NPAFC
Doc. 1343
Rev. _______

Forecasting Pink Salmon Harvest in Southeast Alaska from Juvenile Salmon Abundance and Associated Environmental Parameters: 2010 Returns and 2011 Forecast

by

Alex C. Wertheimer, Joseph A. Orsi, Emily A. Fergusson, and Molly V. Sturdevant

Auke Bay Laboratories, Alaska Fisheries Science Center,
NOAA Fisheries, United States Department of Commerce,
Ted Stevens Marine Research Institute,
17109 Point Lena Loop Road,
Juneau, AK 99801 USA

Submitted to the

NORTH PACIFIC ANADROMOUS FISH COMMISSION

by

the United States of America

October 2011

THIS PAPER MAY BE CITED IN THE FOLLOWING MANNER:

Wertheimer, A. C., J. A. Orsi, E. A. Fergusson, and M. V. Sturdevant. 2011. Forecasting Pink Salmon Harvest in Southeast Alaska from Juvenile Salmon Abundance and Associated Environmental Parameters: 2010 Returns and 2011 Forecast. NPAFC Doc. 1343. 20 pp. (Available at http://www.npafc.org).

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Abstract

The Southeast Alaska Coastal Monitoring (SECM) project has been sampling juvenile salmon (*Oncorhynchus* spp.) and associated environmental parameters in northern Southeast Alaska (SEAK) annually since 1997 to better understand effects of environmental change on salmon production. A pragmatic application of the annual sampling effort is to forecast the abundance of adult salmon returns in subsequent years. Since 2004, juvenile peak salmon catch per unit effort (CPUE) from SECM, adjusted for highly-correlated environmental parameters, has been used to forecast harvest of adult pink salmon (*O. gorbuscha*) in SEAK. The 2010 forecast of 26.8 M fish was 15% higher than the actual harvest of 23.4 M fish. Six forecasts produced over the period 2004-2010 have been within 0-17% of the actual harvest, with an average forecast deviation of 7.9%. However, the forecast for 2006 did not follow this pattern. The simple CPUE forecast model indicated a downturn in the harvest, but the prediction was 209% higher than the actual harvest. These results show that the CPUE information has great utility for forecasting year class strength of SEAK pink salmon, but additional information may be needed to avoid “misses” such as the forecast for the 2006 return. For the 2011 forecast, model selection included a review of ecosystem indicator variables and considered additional environmental parameters to improve the simple single-parameter CPUE forecast model. The single parameter model was selected as the “best” forecast model for 2011. Juvenile pink salmon CPUE in northern SEAK accounted for 82% of the variability in annual harvest of SEAK pink salmon over the period 1997-2010. The 2011 forecast from this model, using juvenile salmon data collected in 2010, was 56.2 M fish, with an 80% bootstrap confidence interval of 47-62 M fish. Over the past seven years, the use of the SECM time series of CPUE data and associated environmental parameters has largely been successful in forecasting year-class strength of pink salmon in SEAK.

Introduction

The Southeast Alaska Coastal Monitoring (SECM) project has been sampling juvenile salmon (*Oncorhynchus* spp.) and associated environmental parameters in northern Southeast Alaska (SEAK) annually since 1997 to better understand effects of environmental change on salmon production (e.g., Orsi et al. 2009, 2010). A pragmatic application of the information provided by this effort is to forecast the abundance of adult salmon returns in subsequent years. Mortality of juvenile pink (*O. gorbuscha*) and chum (*O. keta*) salmon is high and variable during their initial marine residency, and is thought to be a major determinant of year-class strength (Parker 1968; Mortensen et al. 2000; Willette et al. 2001; Wertheimer and Thrower 2007). Sampling juveniles after this period of high initial mortality may therefore provide information that can be used with associated environmental data to more accurately forecast subsequent adult year class strength.

Pink salmon provide a good test species to determine the utility of indexes of juvenile salmon abundance in marine habitats for forecasting because of their short, two-year life cycle. Sibling recruit models are not appropriate for this species because no leading indicator information exists (i.e., only one age class occurs in the fishery). Spawner/recruit models have also performed poorly for predicting pink salmon returns, due to high uncertainty in estimating spawner abundance and high variability in marine survival (Heard 1991; Haeseker et al. 2005). The exponential smoothing model that the Alaska Department of Fish and Game (ADFG) employs using the time series of annual harvests has provided more accurate forecasts of SEAK pink salmon than spawner/recruit analyses have (Plotnick and Eggers 2004; Eggers 2006). Recently, a highly significant relationship was documented between juvenile pink salmon catch per unit effort (CPUE) from the SECM research and the SEAK harvest (Wertheimer et al. 2006). Juvenile pink salmon CPUE has since been used to produce improved forecasts for SEAK pink salmon either as a direct indicator of run strength when modified by associated environmental data (Wertheimer et al. 2009, 2010) or as auxiliary data to improve the ADFG exponential smoothing model (Heinl 2008). This paper reports on the efficacy of using the SECM data for forecasting the 2010 SEAK pink salmon harvest and on the development of a prediction model for the 2011 forecast.

