NPAFC
Doc. 489
Rev.

Recoveries of Thermally Marked Maturing Pink Salmon in the Gulf of Alaska in the Summers of 1998 and 1999

by

Morihiko Kawana and Shigehiko Urawa
National Salmon Resources Center, Fisheries Agency of Japan, Nakanoshima, Sapporo 062-0922, Japan

Gen Anma, Shogo Takagi, and Yoshihiko Kamei
Hokkaido University, Faculty of Fisheries, Hakodate, Hokkaido 041-8611, Japan

Takayuki Shoji
Hokkaido University, Graduate School of Pharmaceutical Sciences, Sapporo 060-0812, Japan

Masa-aki Fukuwaka
Hokkaido National Research Institute of Fisheries, Fisheries Agency of Japan, Kushiro, Hokkaido 085-0802, Japan

Kristen Munk and Peter T. Hagen
Alaska Department of Fish and Game, Juneau, AK 99802-5526, USA

and

Edward V. Farley, Jr.
National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratory, Juneau, AK 99801-862, USA

Submitted to the

NORTH PACIFIC ANADROMOUS FISH COMMISSION

by

Japan

October 2000

THIS PAPER MAY BE CITED IN THE FOLLOWING MANNER:
Kawana, M., S. Urawa, G. Anma, S. Takagi, Y. Kamei, T. Shoji, M. Fukuwaka, K. Munk, P. T. Hagen, and E. V. Farly. 2000. Recoveries of thermally marked maturing pink salmon in the Gulf of Alaska in the summer of 1998 and 1999. (NPAFC Doc. 489). National Salmon Resources Center, Fisheries Agency of Japan, 2-2 Nakanoshima, Toyohira-ku, Sapporo, Hokkaido 062-0922, Japan. 9 p.

Recoveries of Thermally Marked Maturing Pink Salmon in the Gulf of Alaska in the Summers of 1998 and 1999

Morihiko Kawana[*1], Shigehiko Urawa[*1], Gen Anma[*2], Shogo Takagi[*2], Yoshihiko Kamei[*2], Takayuki Shoji[*3], Masa-aki Fukuwaka[*4], Kristen Munk[*5], Peter T. Hagen[*5], and Edward V. Farley, Jr.[*6]

[*1]*National Salmon Resources Center, Fisheries Agency of Japan, Nakanoshima, Sapporo 062-0922, Japan*

[*2]*Hokkaido University, Faculty of Fisheries, Hakodate 041-8611, Japan*

[*3]*Hokkaido University, Graduate School of Pharmaceutical Sciences, Sapporo 060-0812, Japan*

[*4]*Hokkaido National Research Institute of Fisheries, Fisheries Agency of Japan, Kushiro 085-0802, Japan*

[*5]*Alaska Department of Fish and Game, Juneau, AK 99802-5526, USA*

[*6]*National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratory, Juneau, AK 99801-862, USA*

Abstract

We detected otolith thermal marks induced by Alaskan hatcheries to determine the ocean distribution and migration of Alaskan pink salmon (*Oncorhynchus gorbuscha*) in the Gulf of Alaska. One hundred and seventeen thermally marked pink salmon were found among 1,029 maturing fish caught along two offshore transects (145°W and 165°W) during June and July 1998 and 1999. Along the 145°W transect, 25 thermally marked fish from three Prince William Sound hatcheries (PWS, southcentral Alaska) were found (8.1%, n=307) in 1998, and 86 thermally marked fish were found (15.1%, n=568) in 1999. Their origins were Armin F. Koernig Hatchery (AFK, n=45), Cannery Creek Hatchery (CCH, n=27), and Wally H. Noerenberg Hatchery (WHN, n=39). Along the 165°W transect, only four thermally marked fish were found (5.3%, n=76) in 1998, and two thermally marked fish were found (2.6%, n=78) in 1999. Their origins were AFK (n=3), CCH (n=2), and WHN (n=1). Along the 145°W transect, differences of body sizes among locations and among PWS hatcheries were not significant in 1999, however the 1997 brood-year stocks caught in 1999 were smaller in fork length than the 1996 brood-year stock in 1998. PWS hatchery fish were more abundant in northern waters than in southern waters along both transects, which corresponded to the direction of their homeward migration.

