Salmon Abundance in Offshore Waters of the North Pacific Ocean and Its Relationship to Coastal Salmon Returns

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Ishida, Y., and S. Ito. 1998. Salmon abundance in offshore waters of the North Pacific Ocean and its relationship to coastal salmon returns. N. Pac. Anadr. Fish Comm. Bull. No. 1: 334-339

Catch-per-unit-effort (CPUE: fish/tan caught by commercial-type gillnet with mesh sizes from 112 to 130 mm) was calculated using the data collected on board Japanese salmon research vessels in offshore waters of the North Pacific Ocean from 1972 to 1995. These data were stratified by month, 2 degree latitude by 5 degree longitude areas (2x5 areas), species, and maturity, and related to the returns of Japanese chum salmon and Bristol Bay sockeye salmon. Significant correlations and high average CPUEs (sockeye>0.1 and chum>0.3 fish/tan) were found in several areas. There were significant correlations between the abundance of immature chum salmon occurring in areas south of the Aleutian Islands in June (r=0.55* to 0.79**) and the central Bering Sea in July (r=0.51* to 0.63*) and the return of Japanese chum salmon the following year. There were also significant correlations between CPUE of maturing chum salmon in areas south of the Aleutian Islands in June (r=0.57* to 0.85**) and central Bering Sea in June (r=0.68* to 0.79**) and July (r=0.46* to 0.74**)and the current year return of Japanese chum salmon. The abundance of immature fish in areas south of the Aleutian Islands (r=0.47* to 0.65**) and central Bering Sea (r=0.48* to 0.64*) in July was significantly correlated with the returns of Bristol Bay sockeye salmon the following year. There were also significant correlations between the abundance of maturing sockeye in areas south of the Aleutian Islands in June (r=0.65** to 0.86**) and July (r=0.69**) and the current year return of Bristol Bay sockeye salmon. These correlations suggest that abundance of salmon in offshore areas based on CPUE of commercial-type gillnet operations could be used to develop pre-season forecasts of Japanese chum salmon and Bristol Bay sockeye returns.

INTRODUCTION

Accurate forecasts of salmon returns to coastal areas are used for more effective coastal and inshore fisheries management and particularly useful to managers and fishers for harvest planning decisions relating efficient use of their resources. Pre-season forecasts have been conducted based on the level of parent escapement, numbers of juvenile fish migrating to the ocean, information from the fisheries in offshore waters, and environmental indices such as sea surface temperature (Henderson et al. 1987; Eggers et al. 1983). Data on catch-per-unit-effort (CPUE) obtained from the Japanese salmon research vessels on the high seas had been used to forecast sockeye salmon returning to Bristol Bay (Fried et al. 1987; Ishida et al. 1989).

The objectives of this study were to examine the possibility of forecasting salmon returns of Japanese chum and Bristol Bay sockeye salmon based on CPUE data obtained from gillnet operations of the Japanese salmon research vessels which have been conducted for many years and to make recommendations to improve the accuracy of this method.

MATERIALS AND METHODS

Salmon research vessels have used research-type gillnets (containing 10 different mesh sizes ranging from 48 to 157 mm), commercial-type gillnets with mesh sizes ranging from 112 to 130 mm, and longlines. We used data obtained by commercial-type gillnets because this gear was most efficient at capturing maturing fish returning in the present year (t) and immature fish returning in the following year (t+1). Maturity was determined from gonad weights (Takagi 1961).

