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Forecasting Pink Salmon Harvest in Southeast Alaska from Juvenile Salmon Abundance and Associated Environmental Parameters: 2009 Harvest and 2010 Forecast

by

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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 this 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, modified by other environmental parameters as appropriate, has been used to forecast harvest of adult pink salmon (*O. gorbuscha*) in SEAK. The 2009 return of 38.0 million fish was 17% below the forecast of 44.4 million. This represents the fifth forecast over the period 2004-2009 which was within 0-17% of the actual harvest. Conversely, the forecast for 2006 did not follow this pattern and was 200% higher than the actual harvest; however, the simple CPUE forecast model did indicate a downturn in harvest that year. These results show that the CPUE information has great utility for forecasting year class strength of SEAK pink salmon, but additional environmental data are needed to avoid "misses" such as the forecast of the 2006 return. Beginning with the forecast for the 2007 return, the simple CPUE forecast model was enhanced to include stepwise multiple regression, jackknife hindcast analysis, and bootstrap confidence intervals. For 2010, a three-parameter model was selected as the "best" forecast model. Juvenile pink salmon CPUE in northern SEAK accounted for 82% of the variability in annual harvest of SEAK pink salmon over the period 1997-2009. The amount of variability explained was improved to 94% when the May 20-m integrated sea water temperatures and an index of the El Niño Southern Oscillation (ENSO) were included in the model. The forecast for the 2010 harvest was 26.8 million fish, with an 80% bootstrap confidence interval of 18-35 million fish. Preliminary end of the season pink salmon harvests for 2010 are currently 23.4 million (17 Sept 2010, Alaska Department of Fish and Game) and are within 15% of the SECM 2010 harvest forecast.

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 (Orsi et al. 2008, 2009). A pragmatic data application of this effort is to forecast the abundance of adult salmon returns in subsequent years. Year-class strength is influenced by the high and variable mortality of juvenile pink (*O. gorbuscha*) and chum (*O. keta*) salmon during their initial marine residency (Parker 1968; Mortensen et al. 2000; Willette et al. 2001; Wertheimer and Thrower 2007). Sampling juveniles after this period of high initial mortality may provide information that can be used with associated environmental data to forecast abundance.

Pink salmon provide a good test species to determine the utility of indexes of juvenile abundance in marine habitats for forecasting because of their short, two-year life cycle from spawning to recruitment. Sibling recruit models are not appropriate for this species because no leading indicator information exists (i.e., only one age class occurs). However, spawner/recruit analyses 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); instead, Alaska Department of Fish and Game (ADFG) predictions from an exponential smoothing model for the time series of annual harvests have provided more accurate forecasts of SEAK pink salmon than spawner/recruit analyses (Plotnick and Eggers 2004; Eggers 2006). Taking a different approach, Wertheimer et al. (2006) found a highly significant relationship between juvenile pink salmon catch per unit effort (CPUE) from the SECM sampling and the SEAK harvest. Juvenile pink salmon CPUE has subsequently been used to produce improved forecasts for SEAK pink salmon either as auxiliary data to improve the ADFG exponential smoothing model (Heinl 2009) or as a direct indicator of run strength when modified by associated environmental data (Wertheimer et al. 2008, 2009). This paper reports on the efficacy of using the SECM data for forecasting the 2009 SEAK pink salmon harvest and on the development of a prediction model for the 2010 forecast.

Methods

Study Area

This paper focuses on forecasting the harvest of adult pink salmon in SEAK a year in advance, using information on juveniles and their associated biophysical (biological and physical) parameters from the prior year (Table 1). Spawning aggregates of pink salmon in the SEAK region originate from over 2,000 streams (Baker et al. 1996). 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 North Pacific Anadromous Fish Commission (NPAFC) documents (e.g., Orsi et al. 2007, 2008, 2009). 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 2009 (Figure 1)

