REVIEW & SYNTHESIS OF S.E. ALASKA MARINE JUVENILE CHINOOK RESEARCH PROGRAMS AND FINDINGS

Extended Abstract:

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Chinook salmon are the largest and least abundant of the five species of Pacific salmon spawning in southeast Alaska (SEAK). They occur primarily in large mainland river systems in the region, with only a few small stocks found among the myriad island streams in the Alexander Archipelago (Halupka et al. 2000). Chinook salmon in SEAK are stream-type; most rear in freshwater for a year and emigrate as yearling smolts. Hatchery production of Chinook salmon to enhance commercial and recreational fisheries has been developed in the region (Heard et al. 1995). Hatchery brood stocks are derived from SEAK wild stocks, and hatcheries are located at least 50 km from watersheds with natural Chinook production. As with other stocks of Chinook salmon in Alaska, there is concern about declines in productivity and escapements of Chinook salmon in SEAK (ADFG 2013). To provide insight into how conditions in the marine environment are affecting Chinook salmon in the region, this presentation focuses on three information sets relevant to the survival and marine ecology of juvenile Chinook salmon in SEAK: 1) coded-wire tag (CWT) studies providing estimates of marine survival of SEAK wild and hatchery Chinook salmon stocks; 2) long-term marine survival data for Chinook salmon released at the Little Port Walter (LPW) Marine Station; and 3) the Southeast Alaska Coastal Monitoring (SECM) program.

CWT Studies

There has been extensive CWT marking of both hatchery and wild SEAK Chinook salmon, directed at evaluating efficacy of hatchery programs, improving understanding of life-history and production parameters of wild stocks, assessing contributions to regional fisheries, and providing information for harvest management. Tagged hatchery fish are released from facilities operated by private non-profit hatchery organizations and at the LPW marine station operated by the Federal government. Wild-stock tagging is carried out by the Alaska Department of Fish and Game (ADFG). The release of CWT fish into the marine environment allows direct estimation of marine survival, defined here as the total estimated catch and escapement of tagged groups divided by the number of tagged smolts released. For this presentation, CWT data are used to compare trends in marine survival for hatchery and wild stocks of SEAK Chinook salmon; for cross-correlation analysis to evaluate local and regional coherence in the survival rates between release sites; and to examine the association of survival rates with regional-scale environmental factors. Hatchery and wild stocks used were those that had information through the 2007 brood (the last brood year with recovery data complete through age-6) and at least 10 years of tagging data. Because hatchery releases often involve multiple releases at different sizes and culture strategies, only tag groups of yearling smolts derived from the same ancestral stock and released at the “standard” time and location by the hatchery were included in the analyses. Annual average hatchery smolt weight was a weighted average of average group weight and number released. Mini-jacks (age-2 returns) were excluded from the calculation of marine survival. For statistical comparisons, marine survival rates were transformed using the square root arcsine. The statistical comparisons were done as exploratory data analysis, with $P < 0.05$ considered significant. No corrections in probability assignments were made for multiple comparisons or autocorrelation in the time series.

A total of 8 hatchery and 4 wild stocks were compiled for comparisons (Figure 1, Table 1). Length of time series of data ranged from the past 10 complete broods (1998-2007) to as far back as the 1976 brood (Table 1). Smolts from wild stocks are notably smaller than yearling smolts released at the various hatcheries, averaging 3-5 g versus 14-42 g. However, survival rates were generally as high or higher for the wild smolts (Table 1). Trends in survival were evaluated as the slope of the regression of survival with year, with three different time periods considered (Figure 2). For the most recent time period, negative slopes were observed for all four wild stocks and seven of the eight hatchery stocks (Figure 2A). At $P < 0.05$, three of the negative slopes and the one positive slope were different from zero. The stock with the positive slope, Neets Bay, underwent a major change in hatchery strategy in the mid-1990s (Susan Doherty, SSRAA, personal communication) but this transition was complete prior to the 1998-BY. For the 10 stocks with data extending back to the 1988-1992 broods, negative slopes again predominated (8 versus 2), with significant negative slopes for two northern SEAK hatcheries and significant positive slopes for two southern SEAK hatcheries (Figure 2B). For five stocks with data extending back to 1976-1982 broods, three hatchery stocks had slopes virtually identical to zero, and three were negative; two of the negative slopes were significantly different from zero (Figure 2C). In summary, marine survivals have tended to have a downward trajectory, with more pronounced declines for the most recent years. The general decline is also reflected in that average marine survivals for the last five complete brood years (2003-2007) are below long-term averages for 11 of the 12 stocks (Table 1). The exception is Neets Bay, which may have been an effect of the recent change in culture strategy.

For wild stocks of Chinook salmon, the tagging programs have also allowed estimation of smolt production (Figure 3). Three of the wild stocks (Chilkat, Taku, and Unuk) have shown a positive slope in smolt numbers over time up to the 2007 brood, while the Stikine has had a negative slope; none of the slopes was significantly different from zero. Thus any declines in productivity in these wild stocks in recent years are more likely attributable to marine rather than freshwater factors. Riddell et al. (2013) also attributed recent declines in many southern British Columbia Chinook salmon to conditions in marine habitats affecting early marine survival.

