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A Comparison of the Diets of Hatchery and Wild Coho Salmon (*Oncorhynchus kisutch*) in the Strait of Georgia from 1997–2007

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Abstract: Wild and hatchery-reared coho salmon (*Oncorhynchus kisutch*) have now co-existed in the Strait of Georgia for over 30 years, and have exhibited considerable variation in marine survival rates. This study is the first to compare diets of juvenile hatchery and wild coho salmon during the critical early marine period of this species. From 1997–2007, over 10,000 stomachs from juvenile coho salmon captured in the Strait of Georgia were examined. Diets in July were dominated by decapods (primarily crab megalops) and fish (primarily herring). In September, euphausiids and amphipods (primarily hyperiids) dominated. The variability between hatchery and wild coho salmon diet was larger in September than in July. Prey volume, stomach fullness and fork length were significantly correlated between hatchery and wild coho salmon in the July and September surveys. While coho salmon captured in September surveys had significantly higher percentages of empty stomachs than those from July, there were no significant differences in the percentage of empty stomachs between hatchery and wild coho salmon in either survey. Shifts in diet composition occurred both annually and seasonally, but the trends for both groups of coho salmon were the same. Thus, we conclude there were no significant differences observed between hatchery and wild coho salmon in either appetite (volume of prey in the stomach) or in diet (composition of stomach contents) in either July or September surveys from 1997–2007 in the Strait of Georgia, British Columbia, Canada.

Keywords: coho salmon, hatchery, wild, diet, seasonal, Strait of Georgia, interaction, survival

INTRODUCTION

Coho salmon (*Oncorhynchus kisutch*) are an anadromous Pacific salmonid found on the west coast of North America from California to Alaska. Typically, young coho salmon spend 1–2 years in freshwater rivers and lakes before undergoing a spring transformation (termed "smoltification") and subsequent migration to the marine environment in the late spring or early summer. Smolts spend several weeks to months in the near-shore or estuarine regions prior to a second major migration to winter feeding grounds in October–November (Groot and Margolis 1991). For the coho populations utilizing the Strait of Georgia, British Columbia, this winter feeding ground is off the southwest coast of Vancouver Island (Fig. 1). Adult coho salmon then return to spawn in their natal rivers in the following late summer/early fall. Although some small programs had been initiated in the 1960s, enhancement of coho salmon productivity in British Columbia began in the 1970s with the multiple goals of increasing commercial and recreational fishing opportunities and providing economic opportunity for First Nation, coastal and other public groups (Lehmann and Irvine 2005). Currently, there are eight major hatcheries producing coho salmon which utilize the Strait of Georgia as an early rearing area, as well as a number of smaller facilities. Total production of coho salmon (Fig. 2) was 8–10 million throughout most of the 1990s, but has declined recently. Wild salmon stocks are currently not consistently monitored, and assessment data exists only for a few streams.

Coho salmon stocks utilizing the Strait of Georgia historically supported a strong commercial and recreational fishery. Beginning in the early 1980s, however, a long-term decline in coho marine survival began (Beamish et al. 2002, 2008). Throughout the 1990s, marine survival averaged < 2%, down from the 10–15% range observed in the early years of enhancement. Furthermore, in the 1990s adult coho began remaining in the over-winter feeding grounds on the west coast until immediately prior to entering the river system for spawning, rather than returning to the Strait of Georgia in early spring (Beamish et al. 2008). Combined with low marine survival, this effect was disastrous to the fishery. In 1995, management decisions closed the commercial fishery in the Strait of Georgia and in 1998 placed further restrictions on the recreational fishery. At this time, a mass marking program (adipose fin clip) for hatchery coho salmon was also instituted to provide relief for wild coho salmon stocks (via non-retention of unclipped coho). Hatchery coho salmon were dominating the population at this time (Sweet-

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ing et al. 2003), but that trend appears to have been recently reversed (Beamish et al. 2008). The mass marking program initiated in the late 1990s provided an excellent opportunity to differentiate between large numbers of hatchery and wild coho salmon compared to the low numbers (typically 2–5% of releases) of fish implanted with coded wire tags (CWTs). In 1997 only 10% of the all hatchery coho salmon were adipose fin-clipped, whereas from 1998–2007 the clip rate averaged 76% (range 67–89%).

Beginning in 1997, we conducted juvenile Pacific salmon surveys in the Strait of Georgia and surrounding waters in the summer (July) and early fall (September). As part of these surveys, we analyzed coho salmon stomach fullness ("appetite") and volumes (including the prevalence of empty stomachs), as well as identifying the percentage of prey items (the "diet") present in the stomach. In this paper, we summarize 11 years of surveys in July and September in the Strait of Georgia (1997–2007) and examine the hypothesis that juvenile hatchery-reared and wild coho have similar appetites (assessed as average stomach prey volumes) and diets (assessed as percentages of group prey items) during these critical early months in the marine environment.

