Forecasting Pink Salmon Abundance in Southeast Alaska from Juvenile Salmon Abundance and Associated Environmental Parameters

Final Report
January 7, 2010

Pacific Salmon Commission
Northern Fund Project NF-2008-I-25

PERIOD COVERED: April 1, 2008 to March 31, 2010
PERIOD FUNDED: April 1, 2008 to March 31, 2010
TOTAL PSC FUNDS AWARDED: $77,960
PSC FUNDS RECEIVED: $70,164

Principal Investigator:
Alex C. Wertheimer, Fishery Research Biologist
NOAA Fisheries, Alaska Fisheries Science Center Auke Bay Laboratories
17109 Pt. Lena Loop Road
Juneau, AK 99801
Alex.Wertheimer@noaa.gov

Co-investigators:
Joseph A. Orsi, Molly V. Sturdevant, and Emily A. Fergusson
Fishery Research Biologists
NOAA Fisheries, Alaska Fisheries Science Center Auke Bay Laboratories
17109 Pt. Lena Loop Road
Juneau, AK 99801

The Southeast Coastal Monitoring project (SECM) is a component of the NOAA Auke Bay Laboratories salmon research program which has sampled juvenile salmon and associated biophysical parameters in northern Southeast Alaska (SEAK) since 1997 utilizing the NOAA Ship *John N. Cobb* and chartered trawl vessels. Sampling juveniles as they migrate to the Gulf of Alaska, after high-mortality periods of freshwater incubation and early marine residency, provides information on year-class strength that can be used with associated environmental data to forecast abundance of the fish when they return as adults. Data from these annual surveys have been used to develop models that predicted SEAK pink salmon harvests within 16% of actual harvests for 2004, 2005, 2007, 2008, and 2009. However, this forecast accuracy was not achieved in 2006, when pink salmon harvest was well below both the SECM forecast based on juvenile salmon abundance and the Alaska Department of Fish and Game (ADF&G) forecast based on previous pink salmon harvest time series. Despite this overestimate, the 2006 SECM forecast accurately identified a decline in average pink salmon harvest. The ADF&G is now incorporating the SECM juvenile data into their annual harvest time series forecast.

The Northern Fund (NF) has provided support to SECM to improve the forecast modeling and to increase the geographic scope of the data collected. Wertheimer et al. (2008a) and Orsi et al. (2008a) reported on improvements to the forecast model and the successful expansion of sampling in 2005-2007. In 2008, the NF continued support, including funding for a second year of fishing efficiency calibration tests between the ADF&G R/V *Medeia* and the *John N. Cobb* in anticipation of the deactivation of the *John N. Cobb* after the 2008 season. Unfortunately, a major mechanical breakdown of the *John N. Cobb* made it unusable for sampling in 2008 and thereafter. Consequently, NOAA chartered a trawler (the F/V *Steller*) to replace the *John N. Cobb* for sampling the northern SEAK stations; fishing power of this vessel was calibrated to the *Medeia* to maintain the core forecasting time series. Results from the 2008 sampling were reported in Orsi et al. (2009a); results for the forecast model developed from the 2008 sampling efforts were reported in Wertheimer et al. (2009a); and results from the calibration analysis were reported in Wertheimer et al. (2009b). No funding applications to the NF for support of research proposed in 2009 were awarded due to the international economic downturn. Because of the truncated sampling in 2008, funds remained from the 2008 SECM project that could be carried over for additional work in 2009. The Northern Fund Committee approved use of the carryover funds as matching funds for other support awarded by the Alaska Sustainable Salmon Fund (AKSSF). Therefore, this final report includes summaries from both the 2008 and 2009 sampling seasons. Sampling in 2009 was successfully completed in both regions using another chartered trawl vessel, the F/V *Chellissa*, in July and August, but funding was not in place in time for a June chartering. The *Chellissa*'s fishing power was calibrated to the *Medeia* in July so that the entire time series could be compared to the original *John N. Cobb* data.