Local coherence of marine survival rates was examined with cross-correlation of the 12 hatchery and wild stock marine survival series, and plotting the bivariate correlation coefficient as a function of water-distance between the marine point-of-entry for each tagged stock. High variability in correlation was observed over even relatively short distances (Figure 4A), but high correlations (>0.5) were much more frequent for closer stocks (Figure 4B). Only 1 of 33 pairs located more than 300 km apart had an $r > 0.5$, and four of five (80%) of the pairs entering the marine environment within 100 km of each other had $r > 0.5$. Sharma et al. (2012) also found local coherence in marine survival rates and that correlations > 0.4 were rare at distances beyond 400 km for paired comparisons of Chinook salmon survival rates for 22 stocks of Chinook salmon distributed from northern California to SEAK. Stock and stock-type as well as geographic proximity influenced the degree of correlation. For hatchery stocks with similar ancestral origin, and wild stocks with “outside” distributions, correlation of survival time series tended to be higher over a broader range of distance between marine entry points (Figure 4C).

Four region-scale environment variables, two physical and two biological, were evaluated for correlation with the marine survival time series. One physical variable was the November to March average for the Pacific Decadal Oscillation (PDO) during the winter prior to Chinook salmon entry into the ocean; this index has been linked to year-class strength of juvenile salmon in their first year at sea (Mantua et al. 1997). The second physical variable was the June-July-August average in the year of ocean entry for the North Pacific Index (NPI); NPI is a measure of atmospheric air pressure in the GOA thought to affect upwelling and downwelling oceanographic conditions (Trenberth and Hurrell 1994), and has been significantly correlated with year-class strength of pink salmon in SEAK (Wertheimer et al. 2013). One biological variable was a juvenile salmon index, an index to the number of juvenile hatchery pink and chum and juvenile wild pink salmon in the SEAK region. Both hatchery releases and pink salmon harvests have increased greatly over the past 40 years, and the increased abundance of juveniles has been identified as potentially a predator buffer or competition for other salmon species in the marine environment of SEAK (Briscoe et al. 2005; LaCroix et al. 2008 ; Mallick et al 2008). The index was generated by combining a standardized time series of the number of annual releases of pink and chum salmon in the region (from ADFG 2014a) and a standardized time series of SEAK pink salmon harvests (from ADFG 2014b). Harvest was used as an index of juvenile pink salmon because of the strong relationship observed between SEAK pink salmon harvest and catch of juvenile pink salmon during SECM sampling (Wertheimer et al. 2013); the standardized harvest data was lagged one year to coincide with the juvenile year. The second biological variable was an abundance index to the number of humpback whales in SEAK. Humpback whales have been increasing since being protected in the 1960s; they are large consumers of zooplankton and small fishes, and have been observed predating on juvenile salmon, including hatchery releases of Chinook salmon (personal communication, Roger Vallion, Northern Southeast Alaska Aquaculture Association). The index to humpback numbers were derived from population estimates and population growth rates in SEAK reported by Hendrix et al. (2008).

The correlations of the survival data to the regional factors considered are summarized in Table 2. No consistent pattern was apparent for the PDO, NPI, or the juvenile salmon index across the region. Survival was negatively correlated with PDO for five stocks, and positively for seven stocks; two of the positive correlations were significant. For the NPI, survivals for four of the stocks were negatively correlated, and four positively; none of the correlations was significant. These results suggest no consistent effect for the physical parameters. Survivals for seven of the stocks were negatively correlated with the juvenile salmon index, and five positively; one of the negative correlations and two of the positive correlations were significant. These results are consistent with the concept that density of other juvenile salmon could have either positive or negative impact on marine survival, depending on whether predator-buffering or competition is the more important factor affecting survival (Holtby et al. 1990; Mallick et al. 2009). The whale index had the most consistent relationship with Chinook salmon survivals; 11 of the 12 stocks were negatively correlated with whale abundance, and four of these correlations were significant. While the correlations may simply be a coincident of unrelated population trajectories, the results highlight the importance of on-going research of the potential impact of whale predation on juvenile salmon, especially at hatchery release locations.

LPW Long-Term Data Series

The LPW marine station is a facility on Baranof Island (Figure 1) operated by the NOAA Fisheries/National Marine Fisheries Service Auke Bay Laboratories. It is the oldest year-round biological research station in Alaska and has been host to a wide variety of fisheries research projects since 1934. Research on Alaska stocks of Chinook salmon was initiated with the 1976 brood, and has included brood stock development, evaluation of hatchery technologies and rearing strategies, genetics, fisheries distribution and contributions, and maintenance of a long-term marine survival time series. Two stocks, one derived from Chinook salmon from the Unuk River and one derived from Chinook salmon from the Chickamin River, have been released at LPW starting with the 1976 brood. Unuk River Chinook salmon gametes were transplanted to LPW for the 1976-1980 broods, and releases have been made annually from each subsequent brood from fish returning to LPW, with the exception of the 2000 BY. For the Chickamin stock, only one transplant occurred in 1976, and subsequent releases were progeny from returns from that transplant. As a result, there are less brood years represented in the Chickamin time series since 1976, 22 years versus 31 years for the Unuk stock (Table 1). Marine survival for smolts with similar culture history are highly correlated between the two stocks ($r = 0.92$, Figure 5), again emphasizing the importance of local conditions on survival.