Catch-per-unit-effort (CPUE:fish/tan caught by commercial-type gillnets) was calculated using the data collected on board Japanese salmon research vessels in offshore waters of the North Pacific Ocean from 1972 to 1995. These data were stratified by month, 2 degree latitude by 5 degree longitude areas (2x5 areas), species, and maturity, and related with the returns of Japanese chum salmon and Bristol Bay sockeye salmon (Kaeriyama 1996; ADF&GD 1997). We calculated the correlation between CPUE value of maturing fish at each area in year t and number of fish returning to the coastal area in year t, and the correlation between CPUE values of immature fish in year t and the number of fish returning to coastal area in year t+1. Strata used for forecasting were selected from strata with high average CPUE (sockeye>0.1 and chum>0.3 fish/tan), 10 or more years of data, and significant correlation coefficient (P<0.05). For each strata selected, a regression of number of salmon returning to coastal areas and CPUE was calculated. These were used to predict the number of salmon returning to coastal areas in 1996 and 1997 from CPUE values of maturing and immature fish in July, 1996.

RESULTS

Japanese Chum Salmon

There were significant correlations between the return of Japanese chum and immature chum salmon occurring in several areas south of the Aleutian Islands in June (r=0.55* to 0.79**) and central Bering Sea in July (r=0.51* to 0.63*). Significant correlations with maturing fish were also found in areas south of the Aleutian Islands in June (r=0.57* to 0.85**) and central Bering Sea in June (r=0.68* to 0.79**) and July (r=0.46* to 0.74**) (Fig.1 and Fig. 2).

Fig. 1 Correlation coefficients between CPUE of immature chum salmon in 2° x 5° area in June and July of year t and return of Japanese chum salmon in year t+1. Shaded areas indicate higher average CPUE (immature >0.3 fish/tan) and significant correlation coefficient (P<0.05).

