

NPAFC
Doc.328
Rev.

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Submitted to the
NORTH PACIFIC ANADROMOUS FISH COMMISSION
by
JAPAN AND THE UNITED STATES OF AMERICA
October 1998

THIS PAPER MAY BE CITED IN THE FOLLOWING MANNER:

Ishida, Y., and N. D. Davis. 1998. Chum salmon feeding habits in relation to growth reduction. (NPAFC Doc.328). National Research Institute of Far Seas Fisheries, Japan, Japan. 7 p.

Chum Salmon Feeding Habits in Relation to Growth Reduction

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ABSTRACT

Feeding ecology of chum salmon was examined and related to their growth reduction in the third year of ocean life. Analysis of chum salmon stomach contents by age group indicated that age 0.1 fish contained a relatively high proportion of amphipods as compared to the other age groups. However, prey composition was similar among older chum salmon (age 0.2 to 0.5). Captured food weight, an index of the amount of food consumed, of immature age 0.2 chum salmon was the highest, followed by maturing age 0.3, immature age 0.3, and immature age 0.1. Growth reduction of chum salmon in the third year of ocean life may be partly due to a requirement of immature age 0.2 fish chum salmon to consume a large amount of prey.

INTRODUCTION

Production of Pacific salmon has increased sharply due to advances in fisheries management, artificial enhancement, and favorable ocean conditions in recent years (Pearcy 1992). However, there is evidence that the average size at maturity has decreased in some salmon stocks as ocean abundance has increased (Bigler et al. 1996). Chum salmon are the second largest stocks of the Pacific salmon and constitute up to 30% of the average salmon catch in the North Pacific Ocean (Beamish and Bouillon 1993).

Scale measurement data indicated that growth reduction of Japanese and Russian age 0.3 chum salmon occurred in the third year of ocean life when they were immature age 0.2. Significant negative relationships between catch per unit of effort (CPUE) and mean body weight of chum salmon were observed in summer in the central North Pacific Ocean (Ishida et al. 1993). For Japanese chum salmon, growth reduction in the third year of ocean life was also more significant than those in other years and a significant negative relationship was found between chum salmon population size and fork length (Kaeriyama 1996). These results suggest that density dependent effects may be one of several causes for the recent growth reduction in size of chum salmon in the North Pacific Ocean.

However, the mechanisms for density dependent effects on chum salmon growth reduction have not been clarified. Our purpose is to elucidate changes in feeding habits of chum salmon by age and maturity, and to relate them to growth reduction in the third year of ocean life.

METHODS

During the summer from 1991 to 1997, chum salmon were sampled from fishing operations of the *Wakatake maru* in the central Bering Sea along a transect at 177°-30'W from 55°-30'N to 58°-30'N and approximately in the central Bering Sea along an east-west transect at 56°-30'N between approximately 56°-30'N from 177°-30'W to 177°-30'E (Nagasawa et al. 1997). Biological data, including fork length (mm), body weight (g), sex, and gonad weight (g), and stomach contents data were collected from surface longline catch. Catch per unit of effort (CPUE) values were calculated from catches by non-selective research gillnet (C-gear; 10 mesh sizes ranging from 48 to 157 mm; Nagasawa et al. 1997). Stomach content index (SCI; stomach content weight X100/body weight) and percent prey composition were examined by chum salmon age and maturity group. Captured food weight (CFW), an index of the amount of food consumed by chum salmon age-maturity group, was calculated as follows (Tadokoro et al. 1996):

$$\text{CFW} = (\text{CPUE}) \times (\text{Body weight}) \times (100 - \text{Empty \%}) \times (\text{Stomach content index})$$

Morishita's index of diversity (1964) was calculated for each chum salmon age-maturity group.

Morisita's Index = $N(N-1) / \sum(n_i(n_i-1))$, where $N=100$ and n_i =mean percent composition in each prey category.

RESULTS AND DISCUSSION

Age 0.1 chum salmon contained a high percentage of amphipods (AM) compared with other age groups (Table 1). However, prey composition was generally similar among older age groups (0.2 to 0.5) and contained more gelatinous zooplankton and euphausiids than younger chum salmon (Fig. 1). Morishita's index of diversity in stomach contents was the highest for age 0.1 fish and decreased as age increased (Table 1).