As noted previously, much smaller wild smolts have marine survivals equal on average to those of much larger hatchery fish (Table 1), suggesting that size-selective predation is not a critical factor for SEAK Chinook salmon. Comparisons of smolt size over time can be confounded, however, by hatchery effects, location effects, and year effects. At LPW, CWT groups of yearling Unuk-stock smolts have been cultured under similar conditions and released at the same time, but at different average sizes. Martin and Wertheimer (1989) found that for the 1977 and 1978 broods, larger smolts had higher marine survival and younger age at maturity than smaller smolt. Their analysis was expanded in this report to include six additional brood years of LPW-Unuk stock yearling smolts cultured under similar conditions and released at different average sizes, where “large” smolts were at least double the weight of ”small” smolts (Figure 7). To account for the effect of younger age at return from larger smolts, marine survivals were determined to Age-3 recruitment using cohort reconstruction methods and the age-specific natural mortality rates from the Pacific Salmon Commission Chinook salmon model (CTC 2014). For all eight brood years for which comparative groups were available, survival to Age 3 was higher for larger smolts (Figure 7). The proportionate increase in survival was greater when the small smolt average size was 12 g or less, ranging from 225% to over 500% increased survival. These results are consistent with both size-selective predation as an important factor affecting marine survival of juvenile salmon (Parker 1971; Willette et al. 2001; Wertheimer and Thrower 2007) and the critical-size hypothesis for juvenile salmon entering their first winter at sea (Beamish and Mahnken 2001; Moss et al. 2005). The results also suggest that the foraging and predator avoidance experience of wild smolts compensates for their smaller size at entry into the marine environment.

The long-term LPW time series were also used to examine the effects of local and regional factors on interannual variability in survival. Seven parameters were considered, the four regional factors identified in Table 2, and three additional “local” parameters that could be affecting early marine survival: 1) May-June average water temperatures in Sashin Creek (FW-Temp), the stream flowing into LPW and directly affecting surface water temperatures in the LPW estuary (Powers 1963); 2) 2-m depth May-June average seawater temperatures (SW-Temp) in the LPW estuary; and 3) the number of hatchery pink or chum salmon released within 20 km of LPW. A backward/forward stepwise regression approach was used, with a $P < .15$ for a variable to enter the model. The amount of variability explained (adjusted R^2) and the Akiake Information Criterion corrected (AICc) for small sample sizes (Shono 2000) were compared for each significant step of the stepwise regression.

The LPW-Unuk survivals were significantly correlated with temperature conditions, including FW-Temp, SW-Temp, and the PDO (Table 6). The LPW-Chickamin stock was similarly significantly correlated with FW-Temp and PDO, but was also significantly correlated with all three biological parameters: local hatchery releases, juvenile salmon index, and whales.

Regression model results for the two stocks are summarized in Table 5. For the LPW-Unuk stock, the model with FW-Temp, juvenile salmon index, and PDO explained the most variability (R^2 = 38%); AIC_c values were similar for this model and two-parameter models containing FW-Temp with either the juvenile salmon index or PDO. For the Chickamin stock, the model with PDO, juvenile salmon index, FW-Temp, and SW-temp had both the highest R^2 (70%) and discernibly lower AIC_c (difference >2, Burnham and Anderson 2002). The results for both stocks indicate a positive influence of local surface water temperatures and regional temperature conditions and a negative influence of the regional-scale abundance of juvenile salmon during the first year at sea on the observed variability in survival for the Chinook salmon smolts at LPW. For the Chickamin stock, local SW temperatures had a negative effect in the model. This seems contradictory to the positive effect of the PDO, but is consistent with the effect of summer seawater temperatures in Icy Strait in models relating pink salmon year class strength to juvenile abundance and environmental factors (Wertheimer et al. 2013). While the factors affecting marine survival of LPW Chinook are similar for both stocks, about twice as much variation in survival is explained for the LPW-Chickamin releases even though the survival time series are highly correlated. This is likely due to the “missing” brood years of Chickamin stock in the late 70’s and 80’s, when interannual variability in survival was extremely high for Unuk stock releases (Figure 5).

The factors associated with LPW survivals may not have similar effects on marine survivals of other SEAK stocks. Mallick et al. (2008) found that for 14 SEAK coho salmon stocks, marine survivals are not equally influenced by the same factors. A preliminary analyses using stepwise regression to relate marine survival of the other 10 SEAK Chinook stocks to only the four regional environmental parameters in Table 2 indicates differing effects on the stocks (Table 5). For the stocks with resultant regression models significant at $P < 0.05$, the juvenile salmon index had a positive effect on two stocks and a negative effect on two stocks; whales had a negative effect on five stocks and a positive effect on one stock; and PDO had a negative effect on one stock. The next step with this line of inquiry for SEAK hatchery and wild Chinook salmon is to further develop sets of local and regional factors for evaluating with all 12 of the marine survival time-series.

Southeast Coastal Monitoring Program

The SECM survey was implemented in 1997 to identify the relationships between year-class strength of juvenile salmon and biophysical parameters that influence their habitat use, marine growth, prey fields, predation, and stock interactions (NOAA 2014). SECM sampling occurs primarily around Icy Strait (58°N, 136°W) in the northern region (Figure 1). Chinook salmon are the least abundant juvenile salmon species sampled (Orsi et al. 2012, 2013a); in 2011 and 2012, juvenile Chinook salmon comprised 0.1% and 0.2% of the juvenile salmon captured in SECM surveys (Table 6). This low catch is consistent with the low number and abundance of Chinook salmon salmon in SEAK relative to other species. Because the trawl used for SECM sampling fishes the surface to 24 m depth, Chinook salmon juveniles may also be less susceptible to capture, as they distribute deeper in the water column than other juvenile salmon (Orsi and Wertheimer 1995). Orsi et al. (2000) found that juvenile Chinook salmon have different habitat utilization patterns than the other species of Pacific salmon, occurring more frequently in nearshore waters and becoming more abundant in Icy Strait later in the summer when the abundance of other species had declined (Figure 7). Juvenile Chinook salmon have different diets than juveniles of the other salmon species in SEAK). They are much more piscivorous than pink, chum, or sockeye salmon juveniles (Table 7). While juvenile coho salmon also can be highly piscivorous, Weitkamp and Sturdevant (2006) analyzed SECM diet data from 1997-2000, and found that Chinook salmon juveniles ate more biomass of fish and less of crustaceans than coho salmon juveniles. These differences in temporal and spatial distribution and in feeding habits indicate that juvenile Chinook salmon utilize the SEAK nearshore and coastal marine ecosystem differentially from the other salmon species.