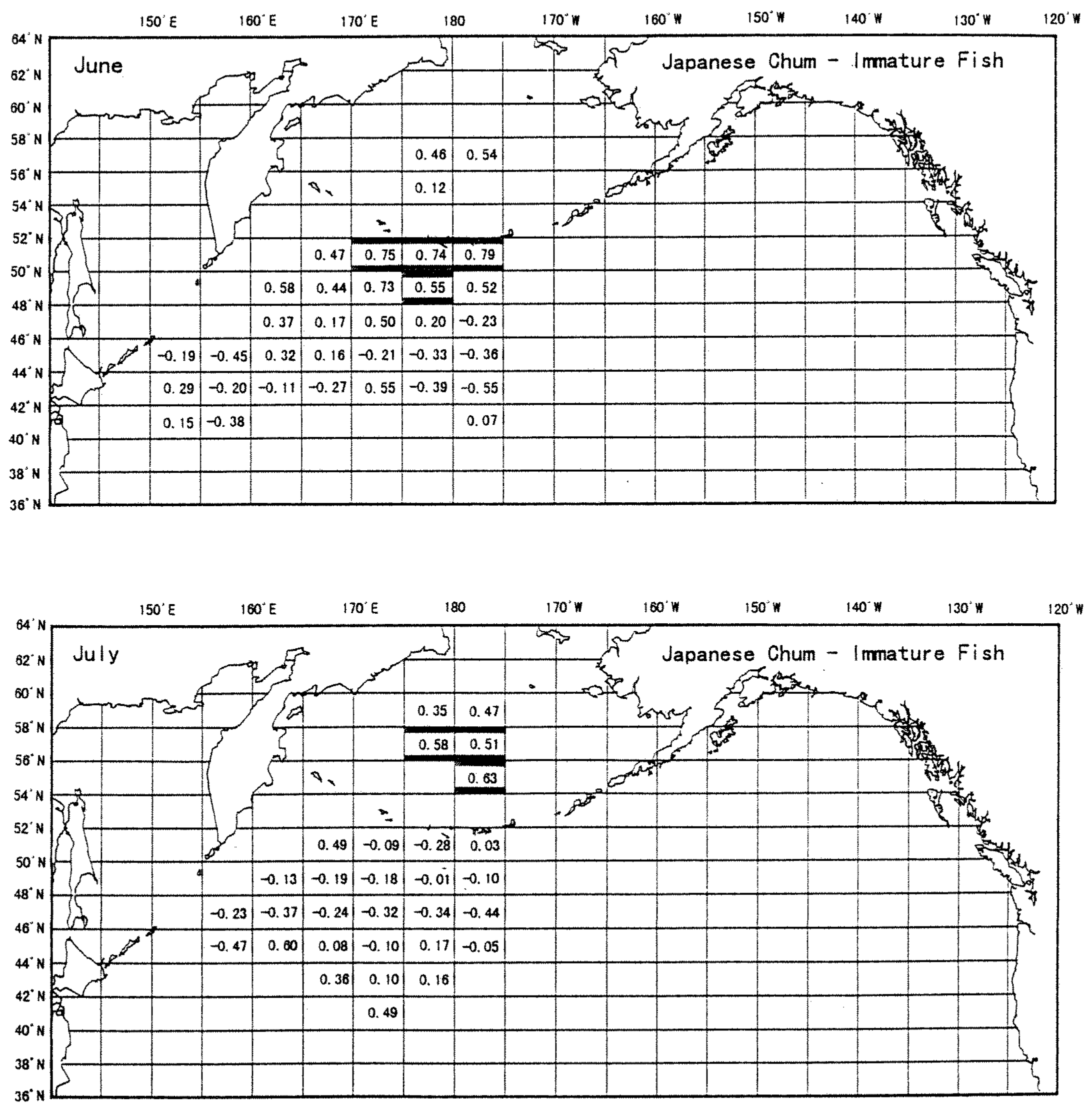
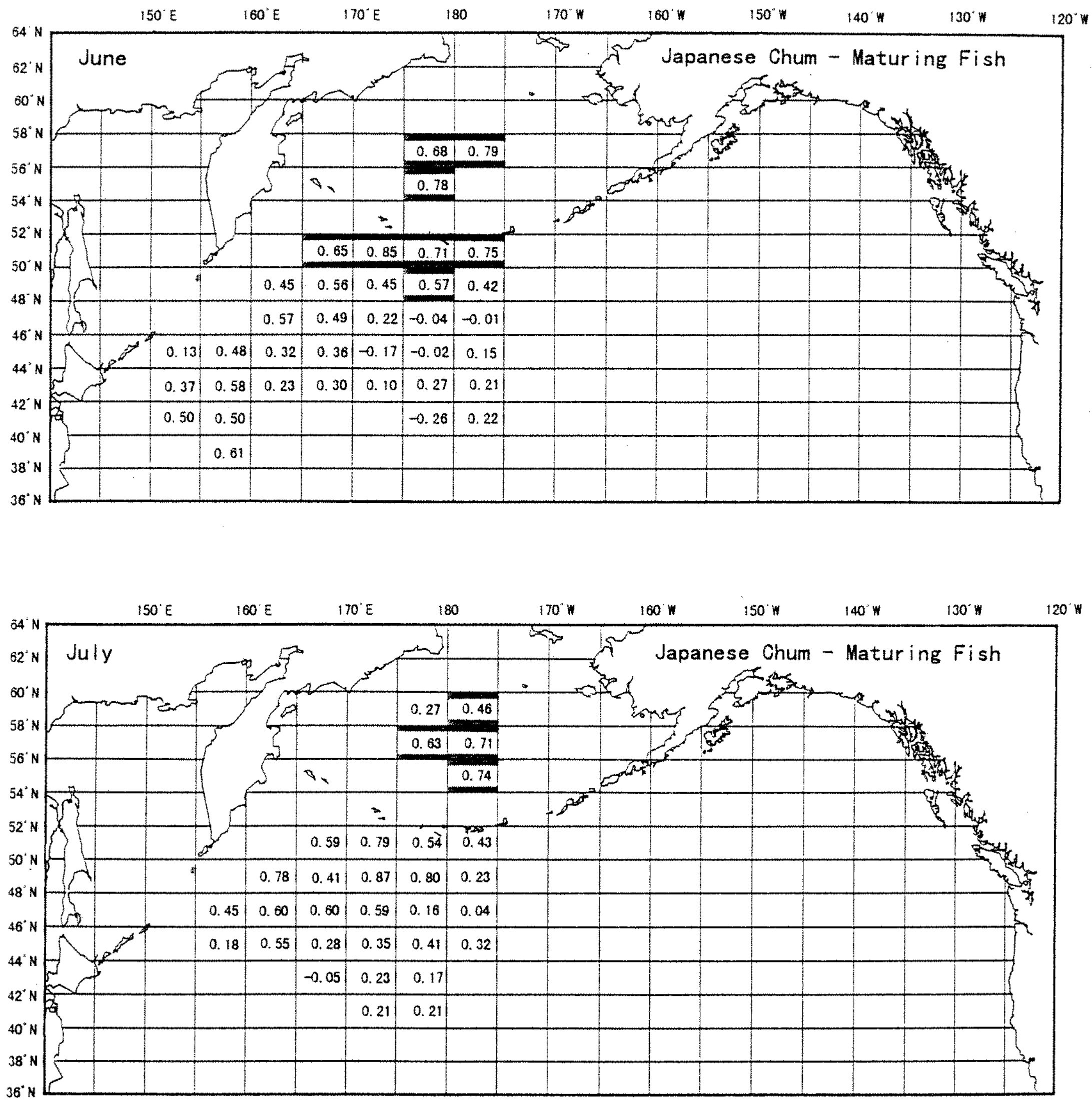


