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

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ABSTRACT: A Gulf of Alaska research cruise during July and August 1996 provided ocean recoveries of 698 juvenile pink *Oncorhynchus gorbuscha* and 350 chum *O. keta* salmon thermally marked during incubation at Alaskan and Canadian hatcheries. We obtained the recoveries from 2,343 pink and 1,695 chum salmon examined for thermal marks. The marked salmon migrated westerly; those released from southeastern Alaska hatcheries were caught as far west as Cape Puget and Cape Hinchinbrook, whereas pink salmon released from Prince William Sound hatcheries were found as far west as Mitrofanina Island. Our results indicate that a modest research sampling program can collect sufficient numbers of thermally marked salmon for detailed studies of the growth and development of individual salmon stocks.

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 northern 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 northern Pacific Ocean from hatcheries in Washington, British Columbia, and Alaska have numbered in the billions. Alaskan hatcheries alone released over 800 million thermally marked salmon into the northern Pacific Ocean in 1996 (Thermal Mark Database, Alaska Department of Fish and Game, Otolith Processing Lab, Juneau).

In 1996, scientists 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 imma-

ture salmonids and then identify hatchery versus wild stocks and determine hatchery origins.

In this paper we summarize recovery information, including average lengths and weights at recovery, for thermally marked juvenile pink *Oncorhynchus gorbuscha* and chum *O. keta* salmon caught in the coastal waters of the Gulf of Alaska in July and August 1996. These findings will be expanded by data collected on the 1997 and 1998 cruises and will be more fully analyzed and reported in a subsequent publication. Nevertheless, we are publishing the 1996 findings simplistically in this paper to emphasize the importance, utility, and quantity of information that these pioneering efforts in thermal marking will provide and to enable these early findings to be applied by those responsible for planning hatchery thermal marking in the immediate future.

CRUISE

During July and August 1996, the Auke Bay Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, conducted a survey examining

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the distribution of juvenile, immature, and maturing salmon in the northern Pacific Ocean. The 6-week cruise, beginning at Cape Muzon near Dixon Entrance and extending through the Gulf of Alaska west to Amchitka Pass, also included parts of the southern Bering Sea and Bristol Bay (Carlson et. al. 1996; Figure 1).

The fishing gear was a midwater rope trawl, model 400/580, made by Cantrawl Pacific Ltd. 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 (nmi) apart and roughly perpendicular to shore. Most transects ran from prominent points of land to 60 nmi offshore, but in areas with a broad continental shelf they extended up to 120 nmi offshore (Figure 1). Sampling began nearshore and continued seaward over the shelf, and beyond, to oceanic depths. Most tows lasted 1 h and usually covered 5 nmi. 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; age .0) and immature (second or third ocean year; age .1 or older) salmon were identified and sorted by species, and fork length was recorded for each fish. Specimens were frozen whole for further laboratory analyses.