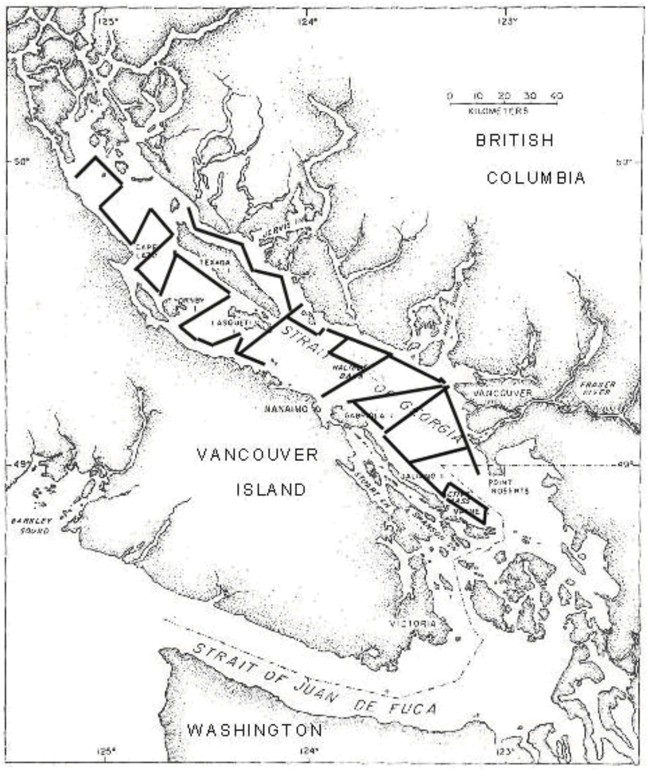


Fig. 1. Map of the Strait of Georgia and surrounding area, showing survey track lines in effect since 1997.

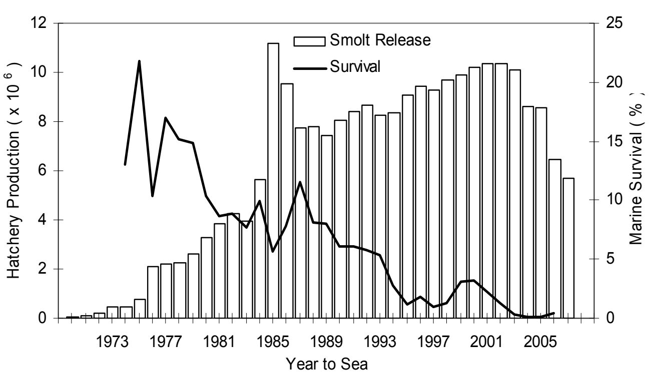


Fig. 2. Production (open bars) and marine survival (solid line) for British Columbia hatcheries releasing coho into the Strait of Georgia. Data from DFO.

MATERIALS AND METHODS

Annual surveys have been conducted in the Strait of Georgia in July and September from 1997–2007, with the exception of July 2003. Over this time period, the track lines (Fig. 1) and the fishing gear have remained constant. The fishing platform in most years has been the CCG vessel *W.E. Ricker*, but there have been some surveys using charter vessels (the M/V *Frosti* and M/V *Viking Storm*). To our knowledge, there does not appear to be any impact of fishing platform on catch, individual fish size or dietary data in these surveys. Details of the fishing gear and survey design can be seen in previous papers (Beamish et al. 2000; Sweeting et al. 2003). The gear used in these surveys is a modified 250/350/14 midwater rope trawl (Cantrawl Pacific Ltd., Richmond, British Columbia) with an average opening of approximately 14 by 32 meters under nominal fishing conditions. All sets are 30 minutes in duration and are conducted at 5 knots, as much as possible, under wind and tide conditions. To assess the vertical as well as horizontal distributions of juvenile coho salmon within the water column, the fishing effort was partitioned into 15-meter strata, roughly the height of the net opening. Thus, fishing was conducted at the surface, at 15m, at 30m, etc. This stratification was, however, weighted to surface tows such that ~half of our effort was surface tows (48% of the July survey sets, and 50% of the September survey sets). These surveys are part of a number of long-term projects investigating the Strait of Georgia ecosystem (Beamish et al. 2000, 2004; Sweeting et al. 2003). To normalize effort among surveys and years, catch data is expressed as catch per unit effort (CPUE) or, in this case, catch per hour. Survey dates, total number of sets, total coho catch, CPUE and average fork length data for the July and September surveys are shown in Tables 1 and 2, respectively.

Upon retrieval of the net, the entire catch was emptied into totes and immediately separated into individual species. All juvenile coho salmon were counted, examined for adipose clips, and checked for coded wire tags. Fork lengths were measured (to the nearest mm); sub-samples were then taken (n = 15–30) for a more intensive analysis including fork length, body weight (to the nearest 0.1 g, when weather conditions permitted), removal of otoliths and dietary anal-

Table 1. Total catch, average CPUE, and average fork length (mm) of juvenile coho salmon captured during July surveys in the Strait of Georgia from 1997-2007.

Year	Date	Number of sets	Total catch	CPUE (± SD)	Fork length (mm) (± SD)	N
1997	June 17–20, July 06–11	53	522	15.0 (42.8)	159.2 (22.54)	520
1998	June 30–July 09	60	1,245	38.1 (57.6)	172.8 (23.27)	1,220
1999	June 30–July 08	78	1,649	41.8 (66.2)	167.6 (22.31)	1,639
2000	July 11–July 20	72	4,628	126.1 (221.5)	199.7 (23.33)	3,361
2001	July 07–July 15	76	4,299	116.8 (168.5)	185.7 (21.31)	2,957
2002	July 02–July 11	86	1,887	42.8 (59.7)	170.3 (22.84)	1,887
2003	NO SURVEY	-	-	-	-	-
2004	July 04–July 13	91	2,709	59.7 (83.6)	178.9 (28.19)	2,257
2005	July 14–July 21	76	416	11.0 (23.9)	190.9 (24.28)	414
2006	July 09–July 20	65	3,338	102.4 (333.1)	194.0 (23.66)	2,257
2007	July 08–July 15	74	1,293	41.7 (64.6)	153.6 (23.17)	1,236

Table 2. Total catch, average CPUE, and average fork length (mm) of juvenile coho salmon captured during September surveys in the Strait of Georgia from 1997-2007.