The CPUE of juvenile pink salmon sampled by SECM has been highly correlated with year class success of SEAK pink salmon, and has been used to effectively forecast regional harvest of pink salmon (Wertheimer et al. 2013). Orsi et al. (2013b) has looked at the use of catch per unit effort (CPUE) for juvenile Chinook salmon in August and immature (ocean Age 1) Chinook salmon in June as indicators of brood year marine survival for stocks of northern SEAK Chinook salmon that migrate through Icy Strait. This presentation updates the correlative evaluation of SECM Chinook CPUE with four northern SEAK stocks (Table 8). No significant correlations were found between juvenile Chinook CPUE and marine survival. Correlations were uniformly higher between ocean Age-1 CPUE and survival, and were significant with $r > 0.7$ for Chilkat wild, Macaulay Hatchery, and Hidden Falls Hatchery stocks. These results support the hypothesis that a critical period for Chinook salmon production occurs prior to their second ocean summer and that the relative abundance of ocean Age-1 Chinook salmon in SECM sampling may be indicative of survival through the first ocean year. The results should be considered with caution, as numbers of juvenile and Age-1 Chinook salmon sampled by SECM are generally low. However, an advantage of long-term monitoring programs such as SECM is the capability to test this type of hypothesis. The CPUE of age-1 Chinook salmon in 2013 was the highest on record. If these catches are indicative of strong year classes, they should be associated with high marine survival of the 2010 broods.

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Table 1. Stock origin, brood years (BY), average smolt size, and average marine survival of 12 stocks of wild and hatchery southeast Alaska Chinook salmon marked with coded-wire tags.

Stock	Stock Type	Stock Origin	Brood-year Range	Number Brood Years	Average Smolt Size (g)	Average Marine Survival	
						All Broods	1998-2007
Chilkat River	Wild	Chilkat River	1998-2007	10	4.2	3.1%	2.6%
Taku River	Wild	Taku River	1992-2007	16	4.3	3.1%	2.3%
Stikine River	Wild	Stikine River.	1998-2007	10	4.6	1.8%	1.2%
Unuk River	Wild	Unuk River.	1992-2007	16	3.2	2.4%	2.1%
Macaulay	Hatchery	Andrews Creek	1989-2007	15[1]	24.1	1.5%	0.9%
Hidden Falls	Hatchery	Andrews Creek	1981-2007	27	30.0	1.6%	1.1%
Medvejie	Hatchery	Andrews Creek	1982-2007	25[2]	42.0	2.0%	1.6%
Crystal Lake	Hatchery	Andrews Creek	1990-2007	18	13.9	0.7%	0.3%
LPW-U[3]	Hatchery	Unuk River	1976-2007	31[3]	25.6	3.1%	1.8%
LPW-C[4]	Hatchery	Chickamin River	1976-2007	22[4]	25.8	2.7%	1.2%
Neets Bay	Hatchery	Chickamin River	1981-2007	25[5]	29.1	2.5%	3.7%
Whitman Lake	Hatchery	Chickamin River	1980-2007	24[6]	25.1	2.6%	2.4%

[1]Excludes 1993-1996BY of King Salmon River releases

[2]Excludes 1990BY

[3]LPW-U is Little Port Walter Unuk stock. Excludes 2000BY.

[4]LPW-C is Little Port Walter Chickamin stock. Excludes 1977-1980BY; 1983-1985BY; and 2000BY.

[5]Excludes 1993BY

[6]Excludes 1981-1982BY

Table 2. Correlation of marine survival time series for 12 stocks of southeast Alaska Chinook salmon with four indexes of physical or biological environmental factors potentially affecting juvenile Chinook salmon.
Numbers shown are the Pearson's correlation coefficients (r); bolded numbers indicate significant difference of the correlation from zero at *P* < 0.05 (not corrected for multiple comparisons).

Stock	Pacific Decadal Oscillation (PDO)	Ntorh Pacific Index (NPI)	Juvenile Salmon Abundance Index	Humpback Whale Abundance Index
Chilkat River	-0.105	0.328	-0.094	**-0.686**
Taku River	-0.015	0.131	-0.014	**-0.589**
Stikine River	-0.438	-0.303	0.192	-0.419
Unuk River	-0.043	-0.075	0.335	-0.143
Macaulay	-0.048	0.027	-0.004	**-0.682**
Hidden Falls	-0.056	0.202	**0.557**	-0.029
Medvejie	-0.233	0.363	**0.420**	-0.218
LPW-U	**0.496**	0.178	-0.144	-0.337
LPW-C	**0.581**	0.285	**-0.475**	**-0.509**
Crystal Lake	0.221	-0.082	0.391	-0.190
Neets Bay	0.085	-0.005	-0.363	0.239
Whitman Lake	0.311	0.061	-0.309	-0.148

Table 3. Correlation coefficients for local and regional environmental factors and marine survival of two stocks of yearling Chinook salmon smolts released at Little Port Walter from brood years 1976-2007. Parameters with statistically significant correlations are in bold text for *P* < 0.05.