Data Descriptions and Sources

Parameters considered for the forecasting models included pink salmon harvest as the response variable and 16 biophysical parameters as potential predictive variables. These potential predictive variables were either collected by SECM or were indexes of basin-scale environmental conditions that influence temperature and productivity in the Gulf of Alaska (GOA). The harvest data were collected and reported by the ADFG (2009), 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. However, the escapement index of pink salmon in SEAK is not necessarily an accurate or precise estimate of escapement. In addition, catches and escapements in northern and southern SEAK are not always synchronous in year-class strength (Byerly et al. 1999; ADFG 2009; S. Heinl, ADFG, pers. comm.). 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 unrealistically assumes an average exploitation rate to predict harvest. 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 1.Two indexes of juvenile pink salmon abundance in northern SEAK were evaluated. One 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 was previously identified as having the highest correlation with harvest and providing the best performance among potential CPUE metrics for forecasting harvest (Orsi et al. 2006a; Wertheimer et al. 2006, 2009). The second measure 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).

Three measures of growth and condition of juvenile pink salmon captured in northern SEAK in 2009 were considered as indicators of biological variation that could influence pink salmon harvest (Table 1). These were: 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); and 3) the average whole body 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 20-m settled volume (ml), an index of upper water column zooplankton (May/June Average Zooplankton 20-m); and 2) average May and June 333-bongo standing crop (displacement volume divided by water volume filtered, ml/m^3) as an index of integrated zooplankton to 200-m depth (May/June Zooplankton Total Water Column).

Six measures of local physical conditions were collected by SECM and were evaluated for their influence on pink salmon harvest. These measures were: 1) May 3-m water temperature (°C, May 3-m Water Temperature); 2) May upper 20-m integrated average water temperature (°C, May 20-m Integrated Water Temperature); 3) May upper 20-m integrated water temperature anomalies relative to the long-term SECM time series (°C, May 20-m Temperature Anomalies); 4) June upper 20-m integrated average water temperature (°C, June 20-m Integrated Water Temperature); 5) June average mixed-layer depth (MLD, June Mixed-layer Depth); and 6) July 3-m salinity (PSU, July 3-m Salinity).

Four 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 index was the annual November to March average of the Pacific Decadal Oscillation (PDO) during the winter prior to juvenile pink salmon seaward migration (Pacific Decadal Oscillation). 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). A second 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). A third index was the annual sum of the monthly multivariate El Niño Southern Oscillation (ENSO) index (NCDC 2007) from the year prior to juvenile seaward migration (ENSO juvenile). A fourth index was the same ENSO index for the year of adult residence in the GOA (ENSO adult). Thus, for the 2009 forecast model, the ENSO juvenile index included the monthly sum of the Jan-Dec 2007 ENSO index, while the ENSO adult index included the monthly sum of the Jan-Dec 2008 ENSO index. The ENSO indexes were used as indicators of ocean conditions encountered by both the seaward migrating juveniles and the returning adults.

Forecast Model Development

A four-step process was applied to identify the "best" forecast model for predicting pink salmon harvest in SEAK. The first step was to develop a regression model of harvest and juvenile salmon CPUE, with physical conditions, zooplankton volumes, and pink salmon growth indices considered as additional parameters. The potential model was

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

where γ is the coefficient for environmental variable X. Backward/forward stepwise regression with an alpha value of $P < 0.1$ 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 final step was to compare bootstrap confidence intervals (CIs) to the regression prediction intervals for the forecasts to examine the effects of process 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 1997-2008 were used to construct the regression models with SEAK harvest as the dependent variable, and the appropriate averages of the simulated catches for 2009 were used to forecast 2010 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 10% and highest 10% were removed to define the 80% bootstrap CIs. These results were then compared to the prediction CIs for the regression model based on the observed annual average catches.

Results

Forecast Efficacy

In 2009, the SECM forecast of 44.4 million pink salmon was 17% higher than the actual harvest of 38.0 million fish (Table 2). With the addition of the 2009 results, five of the six SECM forecasts since 2004 were within 0-17% of the actual harvests (Figure 2). Only in 2006 was the harvest 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 2009 forecast based on an exponential smoothing model of harvest data was also improved by including the SECM Peak CPUE data. That forecast was for a harvest of 41 million pink salmon; without modifying the forecast with the SECM juvenile data, the forecast would have been 51 million fish (Table 2; Heinl 2009).