Year	Date	Number of sets	Total catch	CPUE (± SD)	Fork length (mm) (± SD)	N
1997	September 08–22, 25–27	110	2,399	28.8 (53.9)	243.2 (21.75)	2,399
1998	September 08–10,12–16,23–24	78	1,510	38.4 (79.5)	243.2 (27.70)	1,385
1999	August 31–September 08	73	2,022	55.2 (121.4)	229.3 (21.80)	1,600
2000	September 09–10, 14–24, October 01	82	1,546	32.5 (42.5)	247.6 (22.92)	1,536
2001	September 16–27	87	2,040	46.6 (78.5)	254.5 (23.28)	1,794
2002	September 20–28	74	643	16.9 (40.9)	245.6 (23.13)	566
2003	September 13–22	77	843	21.8 (42.8)	231.8 (22.08)	752
2004	October 07–18	64	355	11.0 (27.0)	251.9 (24.20)	355
2005	September 14–21, 28–29	63	507	16.1 (29.2)	252.1 (24.80)	506
2006	September 08–21, October 01	59	626	21.0 (44.8)	258.8 (21.12)	626
2007	September 17–25	71	328	10.2 (41.3)	224.1 (26.48)	287

ysis. Obtaining the body weight data also allowed for the calculation of individual condition factor, using the standard formula:

Condition Factor (K) = Weight (g) / Length (mm)^3 x 100,000 (Ricker 1975)

Diet analysis involved opening the stomach from the cardiac to pyloric constrictions and removal of the contents to a Petri dish. For each stomach, a visual estimate of fullness (%) and prey volume (cc) was determined from these fresh stomach contents. Stomach volumes estimated to be less than 0.1 cc were considered empty. Thus, all stomach analyses were performed on the ship, with no preservation. This diet analysis and methodology has been performed for the entire time series by the same experienced person and all stomach contents were examined within an hour of capture. Stomach contents were broken down (by %) to the genus level (or species, when possible), as well as to life-history stage. The subsequent contribution of each food group to the overall diet was calculated as the percent contribution of each prey group (in cc) to the total volume examined over the survey. To scale for differences in fish sizes, we calculated a stomach volume index for each fish:

Stomach Volume Index = Stomach volume (cc) • 100/ body weight (g)

For ease of analysis and discussion, the diet items are organized into major prey groups: amphipods (hyperids and gammarids), decapods (crab and shrimp), euphausiids (primarily *Euphausia pacifica*), fish (primarily herring, but including sandlance, smelt, juvenile hake, juvenile walleye pollock, larval fishes and fish remains), and a category called “other”, which includes a wide range of low frequency items. Items in this final category are rare in the coho diet and, as a category, rarely exceeded 2–3% of the total coho salmon stomach prey volume.

Finally, it is important to acknowledge that the ‘wild’ coho salmon discussed throughout this paper were in fact mostly wild, with a percentage of unclipped hatchery-reared fish as not all hatchery fish received adipose fin clips. The hatchery coho salmon group, on the other hand, is composed entirely of fish of hatchery origin.

Statistical Tests

Basic descriptive statistics were performed utilizing built-in Excel (Microsoft) programs. All other statistical tests were performed using InStat (GraphPad Software, USA). All data were initially examined for normality (Instat) and significance was accepted at the α = 0.05 level. Student's *t*-tests were used to assess within-survey differences in fork length, weight, condition factor, stomach volume and fullness between hatchery and wild fish. If the data were determined to be non-parametric, then Welch's approximate *T*-test was used (InStat), which does not assume equal variances.

RESULTS

Over the course of this study (1997–2007), over 10,000 juvenile coho salmon stomachs were examined: 5,937 in July surveys and 4,677 in September (Table 3). For July surveys, the number of stomachs assessed represented an overall average of 35.8% of the total catch of juvenile coho salmon (range: 17% to 59%). For September surveys, the 4,677 stomachs examined represented an overall average of 41.9% of the total catch over the time series (range: 23% to 52%). The lower percentage values represent years of high juvenile coho salmon catch (e.g., the high catches in the 2000, 2001 and 2006 July surveys also have the three lowest percentages of juvenile coho salmon stomachs assessed). There was also no impact of depth of capture on the fork length, diet or appetite of juvenile coho salmon (data not shown). Catches and CPUE of juvenile coho salmon did decrease with depth, as noted in the literature.

There were no consistent differences in the percentages of empty stomachs in the July and September surveys between juvenile hatchery and wild coho salmon, other than the July surveys of 2004, 2005 and 2006 (Fig. 3). The overall 1997–2007 average percentage of coho with empty stomachs in the July surveys were 5.6% (± 5.93 SD) and 6.3% (± 4.31 SD) between hatchery and wild, respectively, which was not significantly different ($t = 0.302$; $P = 0.766$). There were also no significant differences in the overall percentage of empty stomachs between hatchery and wild coho salmon in the September surveys: 16.1% ± 10.00 and 18.7% ± 7.81, respectively ($t = 0.679$; $P = 0.505$). There was, however, a clear seasonal difference, as the average percent of empty stomachs in the 11 September surveys was approximately three times larger than that seen in the 10 July surveys for both hatchery ($t = 2.88$; $P < 0.01$) and wild ($t = 4.56$; $P < 0.01$) coho salmon.