	Unuk Stock		**Chickamin Stock**	
Parameter	**r**	**P-Value**	**r**	**P-Value**
Local				
FW May/June Temperature	**.548**	**0.001**	**.514**	**0.014**
SW May/June Temperatures	**.417**	**0.020**	.202	0.368
Pink/chum hatchery releases	-.284	0.122	**-.482**	**0.023**
Regional				
PDO	**.496**	**0.005**	**.581**	**0.005**
NPI	.178	0.339	.285	0.198
Juvenile salmon index	-.144	0.144	**-.475**	**0.025**
Whale index	-.337	0.064	**-.509**	**0.016**

Table 4. Regression models relating marine survival of two stocks of yearling Chinook salmon smolts released at Little Port Walter from brood years 1976-2007 to local and regional environmental factors. R^2 = coefficient of determination for model; AIC_c = Akiake Information Criterion (corrected); P = statistical significance of regression equation. Plus or minus signs before a factor indicate direction of effect on marine survival.

Model	**Adjusted R^2**	**AIC_C**	**Regression *P* -value**
Unuk Stock			
+FWTemp	28%	-85.768	0.001
+FWTemp – Juv.Index	35%	-87.679	0.001
+FWTemp + PDO	34%	-87.448	0.001
+FWTemp – Juv. Index + PDO	38%	-87.597	0.001
Chickamin Stock			
+PDO	30%	-92.254	0.005
+PDO – Juv.Index	51%	-101.956	<.001
+PDO – Juv.Index + FWTemp	65%	-111.579	<.001
+PDO – Juv. Index + FWTemp – SWTemp	70%	-115.672	<.001

Table 5. Factors identified in stepwise regression models relating marine survival of four wild stocks and six hatchery stocks in relation to four region-scale environmental factors: PDO, NPI, juvenile salmon index (JSI), and whale index. Factors entered or stayed in the model at $P < 0.15$. Plus or minus signs before a factor indicate direction of effect on marine survival.

Stock	**Model**	**Adjusted R^2**	**Regression *P* -value**
Chilkat River	– Whales – JSI	60%	0.016
Taku River	– Whales	35%	0.016
Stikine River	none	---	---
Unuk River	none	---	---
Macaulay	– Whales	42%	0.005
Hidden Falls	+ JSI – Whales	32%	0.004
Medvejie	+ JSI – Whales – PDO	31%	0.014
Crystal Lake	+ JSI	10%	0.109
Neets Bay	– JSI + Whales	22%	0.022
Whitman Lake	+ PDO	6%	0.122

Table 6. Number and percentage by species of juvenile salmon sampled in SECM surveys in 2011 and 2012.

	2011		2012	
Species	**Number**	**Percent Total**	**Number**	**Percent Total**
Pink	2929	74.0%	32827	56.7%
Chum	1211	20.0%	8880	23.4%
Sockeye	408	2.9%	1296	7.9%
Coho	606	3.0%	1336	11.7%
Chinook	11	0.1%	38	0.2%
Chinook ocean Age-1	101	0.1%	31	1.9%

Table 7. Composition of diets of juvenile salmon by percent weight of prey category for juvenile Chinook salmon sampled in SECM during summer, 1999.

Prey Category	**Pink Salmon**	**Chum Salmon**	**Sockeye Salmon**	**Coho Salmon**	**Chinoook Salmon**
Fish	0.0	0.0	0.0	54.7	67.6
Euphausids	3.5	2.7	32.6	20.2	0.3
Decapods	7.6	0.6	0.4	23.7	14.2
Larvacea	88.0	96.4	66.3	0.0	0.0
Hyperiids	0.1	0	0.3	1.3	4
Insects	0	0	0	0	4.9
Other	0.9	0.3	0.4	0.1	9.0

Table 8. Correlation of marine survival of four stocks of Chinook salmon and August average CPUE of juveniles and June average CPUE of ocean-Age 1 Chinook salmon captured in SECM sampling, 1997-2009. Correlations significant for $P < 0.05$ are bolded.

Stock	**Brood Years**	**Correlation with juvenile CPUE**	**Correlation with ocean Age-1 CPUE**
Chilkat Wild	1998-2007	- 0.048	**0.733**
Taku Wild	1995-2007	0.352	0.502
Macaulay Hatchery	1997-2007	0.056	**0.879**
Hidden Falls Hatchery	1995-2007	0.499	**0.745**