The CPUE values for immature age 0.1s are slightly higher than the values for immature 0.2s, although considering both maturity groups combined, the 0.2s are slightly more abundant. In any case, the abundance of age 0.1 chum salmon is less than expected, assuming that the youngest fish would have been exposed to ocean mortality for a shorter time period than older fish. The relatively low abundance of the youngest chum salmon

(age 0.1) may be due a reduced catchability in the gillnet and to differences in the distribution of chum salmon by age in the Bering Sea. For example, age 0.1 Asian and North American chum salmon stocks may not be fully intermingling in the sampling area in the summer. The CFW for immature chum salmon age 0.2 was the highest value among the age maturity groups, which included maturing 0.3, immature 0.3, and immature 0.1 in descending order (Table 2 and Fig. 2). Growth reduction of chum salmon in the third year of ocean life may be partly due to a requirement of immature age 0.2 fish chum salmon to consume a large amount of prey.

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Table 1

Table 1. Chum salmon stomach samples collected from the central Bering Sea by longline operations of the *Wakatake maru* in June and July, 1991–1997.

The total number examined (N), mean fork length (FL, mm), mean body weight (BW, g), and percent empty stomachs (% empty) were calculated based on all chum stomach samples examined.

Remaining table values were calculated from those stomach samples that contain prey. Mean prey weight (PW, g), mean stomach content index (SCI; stomach content weight x 100/body weight), mean percent composition of prey categories euphausiids (EU), copepods (CO), amphipods (AM), crab larvae (CR), squid (SQ), pteropds (PT), fish (FI), polychaetes (PO), chaetognaths (CH), gelatinous zooplankton (GE, including medusae, ctenophores, salps), all other groups (OTH; including appendicularia, ostracods, heteropods, mysids, all other groups), and unidentified material (UNID).

Age	Maturity	N	FL	BW	% Empty	PW	SCI	Mean Percent Composition of Prey Categories												Morishita's Index	
								EU	CO	AM	CR	SQ	PT	FI	PO	CH	GE	OTH	UNID		
0.1	IM	103	368	504	4	7.1	1.431	4	5	26	1	7	10	12	0	6	11	4	14	7.734	
	MT	1	359	510	0	7.0	1.373	0	0	40	25	10	0	25	0	0	0	0	0	0	3.474
	Total	104	368	504	4	7.1	1.431	3	5	26	2	7	10	12	0	6	11	4	14	7.759	
0.2	IM	376	442	935	1	12.0	1.285	11	5	9	0	8	9	11	1	1	21	12	12	8.808	
	MT	53	481	1260	0	16.8	1.387	13	4	4	1	13	6	11	2	0	25	5	16	7.399	
	Total	429	446	975	1	12.6	1.297	12	5	9	0	9	8	10	1	1	21	11	13	8.777	
0.3	IM	187	506	1472	3	17.0	1.149	19	7	9	0	6	10	9	0	0	22	5	13	7.698	
	MT	266	559	2049	3	22.9	1.136	19	5	4	0	6	11	6	1	0	23	9	16	7.269	
	Total	453	537	1811	3	20.4	1.142	19	6	6	0	6	11	7	1	0	22	7	15	7.627	
0.4	IM	8	549	1940	0	18.9	1.024	21	14	3	0	8	19	0	0	0	15	0	20	6.203	
	MT	92	612	2781	3	23.7	0.869	17	2	4	0	5	13	7	1	1	27	10	13	6.818	
	Total	100	607	2741	3	23.3	0.881	18	3	4	0	5	13	6	1	1	26	9	14	6.904	
0.5	IM	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	MT	11	658	3535	0	17.4	0.517	19	1	1	0	2	11	12	0	1	32	11	10	5.568	
	Total	11	658	3535	0	17.4	0.517	19	1	1	0	2	11	12	0	1	32	11	10	5.568	
Total	IM	674	449	1030	2	12.7	1.266	13	6	12	0	8	9	10	1	1	19	8	13	9.083	
	MT	423	563	2144	3	22.1	1.095	18	4	4	0	7	11	7	1	0	24	9	15	7.290	
	Total	1097	493	1460	2	16.3	1.200	14	5	9	0	7	10	9	1	1	21	9	14	8.594	

Table 2

Table 2. Captured food weight (CFW) estimated for age and maturity groups of chum salmon caught in the central Berin Sea in summer, 1991-1997.
 CPUE=fish/tan, BW=mean body weight (g), Empty=percent of empty stomachs, SCI=stomach contents index

