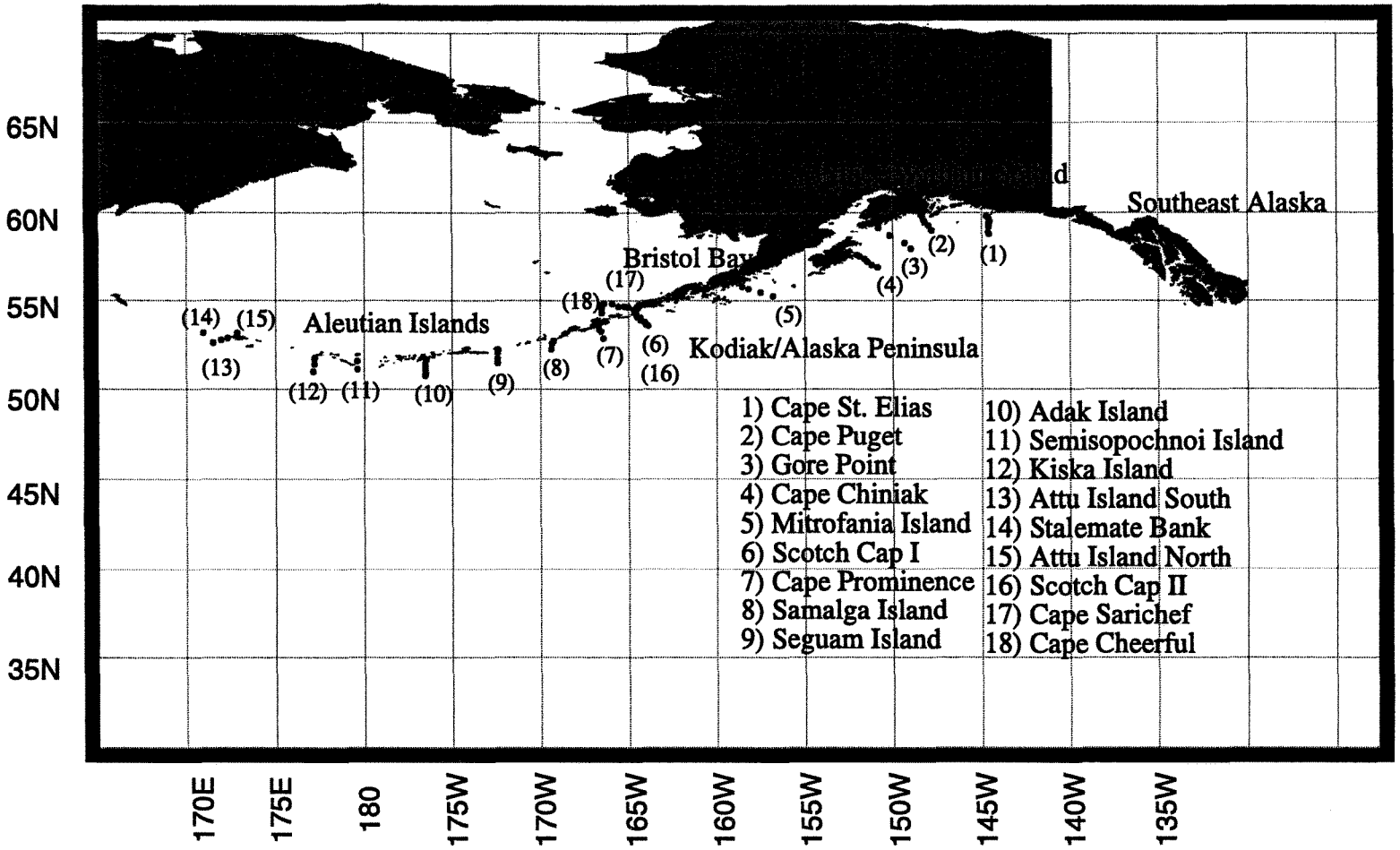

Figure 1. Overview map of the North Pacific Ocean showing area covered and transects sampled by the F/V GREAT PACIFIC during July and August 1998.