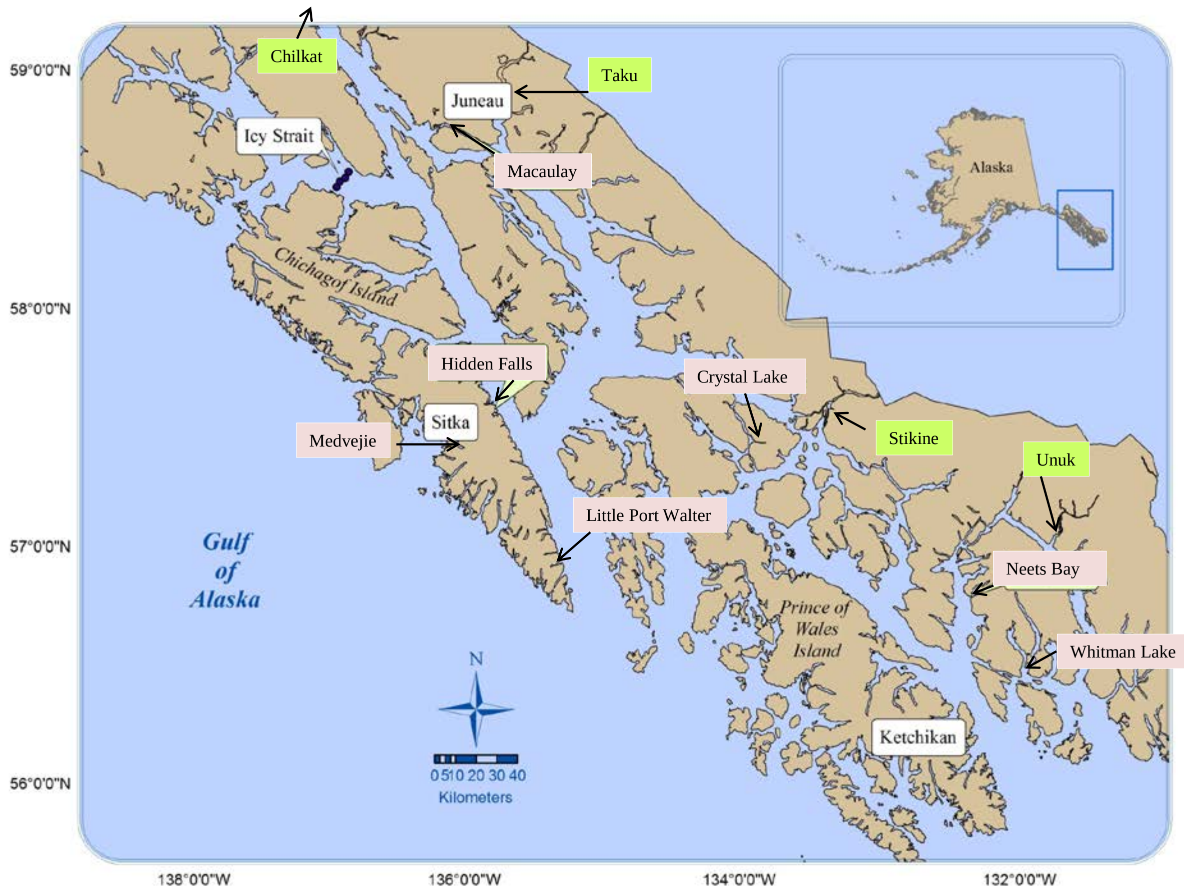

Figure 1. Southeast Alaska, showing locations of hatchery stocks (pink boxes) and wild stocks (green boxes) used in this report. The SECM Icy Strait transect is also shown as the dotted line.

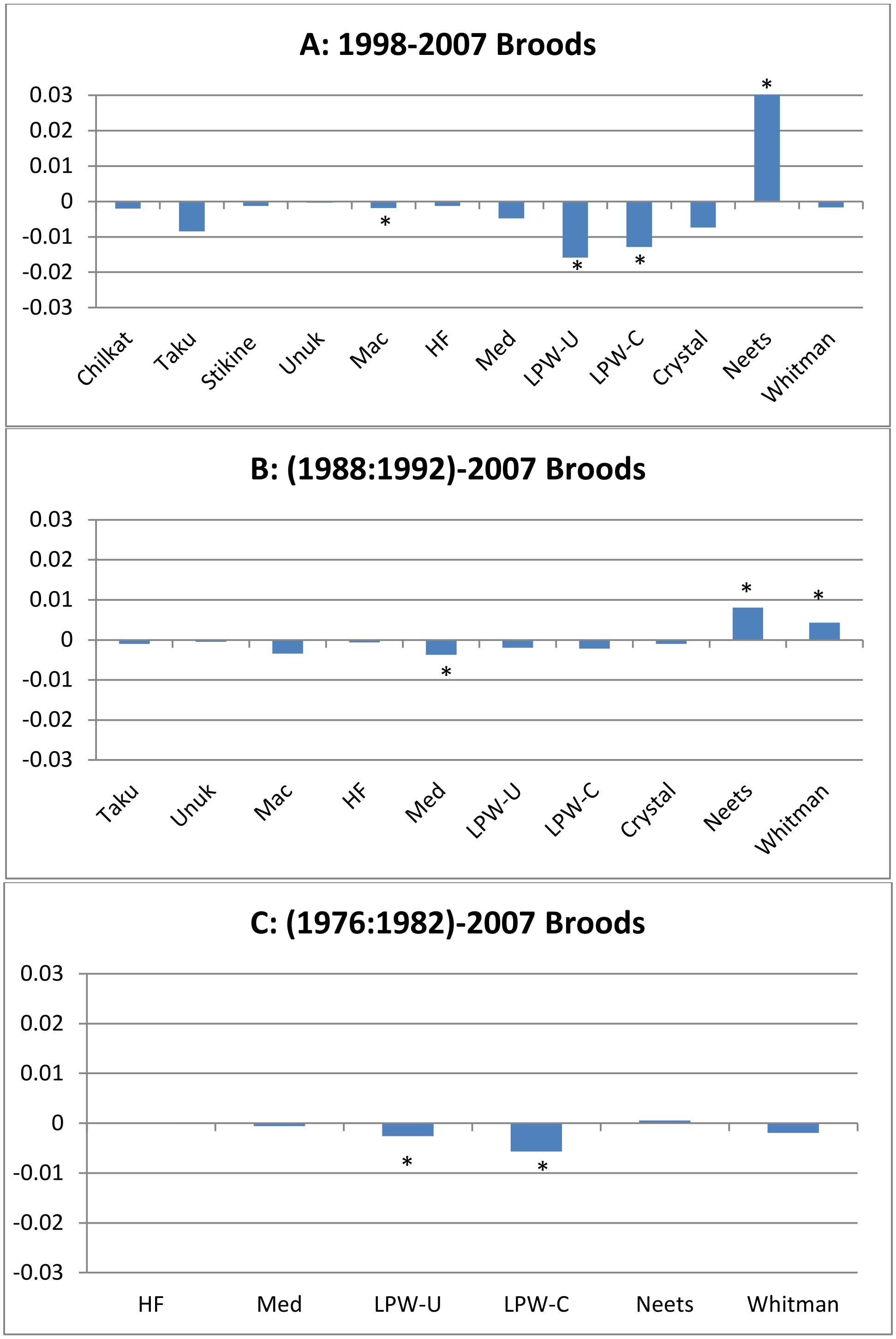

Figure 2. Slopes of linear regression of marine survival with brood year for SEAK Chinook salmon over three time ranges. Asterisks indicate slopes significantly ($P < 0.05$) different from zero.