Fig. 2 Correlation coefficients between CPUE of maturing chum salmon in 2° x 5° area in June and July of year t and retun of Japanese chum salmon in year t. Shaded areas indicate higher average CPUE (maturing >0.3 fish/tan) and significant correlation coefficient (P<0.05).



The number of fish returning to coastal area in 1996 was estimated to be 41-59 million fish (mean 47 million fish, S.D. 8 million fish) from CPUE value (1.56-6.10 fish per tan) of maturing fish in the Bering Sea in July, 1996. The number of fish returning to coastal area in 1997 was estimated to be 40 -52 million fish (mean 45 million fish, S.D. 6 million fish) from CPUE value (0.91-3.32 fish per tan) of immature fish in 1996 (Table 1).

Bristol Bay Sockeye Salmon

For Bristol Bay sockeye salmon, the abundance of immature fish in areas south of the Aleutian Islands and central Bering Sea in July was significantly correlated with their returns (r=0.47* to 0.65** and r=0.48* to 0.64*, respectively). There were also significant correlations of returning fish to those maturing in areas south of the Aleutian Islands in June (r=0.65** to 0.86**) and July (r=0.69**). Strong correlations found in these time and area strata are useful for pre-season forecasts of these salmonids (Fig.3 and Fig.4).

The number of fish returning to coastal area in 1996 was estimated to be 67 million fish from CPUE value (1.88 fish per tan) of maturing fish in July, 1996. The number of fish returning to coastal area in 1997 was estimated to be 29-60 million fish (mean 41 million fish, S.D. 12 million fish) from CPUE value (0.29-3.11 fish per tan) of immature fish in 1996 (Table 1).

DISCUSSION

The significant correlations between CPUE of maturing and immature chum and sockeye salmon in Japanese research vessel surveys of offshore waters and respective inshore runs suggests the use of this information to develop preseason forecasts of Japanese chum salmon and Bristol Bay sockeye salmon runs. The areas and times where strong correlations were found corresponded to areas and times where these major stocks of salmon are known to occur, based on tag recovery data. Japanese chum salmon are distributed in the Gulf of Alaska, central and western North Pacific, and are concentrated in the Bering Sea, during July. Bristol Bay sockeye salmon are distributed in the Gulf of Alaska, waters of south of Aleutian Islands, and the Bering Sea (Myers et al. 1990).