Introduction

Pink salmon (*Oncorhynchus gorbuscha*) distributed in the Gulf of Alaska were originating in Washington, British Columbia, Alaska, eastern Kamchatka, and northward to Anadyr Bay (Myers 1994, updated from Takagi et al. 1981). Recently, large number of Alaskan hatchery pink salmon

were thermally marked and released in the Gulf of Alaska (Geiger and Munk 1998). Thermal marks are an effective tool for stock identification in high-seas and coastal waters (Farley and Munk 1997; Ignell et al. 1997; Farley et al. 1999; Kawana et al. 1999; Urawa et al. 1999). Salmon otoliths are thermally marked by exposing fish to alternating (relatively lower and higher) temperatures (Volk et al. 1990), whereby a "thermal ring" (dark ring) is induced by exposure to the lower temperature (Munk et al. 1993). Different thermal marks are made by varying the number and spacing of thermal rings in the RBr code structure in Alaskan hatcheries (Munk and Geiger 1998). For brood-year 1997 stocks, about 551 million pink salmon were thermally marked and released from southcentral and southeastern Alaskan hatcheries. More than 98% of thermally marked fish were released from Prince William Sound (PWS) hatcheries in southcentral Alaska, where all hatchery pink salmon were thermally marked (Joyce and Evans 1998; Munk and Geiger 1998). To investigate the ocean distribution of PWS hatchery fish, we detected thermally marked otoliths from maturing pink salmon caught in the Gulf of Alaska in the summers of 1998 and 1999.

Materials and Methods

Releases of thermally marked fish

For brood-year 1996 stocks, thermally marked pink salmon were released from four PWS hatcheries: Solomon Gulch Hatchery (SGH, n=188.86 million), Cannery Creek Hatchery (CCH, n=136.84 million), Wally H. Noerenberg Hatchery (WHN, n=106.44 million), and Armin F. Koernig Hatchery (AFK, n=51.56 million). In addition, about 5.90 million pink salmon with thermal marks were released from Gastineau Hatchery (GH, southeastern Alaska).

For brood-year 1997 stocks, thermally marked pink salmon were released from four PWS hatcheries: SGH (n=195.16 million), CCH (n=137.57 million), AFK (n=105.97 million), and WHN (n=103.67 million). In addition, about 8.71 million pink salmon with thermal marks were released from GH (Table 1; Munk and Geiger 1998).

Mixture Fish samples

Pink salmon were caught by gillnets (non-selective varied research mesh, traditional commercial mesh, and experimental mesh) in two offshore transects (145°W and 165°W) by the T/S *Oshoro maru* in the Gulf of Alaska during June and July. The total catches were 813 and 1,122 fish in 1998 and 1999, respectively (Walker et al. 1998; Yamaguchi et al. 1999). Fork length (mm), body weight (g), sex, and gonad weight (g) were recorded and sagittal otoliths were collected from 383 and 646 fish in 1998 and 1999, respectively. Scales were also collected for age determination.

The catch per unit effort (CPUE) was calculated as total catch (number of fish) per one set of non-selective varied research mesh gillnet (30 tans, 1 tan =50 m long and approximately 6 m depth; Takagi 1975; Walker et al. 1998; Yamaguchi et al. 1999). A gonadosomatic index (GSI) was calculated as 100 × gonad weight (g) / body weight (g) to examine maturity. Fork length, body weight, gonad weight, and GSI were compared by Mann-Whitney’s U test or

Kruskal-Wallis test.

Otolith Analysis

The left sagittal otoliths were mounted on individually labeled glass slides using thermoplastic cement. If the left otolith was missing or ground through the primordia, then the right otolith was used. Otoliths were ground to expose the primordia and examined under a microscope. Thermal marks were recorded in the RBr code structure (Munk and Geiger 1998). If the same RBr code was used for a brood year class at different hatcheries, then microstructural patterns were compared with voucher specimens that were collected from the hatcheries before release. All otoliths were read independently by two readers.