The project objectives for NF-2008-I-25 were: (1) Sample juvenile salmon and associated environmental data in northern and southern Southeast Alaska; (2) Develop harvest forecasts for the 2009 return year, and assess the utility of incorporating southern Southeast Alaska juvenile

salmon data into current forecast models; and (3) Determine a calibration factor for comparing juvenile salmon catches between two research vessels using the same sampling gear. The work completed to meet these objectives is summarized below; the documents produced from the project to date are cited where appropriate and are attached as part of this final report.

Objective 1. Sample juvenile salmon and associated environmental data in northern and southern Southeast Alaska.

2008 Revised Objectives:

SECM sampling objectives for 2008 were modified in response to the fatal mechanical failure of the *John N. Cobb* before the scheduled June survey. The original sample plan called for 38 vessel days using the *John N. Cobb* (Heard et al. 2008). Overall, 22 of the 38 days planned were used, primarily with other vessels (Orsi et al. 2009a). Scheduled oceanographic sampling in May was accomplished using the *John N. Cobb*. Under an emergency procurement procedure, the F/V *Steller* was chartered for June and July sampling in the northern region. However, sampling scheduled for the southern region in these months could not be conducted due to the *Steller*'s small size and time constraints. Thus, a core objective, to confirm the regional concordance in timing and relative abundance of juvenile salmon, could not be completed in 2008. Sampling was conducted in the northern region in August by charter of the *Medeia*. A detailed report of sampling methods and the catch and biophysical data collected in 2008 was presented in an NPAFC document (Orsi et al. 2009b), and is attached to this final report. Orsi et al. (2009b) is the first in the series of annual NPAFC documents for SECM sampling that includes interannual comparisons of catches, biophysical conditions, and juvenile salmon condition, and thus extends the comparisons reported in the three-year summary of regional comparisons presented as a final report to the PSC Northern Fund (Wertheimer et al. 2008a) and in the Pink and Chum Salmon Workshop proceedings (Orsi et al. 2008b). Additional long-term comparisons were recently presented as a feature article on the NOAA Alaska Fisheries Science Center (AFSC) website at http://www.afsc.noaa.gov/ (Orsi et al. 2009c).

2009 Revised Objectives:

The extension of the NF project timeline allowed sampling of both the northern and southern regions in 2009. As in 2008, SECM sampling objectives had to be modified in response to vessel and funding limitations. The original sample plan called for 40 vessel days using a chartered vessel (Orsi et al. 2009d). These days do not include the *Medeia* charter days for the calibration component of the project. Overall, a vessel was available for the SECM sampling for only 22 of the 40 vessel days (Table 1). However, despite this reduction in planned vessel days, the loss of data was limited to the planned trawl collections in the month of June, in both the southern and northern regions, and the June oceanographic sampling in the southern region; all other

objectives were achieved in fewer days because the sampling schedule was accelerated and because several alternate vessels were employed. Specifically, oceanographic sampling normally conducted in May without accompanying trawls on NOAA or charter vessels was done from the ABL small vessels, R/V *Quest* and R/V *Sashin*, at slightly later than traditional SECM sampling times on schedules adjusted to vessel availability. June oceanographic sampling was also accomplished in the northern region using these NOAA small vessels, but charter funds were not received in adequate time to procure a vessel for June trawling. Trawl sampling was therefore restricted to the months of July and August. The F/V *Chellissa* was chartered for these later months, and sampling was conducted in both the southern and northern regions in July and in the northern region in August. A detailed report of sampling methods and the catch and biophysical data collected in 2009 will be presented in the SECM annual NPAFC document in October of 2010.

Table 1.—Numbers and types of data collected monthly by habitat for the Southeast Coastal Monitoring project with NOAA and charter vessels in the marine waters of the northern and southern regions of Southeast Alaska, May–August 2009.