Methods

Study Area

This paper focuses on forecasting the fishery harvest of adult pink salmon in SEAK, using information on juveniles and their associated biophysical (biological and physical) parameters from the prior year (Table 1). Pink salmon spawn throughout the SEAK region, with spawning aggregates originating from over 2,000 streams (Baker et al. 1996), and are comprised of 98% wild stocks. Data on juvenile pink salmon abundance, size, and growth, and associated environmental parameters have been collected by the SECM project annually since 1997; detailed descriptions of the sampling locations and data collection have been reported in a series of NPAFC documents (e.g., Orsi et al. 2008, 2009, 2010). The SECM data used in the forecasting models are from eight stations along two transects in the strait habitat of northern SEAK, sampled from 1997 to 2010 (Figure 1).

Data Descriptions and Sources

Parameters considered for the forecasting models included pink salmon harvest as the response parameter and 17 potentially-predictive biophysical variables that were either collected by SECM or were indexes of broad-scale environmental conditions that influence temperature and productivity in the Gulf of Alaska (GOA). The harvest data were collected and reported by the ADFG (2010), and included the total harvest for SEAK except for a small number of fish taken in the Yakatat area (Figure 1). One caveat for using harvest as the dependent variable of the juvenile salmon CPUE forecast models is that juvenile salmon CPUE should be an index of total run (harvest plus escapements to the spawning streams) rather than harvest alone. In contrast to harvest data, the escapement index of pink salmon in SEAK is not a precise measure of actual escapement. Wertheimer et al. (2008) examined the incorporation of scaled escapement index data with harvest to develop an index of total run; however, this total run index did not improve the fit of the CPUE forecast model, because it was highly correlated with harvest (r = 0.99). In addition, a forecast of total run must assume an average exploitation rate (percent of fish harvested in relation to the total return) to predict harvest; this is equivalent to assuming that harvest is directly representative of total run. For these reasons, the use of accurate and precise harvest data as a proxy for total run is preferred for developing the forecast models.

The biophysical parameters examined for forecasting harvest are listed in Table 1and represent a subset of the monthly measures selected for their potential influence on pink salmon harvest. . Four indexes of juvenile pink salmon abundance in northern SEAK were evaluated. One parameter was the average Ln(CPUE+1) for catches in either June or July, whichever month had the highest average catches in a given year (Peak CPUE, Table 1). This parameter has been previously identified as having the highest correlation with harvest and providing the best performance among potential CPUE metrics for forecasting harvest (Orsi et al. 2006; Wertheimer et al. 2006, 2009, 2010). The second parameter was the average Ln(CPUE+1) for August in northern SEAK (August CPUE, Table 1). This parameter was included as a possible indicator of delayed migratory timing through northern SEAK that could be associated with low year-class strength (Wertheimer et al. 2008). The third measure was the month in which peak CPUE was observed, and was also chosen to represent migratory timing or seasonality. Parameter values were assigned for the peak month in each year: June = 1, July = 2, and August = 3. The fourth measure was the percentage of juvenile pink salmon represented in the total annual catch of juvenile salmon.

Three measures of growth and condition of juvenile pink salmon were considered as indicators of biological variation that could influence pink salmon harvest (Table 1). These included: 1) a weighted average length (mm, fork length) adjusted to a standard date (Pink Salmon Size July 24); 2) the average annual ln-weight residuals derived from the regression relationship of all paired ln-weights and ln-lengths for pink salmon collected during SECM sampling from 1997-2007 (Condition Index residual); and 3) the average energy content (calories/gram wet weight, determined by bomb calorimetry) of subsamples of juvenile pink salmon captured in July of each year (Energy Content).

Two measures of zooplankton standing crop were evaluated as indicators of secondary production that could influence pink salmon harvest (Table 1). These were:
1) average May and June NORPAC 243-µm settled volume (ml), an index of upper 20-m water column small zooplankton (May/June Average Zooplankton 20-m); and 2) average May and June 333-µm bongo standing crop (displacement volume divided by water volume filtered, ml/m^3), an index of integrated mesozooplankton to 200-m depth (May/June Zooplankton Total Water Column).

Five biophysical measures were chosen to represent conditions that could have a biological link to the growth and survival of juvenile salmon, including: 1) May 3-m water temperature (°C, May 3-m Water Temperature) adjusted to a standard date (May 23); 2) May upper 20-m integrated average water temperature (°C, May 20-m Integrated Water Temperature) adjusted to a standard date (May 23); 3) June upper 20-m integrated average water temperature (°C, June 20-m Integrated Water Temperature); 4) June average mixed-layer depth (MLD, June Mixed-layer Depth); and 5) July 3-m salinity (PSU, July 3-m Salinity).

