North Pacific Anadromous Fish Commission
Technical Report No. 7: 99–100, 2007

Trophic Status of Young Ocean Chum Salmon Estimated by Lipid Analysis

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Keywords: Total lipid content, chum salmon, immature, North Pacific Ocean, Bering Sea

Understanding the trophic status of chum salmon in the ocean is important to estimate their growth and survival potential in the ocean. Total lipid (TL) content is a good indicator of trophic status. Carnivorous fish, including salmonids, have a limited ability to utilize carbohydrates and so dietary lipids are an important energy source for them (Watanabe 1982). Although numerous lipid studies have focused on cultured fish that consume artificial food, few studies have measured lipid content of salmon caught in the high sea (Nomura et al. 2000, 2001, 2002, 2004). Lipid content determination for salmon during their high-sea migration can give an estimate of their trophic status and growth potential (Nomura et al. 2000, 2001).

Chum salmon were caught by surface trawl in the spring (May) of 1999, as well as summer (June–July) and fall (September) 2002–2004 in the Gulf of Alaska, Bering Sea and North Pacific Ocean (Table 1). Fork lengths (FL, cm) and body weights (BW, g) were measured from a sample during the survey. After measuring, these fish were frozen whole (-30°C). Other chum salmon were frozen (-30°C) and subsequently thawed prior to measureming lengths and weights in the laboratory. Scales were collected for age determination and a fillet was carefully removed from the fish. The white muscle was removed from the fillet and homogenized in a food processor. Approximately 10 g of the homogenized white muscle was collected, weighed, and kept frozen at -30°C until further analysis.

The frozen white muscle was thawed and homogenized with 60 ml of methanol and 120 ml of chloroform to extract lipids (Folch et al. 1957). The homogenate was filtered through lipid-free paper into a glass vessel. The crude extract was then mixed in a separator funnel with chloroform, methanol, and water in the volumetric proportions 8:4:3. The lower phase was collected and the solvent was evaporated with a rotary evaporator. The extracted lipid was measured gravimetrically.

Spring samples; TL content in age-.1 fish was low (< 2.3%, mean = 1.3%) and it was also low in age-.2 fish (< 5.5%, mean = 2.0%). In age-.1 and age-.3 fish, total lipid content was higher than age-.1 and age-.2 fish (< 10.9%, mean = 3.9%). The total lipid content in age-.3–.5 fish was significantly higher than that of age-.1–.2 fish.

Summer and fall samples; A total of 660 chum salmon muscle samples from immature fish caught during the summer (June–July) and 622 samples from the fall (September) were analyzed. Average TL content in the white muscle of immature ocean age-.1 summer-caught chum was 1.8% (n = 48), 2.1% (n = 89), and 2.4% (n = 118) in 2002, 2003, and 2004, respectively (Fig. 1). Average TL content in the white muscle of immature ocean age-.1 fall-caught chum was higher: 7.3% (n = 180) in 2002 and 5.2% (n = 198) in 2003 (Fig. 1).

Average TL content in the white muscle of ocean age-.2 summer-caught chum salmon was 5.1% (n = 69), 4.4% (n = 103), and 4.2% (n = 125) in 2002, 2003, and 2004, respectively (Table 1, Fig. 1). The TL in ocean age-.2 chum salmon increased to 11.7% (n = 122) and 8.5% (n = 83) in fall 2002 and 2003. Average TL content observed in each age group during fall was significantly higher than that observed in fish of the same age group collected during

Table 1. Number of fish sampled by ocean age in the Gulf of Alaska in the spring of 1999, and North Pacific Ocean and the Bering Sea in the summer and fall of 2002–2004.

Season	Year	Ocean age					Total
		1	2	3	4	5	
Spring	1999	16	15	33	30	5	99
Summer	2002	48	69	24	5	0	146
Fall	2002	180	122	18	3	0	323
Summer	2003	89	103	40	1	0	233
Fall	2003	198	83	17	1	0	299
Summer	2004	118	125	32	6	0	281

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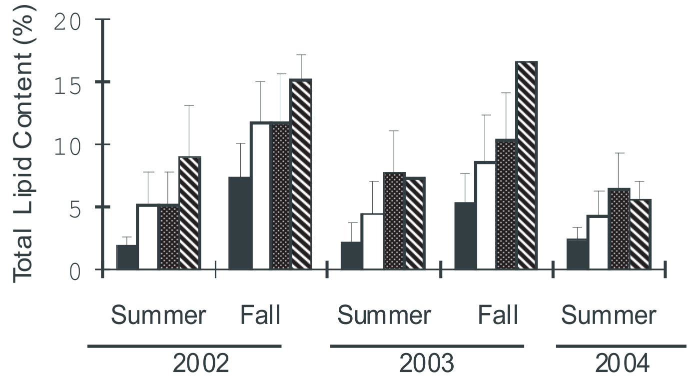
summer.

Our results clearly demonstrate that young (ocean age-.1) chum salmon have lower lipid levels than older salmon, but the starved condition observed in winter and spring (winter TL content = 1.1% and spring TL content = 1.4% in female and 1.2% in male chum salmon; Nomura et al. 2000, 2001) does not occur in this age-group during summer and fall.

Fig. 1. Total lipid content in white muscle of immature chum salmon caught in the Bering Sea in summer (June–July) and fall (September) 2002–2004 by ocean age. Bar height is the mean, and line length is one standard deviation. Solid bar, ocean age-.1; open bar, ocean age-.2; stippled bar, ocean age-.3; and slanted line bar, oean age-.4.



During their ocean migrations, salmon use energy for movement, metabolism, and growth (Crossin et al. 2003). Lower lipid content in young chum salmon as compared to old fish indicates either inadequate intake of dietary lipid, utilization of their lipid for growth, or a combination of these conditions. We hypothesize that during the summer, energy expenditures for growth in ocean age-.1 chum salmon takes priority over lipid storage. During fall the reverse occurs, and lipids are stored at the expense of growth, which promotes survival during winter. If this hypothesis is true, then growth to avoid size-selective predation (Ricker 1964, 1976; Weatherly and Gill 1995) may not occur throughout the year, particularly in the fall when consumption rates may be high. Reduced food availability and high predation in the late summer and fall may critically limit sufficient lipid storage for salmon, particularly young fish, reducing overwinter survival.

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