Results

One hundred and seventeen thermal marks were found among 1,029 maturing pink salmon examined (Table 2). Along the 145°W transect, 25 thermally marked fish were found (8.1%, n=307) in 1998, and 86 marked fish were found (15.1%, n=568) in 1999. Their origins were AFK (n=45), CCH (n=27), and WHN (n=39) in PWS, southcentral Alaska. Along the 165°W transect, only four thermally marked fish were found (5.3%, n=76) in 1998, and two marked fish were found (2.6%, n=78) in 1999. Their origins were AFK (n=3), CCH (n=2), and WHN (n=1). Marked pink salmon released from SGH and GH were not found along either transect.

Among the hatchery origins in the 145°W transect in 1999, differences in the body and gonad measurements were not significant by Kruskal-Wallis test (table 3). Among the locations along the 145°W transect in 1999, differences in the body and gonad measurements were not significant for the PWS hatchery fish by Kruskal-Wallis test ($P>0.05$; Fig. 1). To compare the brood years, fork lengths, GSIs, and female body weights in catches in 1999 were significantly smaller, higher, and heavier, respectively, than those in catches in 1998 for the PWS hatchery fish in 145°W by Mann-Whitney's U test (table 3). The CPUE of marked fish caught in non-selective research gillnets indicated that PWS hatchery fish were more abundant in the northern part of each transect than in the southern part (Fig. 2).

Discussion

All thermally marked pink salmon detected in the present study were from PWS, where all pink salmon released from four hatcheries were thermally marked (Joyce and Evans 1998). Ocean distribution and proportion of thermally marked brood-year 1996 stocks were previously traced as juveniles in coastal waters during July and August 1997 (22.8%; Farley and Munk 1998), and as maturing in offshore waters in May 1998 (26.3%; Farley et al. 1999). Our results of proportion of the thermally marked maturing during June and July 1998 were lower than these previous studies. Brood-year 1997 stocks were also traced as juveniles during July and August 1998 (6.5%; Farley et al. 1999), however, our results of proportion of the thermally marked

maturing during June and July 1999 were higher than that of the juveniles. Of the four PWS hatchery fish, only SGH fish were not found even though they represented 39% and 36% of the total releases from the hatcheries in 1996 and 1997 brood-year stocks, respectively, with good quality thermal marks (Joyce et al. 1997; Joyce and Evans 1998; Munk and Geiger 1998). In the 1999 season, Alaskan statewide pink salmon commercial catch of 146 million set a new statewide record with pink salmon catch records set in Southeast Alaska and in PWS (Scott and Geiger 2000). Common property fisheries in PWS catch most of SGH fish in July, and with a later timing of migration, the peak harvest of the other three hatcheries (AFK, CCH, and WHN) occurs in August (CWT & Otolith Processing Laboratory, Alaska Department of Fish and Game unpublished data). Therefore, in July the SGH pink salmon may be distributed closer to the coast of PWS than other PWS hatchery stocks, and outside of our sampling area.

Differences of body size among locations and among PWS hatcheries were not significant. PWS hatchery fish were more abundant in the northern part of each transect than in the southern part, which corresponds to the northward direction of their homeward migrations. In 1998, sexual differences in distribution of PWS hatchery fish were observed. The hatchery males were not distributed in the south of 52°N, whereas five hatchery females were distributed in 50-52°N (Kawana et al. 1999). But in 1999, both males and females were found in the south of 52°N. Another difference between brood years was in body size. The 1997 brood-year stocks caught in 1999 were smaller in fork length than the 1996 brood-year stock in 1998. This may be a result of differences in sample sizes or characters of odd- and even-year stocks of pink salmon. To examine year-to-year variation, we are detecting thermal marks from pink salmon caught in the same waters in 2000.

References

Farley, E. V., and K. Munk. 1997. Incidence of thermally marked pink and chum salmon in the coastal waters of the Gulf of Alaska. Alaska Fish. Res. Bull., 4: 181-187.

Farley, E. V., and K. Munk. 1998. Incidence of thermally marked pink, chum, and sockeye salmon in the coastal waters of the Gulf of Alaska, 1997. (NPAFC Doc. 341) Auke Bay Laboratory, Alaska Fisheries Science Center, NMFS, NOAA, Juneau, Alaska, USA. 18 p.