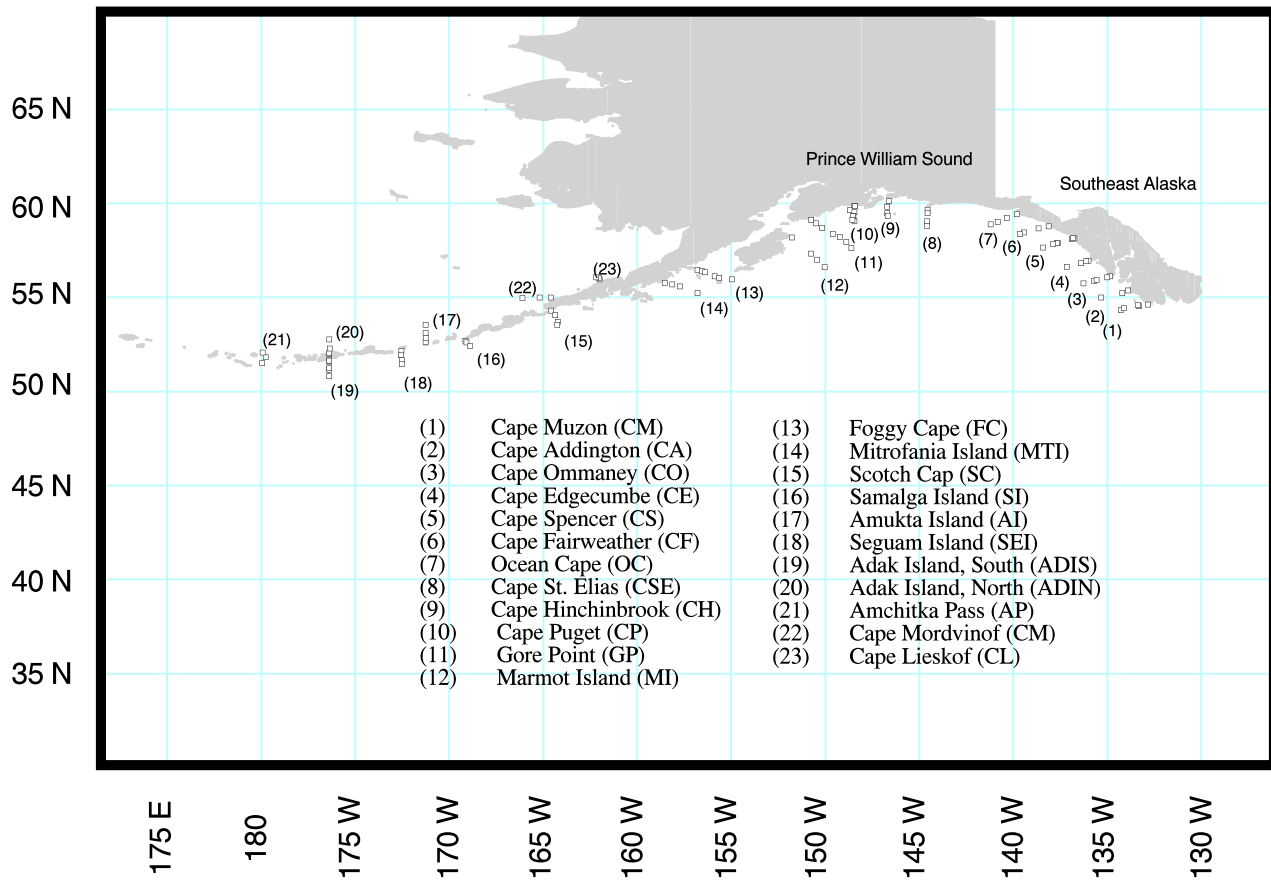


Figure 1. Transects sampled between July and August 1996.

LABORATORY ANALYSES

In the laboratory, specimens were thawed and standard length (measured from tip of snout to posterior end of caudal peduncle) and weight were recorded for subsamples of pink and chum salmon. Left and right sagittal otoliths were dissected, and the left sagittal otoliths were 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 the 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). When disagreements between otolith readers occurred they were resolved by the most experienced otolith reader.

FINDINGS

Thermal Mark/Recoveries

A total of 4,701 juvenile pink and 1,932 juvenile chum salmon were caught in the coastal waters of the Gulf of Alaska during July and August 1996. Subsamples totaling 2,343 pink and 1,695 chum salmon otoliths were