Dates	Vessel	Habitat	Data collection type[1]					
			Rope trawl	CTD cast	Oblique bongo	20-m vertical	WP-2 vertical	Chlorophyll & nutrients
			Northern region					
29 May-3 June	R/V *Quest, Sashin*	Inshore	0	2	1	3	1	1
		Strait	0	8	4	8	0	8
1 July	R/V *Sashin*	Inshore	0	1	1	3	1	1
		Strait	0	8	4	8	0	8
26 July-1 Aug	F/V *Chellissa*	Inshore	0	1	1	3	1	1
		Strait	30	28	4	22	0	8
26-31 July	R/V *Medeia*	Inshore	0	0	0	0	0	0
		Strait	28	0	0	0	0	0
16-21 Aug	F/V *Chellissa*	Inshore	0	1	1	3	1	1
		Strait	16	16	4	16	0	8
			Southern region					
19-25 July	F/V *Chellissa*	Inshore	0	0	0	0	0	0
		Strait	16	15	4	15	0	8

[1]Rope trawl = 20-min hauls with Nordic 264 surface trawl ~20 m H x 24 m W; CTD casts = to 200 m or within 10 m of bottom; oblique bongo = 60-cm diameter frame, 505- and 333-µm paired meshes, towed double obliquely down to and up from a depth of 200 m or within 20 m of the bottom; 20-m vertical = 50-cm diameter frame, 243-µm conical net (Norpac) towed vertically from 20 m; WP-2 vertical = 57-cm diameter frame, 202-µm conical net towed vertically from 200 m or within 10 m of the bottom; chlorophyll and nutrients are from surface seawater samples.

Objective 2. Develop harvest forecasts for the 2009 return year, and assess the utility of incorporating southern Southeast Alaska juvenile salmon data into current forecast models.

2008 Objectives:

Objective 2 was fully met for 2008. The forecast model was developed using the time series of peak June-July catch-per-unit-effort (CPUE) of juvenile pink salmon in northern SEAK and associated environmental data collected by SECM from 1997-2007. The "best" forecast model included juvenile pink salmon CPUEs and an index of May seawater temperatures as parameters. Juvenile pink salmon CPUEs from 2008 were used to forecast the SEAK harvest for 2009. The forecast of 16.1 million pink salmon was within 2% of the actual harvest of 15.9 million. The forecast was presented to the SEAK Purse Seine Task Force on December 2, 2008. A NPAFC document summarizing the model development and forecast was also completed (Wertheimer et al. 2009a), and is attached to this final report. Incorporation of juvenile pink salmon CPUE from southern SEAK for the years 2005-2007 was also evaluated for inclusion in the 2008 forecast model. Because of the high correlation of peak CPUEs between northern and southern SEAK, incorporating the southern SEAK pink salmon catch data did not improve the forecast model. These analyses are also included in Wertheimer et al. (2009a).

2009 Revised Objectives:

The extension of the project for one year allowed an additional year of model development and forecasting. Stepwise regression identified three possible forecast models (Table 2). Based on the percentage of variation explained, the Akiake Information Criterion, and a jackknife hind-casting analysis, the three-parameter model was selected as the best forecast model. The three parameters were juvenile pink salmon peak CPUE, May seawater temperatures, and an index of the El Niño Southern Oscillation (ENSO). The 2009 calibrated juvenile pink salmon CPUE (see Objective 3, below) was used in the model to forecast the 2010 harvest. Because there was no trawl sampling in June, the July CPUE was assumed to be the peak catch; July CPUEs have been higher than June for 10 of the past 12 SECM sampling years. The three-parameter model for 2010 predicts a SEAK harvest of 26.8 million pink salmon, with a bootstrap 80% confidence interval of 18-35 million fish. These results were presented at the SEAK Purse Seine Task Force meeting in Ketchikan, Alaska, on December 8, 2009. A NPAFC document summarizing these analyses, the model development, and the 2010 forecast will be completed by September 2010.

Table 2.— Southeast Alaska Coastal Monitoring (SECM) project's predicted total adult pink salmon harvest (millions, M) for Southeast Alaska (SEAK) for 2010 from the three best forecast models selected according to the lowest Akiake Information Criterion (corrected; AIC_c) and their 80% confidence intervals. The regression models relate juvenile catch per unit effort (CPUE) of pink salmon in year *y* to adult harvest in SEAK in year *y* +1, for *y* = 1997-2007. R^2 = coefficient of determination for model; *P* = statistical significance of regression equation. The 3-parameter model best fits the 12-year time series of SECM data parameters and subsequent SEAK pink salmon harvests from 1998 to 2009; the harvest prediction and confidence interval for this model are in bold type. See Wertheimer et al. 2008a, 2009a for comparison to models selected in prior years.

