

AYK-SSI Escapement Goal Expert Panel: PHASE 2

Final Report

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Arctic Yukon Kuskokwim Sustainable Salmon Initiative

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Executive Summary

In 2008, AYK SSI called for an expert panel to advise on quantitative methods to establish suitable escapement goals for AYK salmon stocks, where those methods would incorporate uncertainty and consider competing management objectives. Specifically, the Panel used a quantitative modeling approach known as management strategy evaluation (MSE), which simulates the entire management system along with key uncertainties. The Panel's work was well-received by ADFG staff and fostered discussions of how uncertainty and risk could be more effectively included in harvest policy deliberations. However, the Panel's analyses were highly technical and therefore a second phase of Panel work was initiated to broaden the influence of these types of analyses on AYK salmon management.

Here we report on the Panel's second phase of work, which involved (1) building capacity of ADFG managers and decision makers via technology transfer to promote effective use of the models, (2) developing tools to communicate the rationale, approach, and implications of policy analyses to a broad audience, including stakeholders, and (3) applying the MSE approach to other AYK salmon fisheries. Technology transfer with ADFG staff was accomplished by conducting two workshops, which instructed participants on the construction, use, and interpretation of MSE. To advance communication of the Panel's work, we created a narrated slideshow/video that communicates the basic concepts of MSE, and we facilitated the continued development of the computing tool, Vismon, which aids visualization of MSE results.

Three new harvest policy analyses were conducted in the Panel's Phase 2 work. First, a Bayesian state-space run reconstruction and stock-recruitment model was created for Nome Subdistrict chum salmon stocks. This model integrated all available air survey and weir data from eight tributaries, harvest data, and age composition information to estimate spawner-recruit

parameters for the aggregate stock. Parameter estimates from this model were used in an MSE model that evaluated harvest policy tradeoffs associated with a range of escapement goals and commercial fishery harvest rates. Similar to other analyses of this type, we found that subsistence performance could be improved and the frequency of commercial fishery closure reduced by moving toward policies that incorporate a lower escapement goal but also lower commercial harvest rates. Second, we completed a harvest policy analysis for the mainstem Canadian portion of the Yukon River Chinook salmon stock, using a similar approach to the Nome Subdistrict chum salmon analysis. We found strong harvest policy tradeoffs between US commercial and Canadian fisheries. Specifically, reducing escapement goals and lowering the US commercial harvest rate could, over the long term, increase the probability of meeting border passage obligations. Third, we conducted an analysis of an in-season management strategy aimed at meeting border passage for Yukon River fall chum salmon. The management strategy attempted to avoid harvesting salmon of the mainstem Canadian stock by adjusting daily harvest rates downward when the Canadian portion comprised a large proportion of the run. This approach resulted in negligible increases in border passage and the probability of meeting the border passage obligations. Capacity building, improved communications products, and the new analyses should continue to foster continued interest in uncertainty-based approaches to harvest policy analysis such as MSE in the AYK region and beyond.

Introduction

In 2008, AYK SSI called for an expert panel to consider and advise on methods to establish suitable escapement goals for AYK salmon stocks. A central aim of the Panel in its assessment of scientifically defensible harvest policies is the explicit consideration of four key aspects of AYK salmon management. First, there are usually many – potentially conflicting – interests associated with a salmon fishery. Thus, the Panel believes the expected performance of alternative policies should be evaluated by considering a variety of performance indicators that reflect these different interests. Second, we have far from perfect knowledge of AYK salmon population dynamics and a limited ability to measure harvest and abundance. This uncertainty means that decisions we make will have uncertain outcomes, which creates risk. Sound policy should explicitly consider this risk, not simply ignore it or adjust for it arbitrarily. Third, our level of ignorance about many AYK stocks is higher than for many other salmon fisheries, which can preclude the use of data intensive methods for determining harvest policies. Finally, there is now strong evidence that the productivity of salmon populations can vary considerably over time, likely due to decadal-scale variations in oceanic conditions. A policy that appears to have performed well (or poorly) in recent years may lead to very different outcomes in the future, which gives rise to an additional element of risk that should be accounted for in the policy analysis.

