Handling Time and Profitability of Food in Juvenile Chum Salmon: Effects of Fish Size, Food Size, and Satiation

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As a first step toward understanding the size selective foraging of juvenile chum salmon by the optimal foraging approach, handling time and profitability of food were measured by feeding experiments with an artificial food, and the effects of fish size, food size, and satiation were examined.

The experiment was conducted five times when juvenile chum salmon grew to the target fork lengths (FL), of 40, 50, 60, 70, and 90 mm (Table 1). Juveniles were held individually in aquaria (30 x 60 x 30 cm) under natural photoperiod. The water temperature was maintained at 10.5°C. The fish were fed to satiation each day on a specified size of food (a commercial dry pellet). The food size offered on a given day was randomly chosen from the size range applicable to that size fish. Each trial was recorded by a video camera so that handling time could be estimated.

Table 1. Average fork length (FL), number of fish examined, and size of food offered in each experimental group of juvenile chum salmon.

	Group				
	40	50	60	70	90
FL (mm)	45.5	57.8	68.0	77.4	96.2
No. of fish	4	4	5	5	5
Food size (mm)					
0.86	○				
1.20	○	○			
1.80	○	○	○	○	
2.03	○	○	○	○	○
2.58		○	○	○	○
3.68			○	○	○
4.38					○

Handling time was defined as the time taken for swallowing one food pellet after it was captured. Average handling time (h_t) per individual was estimated from

$$h_t = f\,T_f + T_{su},$$

where f is the average number of failures preceding a successful feeding, T_f is the average time spent per failed feeding, and T_{su} is the average time spent per successful feeding. f was estimated by $(1\text{-}S)/S$, where S is the proportion of attacks that resulted in success (Bence and Murdoch 1986).

To examine the effect of the average handling time was estimated at low and high levels of satiation. The handling time at high satiation level was derived from the data of $n/n_t > 0.5$ where n is the nth food taken in a feeding sequence and n_t is the total number of food consumed in a trial.

The profitability of food to a fish was indicated by handling cost (handling time/mg dry weight of food). The cost of handling in a given fish size was computed from the following relationships:

handling time, food size, and gape size (see Fig. 1);

gape size (GS) and fish size (FL): $GS = 0.24FL^{0.754}$; and

dry weight (DW) and size (L) of food: $DW = 0.614L^{2.62}$.

Handling time increased exponentially with increasing relative food size (food size/gape size) in each size group at both satiation levels (Fig. 1). The relationships differed significantly between size groups of 40–50 mm and 60–90 mm at the low satiation level (ANCOVA, $F_{4,\,86} = 11.78$, $p < 0.001$) and the high satiation level (ANCOVA, $F_{4,\,86} = 13.62$, $p < 0.001$). Handling time was prolonged significantly as juveniles approached satiation in the 40–50 mm group (ANCOVA, $F_{4,\,61} = 14.92$, $p < 0.001$) and the 60–90 mm group (ANCOVA, $F_{4,\,117} = 19.62$, $p < 0.001$).

Handling cost was inversely related to food size, suggesting that larger food particles are more profitable for juvenile chum salmon (Fig. 2). In the course of growth from 40 mm to 60 mm FL, juveniles began to feed more efficiently on a broader range of food particle size. Satiation raised the regression curves, and improved the fit. This implies that juveniles would benefit by intensifying food size selectivity during the course of satiation.

The size (50–60 mm FL) at which juvenile chum salmon change handling time and handling cost is remarkably consistent with the size when they develop from fry to fingerling, move from littoral to more pelagic habitat, and broaden their prey size in the ocean (e.g., Okada and Taniguchi 1971; Kaeriyama 1989).

Fig. 1. Relations between handling time and the ratio of food size to gape size at low (A) and high (B) satiation levels in juvenile chum salmon. Solid curves indicate regression curves for the groups of 40 and 50 mm: (A) y = 2.31 exp(5.30x); (B) y = 4.42 exp(4.55x). Bold-solid curves indicate regression curves for the groups of 60, 70 and 90 mm: (A) y = 2.21 exp(3.88x); (B) y = 4.31 exp(3.03x).

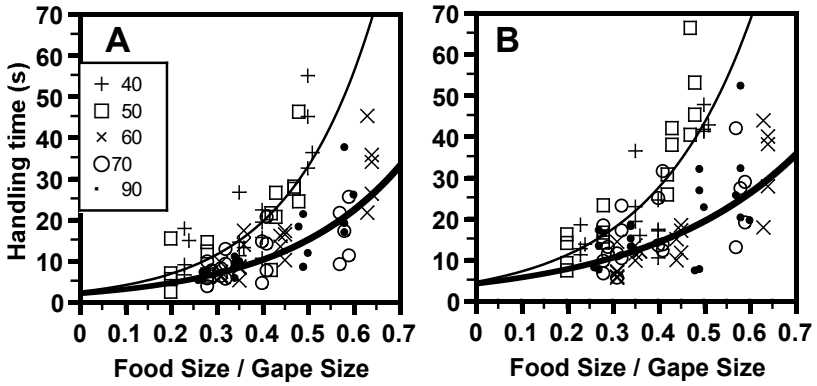
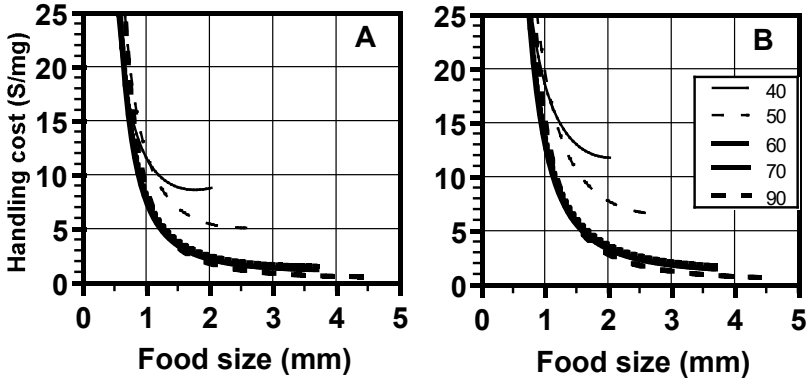


Fig. 2. Relations between handling cost (handling time/milligram dry weight of food) and food size at low (A) and high (B) satiation levels in juvenile chum salmon. Fish size (mm, fork length) for the curves is indicated in the legend. Each curve ends at the maximum food size that the fish is capable of handling.



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