Three indexes of basin-scale physical conditions that affect the entire GOA and North Pacific Ocean were also evaluated for their influence on pink salmon harvest (Table 1). One was the annual November to March average for the Pacific Decadal Oscillation (PDO) during the winter prior to juvenile pink salmon seaward migration. The PDO is an index of environmental conditions that has been linked to year-class strength of juvenile salmon in their first year at sea (Mantua et al. 1997). The second basin-scale index was the June-July-August average of the North Pacific Index (NPI), a measure of atmospheric air pressure in the GOA thought to affect upwelling and downwelling oceanographic conditions (Trenberth and Hurrell 1994). The third was the annual sum of the monthly multivariate El Niño Southern Oscillation (ENSO) index (NCDC 2007) from the year prior to adult residence in the GOA. The ENSO index was used as an indicator of ocean conditions encountered by immature and adult pink salmon in the GOA.

Forecast Model Development

The four-step process previously used (Wertheimer et al. 2009, 2010) to identify the "best" forecast model for predicting pink salmon harvest in SEAK was repeated, with the addition of a fifth step to place model forecasts in the context of auxiliary run-strength indicators. The first step was to develop a regression model of harvest and juvenile salmon CPUE, with physical conditions, zooplankton measures, and pink salmon growth indices considered as additional parameters. The potential model was

$$\mathrm{Ln(Harvest)} = \alpha + \beta(\mathrm{Ln(CPUE)}) + \gamma_1 X_1 + \ldots + \gamma_n X_n + \varepsilon,$$

where γ is the coefficient for environmental variable *X*. Backward/forward stepwise regression with an alpha value of $P < 0.05$ was used to determine whether an environmental variable was added or retained in the model.

The second step was to calculate the Akiake Information Criterion (AIC) for each significant step of the stepwise regression, to prevent over-parameterization of the model. The AIC was corrected (AIC_c) for small sample sizes (Shono 2000).

The third step was a jackknife approach to evaluate "hindcast" forecast accuracy over the entire SECM time series. This procedure generated forecast model parameters by excluding a year of juvenile data, then used the excluded year to "forecast" harvest for the associated harvest year; this process was repeated so that each year in the time series was excluded and used to generate a forecast. The average relative forecast error was then calculated for each model.

The fourth step in developing the model was to compare bootstrap confidence intervals (CIs) to the regression prediction intervals (PIs) for the forecasts to examine the effect of process error and measurement error on the forecasts. For the bootstrap approach, juvenile pink salmon catches for each month in each year were randomly re-sampled n_{my} times, where *n* is the number of hauls in month *m* in year *y*, and then the re-sampled catches for each month and year were averaged. Average simulated catches of juvenile pink salmon for the years 1997-2009 were used to construct the regression models with SEAK harvest as the dependent variable, and the appropriate averages of the simulated catches for 2010 were used to forecast 2011 harvest. This process was repeated 1,000 times, generating 1,000 forecasts for each model. The forecasts were ordered from lowest to highest, and the lowest and highest 10% were removed to define the 80% bootstrap CIs. These results were then compared to the PIs for the regression model based on the observed annual average catches.

For the 2011 forecast, a fifth step was added to the process of selecting the "best" forecast model. Parameters that had significant bivariate correlation with the SEAK harvest (Table 1) or that were significant auxiliary variables in the stepwise regression model were ranked for each of the 14 years that SECM data has been collected, and tabulated with ranks of the SEAK harvest by year. These parameters were considered to be indicators of ecosystem conditions that could contribute to salmon survival (Peterson et al. 2010), and their relative ranks in 2010 were considered for selecting the best regression model to forecast the 2011 harvest.

Results

Forecast Efficacy

In 2010, the SECM forecast of 26.8 M pink salmon was 15% higher than the actual 2010 harvest of 23.4 M fish (Table 2). Including the 2010 results, six of the seven SECM forecasts since 2004 have been within 0-17% of the actual harvest (Figure 2), and within the associated 80% confidence intervals. Only in 2006 has the harvest been substantially different from the forecast; in that year, the actual harvest was well outside the 80% confidence interval of the forecast (Figure 2).

The ADFG forecast for SEAK pink salmon returning in 2010 was 19 M (Heinl 2010). This forecast is based on an exponential smoothing model of harvest trends for even-year pink salmon harvests in SEAK adjusted by the SECM peak juvenile CPUE data. The unmodified exponential smoothing model provided a forecast of 22 M, closer to the actual harvest in 2010 (Table 2).

2011 Forecast

Bivariate correlations were computed between SEAK pink salmon harvests for 2004-2010 using 17 potential prediction variables (Table 1). Four of these parameters were significantly ($P < 0.05$) correlated with SEAK pink salmon harvest; three of the four were measures of juvenile pink salmon abundance or timing. For 2010 as in previous years, Peak CPUE was the parameter most highly correlated with harvest (r =0.92, P < 0.001). Seasonality was negatively correlated with harvest (r =-0.73, P < 0.004), indicating early (June) Peak CPUE is associated with higher harvests. The percentage of juvenile pink salmon in the catch was positively correlated with harvest (r =-0.57, P < 0.040). One basin scale variable, the NPI, was also significantly and positively correlated with harvest (r =0.58, P = 0.047). None of the other parameters evaluated were significantly (P > 0.2) correlated with harvest.