2010 Forecast

Bivariate correlations were computed between SEAK pink salmon harvests for 2004-2009 using the 16 potential predictor variables (Table 1). Two of these parameters were significantly ($P < 0.05$) correlated with SEAK pink salmon harvest: Peak CPUE ($r = 0.92$, $P < 0.001$) and the NPI ($r = 0.58$, $P = 0.047$). No other parameters evaluated were significantly ($P > 0.2$) correlated with harvest.

In the stepwise regression analysis, a three-parameter model including Peak CPUE, May 20-m Integrated Water Temperature, and ENSO juvenile explained 94% of the variability in the harvest data (Adjusted R^2), whereas the simple model using only Peak CPUE explained 82% of the variability (Table 3). The AIC_c decreased at each model step and was lowest for the three-parameter model (Table 3), indicating that it was not over-parameterized and was the most parsimonious. The 2010 forecasts were highest for the simple Peak CPUE model at 31.2 million, lowest for the two-parameter model at 21.2 million, and intermediate for the three-parameter model at 26.8 million.

The jackknife analysis indicated that including additional parameters in the simple Peak CPUE model improved forecast accuracy for the SEAK harvest (Table 4). For the years 1998-2009, including the May temperature data decreased the average absolute percent deviation of the jackknife forecasts from the actual harvests from 27% to 23%. For 2006, the year in which the actual forecast by the simple Peak CPUE model was poor, including May temperature also decreased the deviation of the jackknife forecast from the 2006 harvest, from 186% to 108%. Adding ENSO data to the Peak CPUE+May Temperature model for 1998-2009 further reduced jackknife forecast deviations to an average of 20%, but for 2006 the deviation increased slightly, to 111%.

The 80% bootstrap CIs for the single- and multiple-parameter models for the 2010 forecast were compared with the 80% prediction intervals from the regression equations (Figure 3). These prediction intervals declined as the number of parameters in the model increased; an interval width of 25 million fish for the simple Peak CPUE model declined to 17 million fish for the full three-parameter model. The decreasing interval widths reflected the improved model fit and the corresponding reduction in process error. However, the regression prediction intervals 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 narrowest for the simple CPUE model, with a width of 11 million fish (Figure 3). The CI width increased to 12 million fish for the two-parameter model, and to 18 million fish for the three-parameter model.

Although the wider CI for the three-parameter model relative to the two-parameter model indicates greater uncertainty around the forecast, the three-parameter model was selected as the “best” SECM model for predicting the SEAK harvest in 2010, for several reasons. It had the best fit to the data, explaining 94% of the variability in harvest, it had the lowest AIC_C, and it had the lowest deviation in the jackknife analysis overall. The 2006 jacknife deviation for the three-parameter model was lower than for the simple CPUE model, and was only slightly higher than for the two-parameter model. Thus, at the SEAK Purse Seine Task Force meeting in Ketchikan in December, 2009, a forecast of 26.8 million was presented as the SECM prediction for the 2010 harvest.

Discussion

The 2009 harvest of 38 million pink salmon in SEAK was below the 20 prior years' average of 46 million fish. The SECM forecast model predicted a harvest of 44.4 million fish, which was 17% higher than the actual harvest. However, in the context of large forecast errors 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 5 of the past 6 years, the SECM forecasts have ranged within 0-17% of actual harvest, with an average deviation of 6.5%. This relatively low error rate demonstrates the utility of the juvenile pink salmon information for predicting year-class strength (Figure 2; Table 5).

The exception to these good forecasts was the forecast for the 2006 harvest. The pink salmon return and harvest in 2006 was very poor, and was not accurately forecast by the simple peak juvenile 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, prior to the 2005 early marine period, may have contributed to the poor year-class strength of pink salmon in 2006. The juvenile CPUE should, however, account for low recruitment of pink salmon from streams to the coastal marine environment following these conditions. 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. At sea sampling in late summer 2005, found anomalously high ocean temperatures and abnormal species assemblages in the GOA which could have resulted in negative interactions with seaward migrating pink salmon (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. In 2007 and 2008, two-parameter models incorporating May water temperature data improved the forecasts relative to the simple CPUE model. Forecast deviations from the actual harvests in 2007 and 2008 were low, 10% and 1% for the two-parameter model, but would have increased to 15% and 9% for the simple CPUE model (Table 5). In contrast, the forecast for 2009 was not improved by including additional parameters (Wertheimer et al. 2009). The forecast from the 2009 four-parameter model deviated from the actual harvest by 17%, whereas, if the simple CPUE model had been used, the forecast would have deviated by only 1%. 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.