The average lengths, weights, condition factors, estimated prey volumes and stomach fullness as well as the calculated stomach volume index for the summer surveys from 1997–2007 are shown in Table 4. Coho salmon determined to be of hatchery origin were significantly larger than non-hatchery coho salmon in eight of the 10 years of summer surveys, and to be significantly heavier in seven of 10 years. These differences also appeared in the average condition factor calculations (Table 4), with the wild coho having significantly larger K values in six of 10 years. These differences in condition factor, while significant, were quite small. There was only a single significant difference in the average volume of prey in the stomachs between hatchery and wild coho salmon in the summer surveys, observed in the July 2006 survey. Furthermore, there were no consistent differences in either stomach fullness or in the calculated stomach volume index in the July surveys (Table 4).

Summary data from the September surveys are shown in Table 5. The average fork lengths of hatchery coho salmon in the September surveys were again significantly longer than wild coho in 10 of 11 years and significantly heavier in nine of 11 survey years, as seen in the July surveys. Average condition factor was only significantly different between the two groups of coho salmon in the September 1997 and 2000 surveys. There were no significant differences in average prey volume or in average stomach fullness between the two groups of coho salmon in any September survey from 1997–2007 (Table 5). The range of average stomach volumes in the September surveys (1.0–5.0 cc for hatchery; 1.2–2.0 cc for wild) was slightly larger than those observed in July (0.7–2.4 cc for hatchery; 0.7–1.9 cc for wild), presumably reflecting the larger average size of these juvenile coho salmon after a further 2 months. The average stomach volume index calculated for wild coho salmon was greater

Table 3. Total number of stomachs of juvenile hatchery and wild coho salmon examined during July and September surveys in the Strait of Georgia from 1997–2007. Hatchery coho were determined by the absence of an adipose fin.

Year	July		September	
	Hatchery	Wild	Hatchery	Wild
1997	114	157	60	483
1998	221	338	227	342
1999	264	483	241	403
2000	309	476	266	445
2001	389	474	224	362
2002	276	367	109	225
2003	-	-	166	267
2004	281	350	59	120
2005	53	192	67	151
2006	205	425	74	220
2007	212	351	69	97
Total	2,324	3,613	1,562	3,115

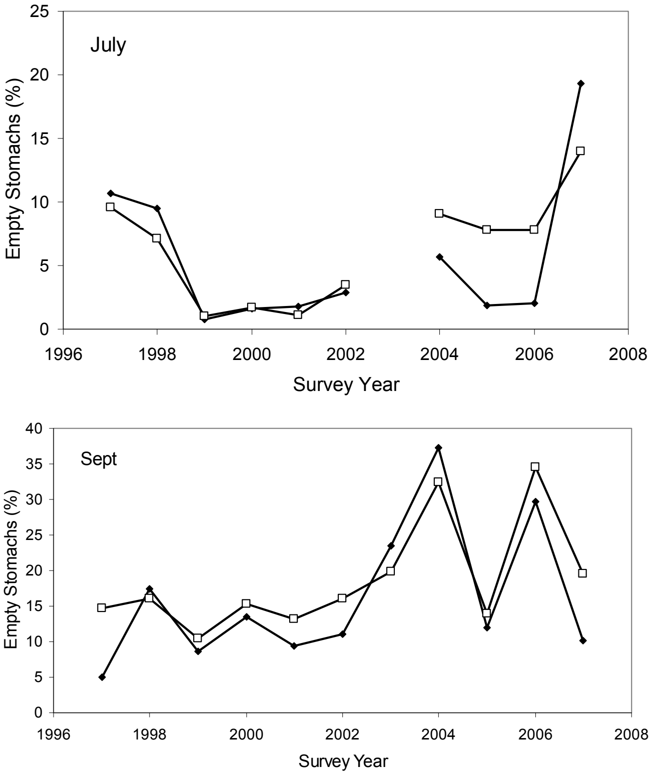


Fig. 3. Percentage of empty stomachs (total volume of prey ≤ 0.1 cc) in juvenile salmon from July and September surveys in the Strait of Georgia, 1997–2007. Closed diamonds represent hatchery coho salmon and open squares denote wild juvenile coho salmon.

than for hatchery fish in almost every September survey, but significantly so for only one of the 11 years (2005). The stomach volume index values for September surveys were also generally lower than the values calculated for the July surveys.

Diet composition of both hatchery and wild coho salmon captured in the July surveys (Fig. 4A, B) were dominated (by percent volume) by two categories: decapods (primarily crab megalops) and fish (primarily herring). In hatchery coho salmon, decapods comprised an average of 49.8% (± 25.37 SD; range: 16.7–87.7%) of stomach prey volume and fish contributed 37.3% (± 28.6 SD; 3.5–77.1%). In wild coho salmon, decapods ranged from 25.2% to 71.5% of the diet volume (average: 44.4% ± 19.58 SD) while the percentage of fish the diet volume ranged from 15.8–69.7% (average: 42.3 ± 23.2 SD). Amphipods, euphausiids and items from the "others" category combined generally comprised roughly 10% of the total stomach volume for both groups of coho (Table 6), although amphipods were significant in the diet in some years (e.g., 2001 and 2005). Furthermore, while there was some yearly variability observed (Fig. 4A, B), the shifts in diet composition were similar between both groups of juvenile coho salmon.