Farley, E. V., K. Munk, and P. T. Hagen. 1999. Incidence of thermally marked pink, chum, and sockeye salmon in the coastal waters of the Gulf of Alaska, 1998. (NPAFC Doc. 446) Auke Bay Laboratory, Alaska Fisheries Science Center, NMFS, NOAA, Juneau, Alaska, USA. 24 p.

Geiger, H. J., and K.M. Munk. 1998. Otolith thermal mark release and mass-processing history in Alaska (USA), 1988-1998. (NPAFC Doc. 368) CWT & Otolith Processing Lab., Alaska Department of Fish and Game, Juneau, Alaska, USA. 9 p.

Ignell, S. E., C. M. Guthrie III, J. H. Helle, and K. Munk. 1997. Incidence of the thermally-marked chum salmon in the 1994-96 Bering Sea pollock B-season trawl fishery. (NPAFC Doc. 246) Auke Bay Laboratory, Alaska Fisheries Science Center, NMFS, NOAA, Juneau, Alaska, USA. 16 p.

Joyce, T. L., D. G. Evans, and K. M. Munk. 1997. Otolith thermal marking of pink salmon in Prince William Sound salmon hatcheries, 1996. Exxon Valdez oil spill restoration project annual report (Restoration Project R96188). Commercial Fisheries Management and Development Division, Alaska Department of Fish and Game, Cordova, Alaska, USA. 27 p.

Joyce, T., D. Evans. 1998. Otolith marking of pink salmon in Prince William Sound hatcheries, 1997. Exxon Valdez oil spill restoration project annual report (Restoration Project 97188). (NPAFC Doc. 372) Commercial Fisheries Management and Development Division, Alaska Department of Fish and Game, Cordova, Alaska, USA. 37 p.

Kawana, M., S. Urawa, G. Anma, Y. Kamei, T. Shoji, M. Fukuwaka, K. Munk, K. W. Myers, and E. V. Farley. 1999. Recoveries of thermally marked maturing pink salmon in the Gulf of Alaska in the summer of 1998. Bull. National Salmon Resources Center, 2:1-8.

Munk, K. M., W. W. Smoker, D. R. Beard, and R. W. Mattson. 1993. A hatchery water-heating system and its application to 100% thermal marking of incubating salmon. Progressive Fish-Culturist., 55: 284-288.

Munk, K. M., and H. J. Geiger. 1998. Thermal marking of otoliths: the "RBr" coding structure of thermal marks. (NPAFC Doc. 367) CWT & Otolith Processing Lab., Alaska Department of Fish and Game, Juneau, Alaska, USA. 19 p.

Myers, K. W. 1994. New conceptual models of high-seas migrations of pink and chum salmon. In Proceedings of the 16th northeast Pacific pink and chum salmon workshop. University of Alaska Fairbanks, Fairbanks, Alaska, USA. pp. 83-96.

Scott, R., and H. J. Geiger. 2000. Run forecasts and harvest projections for 2000 Alaska salmon fisheries and review of the 1999 season. Division of Commercial Fisheries, Alaska Department of Fish and Game, Juneau, Alaska, USA. 81 p.

Takagi, K. 1975. A non-selective salmon gillnet for research operations. Int. North Pac. Fish. Comm. Bull., 32: 13-41.

Takagi, K., K. V. Aro, A. C. Hartt, and M. B. Dell 1981. Distribution and origin of pink salmon (*Oncorhynchus gorbuscha*) in offshore waters of the North Pacific Ocean. Int. North Pac. Fish. Comm. Bull., 40: 195 p.

Urawa, S., M. Kawana, G. Anma, Y. Kamei, T. Shoji, M. Fukuwaka, K. Munk, K. W. Myers, and E. V. Farley. 1999. Stock origin of chum salmon caught in offshore waters of the Gulf of Alaska during the summer of 1998. (NPAFC Doc. 420) National Salmon Resources Center, Fisheries Agency of Japan, Sapporo 062-0922, Japan. 16 p.

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. Am. Fish. Soc. Symp., 7: 203-215.

Walker, R. V., K. Y. Aydin, G. Anma, H. Yamaguchi, Y. Kamei, T. Shoji, M. Kaeriyama, and S. Urawa. 1998. The 1998 international cooperative salmon research cruise of the *Oshoro maru*. (NPAFC Doc. 349) FRI-UW-9812. Fisheries Research Institute, University of Washington, Seattle, Washington, USA. 20 p.

