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Interannual and Spatial Variability in the Feeding Ecology of Juvenile Chinook Salmon and Effects on Survival and Growth

Eric Hertz[1], **Marc Trudel**[1,2], **Rana W. El-Sabaawi**[1], **Strahan Tucker**[2], **Terry D. Beacham**[2], and **Asit Mazumder**[1]

[1]*Department of Biology, University of Victoria, P.O. BOX 3020, Station CSC, Victoria, BC V8W 3N5, Canada*
[2]*Fisheries and Oceans Canada, Pacific Biological Station, 3190 Hammond Bay Road, Nanaimo, BC V9T 6N7, Canada*

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Chinook salmon are important to the ecology, economy, and culture of British Columbia but are declining in abundance. The drivers underlying these declines are generally poorly understood, but they are thought to occur primarily in the marine environment. The mortality of juvenile salmon during early marine life has been shown to be important for determining year-class strength (Pearcy 1992) and is expected to be size-selective. As such, factors that reduce early marine growth may also reduce subsequent return rates.

Early marine growth rates are largely affected by prey quality and quantity (Beauchamp 2009); higher quality and greater prey abundance can lead to higher growth rates. Here, we use stable isotopes to assess relative changes in prey quality and quantity to determine the potential ways these factors affect growth and survival rates of two groups of Chinook salmon.

Stable isotopes of nitrogen and carbon are commonly used to assess the time-integrated feeding ecology of organisms. $\delta^{15}N$ is an indicator of trophic level where higher $\delta^{15}N$ generally relates to higher trophic level. However, differences between regions or years can be obscured by the variability in the $\delta^{15}N$ values of organisms at the base of the food web (primary consumers). To facilitate further comparisons, a relative trophic level can be calculated using the $\delta^{15}N$ of zooplankton and a known trophic enrichment factor. In general, larger prey items are more energy dense, they require less energy to capture, and they contain more digestible material. Thus we expect that salmon growth and survival will be enhanced in years with high $\delta^{15}N$ and high trophic level of juvenile salmon.

There is a relationship between $\delta^{13}C$ and onshore/offshore productivity (Perry et al. 1999). Onshore areas are more productive and have correspondingly higher $\delta^{13}C$ values (Miller et al. 2008) and years with greater productivity may also have higher $\delta^{13}C$. We expect that salmon growth and survival will be positively related to $\delta^{13}C$.

Juvenile Chinook salmon were sampled by rope trawl in October-November in two regions: west coast of Vancouver Island (WCVI) and Southeast Alaska (SEAK) as part of the High Seas Salmon Program (Fisheries and Oceans Canada) from 2000 to 2009 (Table 1; Trudel et al. 2012). Samples were frozen on-board the research vessel at -20°C. In the laboratory at the University of Victoria, samples were dried, ground to a fine powder, packed into tin capsules, and analyzed using a mass spectrometer. A sample of skin tissue was also run for DNA stock assignment. Linear regressions between yearly average isotope values and yearly growth (change in fork length over time) and survival rates were performed.

Table 1. Summary of sample size, average fork length (FL), and average weight of juvenile Chinook salmon collected from surveys in Southeast Alaska (SEAK) and west coast of Vancouver Island (WCVI).

	SEAK			WCVI		
Year	n	FL (mm)	Weight (g)	n	FL (mm)	Weight (g)
2000	34	279.2	309.1	11	201.1	99.3
2001	41	256.5	231.8	49	160.2	50.4
2002	43	274.5	279.3	38	186.5	91.6
2003	10	236.1	172.0	18	200.7	108.1
2004	6	258.0	238.5	14	187.1	84.6
2005	34	226.9	151.4	40	183.8	74.5
2006	29	255.2	221.2	43	191.1	97.9
2007	60	240.9	197.0	299	162.5	53.3
2008	26	240.3	198.7	39	163.9	50.0
2009	15	249.7	197.6	27	159.0	46.1
Total	297	252.7	224.0	577	169.8	63.0

All correspondence should be addressed to E. Hertz.
e-mail: hertzy@uvic.ca

In samples collected from WCVI, positive relationships between $\delta^{15}N$ in the tissue of juvenile Chinook salmon and growth and between tissue-$\delta^{15}N$ and survival were observed (growth: t = 2.7, df = 8, $p = 0.02$; survival: t = 2.4, df = 8, $p = 0.04$; Table 2). We did not observe significant relationships between $\delta^{15}N$ and growth or survival for samples obtained in SEAK (growth: t = -1.2, df = 8, $p = 0.3$; survival: t = -0.5, df = 8, $p = 0.6$). In WCVI samples, the trophic level of juvenile Chinook salmon showed a strong positive relationship with survival (t = 2.6, df = 8, $p = 0.03$) but not with growth (t = 0.9, df = 8, $p = 0.4$). There was no relationship between trophic level and growth or survival in SEAK samples (growth: t = -0.2, df = 8, $p = 0.8$; survival: t = 0.4, df = 8, $p = 0.7$). $\delta^{13}C$ showed a strong positive relationship with growth and survival in WCVI samples (growth: t = 3.1, df = 8, $p = 0.01$; survival: t = 3.1, df = 8, $p = 0.01$) and no relationship in SEAK samples (growth: t = 2.0, df = 8, $p = 0.08$; survival: t = 0.7, df = 8, $p = 0.5$).

Table 2. Adjusted R^2 values for the correlations between isotopic ratios and growth and survival rates of juvenile Chinook salmon obtained from surveys along the west coast of Vancouver Island (WCVI) and in Southeast Alaska (SEAK). Significant ($p < 0.05$) correlations are displayed in bold type.

	WCVI			SEAK		
	$\delta^{15}N$	TL	$\delta^{13}C$	$\delta^{15}N$	TL	$\delta^{13}C$
Growth	**0.43**	-0.03	**0.49**	0.05	-0.12	0.26
Survival	**0.34**	**0.39**	**0.50**	-0.09	-0.11	-0.06

In samples collected from SEAK, the feeding ecology of juvenile Chinook is not driving differences in growth or survival rates. However, in WCVI samples, shifts in feeding ecology have implications for growth and survival rates. The reasons for regional differences may be related to differences in size or oceanography between regions.

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