In the September surveys (Fig. 5A, B), decapods were no longer a major diet category in either hatchery-reared or wild coho salmon (average: 3.5% ± 3.00 SD *vs.* 3.5% ± 3.46 SD, respectively). Fish still contributed about 1/3 of the total volume of diet of both groups of coho. For hatchery coho salmon the average was 30.9% ± 29.09 SD (range: 3.6–92.4%), while for wild coho salmon the average was 31.7% ± 22.24 SD). Euphausiids were now a major diet item in both hatchery (average: 34.6% ± 24.17 SD; range: 3.3–69.5%) and wild coho salmon (average: 35.1 ± 21.32 SD), followed by amphipods (average for hatchery fish: 26.9% ± 17.7 SD; range: 3.1–70.9%; average for wild fish: 26.2% ± 14.65 SD; range: 3.1–50.1%).

The lack of significant differences between juvenile hatchery and wild coho salmon in either July or September allows one to combine the two groups and examine seasonal differences in juvenile coho salmon diet in the marine environment (Table 6). While some annual variability exists, the differences in diet between July and September were significant. The dominance of decapods in July surveys (46.7%) is replaced by a significantly ($P = 0.003$) increased presence of amphipods (26.5%, especially gammarids) and euphausiids (34.8%) ($P = 0.001$). Fish remained approximately 1/3 of the diet (by percent volume) in both July and September ($P > 0.05$, ns).

DISCUSSION

An examination of over 10,000 stomach volumes and diet compositions between hatchery and wild juvenile coho salmon in their early ocean residence failed to disclose any significant differences. Annual variability in diet composition was observed during the 11 years of this study, presumably reflecting variability in prey availability due to climate and ocean conditions. However, the changes in diet composition were seen in both hatchery and wild coho salmon smolts, and overall differences were not significantly different. Comparing the combined July diet with the combined September diet (Table 6), a seasonal shift in diet composition was also observed, that was generally larger and more consistent than annual variability. Again, both groups of coho salmon responded similarly. These results suggest that in the early marine phase (July through September of their first ocean year), there is little difference between hatchery and wild coho salmon in terms of appetite or diet.

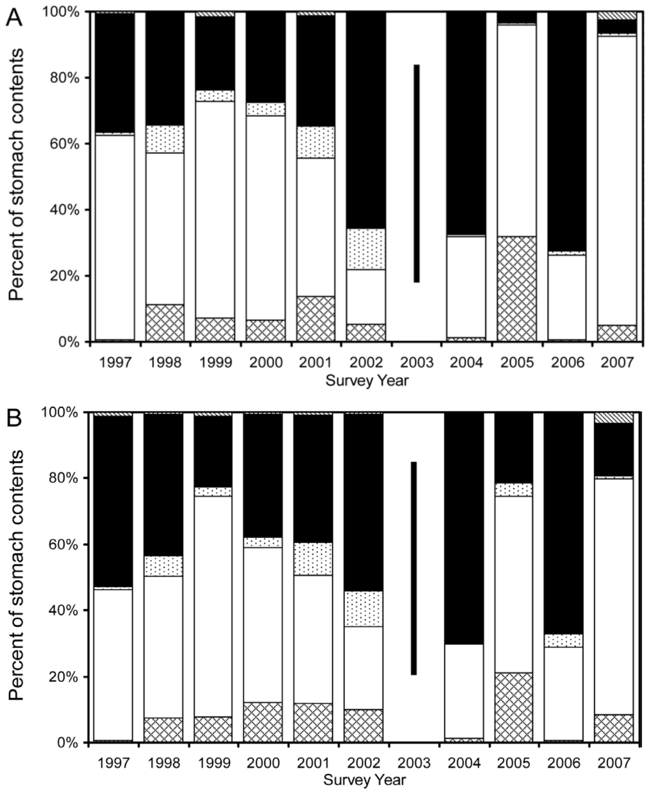
In the July surveys, the major dietary items consisted of decapods and fish. The decapods consumed were primarily crab megalops (probably *Cancer* spp.), with significant contributions by crab zoea and larval shrimp. The fish consumed were primarily juvenile herring, although a wide range of species were observed being consumed by both hatchery and wild coho salmon, including bay pipefish, Pacific sandlance, sculpins, poachers, and various juvenile and larval fish (hake, pollock, rockfish, smelts) that also utilize the Strait of Georgia as early nursery or rearing areas. Fish remains, too digested to be identified to a specific species, and fish eggs were also included in this category. Of particular interest,

Table 4. Average fork lengths (mm) (± standard deviation, n), weights (g) (± SD, n), condition factors (± SD), prey volumes (cc) (± SD), fullness (%) (± SD) and stomach volume index (SVI) (± SD) for clipped (hatchery) and non-clipped (wild) juvenile coho salmon sampled from July surveys in the Strait of Georgia from 1997-2007. An asterisk (*) denotes a significant difference between the two groups at the 0.05 level. The sample size for condition factor and SVI is equal to that for weights, whereas the sample size for prey volume and stomach fullness is equal to fork lengths. Note that no survey was conducted in July of 2003.