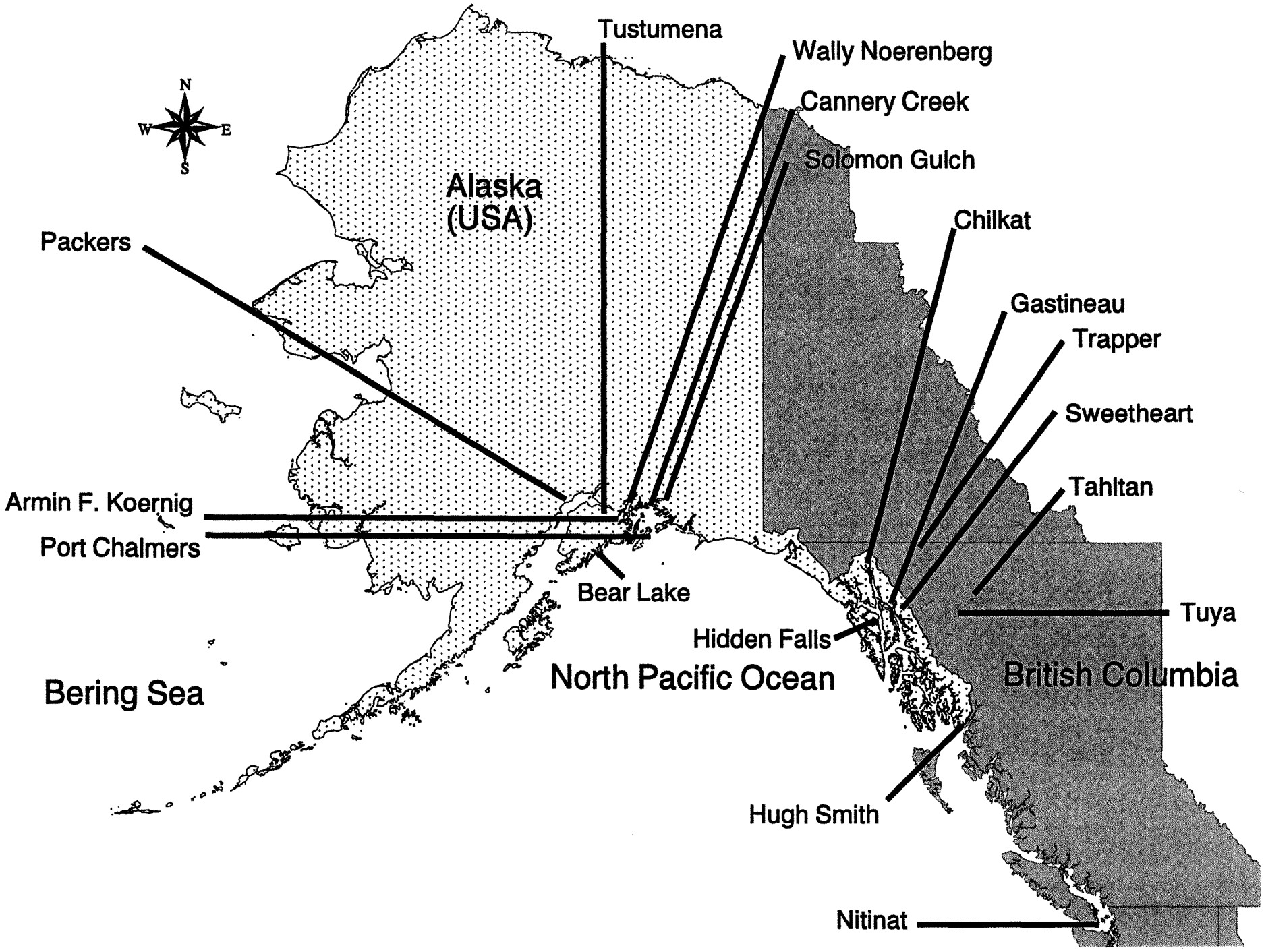

Figure 2. Locations of hatcheries thermally marking salmon.