Models and parameters	Adjusted R^2	Regression *P*-value	AIC_c	Harvest Prediction for 2010	80% Confidence Interval
1 parameter model					
Peak CPUE	82%	92.5	< 0.001	31.2 M	19-44
2 parameter model					
Peak CPUE + May 20m temperature	91%	86.4	< 0.001	21.2 M	12-31
3 parameter model					
Peak CPUE + May 20m temperature + ENSO (juv. yr)	94%	84.8	< 0.001	**26.8 M**	**18-35**

Objective 3. Determine a calibration factor for comparing juvenile salmon catches between two research vessels using the same sampling gear.

2008 Objectives:

Objective 3 was successfully met in 2008. The original plan included a second year of calibration of fishing power between the *John N. Cobb* and the *Medeia* in July 2008, to improve the statistical resolution of the initial comparison between these two vessels that was completed in 2007 (Wertheimer et al. 2008b). However, this was not possible because of the loss of the *John N. Cobb*. Instead, fishing powers of the *Medeia* and the replacement charter vessel *Steller* were calibrated in the northern region in July, thus linking historical catches of the *John N. Cobb* to the *Steller* by an intermediate vessel. Juvenile pink salmon CPUE data from the 2008 sampling were then standardized to *John N. Cobb* "units" and used to forecast 2009 harvest. A NPAFC document summarizing the 2008 calibration sampling and analyses was completed (Wertheimer et al. 2009b), and is attached to this final report.

2009 Revised Objectives:

The extension of the project into 2009 (see revised Objective 1) permitted calibration between the *Medeia* and the *Chellissa*. Paired trawl sampling to calibrate fishing power between these vessels was accomplished in the northern region in July 2009 to maintain the link between current and long-term datasets collected from the *John N. Cobb* (Table 3). Calibration factors were computed from the catch ratio of *Chellissa:Medeia*, then this value was converted to *John N. Cobb* "units" based on the earlier results of *Medeia:John N. Cobb* calibration determined from paired sampling in 2007 (Wertheimer et al. 2008b). Overall, *Medeia* catches were greater than those from paired *John N. Cobb* trawls in 2007, while *Medeia* catches were less than those from paired *Chellissa* trawls in 2009. In contrast, the ratio for the 2008 comparisons was in the opposite direction, with *Medeia* catches greater than those from paired *Steller* trawl catches (Wertheimer et al. 2009b). Juvenile pink salmon CPUE data from the 2009 sampling were standardized to *John N. Cobb* "units" and used to forecast 2010 harvest. A NPAFC document describing the 2009 calibration sampling and analyses will be completed by September 2010.

Table 3.—Calibration factors for adjusting the juvenile salmon species (*Oncorhynchus* spp.) catch of the F/V *Chellissa* for consistency with the long-term SECM data series collected by the NOAA Ship *John N. Cobb*. Fishing efficiencies are from 28 paired comparisons between the ADF&G R/V *Medeia* and the *Chellissa* in 2009 and 26 paired comparisons between the *Medeia* and the *John N. Cobb* in 2007 (Wertheimer et al. 2008a).

Salmon species	Fishing efficiency *Chellissa:Medeia*	Fishing efficiency *Medeia*:*Cobb*	Calibration factor *Chellissa:Cobb*
Pink	1.27	1.19	1.51
Chum	1.19	1.19	1.42
Sockeye	0.99	1.19	1.18
Coho	1.05	1.19	1.25

Scientific Accomplishments

Maintaining the long-term sampling plan and monitoring juvenile salmon abundance and biophysical conditions in Southeast Alaska with support from NF and other funding entities has contributed substantially to our understanding of processes affecting salmon production. The SECM forecasting has been cited as an example of pragmatic application of ocean research to fisheries management (Turner and Haidvogel 2009). The consistency of the research has fostered communications and cooperation with ADF&G, regional aquaculture associations, commercial fishing constituents, academia, and international salmon fisheries organizations such as NPAFC. SECM staff have presented numerous oral reports at scientific meetings and to stakeholder groups. SECM research has culminated in a number of recent scientific publications. In addition to the 11 recent scientific documents produced by SECM and cited in this final report, an additional 11 peer-reviewed publications and 4 scientific documents have been produced from this research since the NF began to provide support in 2004.