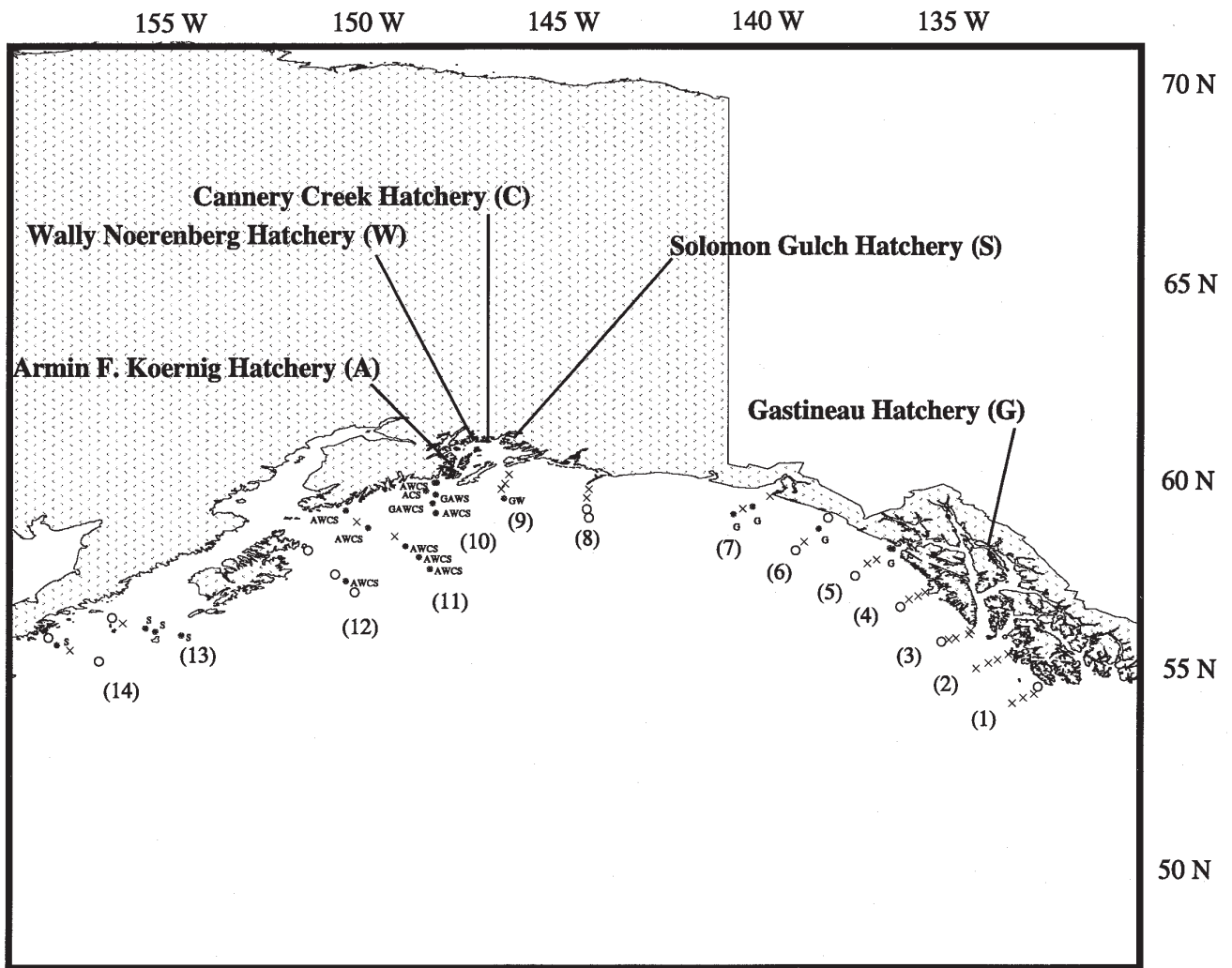


Figure 2. Distribution of hatchery pink salmon recovered between July and August 1996, where • indicates trawl location where hatchery pink salmon were caught; X indicates trawl location where pink salmon were caught, but no thermally marked pink salmon were caught; and ○ indicates trawl location where no juvenile pink salmon were caught.

Table 1. Mean lengths and standard deviations (SD) of 698 hatchery pink salmon juveniles recovered in the Gulf of Alaska during July and August 1996.