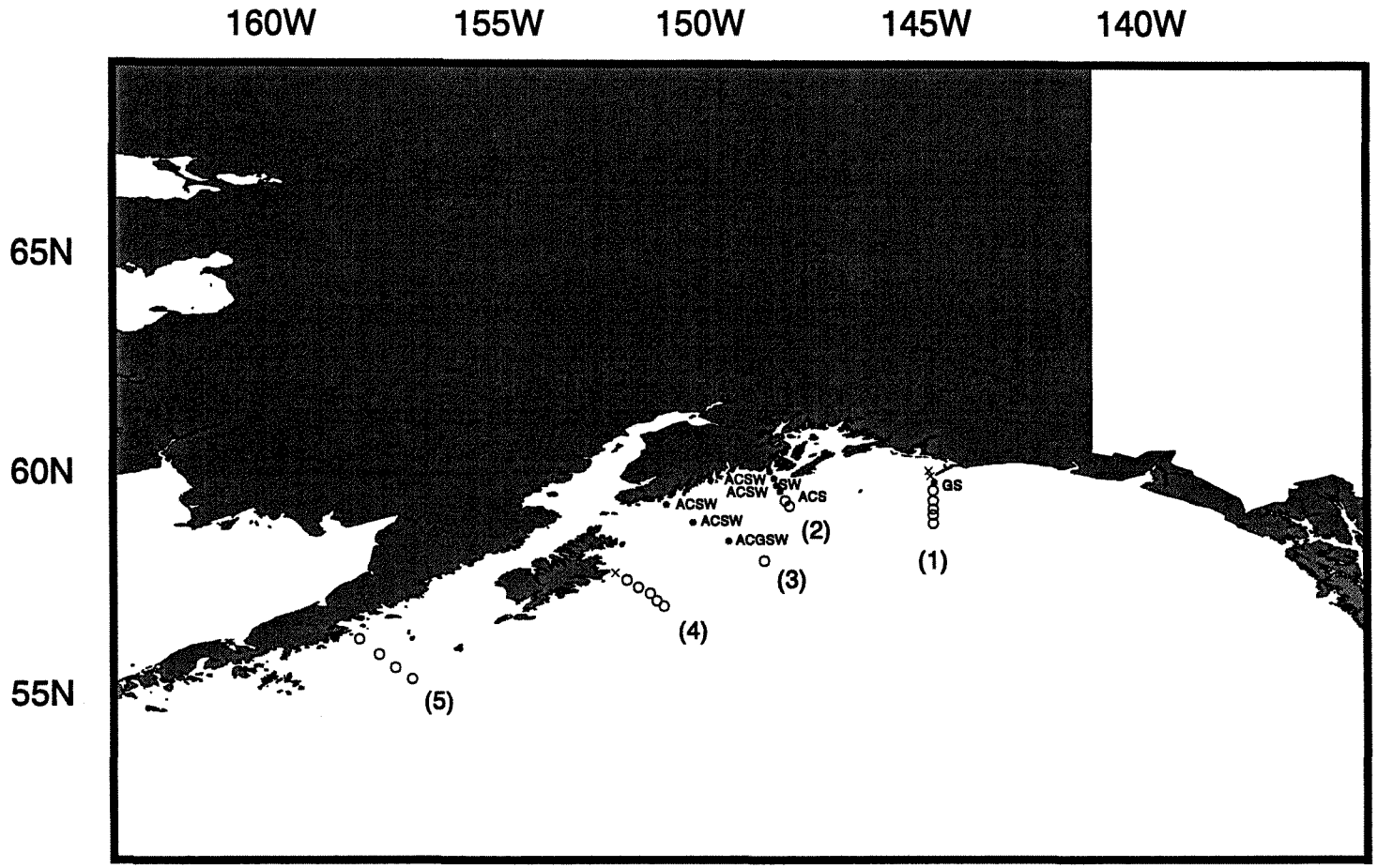

Figure 3. Distribution of juvenile hatchery pink salmon recovered between July and August 1997, where • indicates trawl location where hatchery pink salmon were caught; x indicates trawl location where pink salmon were caught, but no thermally marked pink salmon were caught; and o indicates trawl location where no juvenile pink salmon were caught.
Hatcheries represented include: Armin F. Koernig (A), Cannery Creek (C), Gastineau (G), Solomon Gulch (S), and Wally Noerenberg (W).