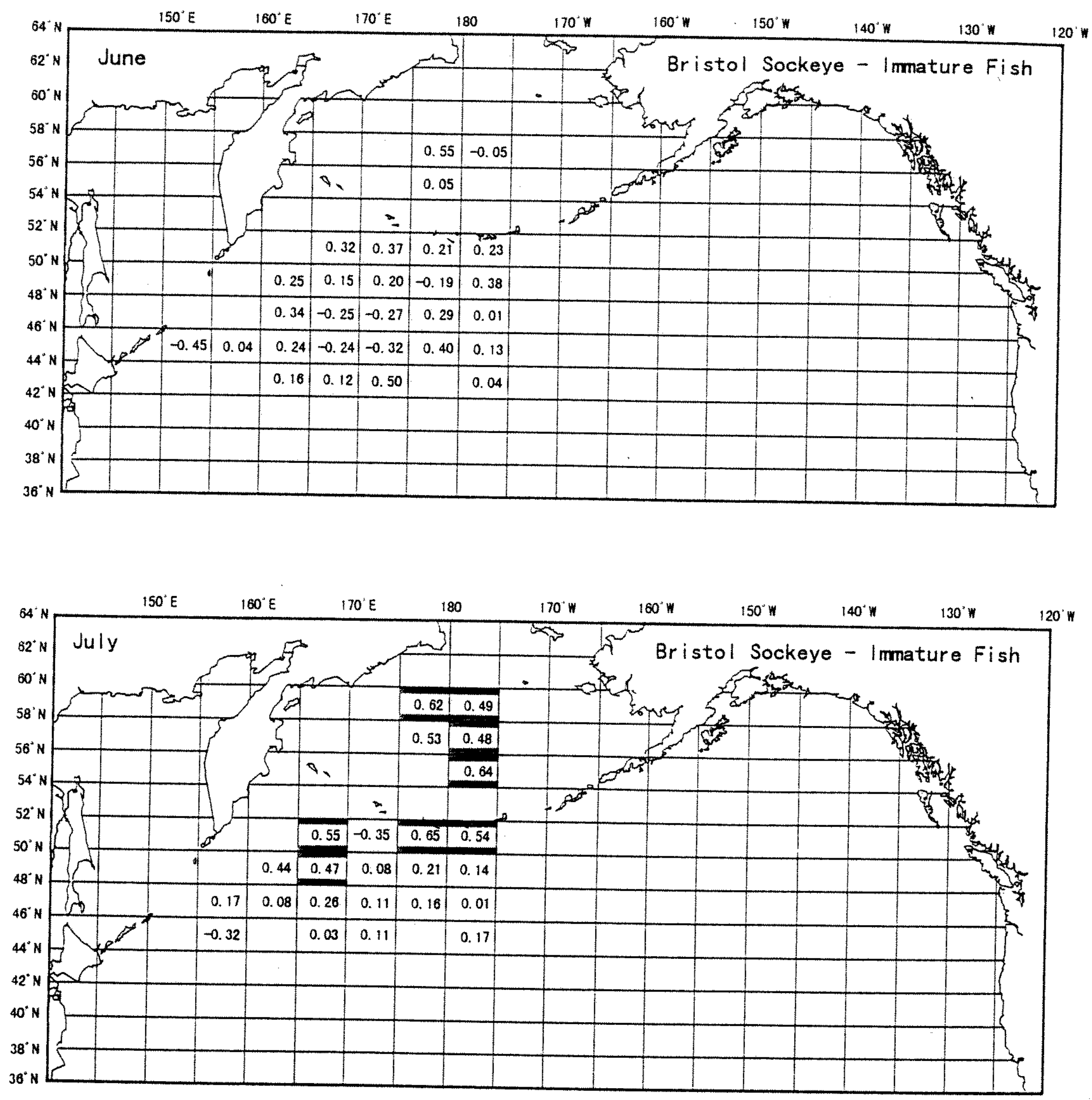
However, there were large discrepancies between the 1996 forecast and the actual run both in Japanese chum salmon and Bristol sockeye salmon. For example, 1996 forecast of Japanese chum was 47 million fish and far below the actual return of 80 million. For Bristol Bay sockeye salmon, 1996 forecast was 67 million and far exceeded the actual run of 38 million.