Date recovered	Lat. north	Long. west	Transect abbr. ^a	Distance from shore (nmi)	GH ^b		AFK ^b			WNH ^b		CCH ^b			SGH ^b				
					n	Mean length (mm)	SD	n	Mean length (mm)	SD	n	Mean length (mm)	SD	n	Mean length (mm)	SD			
7/25/96	58.08	136.47	CS	6	1	103	0.0												
7/26/96	58.09	136.51	CS	7	1	106	0.0												
7/27/96	58.39	138.40	CF	25	3	117	2.1												
7/28/96	59.13	140.22	OC	25	3	111	9.1												
7/28/96	59.01	140.51	OC	44	1	118	0.0												
7/30/96	59.28	146.43	CH	45	1	136	0.0			1	123	0.0							
7/31/96	59.50	148.27	CP	6				10	119	16.3	9	129	14.9	4	123	9.9	21	124	10.5
7/31/96	59.50	148.30	CP	7				10	122	5.9	18	121	8.3	8	116	9.3	35	126	10.1
7/31/96	59.37	148.43	CP	21				2	111	2.1				1	96	0.0	3	126	13.0
7/31/96	59.03	148.28	CP	53				10	122	17.2	12	124	15.0	12	118	12.9	16	123	11.6
8/1/96	59.50	148.27	CP	6				9	114	11.1	9	113	8.9	6	110	10.8	8	119	13.5
8/1/96	59.31	148.28	CP	25	2	152	6.4	5	107	8.0	2	141	35.3				1	187	0.0
8/1/96	59.18	148.33	CP	38	2	151	9.9	8	121	25.4	7	111	13.8	9	108	11.4	12	115	11.7
8/2/97	59.07	150.47	GP	7				9	122	12.8	19	126	19.2	14	115	9.9	26	127	13.6
8/2/96	58.41	150.12	GP	39				11	137	9.0	15	136	5.9	2	131	4.2	50	135	5.9
8/3/96	58.12	149.15	GP	79				22	122	13.5	23	128	16.9	2	126	1.4	36	128	12.4
8/3/96	57.56	148.54	GP	99				30	123	9.8	19	128	9.4	8	125	10.6	31	125	9.0
8/3/96	57.37	148.38	GP	119				8	113	9.3	10	115	6.2	7	117	9.8	11	120	16.4
8/4/96	57.19	150.47	MI	61				17	134	9.5	17	142	9.0	3	135	9.8	38	141	8.7
8/7/96	55.56	154.59	FC	75													5	143	28.1
8/8/96	56.06	155.54	FC	44													1	154	0.0
8/8/96	56.01	155.39	FC	53													1	162	0.0
8/9/96	55.41	158.09	MTI	20													1	154	0.0

^a Transect abbreviations are Cape Spencer (CS), Cape Fairweather (CF), Ocean Cape (OC), Cape Hinchinbrook (CH), Cape Puget (CP), Gore Point (GP), Marmot Island (MI), Foggy Cape (FC), Mitrofanina Island (MTI).

^b Prince William Sound hatcheries: Armin F. Koernig (AFK); Wally Noerenberg (WNH); Cannery Creek (CCH); and Solomon Gulch Hatchery (SGH). Gastineau Hatchery (GH) in southeastern Alaska.

analyzed for hatchery marks. For pink salmon, 696 recoveries of 5 hatchery mark patterns for brood year 1995 were identified in the subsample: 14 marked fish from Gastineau Hatchery, 151 from Armin F. Koernig Hatchery, 161 from Wally Noerenberg Hatchery, 76 from Cannery Creek Hatchery, and 296 from Solomon Gulch Hatchery. For chum salmon, 349 recoveries of 3 hatchery mark patterns for brood year 1995 were identified in the subsample: 208 marked fish from Gastineau Hatchery, 136 from Hidden Falls Hatchery, and 5 from Nitinat Hatchery. The 698 thermally marked pink salmon and 349 chum salmon represented mark rates of 29.7% of the pink salmon and 20.6% of the chum salmon subsamples.

Distribution and Size of Marked Fish

Hatchery salmon were released in the spring of 1996 and recovered between 25 July and 9 August 1996 (Figures 2, 3). Pink salmon from the Gastineau Hatchery in southeastern Alaska were distributed northwest

along the continental shelf from Cape Spencer to Gore Point. Most pink salmon from Prince William Sound hatcheries were distributed southwest along the continental shelf from Gore Point to Marmot Island; however, pink salmon from Solomon Gulch Hatchery were found as far west as Mitrofanina Island. Chum salmon from southeastern Alaska were distributed northwest along the continental shelf from Cape Spencer to Cape Hinchinbrook. Chum salmon from Nitinat Hatchery on the southwestern corner of Vancouver Island, British Columbia, were found along the continental shelf from Cape Edgecumbe to Cape Fairweather.

Sizes of pink and chum 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 (Tables 1-4). This variation in length and weight may have been influenced by varied feeding and release dates, growth rates, migration rates, diet, or condition.