Yamaguchi, H., S. Takagi, Y. Kamei, T. Yoshida, J. Kimura, G. Anma, H. Onishi, R. V. Walker, T. Shoji, and S. Urawa. 1999. The 1999 international cooperative salmon research cruise of the *Oshoro maru*. (NPAFC Doc. 419) Hokkaido University, Hakodate 041-8611, Japan 26 p.

Table 1. A list of thermally marked pink salmon fry (1996 and 1997 brood year class) released from Alaskan hatcheries (revised from Geiger and Munk 1998). SCAK, Southcentral Alaska; SEAK, Southeast Alaska; AFK, Armin F. Koernig Hatchery; CCH, Cannery Creek Hatchery; GH, Gastineau Hatchery; SGH, Solomon Gulch Hatchery; WHN, Wally H. Noerenberg Hatchery.

Region	Facility	Stock	Release site	Date of release	Mean body weight at release (g)	Number of releases (million)	TM ID	RBr
Brood year 1996								
SCAK	AFK	WHN	Sawmill Cove	11-May-97	0.47	16.25	AFK96early	1:1.4+2.3
SCAK	AFK	WHN	Sawmill Cove	27-May-97 - 13-Jun-97	1.22	35.31	AFK96late	1:1.4
SCAK	CCH	CCH	Cannery Creek	7-May-97 - 26-May-97	0.26	136.84	CCH96	1:1.3,2.2 1:1.3,2.3 1:1.3,2.4
SCAK	SGH	SGH	SGH	23-Apr-97, 5-May-97	0.39	188.86	SGH96	1:1.6
SCAK	WHN	WHN	Lake Bay	1-May-97	0.35	75.87	WHN96early	1:1.8
SCAK	WHN	WHN	Lake Bay	7-Jun-97	1.51	30.57	WHN96late	1:1.8+2.3
SEAK	GH	GH	Gastineau Channel	12-May-97	0.55	5.90	GH96	1:1.4
Brood year 1997								
SCAK	WHN	WHN	AFK (Sawmill Bay)	7-May-98	0.39-0.49	66.68	AFK97early	1:1.4
SCAK	WHN	WHN	AFK (Sawmill Bay)	21-May-98	1.1-1.2	19.14	AFK97late	1:1.4+2.3
SCAK	WHN	WHN	AFK (Sawmill Bay)	24-May-98	1.2-1.23	20.15	AFK97late	1:1.4+2.4
SCAK	CCH	CCH	CCH (Unakwik Inlet)	6-May-98 - 29-May-98	0.28-0.42	137.57	CCH97	1:1.3,2.3
SCAK	SGH	SGH	Valdez Arm	23-Apr-98 - 20-May-98	-	195.16	SGH97	1:1.6
SCAK	WHN	Larsen, Ewan, Galena	Lake Bay	1-May-98	0.49	72.95	WHN97early	1:1.8
SCAK	WHN	Larsen, Ewan, Galena	Lake Bay	1-Jun-98	1.53-1.81	30.72	WHN97late	1:1.8+2.3
SEAK	GH	GH	Gastineau Channel	27-Apr-98	-	8.71	GH97	1:1.5

Table 2. A composition of pink salmon hatchery origins caught along the 145°W and 165°W transects in the Gulf of Alaska during June and July 1998 and 1999. PWS, Prince William Sound; AFK, Armin F. Koernig Hatchery; CCH, Cannery Creek Hatchery; WHN, Wally H. Noerenberg Hatchery.