With these issues in mind, the Panel visited the AYK region to meet with managers and research biologists to seek advice on our activities. From this engagement emerged three distinct simulation analyses that were completed in 2011 as Phase 1 of the Panel’s activities (Jones et al. 2011):

- (1) *an analysis of harvest policy trade-offs for the Yukon River fall chum and Kuskokwim River Chinook salmon stocks,*
- (2) *an evaluation of the percentile method for setting escapement goals using historical escapements, and*
- (3) *an analysis of in-season management of Yukon River fall chum salmon harvest management.*

All three analyses were examples of an approach to policy analysis referred to as Management Strategy Evaluation (MSE; Butterworth et al. 1997; Smith et al. 1999). Briefly, MSE is a model-based analysis wherein the entire management process is simulated, including data collection (assessment), management, and the actual system dynamics. For AYK salmon this means collection of harvest and assessment data (to inform decisions and update models), implementation of a control rule (how much harvest to allow for commercial and subsistence fisheries), and salmon stock-recruit dynamics. The MSE model is used to compare the performance of alternative management procedures, including both data collection/analysis and harvest strategies. MSE models include uncertainty, which allows consideration of risk, but also means they can be used to examine the significance of differing levels of uncertainty, thereby enabling consideration of the value of better information (reduced uncertainty) to the management process. Ultimately, MSE models provide a transparent, objective basis for considering alternative approaches to salmon management.

The Panel's Phase 1 work was very well received by ADFG staff and fostered further discussions with managers to explore application of these modeling approaches within the agency. The Panel believed that these types of analyses showed considerable promise as a means to facilitate discussions of how uncertainty and risk could be included in future policy

deliberations for AYK salmon management. However, the Panel also realized that this potential would not be fully realized without an effort to make the technical work of the Panel more accessible to managers and stakeholders, and to apply the analyses to additional salmon populations, thereby broadening the influence of these types of analyses on AYK salmon management. To meet these goals, the Panel undertook a second phase of work that involved three primary activities:

- (1) *technology transfer and capacity building aimed at biologists and decision-makers to promote effective use of the models;*
- (2) *development of communications products to convey the rationale, approach, and implications of policy analyses to a broad audience, including stakeholders; and*
- (3) *application of our approach to other AYK salmon fisheries, including Yukon River Chinook salmon.*

Technology transfer and capacity building involved holding two MSE workshops for agency and regional NGO biologists. Communications products consisted of the development of a narrated slideshow (also available in video format) and continued support for development of Vismon visualization software by Simon Fraser University scientists. The panel applied its MSE approach to two other stocks and conducted three new analyses: (1) a policy analysis for Nome Subdistrict chum salmon, (2) a policy analysis for the Canadian portion of the Yukon River Chinook salmon stock, and (3) an analysis of an in-season management strategy for Yukon fall chum to increase the likelihood of meeting border passage treaty obligations to Canada. In this document, we report on these activities.

1. Technology Transfer and Capacity Building

The Panel conducted two workshops with biologists and managers to increase their familiarity with and understanding of the technical analyses completed in Phase 1. The goal of the workshops was to engender a deep understanding of MSE modeling tools and to empower the managers to use the simulation tools themselves to explore salmon management strategies and management trade-offs. Increased understanding of MSE models by participants should enable them to effectively share the findings of these analyses with stakeholders. The primary target audience was ADFG and USFWS staff, as well as regional NGO biologists.

Workshop 1

Title: Management Strategy Evaluation I - Harvest Policy Trade-offs

Date: April 9-11, 2012

Location: Alaska Pacific University, Anchorage, Alaska

Participants: 27 (see Appendix A)

The first workshop covered MSE models that are used to evaluate alternative harvest policies (escapement goals, harvest rates; see Appendix B for topics and agenda). These models are similar to the harvest policy trade-offs analysis from Phase 1 of the Expert Panel and are described by Collie et al. (2012). The workshop began with a review of the basic components of an age-structured salmon population model implemented using Microsoft Excel on a personal computer. We reviewed basic salmon population dynamics, the construction of dynamic population models using computers, and the elements of stochastic simulation (random number generation, probability distributions). The central activity of the workshop was the construction of an MSE model, led by the Panel, but done individually by participants on their own or shared laptop computers. The Panel provided a spreadsheet template that contained no formulas but

was set up to facilitate the model building exercise. In particular, the Panel incorporated macros into the Excel template that automated the iterative process of running the models many times to generate a distribution of outcomes. We discussed and demonstrated to the participants each equation as it was added to the spreadsheet model. Participants then entered the equations on their own computers. This process was continued until a “generic” MSE model was complete. The Panel then provided parameter estimates from four well-known Alaskan salmon stocks (Kuskokwim River Chinook, Nome Subdistrict chum, Yukon fall chum, Karluk River Chinook salmon) to parameterize the MSE models. Participants formed four groups, each associated with one of the four example stocks. The groups worked on their own to adapt the generic MSE model to their particular stock and were encouraged to rely on their expert knowledge of the stock and fishery dynamics when constructing the models. On the last day, each group reported their results to the class. Model results were visualized with a program called Vismon, which has been developed by scientists at Simon Fraser University. Participants were instructed in the use of VISMON software.