In the stepwise regression analysis, a two-parameter model including Peak CPUE and May 20-m Integrated Water Temperature explained 92% of the variability in the harvest data (Adjusted R^2), as compared to 82% for the simple linear regression with Peak CPUE (Table 3). The AIC_c was lower for the two-parameter model (Table 3), indicating that this model is not over-parameterized. The 2011 forecasts using 2010 juvenile Peak CPUE were 56.2 M for the simple Peak CPUE model and 45.0 M for the two-parameter model.

The jackknife analysis indicated that forecast accuracy of the Peak CPUE forecast model for the SEAK harvest was improved by including the auxiliary parameter. Including this May 20-m integrated temperature data decreased the average absolute percent deviation of the jackknife forecasts from the actual harvests for the years 1998-2009 from 26% to 22%. This improved performance of the two-parameter model was due to its better fit for the 2006 harvest, the year in which the actual forecast by the simple Peak CPUE model was poor. By including this May 20-m integrated temperature, the deviation of the jackknife forecast from the 2006 harvest decreased from 175% to 82%. However, if 2006 is excluded from the jackknife analysis, the one-parameter model actually had *lower* absolute average deviation relative to the two-parameter model, 14% compared to 17%.

The 80% bootstrap CIs for the one- and two-parameter models for the 2011 forecast were compared with the 80% PIs from the regression equations (Figure 3). The regression PIs declined as the number of parameters in the model increased, from an interval width of 24 M fish for the simple Peak CPUE model to an interval width of 18 M fish for the two-parameter model. The decreasing interval widths reflected the improved model fit and the corresponding reduction in process error. However, the regression PIs did not incorporate measurement error because the observations of CPUE are single averages for each sampling year. In contrast, the bootstrap CIs incorporated the measurement error by randomly re-sampling the catches for 1,000 iterations for each year. When measurement error was incorporated in this way, the CIs were narrower for the simple CPUE model (16 M fish) than for the two-parameter model (19 M fish) (Figure 3).

Table 4 lists annual values and ranks of the four parameters in the SEAK time series that were significantly correlated with SEAK harvest (Peak CPUE, Seasonality, percentage of juvenile pinks, and NPI), as well as the significant auxiliary variable in the two-parameter regression model (May 20-m integrated temperature). In 2011, all parameters were ranked in the top quartile for the time series. The only other year in which this occurred was the 1999 harvest year, when the SEAK harvest of 77.8 M fish was the highest observed in the time series (Table 4).

Discussion

The SECM forecast model for 2010 predicted a harvest of 28.6 M pink salmon in SEAK, which was 15% higher than the actual harvest of 23 M. The 2010 harvest was well below the 20 prior years' average of 46 M fish, but was still a substantial increase over the two prior even-year harvests (2006 and 2008).The forecast did detect the increasing trend in even-year harvests, and in the context of errors in large forecasts often associated with pink salmon (Haesaker et al. 2005; Eggers 2006), forecast models that predict within 20% of the actual harvest provide good insight into subsequent year-class strength. Juvenile pink salmon CPUE data from SECM sampling has been used to forecast SEAK harvest since the 2003 juvenile year (2004 return year). For six of the past seven years, the SECM forecasts have ranged within 0-17% of actual harvest, with an average deviation of 7.9%, demonstrating the utility of the juvenile pink salmon information for predicting year-class strength (Figure 2; Table 5).

One exception to the series of accurate SECM forecasts was the over-estimation of the 2006 return of pink salmon. The pink salmon harvest in 2006 was very poor, and was not accurately forecast by the simple juvenile pink salmon CPUE relationship (Figure 2). However, the CPUE model did indicate a decline relative to recent years, which was not apparent in the ADFG forecast that relied only on trends in annual harvests (Table 5). Drought conditions and high stream temperatures in the late summer and fall of 2004 may have contributed to the poor year-class strength of pink salmon outmigrating in 2005 and returning in 2006. The juvenile CPUE should, however, account for low recruitment of pink salmon from streams to the coastal marine environment following these conditions. Alternatively, interannual variation in overwinter mortality after the early marine period may also contribute to variability in year-class strength of Pacific salmon (Beamish and Mahnken 2001; Moss et al. 2005). The poor performance of the CPUE model in 2006 suggests that such a "downstream" mortality event occurred after the SECM 2005 sampling period. In fact, the Northeastern Pacific Ocean was anomalously warm in the summer of 2005, and as a result juvenile salmon may have encumbered higher energetic demands related to ocean temperature, as well as increased negative interactions with unusual migratory predators and competitors documented to occur at this time, such as Humboldt squid (*Dosidicus gigas*), blue sharks (*Prionace glauca*), and Pacific sardines (*Sardinops sagax*) (Orsi et al. 2006b).

Information on environmental conditions that affect juvenile pink salmon as they migrate through SEAK waters and enter the GOA could potentially improve forecast accuracy for the juvenile pink salmon CPUE prediction model, and could help avoid large forecast error due to variability in survival that occurs after the CPUE data are collected. Incorporating environmental data in the forecast models improved forecasts relative to the simple Peak CPUE model in 2007, 2008, and 2010, but not in 2009 (Table 5). Thus, while it is reasonable that including other biophysical data could improve forecast efficacy of the CPUE model, the results to date have been mixed.