Latitude	1998					1999				
	PWS hatchery stocks			Other stocks		PWS hatchery stocks			Other stocks	
(N)	AFK	CCH	WHN	unmarked	% PWS	AFK	CCH	WHN	unmarked	% PWS
145ºW transect										
56°00'	3	3	4	62	12.5	10	6	11	117	18.8
55°00'	3	4	3	50	16.7	10	4	7	74	22.1
54°00'	-	-	-	-	-	12	2	6	76	20.8
53°00'	-	-	-	-	-	1	2	3	56	9.7
52°00'	1	0	0	27	3.6	2	3	2	47	13.0
51°00'	1	0	1	58	3.3	2	0	1	56	5.1
50°00'	0	2	0	16	11.1	0	1	1	56	3.4
49°00'	0	0	0	69	0	-	-	-	-	-
Total	8	9	8	282	8.1	37	18	31	482	15.1
165ºW transect										
50°00'	1	0	0	17	5.6	2	0	0	42	4.5
48°30'	0	2	0	4	33.3	-	-	-	-	-
47°00'	0	0	1	29	3.3	0	0	0	19	0
45°30'	0	0	0	22	0	0	0	0	12	0
44°00'	-	-	-	-	-	0	0	0	3	0
Total	1	2	1	72	5.3	2	0	0	76	2.6

Table 3. A comparison of body and gonad measurements among maturing thermally marked Prince William Sound (PWS) hatcheries pink salmon caught along the 145°W and 165°W transects in the Gulf of Alaska during June and July 1998 and 1999. Values are given as the mean ± SD. Numbers in parentheses are sample sizes. FL, fork length (mm); BW, body weight (g); GW, gonad weight (g); GSI, gonadosomatic index = 100 × gonad weight (g) / body weight (g).

		1999				PWS hatchery total			
Sex	**Measurement**	**Armin F. Koernig**	**Cannery Creek**	**Wally H. Noerenberg**	**Probability**	**1999**	**1998**		**Probability**
145ºW transect									
Female	**FL**	452 ± 15 (23)	440 ± 16 (10)	447 ± 12 (15)	$p > 0.05$	448 ± 15 (48)	483 ± 24 (12)		$p < 0.001$
	BW	1074 ± 126 (23)	1040 ± 107 (10)	1069 ± 132 (14)	$p > 0.05$	1066 ± 122 (47)	1328 ± 227 (12)		$p < 0.01$
	GW	45 ± 13 (23)	39 ± 8 (10)	46 ± 13 (15)	$p > 0.05$	44 ± 12 (48)	47 ± 21 (12)		$p > 0.05$
	GSI	4.18 ± 0.82 (23)	3.77 ± 0.53 (10)	4.16 ± 0.84 (14)	$p > 0.05$	4.08 ± 0.78 (47)	3.54 ± 1.41 (12)		$p < 0.01$
Male	**FL**	441 ± 22 (14)	455 ± 22 (8)	436 ± 21 (16)	$p > 0.05$	442 ± 22 (38)	460 ± 16 (13)		$p < 0.05$
	BW	1022 ± 136 (14)	1145 ± 145 (8)	993 ± 117 (16)	$p > 0.05$	1036 ± 140 (38)	1111 ± 123 (13)		$p > 0.05$
	GW	18 ± 9 (14)	17 ± 5 (8)	21 ± 8 (16)	$p > 0.05$	19 ± 8 (38)	14 ± 6 (13)		$p > 0.05$
	GSI	1.75 ± 0.73 (14)	1.45 ± 0.42 (8)	2.06 ± 0.77 (16)	$p > 0.05$	1.82 ± 0.72 (38)	1.26 ± 0.53 (13)		$p < 0.05$
165ºW transect									
Female	**FL**	430 (1)				430 (1)	487 ± 42 (2)		
	BW	780 (1)				780 (1)	1300 ± 339 (2)		
	GW	18 (1)				18 (1)	24 ± 2 (2)		
	GSI	2.31 (1)				2.31 (1)	1.89 ± 0.66 (2)		
Male	**FL**	436 (1)				436 (1)	462 ± 11 (2)		
	BW	960 (1)				960 (1)	1250 ± 14 (2)		
	GW	8 (1)				8 (1)	22 ± 10 (2)		
	GSI	0.83 (1)				0.83 (1)	1.76 ± 0.81 (2)		

