Time and Spatial Distributions by Age Classes of Chum Salmon in the Central North Pacific and the Bering Sea

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Chum salmon are widely distributed in the North Pacific and the Bering Sea from spring to autumn. It is known that the distribution for maturing chum salmon is father north than that of immature chum salmon in spring (Nagasawa et al. 2005). However, why don't immature and maturing chum salmon migrate in the North Pacific and the Bering Sea together? To answer this question, we examined the time and spatial distribution of chum salmon by each age class in the central North Pacific and the Bering Sea.

To examine the time and spatial distribution of chum salmon by each age class, we used data obtained by Japanese salmon research vessels from 160ºE to 170ºW. The proportion of maturing and immature fish was calculated based on Takagi's maturity definition (Takagi 1961). CPUE is total catch in number per total effort in 30 tans of gillnets.

Figure 1 shows the histogram of CPUE of chum salmon for each of latitude. The predominant age of maturing chum salmon was 0.3 and the predominant ages of immature chum salmon were 0.1 and 0.2. Distribution of chum salmon shifted northward as the summer progressed. In May, chum salmon of age 0.1 to 0.3 were distributed from 43ºN to 45ºN. In June, distribution of age 0.1 chum salmon of extended to 50ºN. On the other hand, maturing chum salmon were distributed from 42ºN to 63ºN, indicating they had already entered the Bering Sea. Age 0.1 chum salmon were distributed in the Bearing Sea from July to August. The distribution of age 0.1 chum salmon was less variable than that of maturing chum salmon. Thus, there were age differences structured in the distribution of chum salmon during spring to summer in the North Pacific and the Bering Sea.

Next, we calculated the migration speed from the position of the mode of distribution assuming the migration of the same stock. Estimated migration speed of maturing chum salmon was 0.68 m/s from May to June (Fig. 2). The speed of age 0.1 chum salmon was 0.27 m/s from May to August. Speed of maturing chum salmon was considerably faster than that of immature chum salmon, age 0.1 and 0.2. These estimated speeds corresponded to one fork length per second roughly. Assuming one fork length per second is the mean swimming speed of salmon, this result suggests that the time change of the distribution of chum salmon correlates with their swimming speed.

Total metabolic cost is a function of body weight, ambient temperature and swimming speed by (Beauchamp et

Fig. 1. Histogram of CPUE of chum salmon in each of latitudes. Black bars are maturing chum salmon and white bars are immature chum salmon.

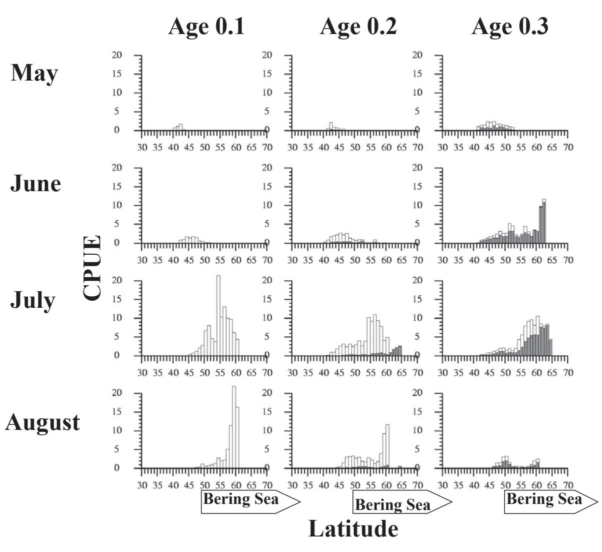
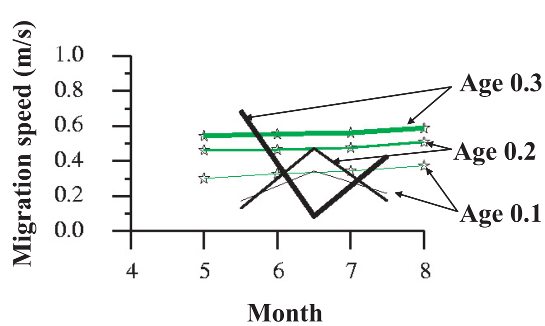


Fig. 2. Time series of monthly migration speed. Green lines are monthly averaged fork length.