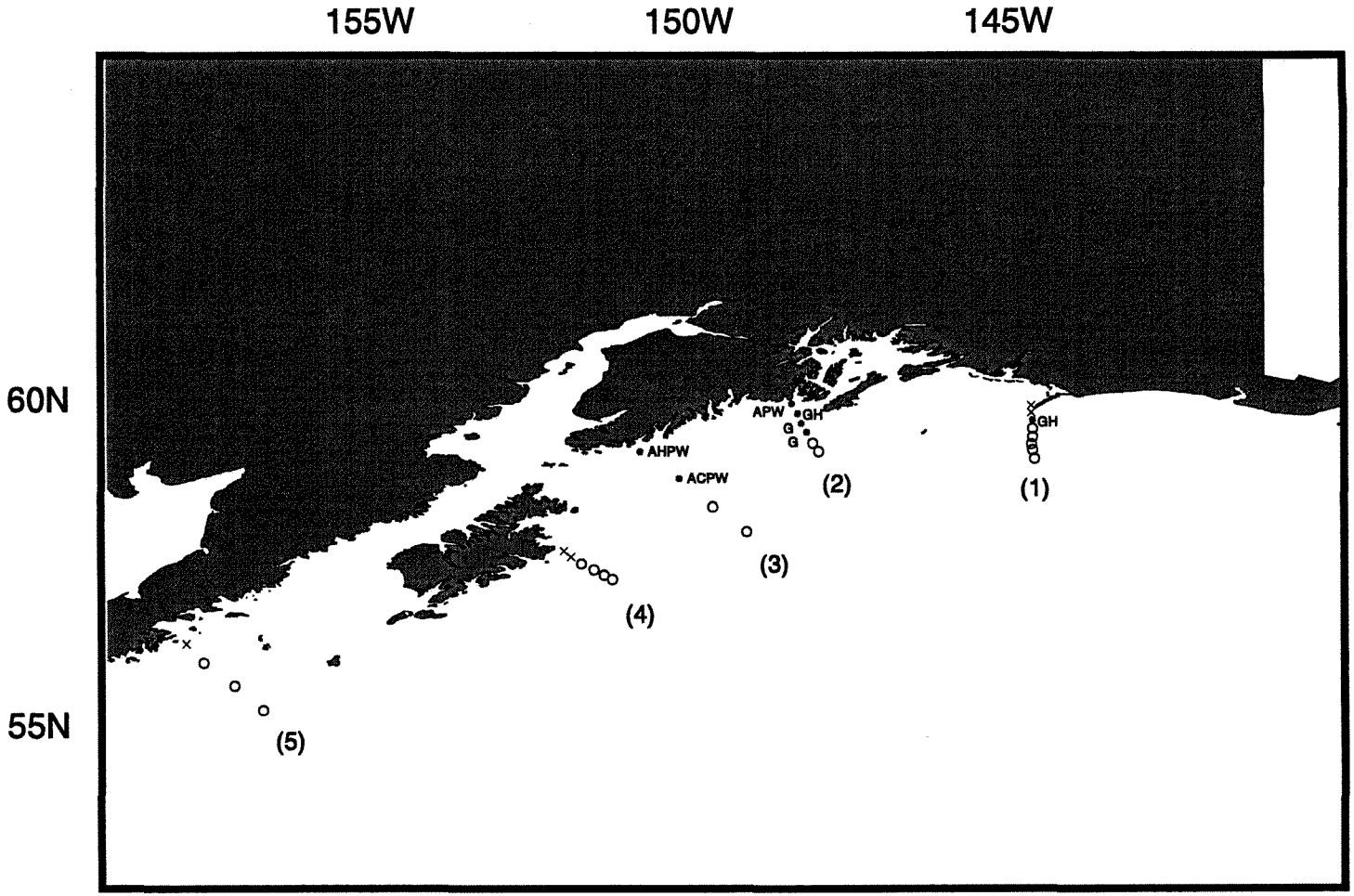

Figure 4. Distribution of juvenile hatchery chum salmon recovered between July and August 1997, where • indicates trawl location where hatchery chum salmon were caught; x indicates trawl location where chum salmon were caught, but no thermally marked chum salmon were caught; and o indicates trawl location where no juvenile chum salmon were caught.
Hatcheries represented include: Armin F. Koernig (A), Cannery Creek (C), Gastineau (G), Hidden Falls (H), Port Chalmers (P), and Wally Noerenberg (W).