In order to improve the present forecasting models, additional variables should be examined in the future analysis. Since the ocean age composition of the inshore Bristol Bay return is quite variable and potential exists for differential vulnerability of salmon ocean age classes to gillnet operations, catches should be stratified by ocean age and forecasts developed for returns of respective ocean age classes. Sampling date and sea surface temperature should be considered as an indicator of the survey timing relative to migratory timing of the stocks forecasted in the area of the survey. Body size should be considered because it may relate to the catch efficiency of gillnet operations and to fish density (Ishida et al. 1993). Total CPUE including other salmon species should also be considered as an indicator of whether gear saturation or interspecific interaction is occurring when other species of fish are abundant.

Table 1. Relationship between CPUE (X) and return (Y). Estimates were made based on CPUE data collected in July, 1996. IM-CPUE was CPUE of immature fish, and MT-CPUE was CPUE of maturing fish.

Stock	Month	Area	Relationship					r	n		X	Y
											1996 MT-CPUE	1996 Forecast
Japanese Chum	July	5875W	Y =	3.09	X	+	25.55	r=0.46*	n=21		6.10	44.39
		5675E	Y =	10.55	X	+	24.14	r=0.63*	n=15		1.56	40.59
		5675W	Y =	10.08	X	+	17.99	r=0.71**	n=21		2.50	43.18
		5475W	Y =	15.34	X	+	16.91	r=0.74**	n=14		2.72	58.64
										Mean	3.22	46.70
										S.D.	1.98	8.12
											1996 IM-CPUE	1997 Forecast
Japanese Chum	July	5675E	Y =	6.17	X	+	34.67	r=0.58*	n=14		0.91	40.28
		5675W	Y =	5.78	X	+	32.65	r=0.51*	n=20		3.32	51.85
		5475W	Y =	5.41	X	+	30.79	r=0.63*	n=13		2.23	42.84
										Mean	2.15	44.99
										S.D.	1.21	6.07
											1996 MT-CPUE	1996 Forecast
Bristol Bay Sockeye	July	5065E	Y =	25.89	X	+	18.31	r=0.69**	n=17		1.88	66.99
											1996 IM-CPUE	1997 Forecast
Bristol Bay Sockeye	July	5875W	Y =	8.16	X	+	30.75	r=0.49*	n=20		0.54	35.16
		5675W	Y =	11.00	X	+	29.39	r=0.48*	n=20		1.50	45.90
		5475W	Y =	12.49	X	+	29.35	r=0.64*	n=13		0.37	33.97
		5065E	Y =	14.13	X	+	16.13	r=0.55*	n=16		3.11	60.07
		4865E	Y =	18.14	X	+	23.91	r=0.48*	n=20		0.29	29.17
										Mean	1.16	40.85
										S.D.	1.19	12.36

Fig. 3 **Correlation coefficients between CPUE of immature sockeye salmon in 2° x 5° area in June and July of year t and return of Bristol Bay sockeye salmon in year t+1. Shaded areas indicate higher average CPUE (immature >0.1 fish/tan) and significant correlation coefficient (P<0.05).**



ACKNOWLEDGEMENTS

We thank Kiyoshi Wakabayashi and Kazuya Nagasawa of the National Research Institute of Far Seas Fisheries, Masahide Kaeriyama of the Hokkaido Salmon Hatchery, and Douglas M. Eggers of the Department of Fish and Game, State of Alaska, for reviewing the manuscript. We also thank anonymous referees for reviewing the manuscript.