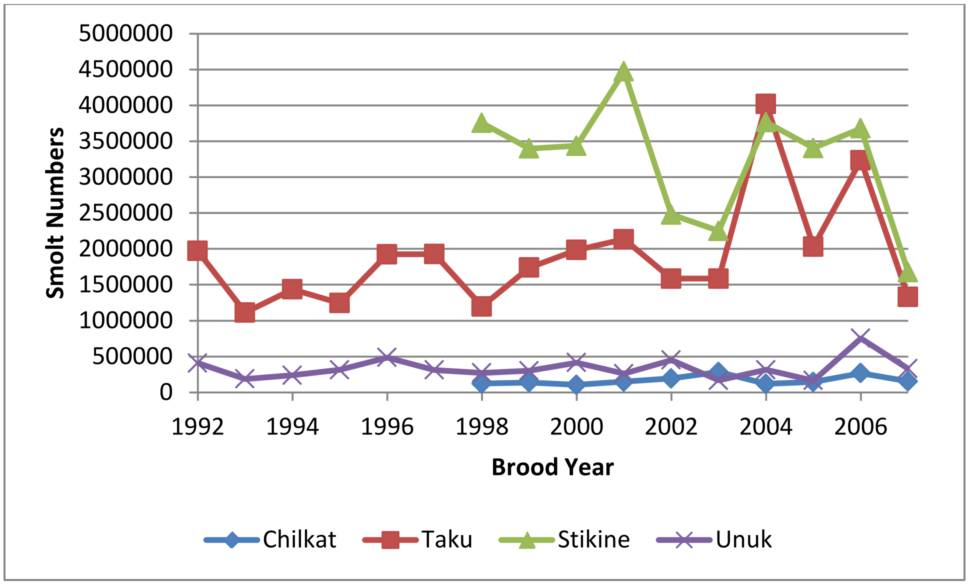

Figure 3. Estimated smolt numbers from four wild stocks of southeast Alaska Chinook salmon (personal communication, P. Richards, Alaska Department Fish and Game).