For the 2011 SECM forecast, the juvenile pink salmon CPUE was the most highly and significantly correlated parameter of all 17 biophysical parameters considered for correlation with SEAK pink salmon harvest; its high correlation (r = 0.92; Table 1) supports its continued use as a key index of year-class strength. The other parameters significantly correlated with harvest were pink salmon seasonality, percent juvenile pink salmon, and the NPI (Table 1). However, these factors did not enter into the stepwise regression model, suggesting that the variation in year-class strength they explain is redundant with the more strongly-correlated CPUE index. The May ocean temperatures entered the model for the fifth consecutive year. The relationship was negative, indicating that cooler temperatures in the GOA in the spring are associated with improved survival of juveniles after the critical early marine period. The significance of this relationship in the two-parameter model is strongly influenced by the poor 2006 year class, which was exposed to warm temperatures as juveniles in the GOA in 2005.

Because of the negative effect of May temperature in the two-parameter model for the 2011 forecast, the high May temperatures in 2010 caused a lower forecast relative to the one-parameter CPUE model. Average May temperatures in 2010 were similar to those that occurred in 2005 (Table 4), the year associated with the inaccurately high forecast for the 2006 adult pink salmon harvest from the single-parameter CPUE model. In 2005, high May temperatures were also followed by higher than average temperatures throughout the summer. In contrast, temperatures after May in 2010 were close to or below the long-term monthly averages (Orsi et al. 2006a; Orsi et al. 2011). Furthermore, the unusual fauna observed in 2005 in the GOA adjacent to SEAK (Orsi et al. 2006) were not observed in 2010. In light of the high rankings of the ecosystem indicators for 2010 (Table 4), and the differences in temperature patterns between 2005 and 2010, we excluded the temperature effect indicated by the two-parameter model; instead, we selected the single-parameter CPUE model as the “best” CPUE forecast model for the 2011 forecast. This model provides a forecast of 56 M fish with an 80% bootstrap CI of 47-62 M (Figure 3).

The ADFG forecast for pink salmon in SEAK has been based on an exponential smoothing model since 2004 (Eggers 2006). This model uses the trend from previous harvests to predict future harvest, which assumes that year-class performance responds to persistent patterns of environmental conditions. However, there is no mechanism in such trend analysis to detect shifts in the direction of such patterns. Thus, the trend analysis predicted a large return (52 M) in 2006, whereas the actual return was very poor (12 M). As a result, since 2006, the ADFG forecast has used the SECM Peak CPUE data to modify the exponential smoothing model forecast (e.g., Heinl 2010). These modified forecasts improved on the unmodified smoothing models for 2007-2009; in 2010, however, the unmodified smoothing model would have provided a better forecast (Table 5). The average absolute deviation (and range) for the modified model from 2007-2010 was still substantially better than the model adjusted with the juvenile data, 13% (4-19%) versus 38% (6-81%). This improved performance for the ADFG model again demonstrates the utility of the juvenile pink salmon abundance index for forecasting year-class strength. In this case, the index is used to modify and adjust a time-series analysis of harvest trends, a very different approach to the SECM forecast approach that uses the Peak CPUE as the main predictive parameter and modifies for associated environmental data. To date, the two approaches have performed similarly for 2007-2010 (Table 5).

The 2011 SECM forecast of 56 M pink salmon represents an excellent potential harvest of pink salmon in SEAK. This would be the fourth highest harvest during the SECM time series (since 1998), and in the upper 20% of harvests since 1960 (Heinl 2010). The forecast is substantially greater than the last odd-year (2009) harvest of 38 M. Similarly, the 2010 SECM forecast effectively detected an upturn in the production of the even-year line of SEAK pink salmon. If validated by the 2011 harvest, the 2011 forecast for the odd-year line would again demonstrate that the juvenile salmon index can detect directional shifts in trends of pink salmon year-class strength.

Acknowledgments

We thank the vessel captains and crews and the many biologists, students, contractors, and volunteers who have contributed to SECM sampling for the past 14 years. The Northern Fund of the Pacific Salmon Commission and the Alaska Sustainable Salmon Fund, have provided essential funding for continuing the SECM sampling. The findings and conclusions in the paper are those of the authors and do not necessarily represent the views of the National Oceanic and Atmospheric Administration, the U.S. Department of Commerce, or the Alaska Department of Fish and Game.

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Table 1.—Correlation coefficients for juvenile pink salmon metrics and associated biophysical parameters in year *y* for 1997-2009 with adult pink salmon harvest in Southeast Alaska (SEAK) in year *y* + 1. Parameters with statistically significant correlations are in bold text; the probabilities were not adjusted for multiple comparisons.