Budget Summary

The NF allocated a total of $77,960 for this project. Of this amount, $38,360 was spent for the 2008 component of the project. For the 2009 extension of the project, $30,277 has been spent to date and $9,323 has been obligated for spending by March 31, 2010, contingent on receipt of the 10% NF hold-back. Spending by Pacific Salmon Commission (PSC) line item is itemized for each year on an annotated PSC budget form for NF-2008-I-25, which is included as Attachment 1.

Limitations in charter vessel availability required an extension of the project and changes in funding allocations to meet project objectives. The costs associated with 2009 vessel charter (PSC line item Equipment Rental) required substantial re-allocation of funds from other line items, such as technician support and otolith processing. These costs were met with funding from the Alaska Sustainable Salmon Fund (AKSSF Project 45956), leveraged by use of the NF in 2009. Travel costs were also increased due to the project extension to meet reporting obligations. Table 4 lists the amount projected, amount spent (including projected spending through March 31), the amount and percent variance, and a short explanation for variances greater than 10% of the projected spending. The spending for the project was tracked by the NOAA National Marine Fisheries Service Management Analyst and Reporting System (MARS). A MARS object class summary is included as Attachment 2.

Table 4.—Project NF-2008-I-25 budget expenditures including amount projected, amount spent (including projected spending through March 31), the amount and percent variance (negative values are shown in parentheses), and a short explanation for variances greater than 10% of the projected spending.

	Projected	Spent	Variance	% Variance	Comments
			Subcontractors & consultants		
Technician support, vessels	$11,200	$0	$11,200	100%	Savings in this line item resulted from utilization of NMFS staff and volunteer labor.
Technician support, laboratory	$13,760	$17,472	($3,712)	(27%)	A higher funding level was required to process samples extending over two years.
Otolith processing	$10,000	$0	$10,000	100%	Otolith processing was supported by AKSSF funding.
Total subcontractor & consultants	**$34,960**	**$17,472**	**$17,488**	**50%**	Variances are explained in subsections above. Positive variance was applied to charter, supplies, and travel.
			Site/project costs		
Travel	$8,000	$10,494	($2,494)	(31%)	Travel to meet reporting obligations increased due to project extension.
Site supplies & materials	$18,000	$23,586	($5,586)	(31%)	Supply costs increased to cover two years of sampling.
Equipment rental	$11,000	$21,151	($10,151)	(92%)	The *Medeia* charter costs increased to account for two years of calibration work.
Work & safety gear	$1,000	$0	$1,000	100%	AKSSF funds were used to cover these costs; positive variance was applied to other line items.
Repairs & maintenance	$5,000	$5,257	($257)	(5%)	
Total site/project costs	**$43,000**	**$60,488**	**($17,488)**	**(44%)**	Variances are explained in subsections above.
Total project costs	**$77,960**	**$77,960**	**$0**	**0%**	

List of Attachments

1. Annotated Pacific Salmon Commission NF-2008-I-25 Budget Spreadsheet
2. Management Analyst and Reporting System (MARS) Summary
3. Orsi et al. 2008. NPAFC Document 1110
4. Wertheimer et al. 2008. NPAFC Document 1112
5. Orsi et al. 2009. NPAFC Document 1181
6. Wertheimer et al. 2009. NPAFC Document 1180
7. Wertheimer et al. 2009. NPAFC Document 1202

Literature cited:

Heard, W.R., E.A. Fergusson, J A. Orsi, M.V. Sturdevant, A.C. Wertheimer, and B.L. Wing. 2008. Southeast Alaska Coastal Monitoring (SECM) Cruise Plan for 2008. NPAFC Doc. 1094, 12 pp. (Available at http://www.npafc.org).