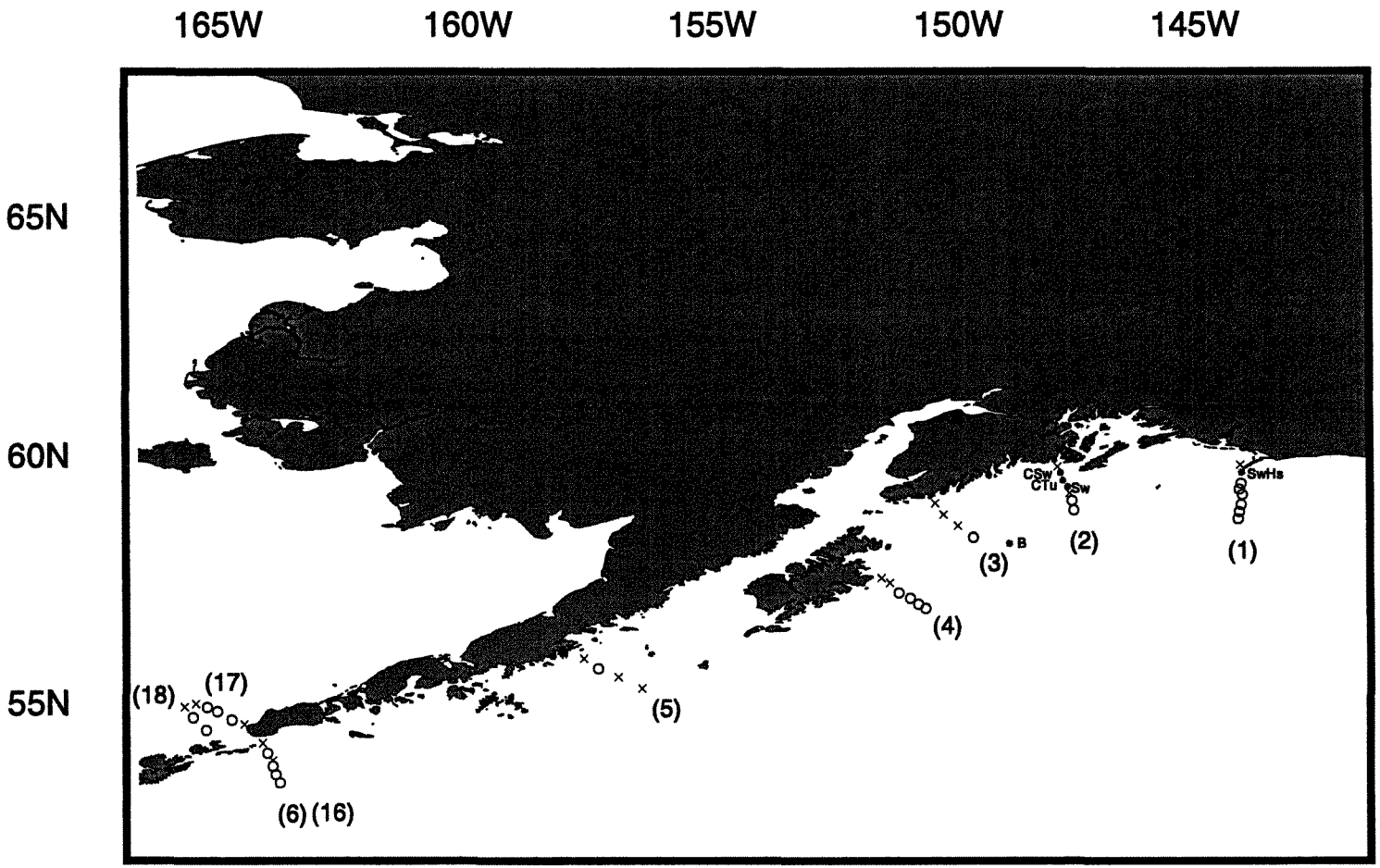

Figure 5. Distribution of juvenile hatchery sockeye salmon recovered between July and August 1997, where • indicates trawl location where hatchery sockeye salmon were caught; x indicates trawl location where sockeye salmon were caught, but no thermally marked sockeye salmon were caught; and o indicates trawl location where no juvenile sockeye salmon were caught.
Hatcheries represented include: Bear Lake (B), Chilkat (C), Hugh Smith (Hs), Sweetheart (Sw), and Tuya (Tu).