Parameter	***r***	***P*-value**
Juvenile pink salmon abundance		
Peak CPUE	**0.92**	**0.001**
August CPUE	-0.37	0.214
Seasonality	**-0.73**	**0.004**
Percentage of Juvenile Pinks	**0.57**	**0.040**
Juvenile pink salmon growth and condition		
Pink Salmon Size July 24	0.26	0.395
Condition Index	-0.11	0.728
Energy Content	0.12	0.691
Zooplankton standing crop		
May/June Average Zooplankton Total Water Column	0.08	0.803
May/June Average Zooplankton 20-m	0.29	0.343
Local-scale physical conditions		
May 3-m Water Temperature	-0.19	0.517
May 20-m Integrated Water Temperature	-0.04	0.907
June 20-m Integrated Water Temperature	-0.11	0.725
June Mixed-layer Depth	-0.08	0.802
July 3-m Salinity	0.29	0.335
Basin-scale physical conditions		
Pacific Decadal Oscillation (Ocean Winter)	0.24	0.435
Northern Pacific Index	**0.62**	**0.024**
El Nino Southern Oscillation (prior year annual average)	0.30	0.326

Table 2.—Southeast Coastal Monitoring (SECM) and Alaska Department of Fish and Game (ADFG) forecasts for 2010 pink salmon harvest in Southeast Alaska (SEAK). The ADFG forecasts are from Heinl (2010). NA = not applicable.

	2010 SEAK pink salmon harvest (M of fish)	**Deviation from actual harvest**
SECM forecast	28.6	15%
ADFG forecast (w/ Peak CPUE data)	19.0	-19%
ADFG forecast (w/o Peak CPUE data)	22.0	-6%
Actual harvest	23.4	NA

Table 3.—Regression models relating juvenile catch per unit effort (CPUE) of pink salmon in year *y* to adult harvest in Southeast Alaska (SEAK) in year *y* +1, for *y* = 1997-2010. R^2 = coefficient of determination for model; AIC_c = Akiake Information Criterion (corrected); *P* = statistical significance of regression equation. Adult harvest is the total for SEAK harvest (except Yakutat).

Model	**Harvest area**	**Adjusted R^2**	**AIC_C**	**Regression *P* -value**	**2011 Prediction (M)**
Ln(PeakCPUE)	SEAK	82%	99.2	<0.001	56.2
Ln(PeakCPUE) + May20-mTemp	SEAK	92%	91.7	<0.001	45.0

Table 4.—Annual measures and rankings (in parentheses) for the Southeast Coastal Monitoring time series for parameters either (1) significantly correlated with Southeast Alaska (SEAK) pink salmon harvest or (2) significant as an auxiliary variables in multiple regression models relating juvenile pink salmon Peak CPUE with SEAK pink salmon harvest.

Adult year	**Juvenile year**	**SEAK harvest (M)**	**Peak CPUE (In+1)**	**Seasonality (peak month)**	**% Pink juveniles**	**NPI Index**	**May 20-m integrated temperature (^{o}C)**
1998	1997	42.5 (8)	2.5 (10)	July (5)	18% (14)	15.6 (10)	7.3 (6)
1999	1998	77.8 (1)	5.6 (1)	June (1)	69% (2)	18.1 (1)	7.8 (3)
2000	1999	20.2 (11)	1.6 (13)	July (5)	22% (12)	15.8 (8)	6.5 (12)
2001	2000	67.0 (2)	3.7 (3)	July (5)	28% (11)	17.0 (4)	6.6 (11)
2002	2001	45.3 (5)	2.9 (6)	July (5)	38% (8)	16.8 (5)	7.1 (8)
2003	2002	52.5 (4)	2.8 (7)	July (5)	48% (5)	15.6 (11)	6.4 (13)
2004	2003	45.3 (6)	3.1 (5)	July (5)	49% (4)	16.1 (7)	7.4 (5)
2005	2004	59.1 (3)	3.9 (2)	June (1)	40% (7)	15.1 (13)	7.6 (4)
2006	2005	11.6 (13)	2.0 (12)	August (11)	31% (10)	15.5 (12)	8.3 (2)
2007	2006	44.8 (7)	2.6 (8)	June (1)	43% (6)	17.0 (3)	6.7 (10)
2008	2007	15.9 (12)	1.2 (14)	August (11)	21% (13)	15.7 (9)	7.0 (9)
2009	2008	38.0 (9)	2.5 (9)	August (11)	58% (3)	16.1 (6)	6.1 (14)
2010	2009	23.4 (10)	2.1 (11)	August (11)	32% (9)	15.1 (14)	7.3 (7)
2011	2010		3.7 (4)	June (1)	85% (1)	17.6 (2)	8.3 (1)

Table 5.—Southeast Alaska (SEAK) pink salmon harvest (in M of fish) and associated forecasts from Southeast Coastal Monitoring (SECM) juvenile CPUE models and Alaska Department Fish and Game (ADFG) exponential smoothing models. Accuracy of the forecast is shown in parentheses. For SECM, both the simple CPUE and the multi-parameter CPUE models (if simple model was not used for forecast) are shown. Similarly for ADFG, both the exponential smoothing model with (2007-2010 only) and without the addition of the SECM juvenile CPUE data are shown (Steve Heinl, ADFG, personal communication).