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 is responsive to patterns of environmental conditions that persist over time. 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 million) in 2006, whereas the actual return was very poor (12 million). To compensate for the limitations of trend analysis, the ADFG forecast has used the SECM Peak CPUE data to modify the exponential smoothing model forecast since 2006 (e.g., Heinl 2009). These modified forecasts have been consistently better than the unmodified smoothing model (Table 5), with average absolute deviation (and range) of 10% (4-19%) versus 49% (29-81%). This improved performance of the ADFG models again demonstrates the utility of the juvenile pink salmon index for forecasting year-class strength. In the ADFG case, the Peak CPUE index is used to modify and adjust a time-series analysis of harvest trends, an inherently different approach from the SECM use of the Peak CPUE as the main predictive parameter for forecasting, with environmental data used as modifiers. To date, the two approaches have performed similarly for 2007-2009: the average absolute deviation (and range) for the SECM forecasts has been 9% (1-17%) (Table 5).

For the 2010 SECM forecast, the juvenile pink salmon CPUE was the most highly and significantly correlated parameter of the 16 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 only other parameter significantly correlated with harvest was the NPI ($r = 0.58$). This measure of atmospheric conditions could indicate climate effects on stream conditions during embryonic development or on ocean conditions during early marine residency, or both. However, the NPI did not enter into the stepwise regression model, suggesting that the variation in year-class strength it explains is redundant with the more strongly-correlated CPUE index. May 20-m integrated water temperatures entered the model for the fourth 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. This relationship was strongly driven by the large negative residual of the simple CPUE model for the poor 2006 year-class, which followed very warm 2005 ocean temperatures in the GOA. The ENSO juvenile index also was significant in the final Peak CPUE model for the second consecutive year, which may indicate that this parameter is useful in detecting basin-scale effects on year-class variation after juvenile pink salmon migrate into the GOA.

The 2010 SECM forecast of 27 million pink salmon is an improvement relative to the poor returns of 2006 and 2008. This result indicates potential recovery of the even-year brood line of pink salmon in SEAK, which has produced substantially lower harvests than the odd-year brood line in recent years. If validated by the 2010 harvest, this result will also demonstrate that the juvenile salmon index can detect directional shifts in trends of pink salmon year-class strength. Preliminary end of the season pink salmon harvests for 2010 are currently 23.4 million (17 Sept 2010, Alaska Department of Fish and Game) and are within 15% of the SECM 2010 harvest forecast.

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Table 1.—Correlation coefficients for catch per unit effort (CPUE) of juvenile pink salmon and associated biophysical parameters in year *y* for 1997-2008 with adult pink salmon harvest in Southeast Alaska in year *y* + 1. Parameters with statistically significant correlations are in bold text.

Parameter	***r***	***P*-value**
Juvenile Pink Salmon Abundance		
Peak CPUE	**0.92**	**0.001**
August CPUE	-0.30	0.340
Juvenile Pink Salmon Growth and Condition		
Pink Salmon Size July 24	0.27	0.316
Condition Index	-0.04	0.913
Energy Content	0.09	0.787
Zooplankton Standing Crop		
May/June Average Zooplankton Total Water Column	0.10	0.762
May/June Average Zooplankton 20-m	0.38	0.219
Local-scale physical conditions		
May 3-m Water Temperature	-0.38	0.225
May 20-m Integrated Water Temperature	-0.17	0.584
May 20-m Temperature Anomalies	-0.31	0.355
June 20-m Integrated Water Temperature	-0.11	0.404
June Mixed-layer Depth	-0.09	0.780
July 3-m Salinity	-0.24	0.505
Basin-scale physical conditions		
Pacific Decadal Oscillation (Ocean Winter)	0.13	0.679
Northern Pacific Index	**0.58**	**0.047**
El Niño Southern Oscillation (Prior year annual average)	-0.22	0.498

Table 2.—Southeast Coastal Monitoring (SECM) and Alaska Department of Fish and Game (ADFG) forecasts for 2009 pink salmon harvest in Southeast Alaska (SEAK). The ADFG forecasts are from Heinl (2009). Na = not applicable.