Workshop 2

Title: Management Strategy Evaluation II - Advanced Topics

Date: April 30-May 1, 2012

Location: ADFG Offices, Anchorage, Alaska

Participants: 7 (see Appendix A)

The originally planned purpose of the second workshop was to instruct participants on creating MSE models for analysis of harvest management strategies within a fishing season (i.e., “in-season management”). After some consideration by the panel on the level of interest, available time, and feasibility, the panel determined that participants might benefit more from an

opportunity to follow up with the Panel on analyses that were conducted in the first workshop, rather than holding a workshop on in-season management. Thus, the second MSE workshop was a less formal affair and served three primary purposes. The first goal was to provide an opportunity for attendees of the first workshop to obtain follow-up guidance from the panel on workshop 1 analyses. In particular, the panel reviewed and provided critique of the MSE for the Kuskokwim Chinook salmon stock. The second goal was to introduce interested individuals to advanced MSE topics that were not covered in the first workshop. The panel demonstrated a fully closed-loop simulation approach in which annual stock assessments were simulated within the MSE model. The third goal of workshop 2 was to teach participants how to write an MSE model using the R program. R is a powerful open-source simulation and statistical analysis tool that is quickly becoming the lingua franca of ecological data analysis. Participants were instructed on how to construct the MSE model from workshop 1 using program R.

2. Development of Communications Products

The analyses conducted by the Panel in Phase 1 were very technical, involving complex statistical analyses and simulation modeling. The results were of considerable importance to stakeholders and managers because they addressed how alternative management strategies performed at meeting stakeholder objectives such as sustaining viable subsistence fisheries. We developed communication products designed to enable managers and stakeholders to understand and thus effectively utilize MSE analyses to inform their preferences for one management strategy over another. The Panel (1) developed a computer-based slideshow guide to MSE that makes our research more transparent and accessible and (2) coordinated additional funding for revision of a desktop computing tool called Vismon, which is used for visualizing policy trade-offs.

Narrated Slideshow

We created a narrated slideshow to serve as an interpretive guide to MSE. The purpose of the slideshow was to stimulate improved understanding of MSE simulation models and discussion of decision-making with respect to AYK salmon management strategies. The slideshow consisted of visual content similar to a Powerpoint presentation with text and animated graphics, as well as a script. It was developed with substantial assistance from QFC education specialist, Angie Leslie, and was created using the software Adobe Capture. We crafted the slides to demonstrate concepts in a way that is understandable to an audience with casual or limited exposure to quantitative modeling and moderate familiarity with salmon fisheries

In addition to the slides, we embedded videos showing fishing-related activities taking place in the lower Yukon River basin. These videos were obtained from the Discovery Channel program entitled “Chef’s Afield”, which previously aired an episode on Yukon River Chinook salmon. A communications specialist from MSU’s College of Agriculture and Natural Resources Communications Department was retained to narrate the slideshow.

The content was made available in either a pure video format that requires no interaction from the viewer (other than starting the video), or an interactive slideshow format that is playable in a web browser. In the interactive version, the viewer manually advances each slide. The interactive version allows the viewer to easily re-view slides of interest, and to proceed at a desired pace that might be slower or faster than the pace of the continuous video version.

The presentation was divided into five modules, each covering a different aspect of MSE (Appendix C). Module 1 provided an introduction to salmon management in the AYK region and presented a brief overview of a process called “decision analysis”, which is a type of structured decision-making that relies on quantitative models to forecast the expected outcome(s) of management decisions (Clemen 1991). Module 2 provided detail on how quantitative models can be used to represent the essentials of salmon population dynamics and fisheries while accounting for key uncertainties. Module 3 demonstrated how the models are used to evaluate the expected outcomes of proposed management options. Module 4 covered uncertainty and risk analysis, as well as situations in which we wish to evaluate harvest policies that have two dimensions (e.g., escapement target and harvest rate). Module 5 focused on visualizing tradeoffs and used the Panel’s analysis of harvest policies for the Yukon River fall chum salmon stock as an example.

The video will be distributed to interested ADFG staff and stakeholder groups and a copy will be submitted to AYKSSI along with this report.