		SECM CPUE Models		ADFG Exp. Smoothing Models	
Year	**SEAK harvest (M)**	**CPUE only**	**Multi-parameter CPUE**	**Trend analysis only**	**Trend analysis w/juvenile data**
2004	45	47 (4%)	NA	50 (11%)	NA
2005	59	59 (0%)	NA	49 (17%)	NA
2006	12	35 (209%)	NA	52 (333%)	NA
2007	45	38 (16%)	40 (10%)	58 (29%)	47 (4%)
2008	16	18 (13%)	16 (1%)	29 (81%)	19 (19%)
2009	38	37 (3%)	44 (17%)	52 (37%)	41 (8%)
2010	23	31 (33%)	29 (15%)	22 (6%)	19 (19%)

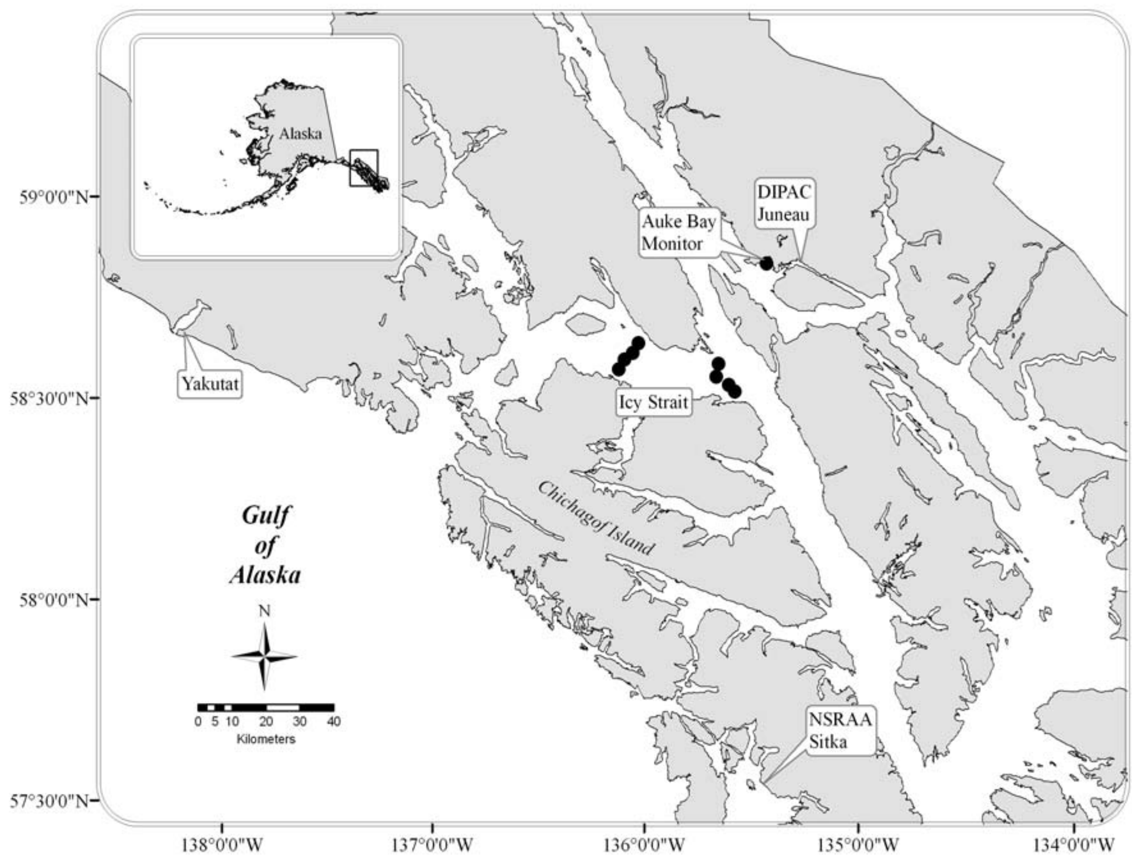

Figure 1.—Stations sampled for juvenile pink salmon and associated environmental parameters along the Icy Strait transects in the northern region of Southeast Alaska for the development of pink salmon harvest forecast models. Stations were sampled monthly during May–August from 1997–2010. Oceanography was conducted all months, and surface trawling for juvenile salmon occurred only from June to August.