	2008 SEAK Pink Salmon Harvest (millions of fish)	**Deviation from Actual Harvest**
SECM Forecast	44.4	17%
ADFG Forecast (w/ Peak CPUE data)	41.0	7%
ADFG Forecast (w/o Peak CPUE data)	52.0	17%
Actual Harvest	38.0	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* = 1997-2009. R^2 = coefficient of determination for model; AIC_c = Akiake Information Criterion (corrected); *P* = statistical significance of regression equation. SEAK harvest excludes Yakutat (see text).

Model	**Harvest Area**	**Adjusted R^2**	**AIC_C**	**Regression *P* -value**	**2010 Prediction (millions)**
ln(PeakCPUE)	SEAK	82%	91.5	<0.001	31.2
ln(PeakCPUE) + May20-mTemp	SEAK	91%	86.4	<0.001	21.2
ln(PeakCPUE) + May20-mTemp + ENSO	SEAK	94%	84.8	<0.001	26.8

Table 4.—Average absolute percent deviation of jackknife forecasts to observed harvests for forecast models for 1998-2009 returns of pink salmon for the Southeast Alaska (SEAK) region and for the northern inside portion of that region. SEAK harvest excludes Yakutat (see text).

Model	**Harvest Area**	**Average Deviation**	**2006 Deviation**
ln(PeakCPUE)	SEAK	27%	186%
ln(PeakCPUE) + May20-mTemp	SEAK	23%	108%
ln(PeakCPUE) + May20-mTemp + ENSO	SEAK	20%	111%

Table 5.—Southeast Alaska pink salmon harvest (in millions of fish) and associated forecasts from Southeast Coastal Monitoring project (SECM) catch per unit effort (CPUE) models and Alaska Department of Fish and Game (ADFG) exponential smoothing models. Accuracy of forecast is shown in parentheses. For SECM, both the simple CPUE and the multi-parameter CPUE models (if the simple model was not used for forecast) are shown. Similarly for ADFG, both the exponential smoothing model with and without (2007-2009 only) the addition of the SECM juvenile CPUE data are shown. (S. Heinl, ADFG, pers. comm.) .

		SECM CPUE Models		**ADFG Exp. Smoothing Models**	
Year	**Harvest**	**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%)