Orsi, J. A., E.A. Fergusson, M.V. Sturdevant, B.L. Wing, A.C. Wertheimer, and W.R. Heard. 2008a. Annual survey of juvenile salmon and ecologically related species and environmental factors in the marine waters of southeastern Alaska, May–August 2007. NPAFC Doc. 1110, 82 p. (Available at http://www.npafc.org).

Orsi, J.A., A.C. Wertheimer, E.A. Fergusson, and M.V. Sturdevant. 2008b. Interactions of hatchery chum salmon with juvenile chum and pink salmon in the marine waters of southeastern Alaska. p 20-24 In: K. Neely et al. (Rapporteurs). Proc. 23rd NE Pacific Pink and Chum Salmon Workshop, Feb. 19-21, 2008, Bellingham, WA, 95 p.

Orsi, J. A., M.V. Sturdevant, E.A. Fergusson, A.C. Wertheimer, B.L. Wing, and W.R. Heard. 2009a. Southeast Alaska Coastal Monitoring (SECM) Survey Plan for 2009. NPAFC Doc. 1153, 14 pp. (Available at http://www.npafc.org).

Orsi, J.A., E.A. Fergusson, M.V. Sturdevant, B.L. Wing, A.C. Wertheimer, and W.R. Heard. 2009b. Annual Survey of Juvenile Salmon, Ecologically-Related Species, and Environmental Factors in the Marine Waters of Southeastern Alaska, May–August 2008. NPAFC Doc. 1181, 72 pp. (Available at http://www.npafc.org).

Orsi, J. A., A.C. Wertheimer, M.V. Sturdevant, E.A. Fergusson, and B.L. Wing. 2009c. Insights from a 12-yr biophysical time series of juvenile pacific salmon in Southeast Alaska: the Southeast Alaska Coastal Monitoring Project (SECM). ASFC Quarterly Research Report Feature Article, July-Aug-Sept 2009. Available at: http://www.afsc.noaa.gov/Quarterly/jas2009/JAS09featurelead.htm.

Orsi, J.A., M.V. Sturdevant, E.A. Fergusson, and A.C. Wertheimer. 2009d. The 2010 Southeast pink salmon forecast from the Southeast Coastal Monitoring (SECM) research project. Oral presentation to the Southeast Alaska Purse Seine Task Force Meeting. December 7, 2009, Ketchikan, Alaska.

Turner, E. and D. B. Haidvogel. 2009. Taking ocean research results to applications: examples and lessons from US GLOBEC. Oceanography 22(4): 233-241.

Wertheimer, A.C., J.A. Orsi, M.V. Sturdevant, and E.A. Fergusson. 2008a. Forecasting pink salmon abundance in Southeast Alaska from juvenile salmon abundance and associated environmental parameters. Final Report Project No. NF-2005-I-10, Pacific Salmon Comm. Northern Fund, 41 pp. Auke Bay Laboratories, 17109 Pt. Lena Loop Rd., Juneau, AK 99801.

Wertheimer, A.C., JA. Orsi, E.A. Fergusson, and M.V. Sturdevant. 2008b. Paired comparisons of juvenile salmon catches between two research vessels fishing Nordic 264 surface trawls in southeastern Alaska, July 2007. NPAFC Doc. 1112, 17 p. (Available at http://www.npafc.org).

Wertheimer, A.C., J.A. Orsi, E.A. Fergusson, and M.V. Sturdevant. 2009a. Forecasting Pink Salmon Harvest in Southeast Alaska from Juvenile Salmon Abundance and Associated Environmental Parameters: 2008 Returns and 2009 Forecast. NPAFC Doc. 1202, 20 pp. (Available at http://www.npafc.org).

Wertheimer, A.C., J.A. Orsi, E.A. Fergusson, and M.V. Sturdevant. 2009b. Calibration of juvenile salmon catches using paired comparisons between two research vessels fishing Nordic 264 surface trawls in southeastern Alaska, July 2008. NPAFC Doc. 1180, 18 pp. (Available at http://www.npafc.org).