Mean lengths and weights of hatchery pink and chum salmon juveniles increased as fish migrated westward. In most instances, juvenile size increased with their distance offshore. 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). One exception was found at Gore Point, where the smallest juvenile hatchery pink salmon from Prince William Sound were caught beyond the continental shelf at the farthest offshore point sampled (119 nmi).

DISCUSSION

Our results suggest 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 northern Pacific Ocean to discover the migration, distribution, growth, and development of individual hatchery stocks.

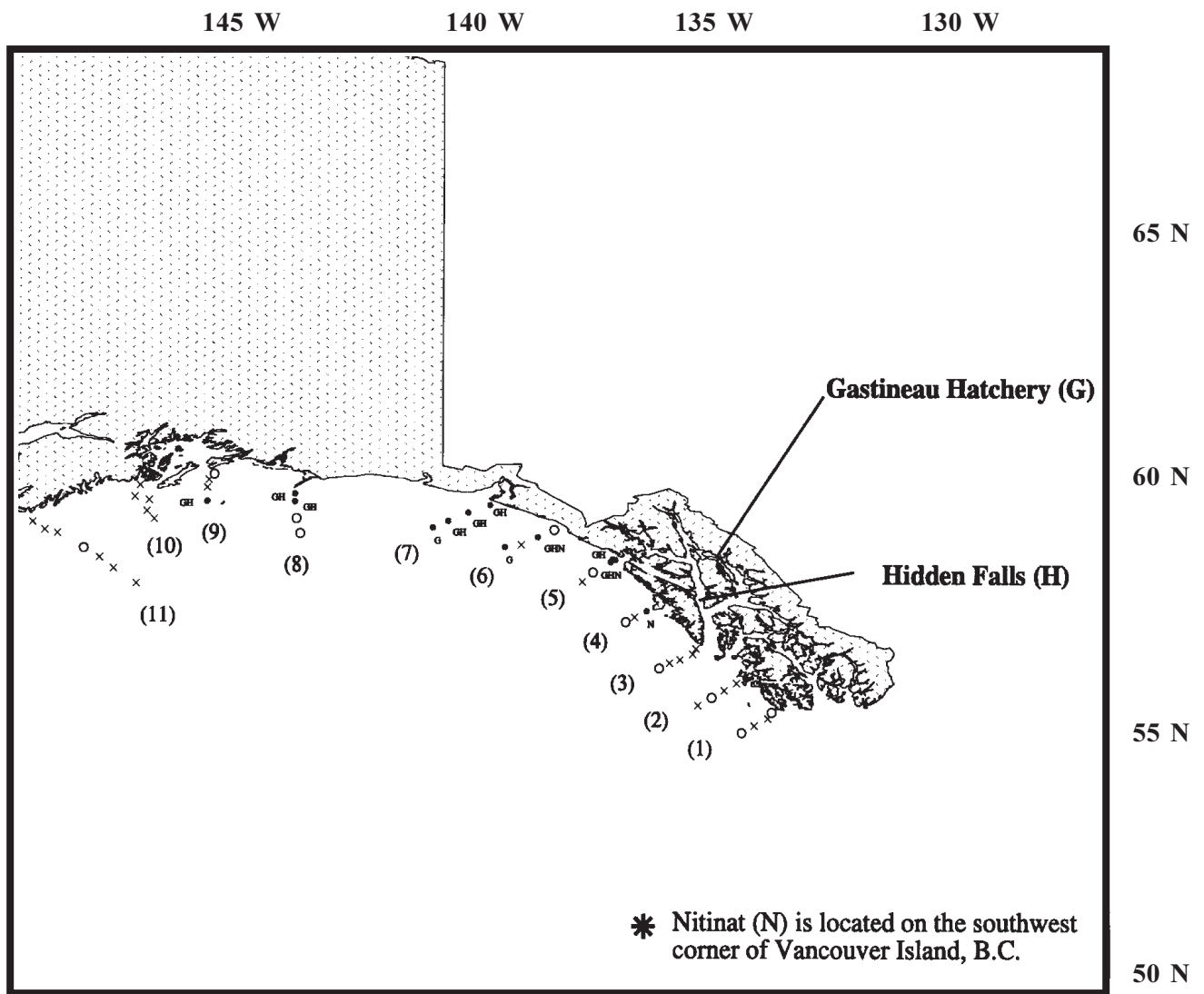


Figure 3. Distribution of hatchery chum salmon recovered between July and August 1996, where • indicates trawl location where hatchery chum salmon were caught; X indicates trawl location where chum salmon were caught, but no thermally marked chum salmon were caught; and ○ indicates trawl location where no juvenile chum salmon were caught.