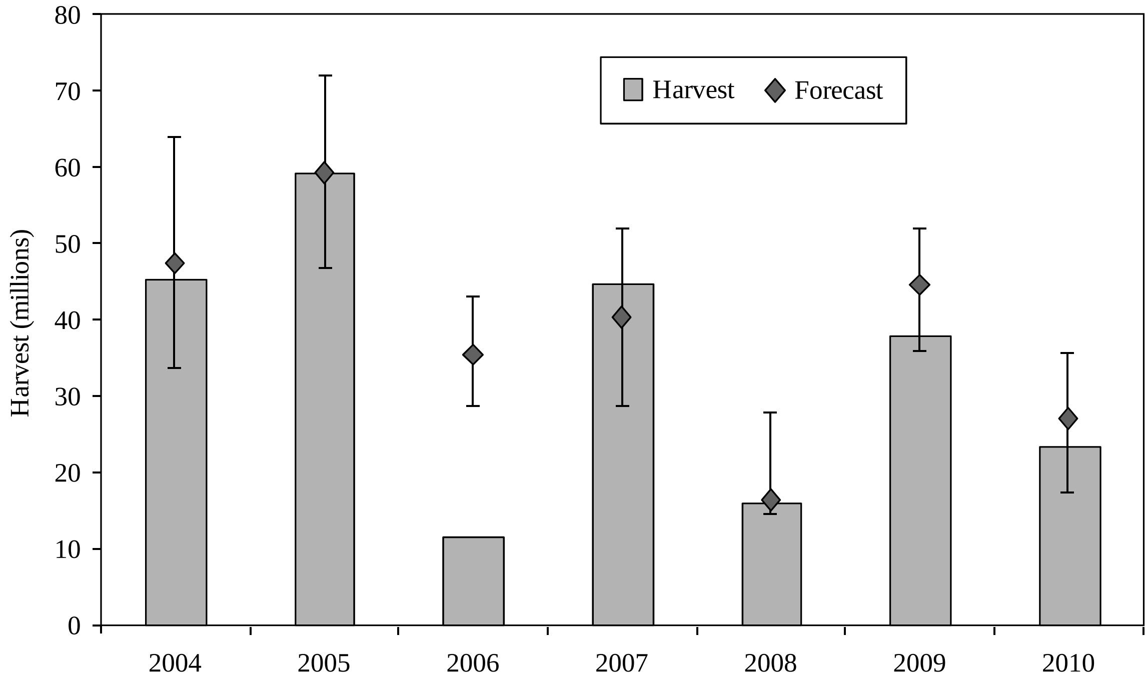

Figure 2.—Southeast Coastal Monitoring (SECM) pink salmon harvest forecasts for Southeast Alaska (SEAK; symbols), associated 80% confidence intervals (lines), and actual SEAK pink salmon harvests (colored bars), 2004-2010.

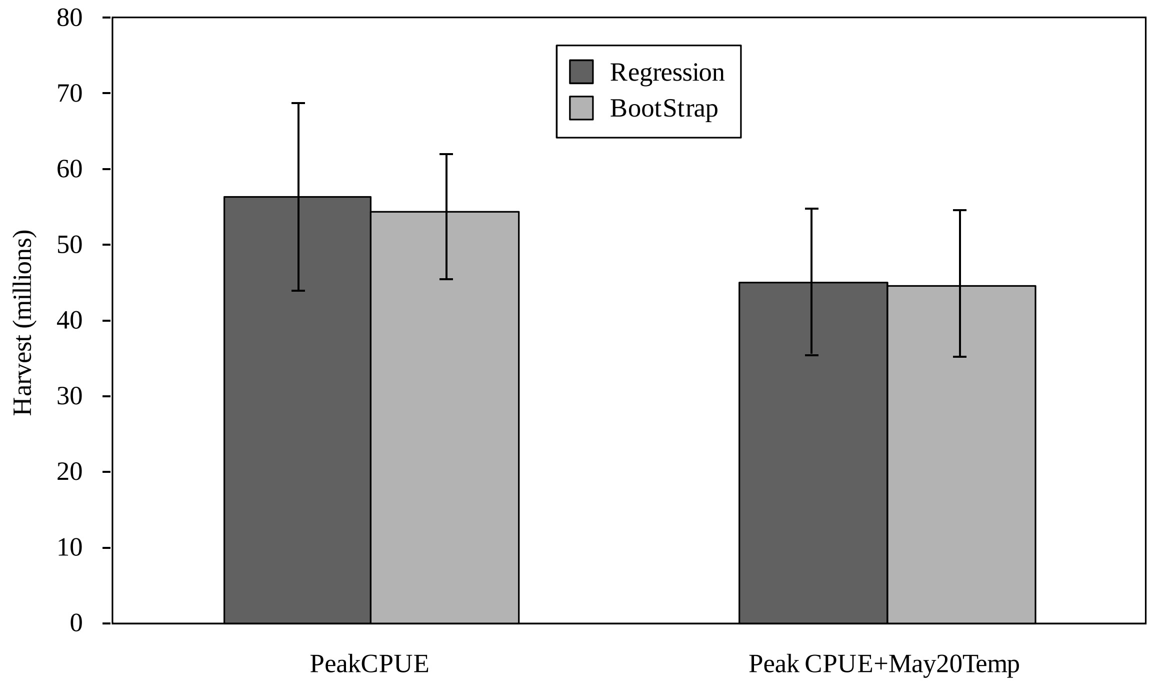

Figure 3.—Parametric regression (dark bars) and bootstrap (light bars) with 80% confidence intervals (lines) for predictions of Southeast Alaska (SEAK) pink salmon harvest in 2011from two models incorporating juvenile Peak CPUE data in 2010. See text for descriptions of parameters included in models.