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al. 1989). The total metabolic cost was estimated from monthly averaged body weight, ambient temperature and swimming speed. Estimated total metabolic costs were dependent on their swimming speed mainly. The total metabolic cost of age 0.1 chum salmon was lower than that of maturing chum salmon from May to June. In June to July, the total metabolic cost of age 0.1 chum salmon was higher than that of maturing chum salmon. It is noted that the total metabolic costs of both immature and maturing salmon were relatively high before they entered the Bering Sea.

In order to reproduce the time change in distribution of chum salmon along latitude, we used the simple one dimensional model. The model which consisted of an advection and diffusion equation written as:

$$\frac{\partial F}{\partial t} = u\frac{\partial F}{\partial x} + D\frac{\partial^2 F}{\partial x^2} \qquad (1)$$

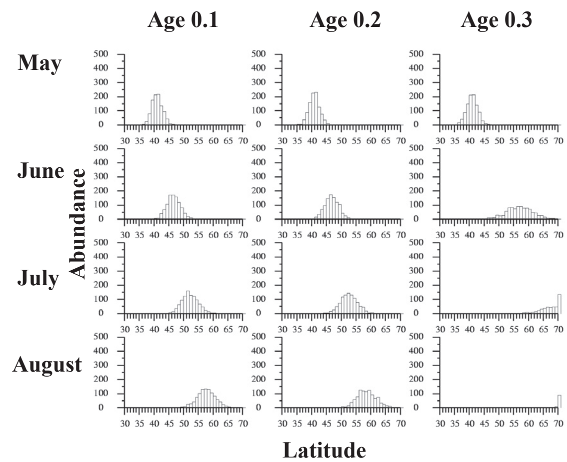
where, F (number) is abundance of salmon; x (m) is latitude; t (s) is time; u (m/s) is northward swimming speed; and D (m^2/s^2) is horizontal diffusivity. In this model, u and D depend on fork length. We did not take into account salmon mortality in the model. It was assumed in the model that there was no passive transportation by current, the swimming direction of salmon was only northward, and there was no influence from other salmon stocks. The initial position of salmon in May was set at 40ºN. Model parameters are listed in Table 1. Values of u and D that were similar to our observations were used in the model. The model was integrated by a time step of six minutes. After each model run, each age class was integrated for 30 days with no advection and same diffusion, then each age class was integrated for 120 days to obtain dynamics of salmon distribution.

The results of the model are shown in Fig. 3. Age 0.1 chum salmon arrived at 50ºN in July, and age 0.3 chum salmon arrived at 50ºN in June. The variance of distribution of age 0.1 salmon was smaller than that of maturing salmon. The model reproduced the northward shift of salmon as the summer season progresses. However, in the case of no advection, the model did not reproduce the observed chum salmon distribution. This indicates that the distribution from spring to summer is not well explained by random swimming only and instead indicates that chum salmon actively swim northward. Therefore, differences in age structured distribution of chum salmon from spring to summer is likely due to differences in their swimming speeds.

Table 1. Model parameters.

Age	0.1	0.2	0.3
u(m/s)	0.25	0.26	0.68
D(m^2/s^2)	5100	5500	39300

Fig. 3. Histogram of CPUE of chum salmon in each of the latitudes calculated by the model.



REFERENCES

Beauchamp, D.A., D.J. Stewart, and G.L. Thomas. 1989. Corroboration of a bioenergetics model for sockeye salmon. Trans. Am. Fish. Soc. 118: 597–607.

Nagasawa, T., T. Azumaya, and M. Fukuwaka. 2005. Which salmon are using the Bering Sea as their feeding area? (Japanese national overview of BASIS research). N. Pac. Anadr. Fish Comm. Tech. Rep. 6: 8–10.

Takagi, T. 1961. The seasonal change of gonad weight of sockeye and chum salmon in the North Pacific Ocean, especially with reference to mature and immature fish. Bull. Hokkaido Reg. Fish. Res. Lab. 23: 17–34. (In Japanese with English abstract).