Age	Maturity	(a) CPUE	(b) Empty	(c) BW	(d) SCI	$a \times (100-b) \times c \times d / 100$ CFW
0.1	IM	1.56	4	504	1.431	1080
	MT	0.01	0	510	1.373	7
	Total	1.57	4	504	1.431	1087
0.2	IM	1.45	1	935	1.285	1725
	MT	0.16	0	1260	1.387	280
	Total	1.61	1	975	1.297	2016
0.3	IM	0.75	3	1472	1.149	1230
	MT	0.69	3	2049	1.136	1558
	Total	1.44	3	1811	1.297	3281
0.4	IM	0.06	0	1940	1.024	119
	MT	0.30	3	2481	0.869	627
	Total	0.36	3	2714	0.881	835
0.5	IM	0.00	-	-	-	-
	MT	0.03	0	3535	0.517	55
	Total	0.03	0	3535	0.517	55
Total	IM	3.82	2	1030	1.266	4882
	MT	1.19	3	2144	1.095	2710
	Total	5.01	2	1460	1.200	8602

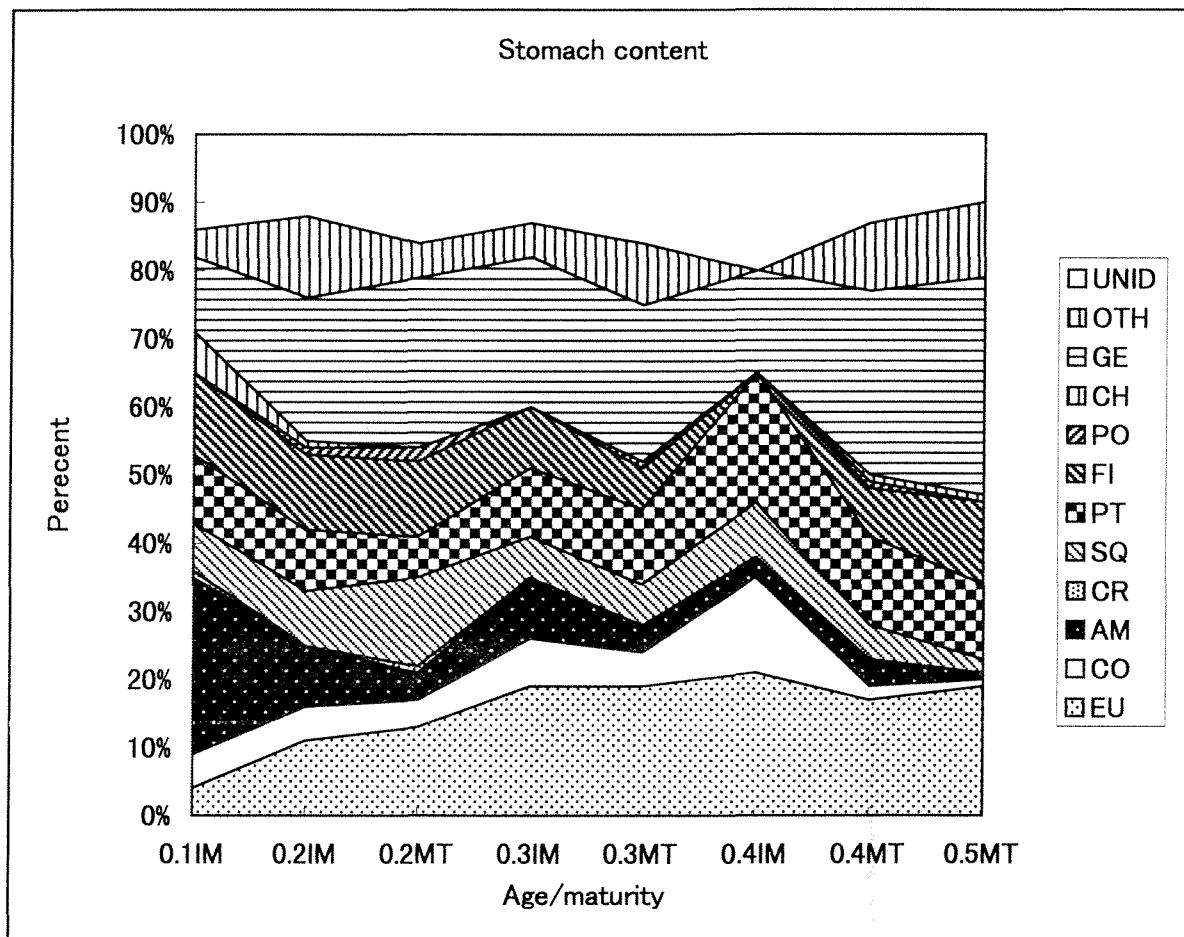


Fig. 1. Mean prey composition estimated from sampling several chum salmon age and maturity groups.