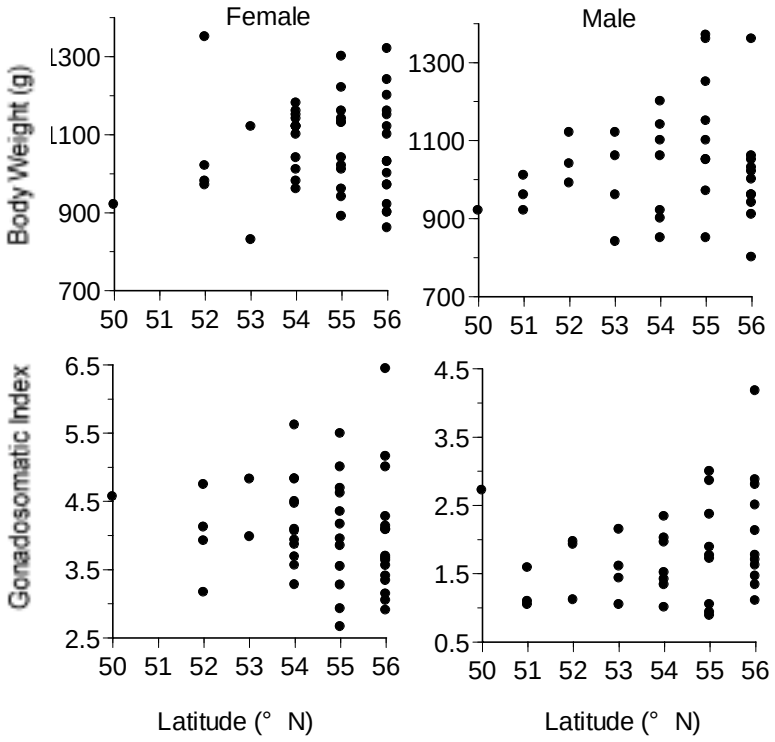

Fig. 1. Relationships between body weight and latitude (upper), and gonadosomatic index and latitude (lower) of thermally marked pink salmon released from Prince William Sound hatchery caught along the 145°W transect in the Gulf of Alaska during June and July 1999.

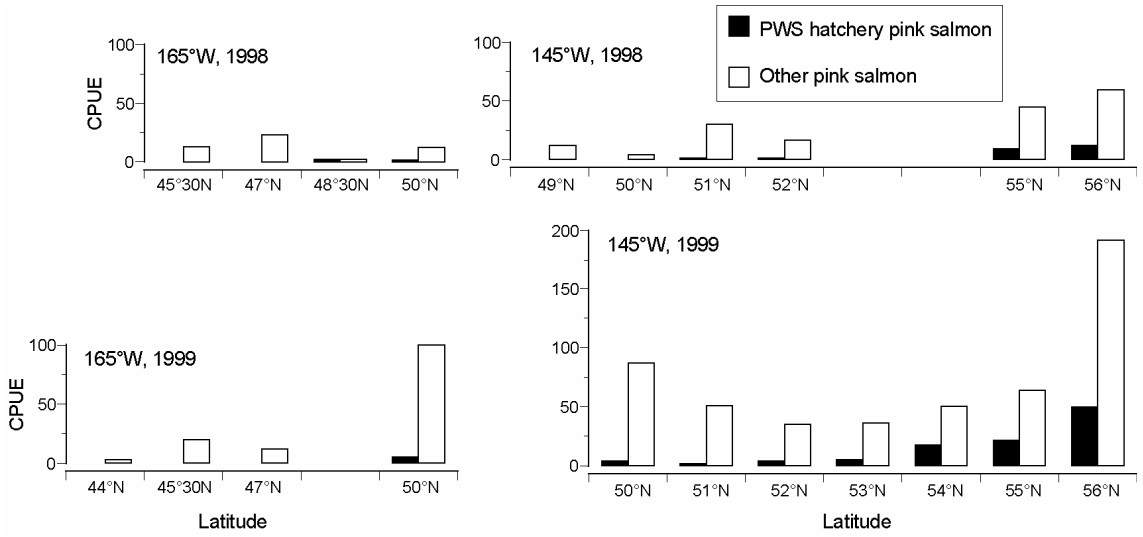

Fig. 2. Catch per unit effort (CPUE) of thermally marked pink salmon released from Prince William Sound (PWS) hatchery caught along the 145°W (upper) and 165°W (lower) transects in the Gulf of Alaska during June and July 1998 and 1999. The CPUE values are based on the catch (number of fish) per one set of a research mesh gillnets (30 tans).