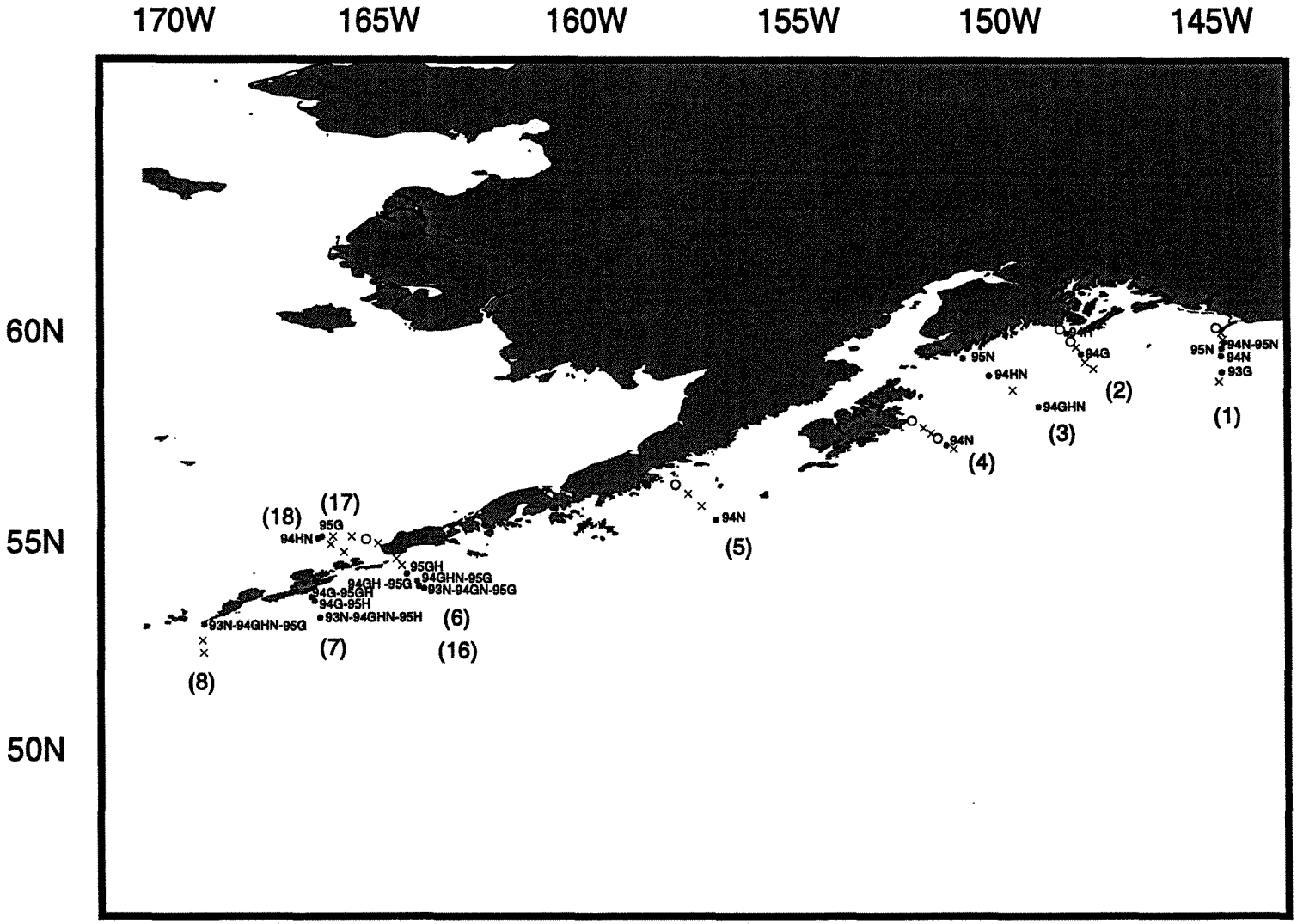

Figure 6. Distribution of immature hatchery chum salmon recovered between July and August 1997, where • indicates trawl location where hatchery chum salmon were caught; x indicates trawl location where chum salmon were caught, but no thermally marked chum salmon were caught; and o indicates trawl location where no immature chum salmon were caught.
Hatcheries represented include: Gastineau (G), Hidden Falls (H), and Nitinat (N). Abbreviations indicate brood year (93, 94, and 95) and hatcher(ies).