Year	Fork length (mm)		Weight (g)		Condition factor		Prey volume (cc)		Stomach fullness (%)		Stomach volume index	
	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild
1997	162.5 (19.55) (112)	167.0 (26.56) (156)	61.6 (24.28) (50)	67.3 (37.95) (78)	1.14 (0.13)	1.17 (0.12)	1.0 (1.01)	1.2 (1.68)	29.7 (20.31)	29.8 (20.86)	2.31 (2.03)	1.98 (2.01)
1998	179.1 (18.54)(221)	180.3 (27.12)(338)	69.1 (24.75)(202)	77.0 (43.59)(301)	1.17 (0.09)	1.20* (0.10)	0.9 (1.16)	1.1 (1.69)	29.2 (22.50)	31.3 (22.81)	1.21 (1.26)	1.41 (2.59)
1999	175.3 (19.54)(264)	170.5* (22.90)(483)	64.1 (24.51)(255)	61.2 (25.99)(472)	1.14 (0.09)	1.16* (0.09)	0.7 (0.51)	0.7 (0.50)	31.2 (19.34)	33.4 (19.79)	1.07 (0.73)	1.27* 0.82)
2000	206.1 (19.12)(309)	193.6* (30.16)(476)	110.5 (31.91)(253)	94.6* (50.98)(407)	1.21 (0.07)	1.21 (0.11)	1.8 (1.41)	1.7 (1.86)	33.6 (17.57)	33.0 (18.33)	1.60 (1.23)	1.76 (1.34)
2001	191.6 (18.68)(389)	182.8* (24.07)(474)	86.4 (26.44)(233)	77.4* (33.68)(305)	1.19 (0.09)	1.23* (0.20)	1.2 (1.00)	1.2 (1.11)	32.9 (16.60)	32.4 (17.15)	1.34 (1.01)	1.55* (1.10)
2002	176.9 (19.31)(276)	164.5* (26.99)(367)	67.4 (24.49)(276)	58.7* (32.14)(366)	1.17 (0.09)	1.20* (0.10)	1.6 (2.08)	1.4 (1.92)	37.2 (22.12)	36.0 (22.06)	2.25 (2.34)	2.31 (2.35)
2003					NO	SURVEY						
2004	194.4 (21.77)(281)	176.5* (30.00)(350)	90.9 (34.42)(240)	72.7* (44.06)(302)	1.20 (0.08)	1.23* (0.11)	2.1 (2.42)	1.9 (2.55)	39.3 (21.23)	36.5 (21.53)	2.44 (2.63)	2.64 (2.61)
2005	204.0 (19.55)(53)	189.9* (25.51)(192)	107.9 (31.40)(53)	89.0* (34.17)(192)	1.24 (0.06)	1.24 (0.09)	1.6 (1.44)	1.3 (2.14)	34.8 (15.40)	29.2* (17.57)	1.55 (1.45)	1.51 (1.88)
2006	207.7 (21.41)(205)	188.1* (26.10)(425)	117.3 (35.67)(175)	89.1* (42.74)(378)	1.25 (0.07)	1.26 (0.08)	2.4 (2.60)	1.9* (2.22)	43.8 (22.39)	40.9 (22.83)	2.08 (2.18)	2.23 (2.36)
2007	165.6 (19.95)(212)	150.3* (27.18)(351)	52.1 (19.95)(197)	42.1* (32.11)(332)	1.07 (0.10)	1.09* (0.11)	1.6 (2.69)	1.5 (2.8)	30.5 (24.20)	32.5 (23.45)	2.72 (3.38)	2.97 (3.34)

Table 5. Average fork lengths (mm) (± standard deviation, n), weights (g) (± SD, n), condition factors (± SD), prey volumes (cc) (± SD), fullness (%) (± SD) and stomach volume index (SVI) (± SD) for clipped (hatchery) and non-clipped (wild) juvenile coho salmon from September surveys in the Strait of Georgia from 1997-2007. An asterisk (*) denotes a significant difference between the two groups at the 0.05 level. The sample size for condition factor and SVI is equal to that for weights, whereas the sample size for prey volume and stomach fullness is equal to that of fork lengths.

Year	Fork length (mm)		Weight (g)		Condition factor		Prey volume (cc)		Stomach fullness (%)		Stomach volume index	
	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild
1997	245.6 (21.24)(60)	246.2 (22.39)(483)	173.4 (54.26)(56)	177.1 (22.39)(423)	1.14 (0.08)	1.17* (0.11)	1.1 (1.47)	1.3 (1.74)	28.0 (23.54)	18.1 (23.39)	0.73 (0.85)	0.67 (0.86)
1998	248.9 (24.66)(228)	234.8* (31.95)(344)	192.8 (61.95)(227)	169.0* (82.00)(341)	1.21 (0.09)	1.22 (0.09)	2.2 (3.85)	1.9 (3.71)	24.3 (28.41)	22.8 (25.29)	1.05 (1.60)	1.02 (1.73)
1999	231.2 (22.04)(241)	224.4* (22.31)(403)	146.5 (43.17)(238)	135.1* (40.08)(394)	1.15 (0.06)	1.16 (0.08)	1.4 (3.86)	1.5 (3.64)	17.6 (19.72)	20.5 (21.29)	0.99 (2.46)	1.08 (2.40)
2000	258.3 (17.90)(266)	244.2* (25.32)(445)	207.8 (47.43)(264)	183.0* (66.86)(442)	1.18 (0.07)	1.21* (0.09)	1.2 (1.91)	1.2 (2.33)	19.7 (18.50)	19.9 (18.49)	0.56 (0.84)	0.68 (1.07)
2001	262.1 (22.89)(224)	248.1* (25.25)(362)	223.1 (61.14)(175)	189.6* 62.87)(270)	1.22 (0.10)	1.21 (0.08)	2.3 (4.77)	1.8 (3.27)	18.9 (20.69)	18.4 (19.17)	1.16 (2.29)	1.10 (1.86)
2002	257.0 (17.12)(109)	242.4* (26.05)(225)	210.8 (41.70)(97)	180.0* (67.94)(215)	1.21 (0.08)	1.21 (0.08)	2.7 (3.91)	2.2 (3.26)	26.4 (23.13)	25.4 (22.74)	1.12 (1.64)	1.28 (1.83)
2003	240.1 (20.42)(166)	229.0* (23.60)(267)	160.7 (41.91)(104)	141.5* (39.83)(193)	1.15 (0.06)	1.16 (0.06)	1.0 (1.61)	1.4 (2.46)	19.5 (20.54)	25.3 (24.27)	0.61 (0.99)	0.86 (1.48)
2004	269.6 (16.42)(59)	251.1* (28.59)(120)	225.5 (45.97)(55)	190.6* (75.12)(107)	1.14 (0.07)	1.15 (0.08)	1.9 (3.81)	2.1 (4.10)	20.2 (24.88)	19.6 (23.24)	1.04 (2.21)	1.11 (2.14)
2005	263.6 (23.08)(67)	247.7* (25.92)(151)	230.6 (73.85)(67)	194.9* (61.82)(151)	1.23 (0.07)	1.24 (0.07)	1.2 (1.93)	1.6 (3.35)	18.7 (16.23)	19.7 (17.83)	0.52 (0.77)	0.82* (1.45)
2006	272.5 (19.20)(74)	257.5* (24.59)(220)	252.0 (59.77)(63)	223.3* (75.33)(185)	1.25 (0.10)	1.24 (0.08)	2.6 (4.35)	2.2 (3.82)	23.7 (25.95)	23.3 (26.54)	0.89 (1.66)	0.96 (1.83)
2007	234.6 (36.02)(61)	220.0* (29.65)(97)	179.5 (130.66)(60)	141.4 (97.62)(97)	1.24 (0.11)	1.23 (0.09)	5.5 (12.78)	2.0 (5.34)	35.7 (24.05)	29.7 (24.01)	1.71 (2.90)	1.27 (1.78)