Table 2. Mean weights and standard deviations (SD) of 698 hatchery pink salmon recovered in the Gulf of Alaska during July and August 1996.

Date recovered	Lat. north	Long. west	Transect abbr. ^a	Distance from shore (nmi)	n	GH ^b		AFK ^b		WNH ^b		CCH ^b		SGH ^b					
						Mean weight (g)	SD	n	Mean weight (g)	SD	n	Mean weight (g)	SD	n	Mean weight (g)	SD			
7/25/96	58.08	136.47	CS	6	1	11.1	0.0												
7/26/96	58.09	136.51	CS	7	1	11.4	0.0												
7/27/96	58.39	138.40	CF	25	3	16.5	1.6												
7/28/96	59.13	140.22	OC	25	3	14.6	3.0												
7/28/96	59.01	140.51	OC	44	1	17.6	0.0												
7/30/96	59.28	146.43	CH	45	1	30.2	0.0			1	19.6	0.0							
7/31/96	59.50	148.27	CP	6				10	17.8	7.5	9	21.7	6.8	4	17.2	4.1	21	18.9	4.7
7/31/96	59.50	148.30	CP	7				10	18.1	3.0	18	17.2	3.6	8	14.9	3.7	35	19.6	5.1
7/31/96	59.37	148.43	CP	21				2	14.4	0.2				1	8.5	0.0	3	22.7	9.0
7/31/96	59.03	148.28	CP	53				10	17.2	7.3	12	19.6	8.1	12	15.9	4.8	16	17.5	5.1
8/1/96	59.50	148.27	CP	6				9	14.7	4.4	9	14.2	3.7	6	13.1	4.0	8	16.9	6.3
8/1/96	59.31	148.28	CP	25	2	36.4	1.6	5	27.2	2.8	2	30.5	21.0				1	76.4	0.0
8/1/96	59.18	148.33	CP	38	2	40.1	4.2	8	22.5	19.3	7	15.2	5.1	9	14.6	4.4	12	40.1	4.2
8/2/97	59.07	150.47	GP	7				9	21.8	7.5	19	25.8	16.2	14	17.9	4.8	26	24.5	8.1
8/2/96	58.41	150.12	GP	39				11	28.9	5.6	15	26.7	3.5	2	25.6	4.2	50	27.4	4.6
8/3/96	58.12	149.15	GP	79				22	21.0	7.3	23	25.3	15.3	2	20.7	2.0	36	24.3	7.7
8/3/96	57.56	148.54	GP	99				30	18.1	5.4	19	20.1	5.2	8	18.8	5.5	31	18.4	4.9
8/3/96	57.37	148.38	GP	119				8	15.8	4.1	10	18.3	4.3	7	18.9	4.9	11	22.0	9.6
8/4/96	57.19	150.47	MI	61				17	26.1	5.3	17	30.8	5.9	3	26.7	6.8	38	29.6	5.7
8/7/96	55.56	154.59	FC	75													5	29.3	28.1
8/8/96	56.06	155.54	FC	44													1	39.7	0.0
8/8/96	56.01	155.39	FC	53													1	51.5	0.0
8/9/96	55.41	158.09	MTI	20													1	39.6	0.0

^a Transect abbreviations are Cape Spencer (CS), Cape Fairweather (CF), Ocean Cape (OC), Cape Hinchinbrook (CH), Cape Puget (CP), Gore Point (GP), Marmot Island (MI), Foggy Cape (FC), Mitrofanina Island (MTI).

^b Prince William Sound hatcheries: Armin F. Koernig (AFK); Wally Noerenberg (WNH); Cannery Creek (CCH); and Solomon Gulch Hatchery (SGH). Gastineau Hatchery (GH) in southeastern Alaska.

Table 3. Mean lengths and standard deviations (SD) of 349 hatchery chum salmon recovered in the Gulf of Alaska during July and August 1996.