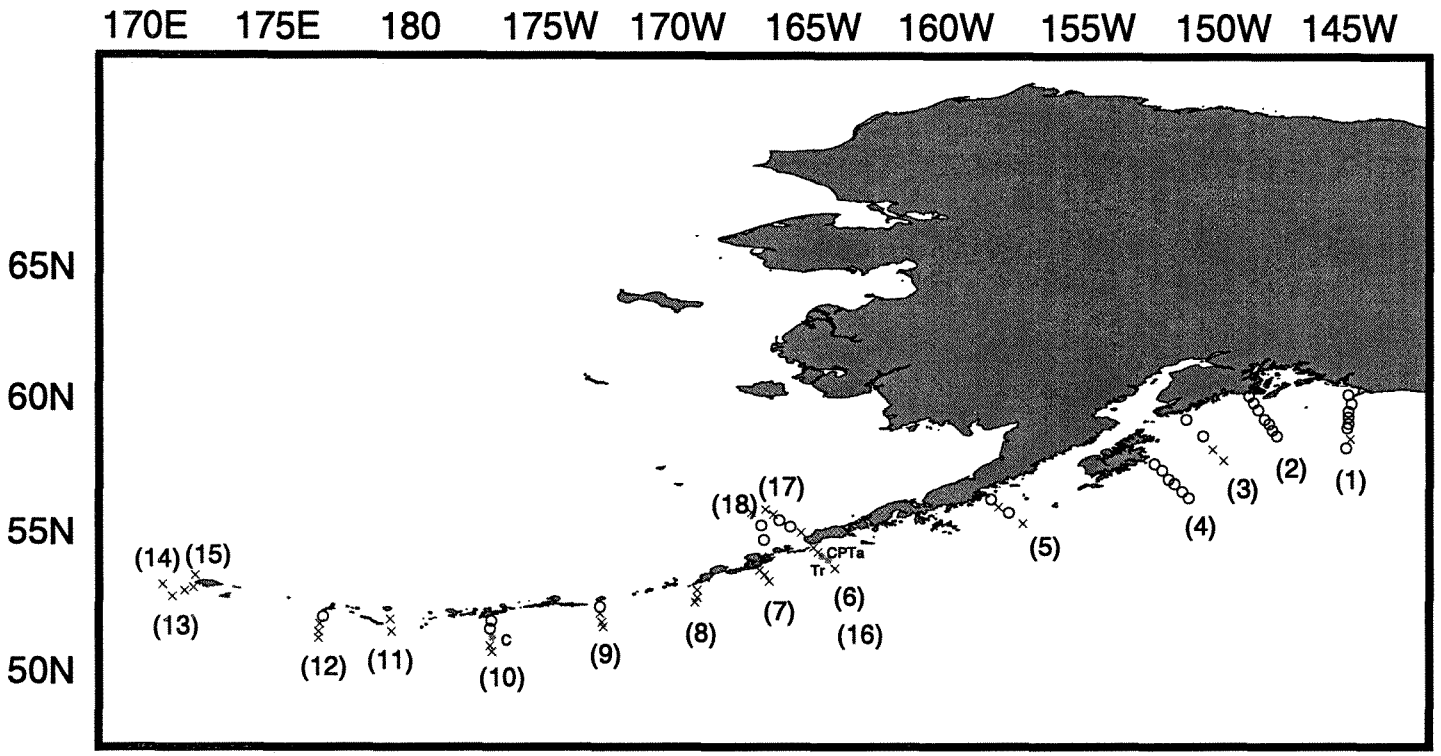

Figure 7. Distribution of immature hatchery sockeye salmon recovered between July and August 1997, where indicates trawl location where hatchery sockeye salmon were caught; x indicates trawl location where sockeye salmon were caught, but no thermally marked sockeye salmon were caught; and o indicates trawl location where no immature sockeye salmon were caught.
Hatcheries represented include: Chilkat (C), Packers (P), Tahltan (Ta), Trapper (Tr).