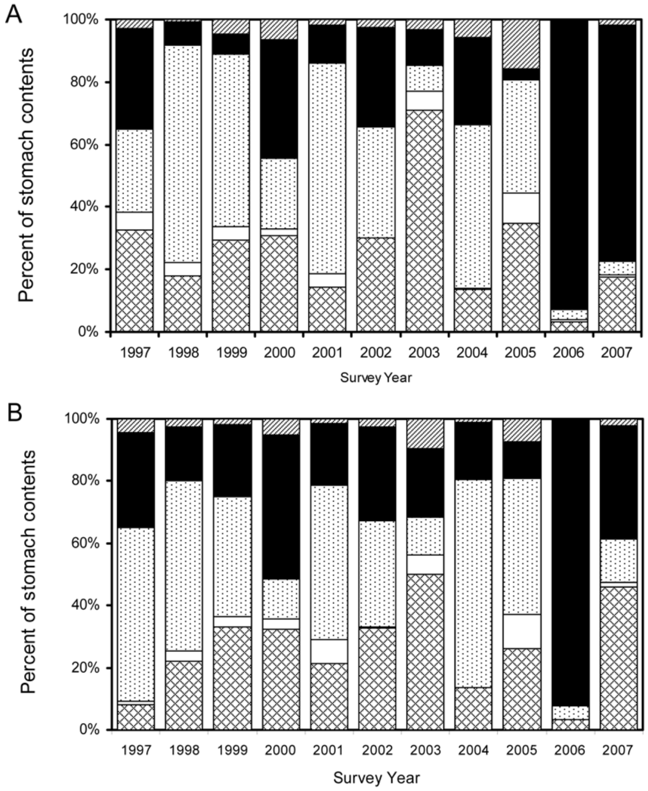


Fig. 4. Prey groups, by percent volume, in stomachs of (A) clipped and (B) non-clipped juvenile coho salmon captured in July surveys in the Strait of Georgia from 1997-2007. Prey groups are as follows: Amphipods (cross-hatch), Decapods (white), Euphausiids (stippled), Fish (diagonal stripe) and Other (black). See text for details. No survey in 2003.

Fig. 5. Prey groups, by percent volume, in stomachs of clipped and non-clipped juvenile coho salmon captured in September surveys in the Strait of Georgia from 1997-2007. Prey groups are as follows: Amphipods (cross-hatch), Decapods (white), Euphausiids (stippled), Fish (diagonal lines) and Other (black). See text for details.

Table 6. Diet composition (percent of total volume) of juvenile coho salmon from July and September surveys in the Strait of Georgia from 1997–2007. Recall that no survey was conducted in July of 2003. Asterisks by the long-term averages of each prey group in July denote significant ($P < 0.05$) differences from the September diets. See text for details of diet groups.

	July					September				
	Amphipod	Decapod	Euphausiid	Fish	Other	Amphipod	Decapod	Euphausiid	Fish	Other
1997	0.6	53.7	1.0	43.8	0.8	20.4	3.4	41.1	31.5	3.6
1998	9.4	43.4	7.4	38.4	0.5	20.0	3.7	62.2	12.4	1.7
1999	7.6	66.0	3.3	21.8	1.3	31.3	3.7	46.9	14.8	3.4
2000	9.2	54.5	3.7	32.2	0.4	31.6	2.9	17.5	42.2	5.8
2001	12.8	40.3	9.9	35.9	1.1	17.9	5.9	58.5	16.1	1.6
2002	7.6	20.9	11.7	59.2	0.5	31.3	0.3	34.8	31.1	2.5
2003	-	-	-	-	-	60.5	6.2	10.1	16.7	6.5
2004	1.2	29.5	0.6	68.9	0.1	13.4	0.3	59.5	23.3	3.4
2005	26.6	58.7	2.3	12.4	0.1	30.4	10.3	39.9	7.9	11.6
2006	0.6	26.9	2.8	69.5	0.3	3.1	0.6	3.9	92.2	0.3
2007	6.6	79.6	0.9	10.0	2.9	31.8	1.1	9.13	56.1	1.9
Average (SD)	9.1* (7.61)	46.7* (19.54)	4.7* (3.99)	38.7 (22.69)	0.8* (0.91)	26.5 (14.63)	3.5 (3.08)	34.8 (21.57)	31.3 (24.76)	3.8 (3.14)