Date recovered	Lat. north	Long. west	Transect abbr. ^a	Distance from shore (nmi)	n	GH ^b		HF ^b		NH ^b			
						Mean length (mm)	SD	n	Mean length (mm)	SD	n	Mean length (mm)	SD
7/24/96	56.57	136.01	CE	6							2	135	1.4
7/25/96	58.08	136.47	CS	6	16	110	6.6	27	112	8.9			
7/25/96	58.05	136.54	CS	11	9	115	9.9	14	119	7.5	1	108	0.0
7/26/96	58.09	136.51	CS	7	5	117	12.3	10	114	10.2	1	108	0.0
7/27/96	58.39	138.40	CF	25	9	113	8.3	24	116	8.6	1	107	0.0
7/27/96	58.26	139.28	CF	48	1	122	0.0						
7/28/96	59.24	139.50	OC	7	17	117	9.1	4	116	5.1			
7/28/96	59.13	140.22	OC	25	73	121	6.9	41	122	6.3			
7/28/96	59.01	140.51	OC	44	4	130	3.7	3	127	4.3			
7/28/96	58.52	141.13	OC	59	2	130	7.1						
7/29/96	59.39	144.35	CSE	8	61	131	6.8	10	128	6.2			
7/29/96	59.28	144.35	CSE	19	8	137	9.1	1	145	0.0			
7/30/96	59.28	146.43	CH	45	3	132	6.0	2	126	5.7			

^a Transect abbreviations are Cape Edgecumbe (CE), Cape Spencer (CS), Cape Fairweather (CF), Ocean Cape (OC), Cape St. Elias (CSE), Cape Hinchinbrook (CH).

^b Southeastern Alaska hatcheries: Gastineau Hatchery (GH) and Hidden Falls (HF). British Columbia hatchery: Nitinat Hatchery (NH).

Table 4. Mean weights and standard deviations (SD) of 349 hatchery chum salmon recovered in the Gulf of Alaska during July and August 1996.

Date recovered	Lat. north	Long. west	Transect abbr. ^a	Distance from shore (nmi)	GH ^b			HF ^b			NH ^b		
					n	Mean weight (g)	SD	n	Mean weight (g)	SD	n	Mean weight (g)	SD
7/24/96	56.57	136.01	CE	6							2	27.2	1.3
7/25/96	58.08	136.47	CS	6	16	13.2	3.1	27	13.9	3.4			
7/25/96	58.05	136.54	CS	11	9	16.4	4.6	14	17.5	3.3	1	19.9	0.0
7/26/96	58.09	136.51	CS	7	5	16.5	5.3	10	15.0	4.9	1	12.9	0.0
7/27/96	58.39	138.40	CF	25	9	16.2	4.1	24	17.6	3.7	1	16.2	0.0
7/27/96	58.26	139.28	CF	48	1	17.3	0.0						
7/28/96	59.24	139.50	OC	7	17	19.9	4.3	4	18.0	2.6			
7/28/96	59.13	140.22	OC	25	73	20.2	3.8	41	20.1	2.9			
7/28/96	59.01	140.51	OC	44	4	25.1	2.5	3	24.8	1.1			
7/28/96	58.52	141.13	OC	59	2	24.9	4.4						
7/29/96	59.39	144.35	CSE	8	61	25.7	4.2	10	22.9	3.9			
7/29/96	59.28	144.35	CSE	19	8	29.8	7.0	1	31.4	0.0			
7/30/96	59.28	146.43	CH	45	3	29.2	0.8	2	23.3	0.6			

^a Transect abbreviations are Cape Edgecumbe (CE), Cape Spencer (CS), Cape Fairweather (CF), Ocean Cape (OC), Cape St. Elias (CSE), Cape Hinchinbrook (CH).

^b Southeastern Alaska hatcheries: Gastineau Hatchery (GH) and Hidden Falls (HF). British Columbia hatchery: Nitinat Hatchery (NH).

However, the large proportion of thermally marked salmon (29.7% pink and 20.6% chum salmon) was unexpected and does not include hatchery fish that were

not thermally marked. Based on these results, future studies to reliably determine the hatchery/wild proportions of ocean-rearing salmon appear to be warranted.

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