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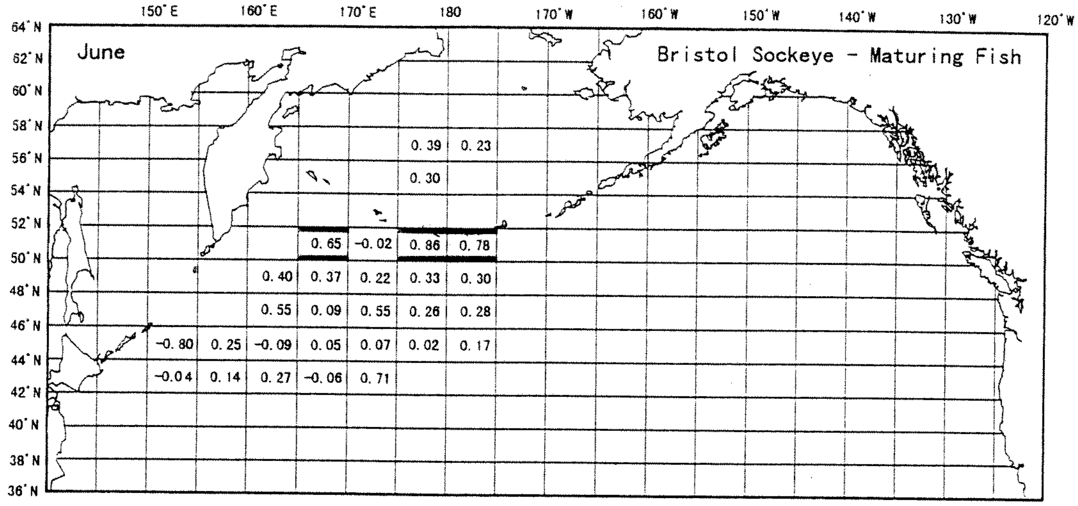
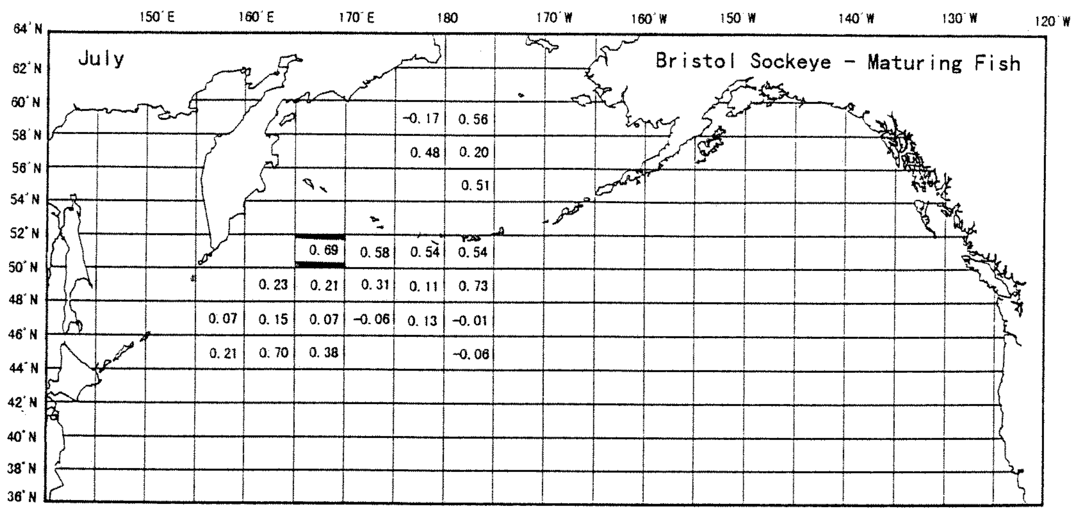
Fig. 4 Correlation coefficients between CPUE of maturing sockeye salmon in 2° x 5° area in June and July of year t and return of Bristol Bay sockeye salmon in year t. Shaded areas indicate higher average CPUE (maturing >0.1 fish/tan) and significant correlation coefficient (P<0.05).





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