however, was the lack of differences in the proportions of dietary categories between the hatchery and wild coho salmon. The lack of significant differences in the percentage contribution of the major food groups to the two diets within each survey suggested that both groups of coho salmon tended to prey on the same species. Furthermore, while there was annual variation observed in the overall diets, the shifts and trends were the same between both groups.

In the September surveys, the individual coho salmon were much larger, having fork lengths an average of 36% greater than in the July surveys. Euphausiids and amphipods became the primary diet categories in September, with fish continuing as major contributors. The shift by juvenile coho salmon to euphausiids and amphipods in the late summer/early autumn may reflect the shift in physiological demands from a diet coupled to increasing overall size to one related to deposition of lipid/energy stores, as suggested by Beamish and Mahnken (2001). Caloric values in the literature suggest that euphausiids (3,111 Joules/g wet wt) and hyperid amphipods (3,952 cal/g dry weight) have more energy per gram than crab larvae (2,981 J/g wet wt) (Davis et al. 1998). However, we note that similar species in different regions and/or seasons may exhibit much different values. Furthermore, the amphipod composition in July diets from 1997–2007 was ~90% hyperids (range: 47.7–99.7%), whereas in September, gammarids comprised over 50% of the amphipod category (range: 27.5–65.5%) (data not shown).

Healey (1980) examined stomach contents in juvenile coho salmon in the Strait of Georgia in 1975 and 1976, using a purse seine (approximately 480 m x 48 m). The average fork lengths of the coho salmon in the 1975 study ranged from an average of 168 mm in June to 263 mm in September, well within the ranges observed for those same months in our study. Healey found that amphipods (type not noted), decapods (primarily crab megalops), and fish (predominantly unidentifiable fish remains, but also herring and sandlance) accounted for 26.6%, 28%, and 34.6%, respectively, of diet items in 1975 and 40.5%, 11% and 28.9% of the diet items, respectively, in 1976. Thus, both the major diet items and the large interannual variability of the diet items in his study were similar to the results from our study.

Size of juvenile hatchery-reared coho salmon entering the marine environment has been shown by many authors to be a critical factor in initial marine survival as well as adult returns (e.g., Bilton 1978; Bilton et al. 1982; Beamish and Mahnken 2001; Kallio-Nyberg 2004; Chittenden et al. 2008), and we have also reported strong correlations between the average size of both hatchery and wild coho salmon and the hatchery marine survival rates in the July surveys (Sweeting et al. 2003; Beamish et al. 2008). There is less information on the impact of size on wild coho survival rates (e.g. Holtby et al. 1990), but the data supports the advantage of size. Saloniemi et al. (2004) demonstrated that wild Atlantic salmon (*Salmo salar*) had higher survival rates of similar sized hatchery-reared progeny and that this was particularly greater in years of poor survival. The 'advantage' of size has been attributed to several wide-ranging impacts: increased hypo-osmoregulatory capacity, enhanced predator avoidance due greater swimming speeds, and wider ranges of prey prospects. In this study, the larger hatchery coho salmon did not possess significantly greater prey volumes in their stomachs in either the July or September surveys, indicating that the food available to the fish was accessed similarly by both groups. This held true even when the size effect was scaled using a stomach volume index. Due to the difficulty of weighing small amounts of stomach material while at sea, we utilized a volume/weight index. This index is similar to indices used in other studies (e.g., Armstrong et al. 2008; Boldt and Haldorson 2002; Brodeur et al. 2007), with similar results and conclusions. Also, there were no significant correlations between fish size and the proportion of any prey group in the diet (data not shown). Thus, the proposed difference in marine survival incurred by larger fish does not appear to be due to increased consumption rates (i.e., "appetite") or prey choice (i.e., "diet")

Another index of appetite, and perhaps survival, is the percentage of empty stomachs. The lack of differences observed between the two groups suggests that both hatchery and wild coho salmon were encountering and consuming food items equally. The range of empty stomach percentage observed in our studies (10–20% in July surveys, 5–35% in September surveys) are higher than earlier studies performed in the same study area (e.g., Landingham et al. 1998; Barraclough and Fulton 1968), but roughly similar to those noted for juvenile coho salmon by Brodeur et al. (2007) and Weitkamp and Sturdevant (2008) in other areas but over similar years. The larger percentage of empty stomachs observed in September surveys than in July surveys suggests that food becomes a limiting factor in the fall, and supports published models on the importance of overwinter survival (e.g., Beamish and Manhken 2001).

In conclusion, a decade of examining stomach volumes and contents failed to demonstrate any significant differences between hatchery and wild juvenile coho salmon in either July or September in the Strait of Georgia, despite some clear differences in size between the two groups. While annual variability existed, hatchery and wild coho salmon tended to follow the same trends and shifts in diet. Seasonal variability in diet was significantly greater than annual shifts, and seemed to support the hypotheses of increased energy storage becoming more important than growth per se in the fall/winter months.

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