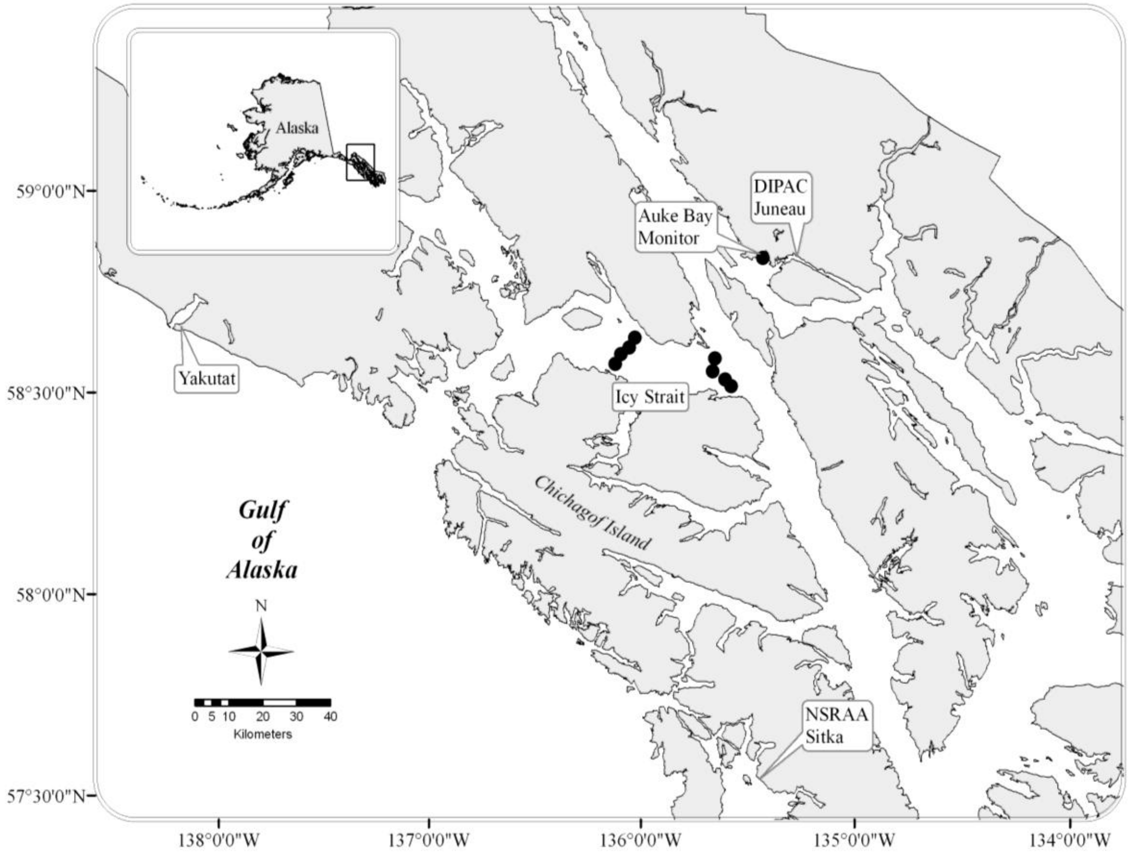

Figure 1.—Stations sampled for juvenile pink salmon along the Icy Strait transects in the northern region of Southeast Alaska for the development of pink salmon harvest forecasting models. Stations were sampled during May–August from 1997–2009.

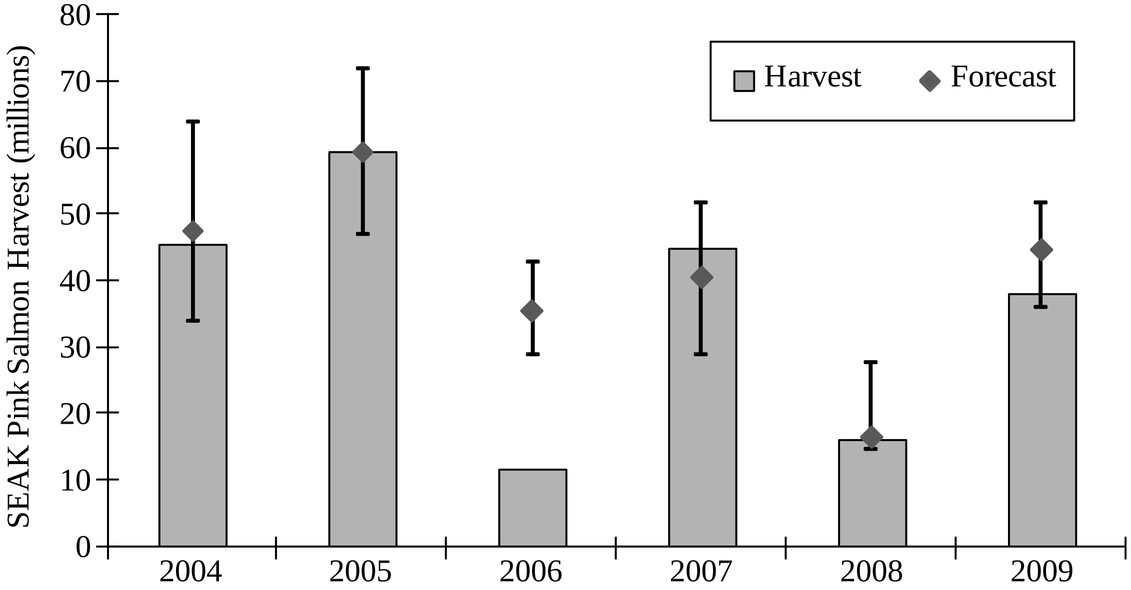

Figure 2.—Southeast Coastal Monitoring (SECM) pink salmon harvest forecasts for Southeast Alaska (SEAK; symbols), associated 80% confidence intervals (lines), and actual SEAK pink salmon harvests (shaded bars), 2004-2009.