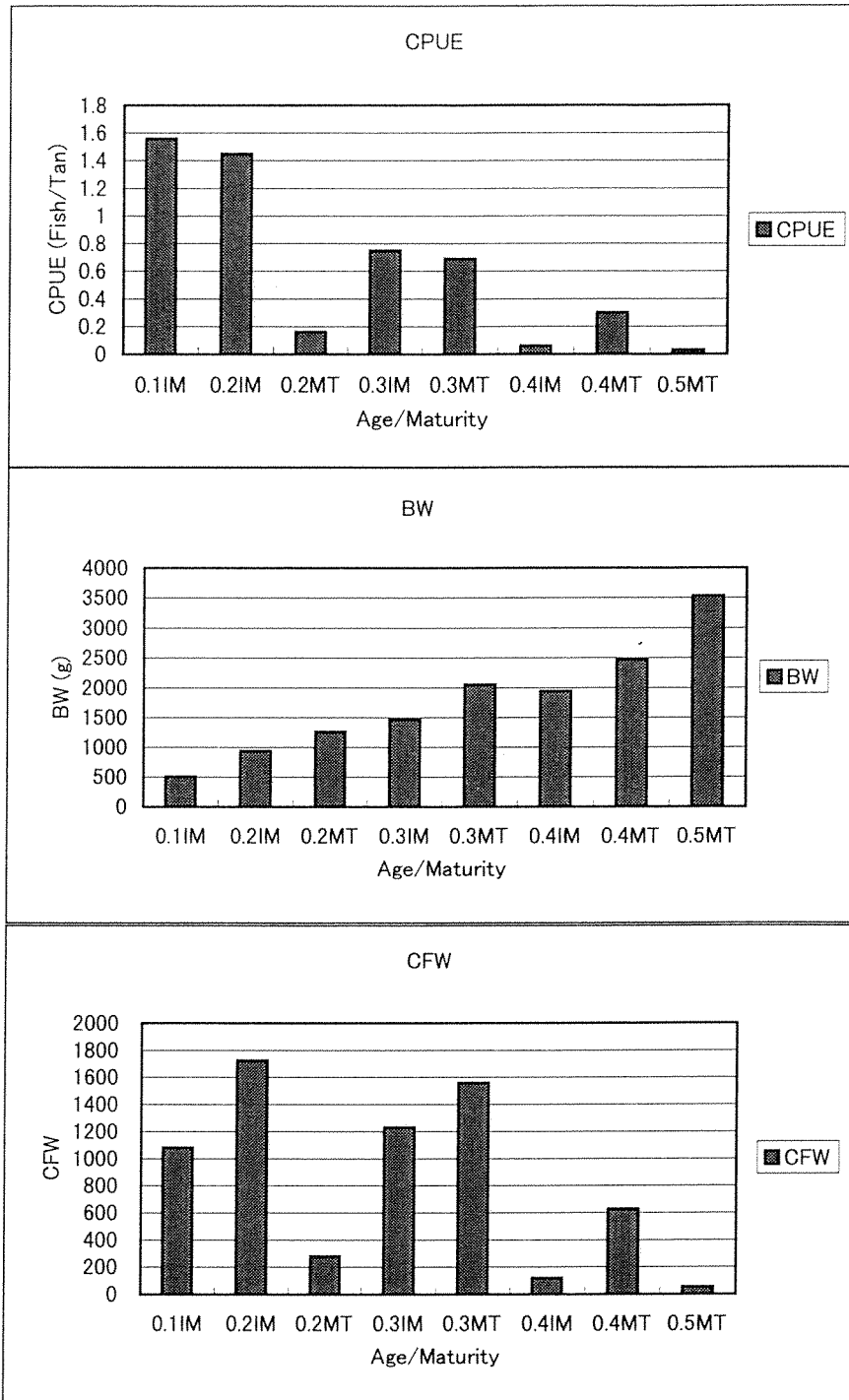


Fig. 2. Changes in catch per unit of effort (CPUE), body weight (BW), and captured food weight (CFW) estimated for each age and maturity group of chum salmon caught in the central Bering Sea, 1991-1997.