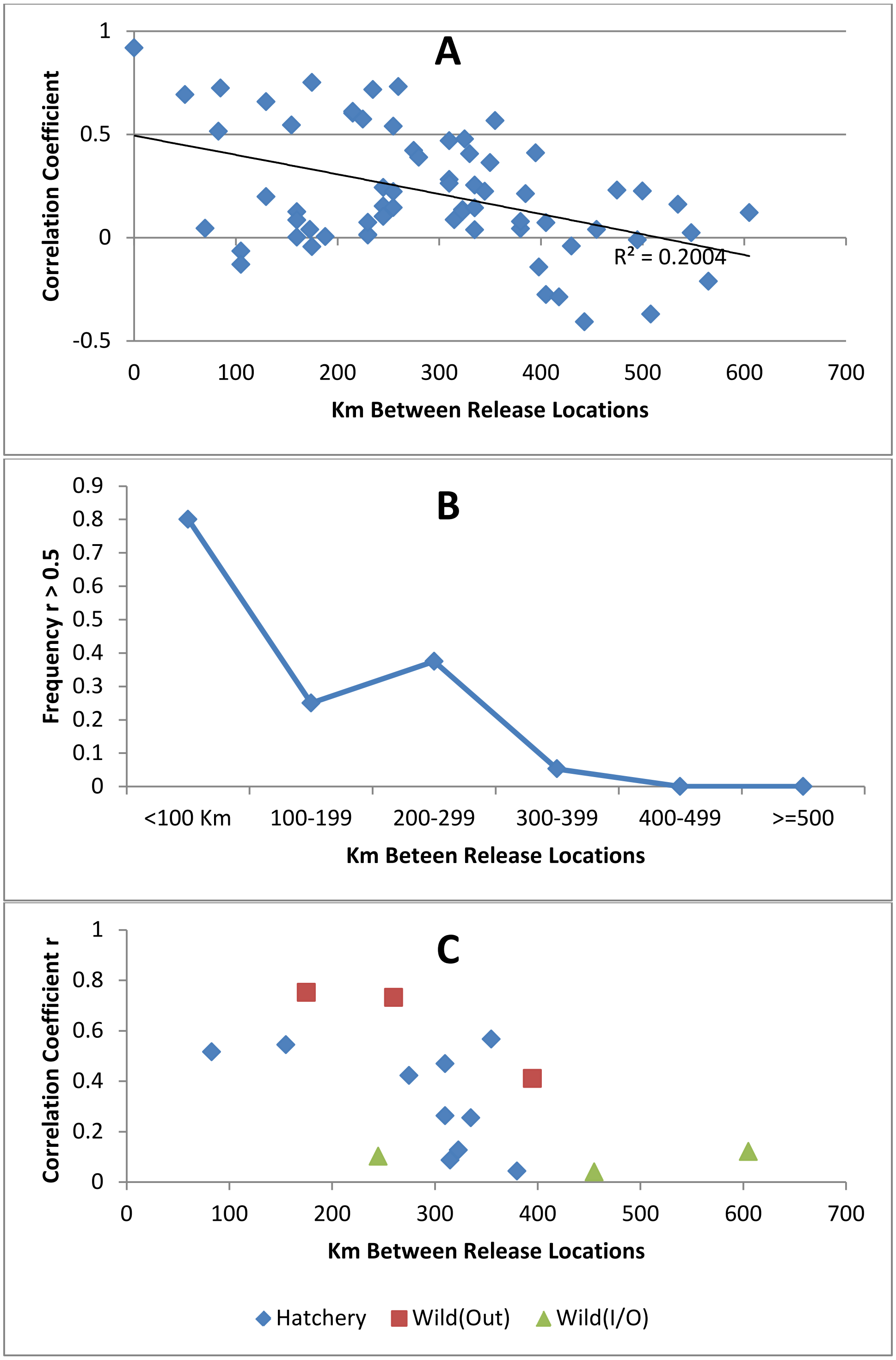

Figure 4. Correlation coefficients of pairwise comparisons plotted by distance between locations. Panel A shows all pairwise comparisons; Panel B shows the frequency of pairs with r > 0.5 for binned distances; and Panel C shows pairwise comparisons between hatchery stocks with the same stock of origin (Hatchery); between outside migrating wild stocks (Wild(Out)); and between outside and inside migrating wild stocks (Wild(I/O)).

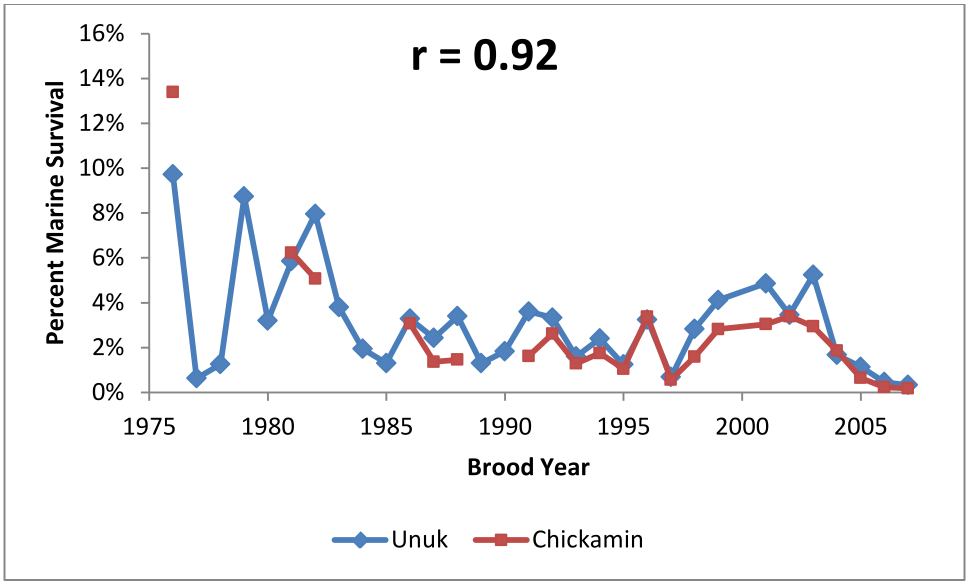

Figure 5. Marine survival over time for Unuk stock and Chickamin stock yearling Chinook salmon smolts cultured at Little Port Walter.

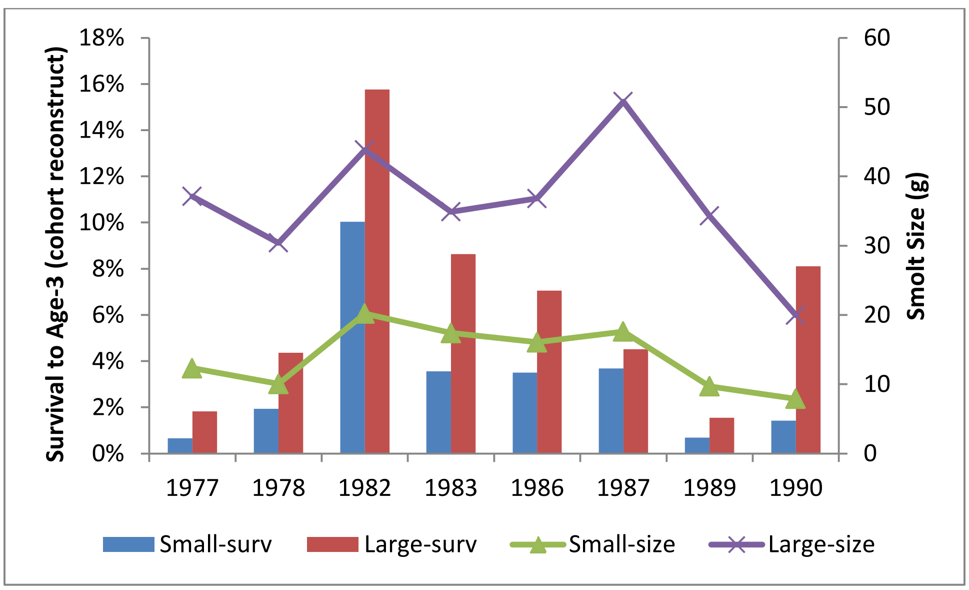

Figure 6. Marine survival to Age-3 and average smolt sizes for paired releases of large and small smolt groups for Unuk stock at Little Port Walter.