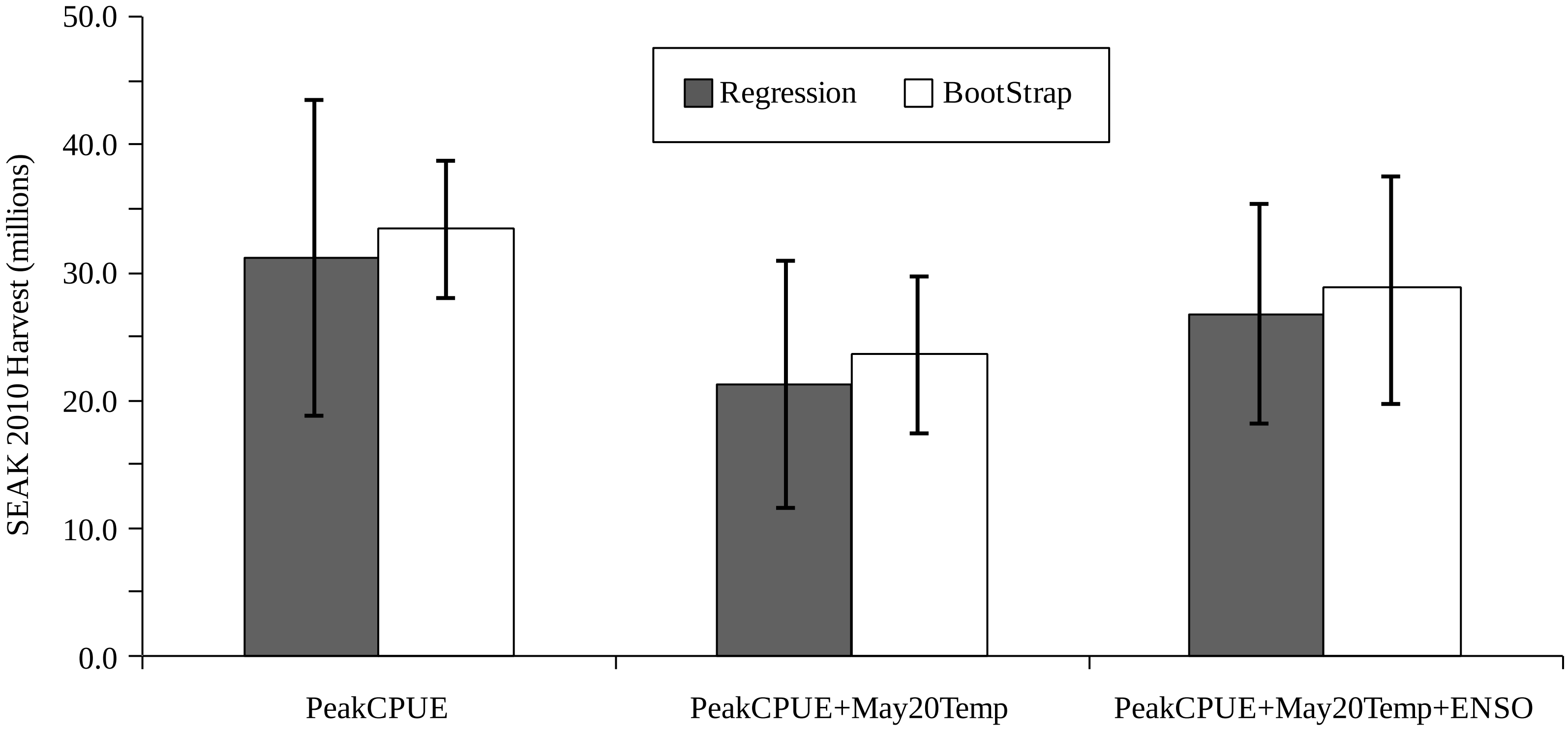

Figure 3.—Parametric regression and bootstrap 80% confidence intervals (lines) for predictions of Southeast Alaska (SEAK) pink salmon harvest in 2010 (shaded bars) from three models incorporating juvenile Peak CPUE data in 2009. See text for descriptions of parameters included in models.