Computer-Based Visualization Tools

A portion of the Phase 2 funds were awarded to scientists at Simon Fraser University (SFU) to support continued development of desk-top computing tools for visualization of complex simulation results. SFU researchers have developed prototype software called Vismon, which is a novel interactive computer tool that supports a variety of ways to visualize and interpret the results of an MSE analysis (Booshehrian et al. 2012). This additional funding commitment allowed the revision and ultimate completion of the development phase of Vismon. The Panel worked with SFU to make the software more user-friendly and to have the desired functionality for proper visualization of the results of MSE simulations. The Panel helped facilitate adoption of the software within ADFG by incorporating a Vismon training module into MSE workshop 1. In addition, the Panel administered a brief survey to workshop 1 participants to assess the utility and ease of application of the revised Vismon program for data visualization. SFU scientists wrote the survey and interpreted the results.

3. New MSE Analyses

Phase 1 work of the Panel led to a growing demand within ADFG for MSE analyses for additional stocks and to address other research questions. Two stocks that were of particular interest were Yukon River Chinook salmon and Nome Subdistrict chum salmon. There was also a desire to conduct analyses that account for the dynamics of mixed fisheries that harvest several stocks simultaneously.

Nome Subdistrict chum salmon

We performed an MSE analysis for the Nome Subdistrict chum salmon stock to evaluate alternative harvest policies. The MSE model was parameterized using estimates from a state-space stock-recruitment analysis that contained an embedded escapement reconstruction sub-model. Embedding the escapement reconstruction was advantageous because it allowed uncertainty in the reconstruction to flow through the analysis and ultimately to be reflected in uncertainty around the stock recruitment parameters. The aggregate Nome Subdistrict chum salmon stock consists of eight major stream-specific stocks: the Bonanza, Cripple, Eldorado, Flambeau, Nome, Sinuk, Snake, and Solomon Rivers. Escapement data also exist for a ninth stock, the Penny River, which we excluded from this analysis due to missing observations and many zero air survey counts.

Our approach to the escapement reconstruction was a significant advance over previous attempts to estimate the aggregate escapement to the 8 major drainages because our analysis incorporated into one model data from all of the rivers, rather than reconstructing the escapements on a river-by river basis. This approach employed linear regression analyses relating escapement in one river to escapement in another river(s) to fill in data gaps with point

estimate of predicted escapement values from these regressions. Therefore, this approach could not account for uncertainty in the relationships between rivers and allow that uncertainty to be carried through to the escapement estimates for year in which no escapement observations existed. Including all of the rivers into one model allowed uncertainty in escapements to each river to be dealt with in an appropriate manner. Namely, this new approach modeled the process (i.e., Dirichlet process; see below) by which the district-aggregated stock enters each of the rivers each year, and treated this process as separate from the process of observing the escaping salmon. This approach allowed for a proper accounting of uncertainty in escapement in year/rivers that lacked escapement observations. This uncertainty could then be carried into the stock-recruitment model, which would then influence the MSE model so that uncertainty in the expected outcome of a particular harvest policy could be appropriately estimated. Uncertainty creates risk. Thus, by properly accounting for uncertainty, the results of our analysis could be used to make an informed assessment of risk associated with various harvest policies.

We assembled all available data on harvest, escapement, and age composition from 1974 to 2011. Air surveys were conducted in most years for the majority of the streams. Weirs were used to estimate escapement since the mid 1990s on the Nome, Snake, and Eldorado Rivers. There were 37 instances of concurrent air survey and weir counts for these three streams since 1974, which helped inform estimates of catchability for the air surveys (see below for details). Escapement age composition data were obtained from the Nome, Snake and Eldorado weirs in most years since the mid 1990s. Additional inputs to the model were estimates of observation uncertainty for each of the data inputs. We allowed for a coefficient of variation of 5% for commercial harvest data, 5% for weir counts, and 15% for subsistence harvest. Observation

uncertainty for the air surveys was estimated in the model. By incorporating observation uncertainty, we allowed for the fact that the data were not perfect.

The model estimated stock recruitment parameters, age-at-maturity coefficients, and annual commercial and subsistence exploitation rates following methodology described in Fleischman and Borba (2009). In addition, the escapement reconstruction sub-model estimated additional parameters representing the proportion of the aggregate escapement that entered each of the eight streams. These proportions were modeled with a hierarchical Dirichlet distribution such that the vector of stream-specific escapement proportions for each year was assumed drawn from a common distribution. Finally, a time invariant catchability coefficient for air surveys (i.e., average proportion of the total escapement counted in the survey) was estimated for each stream. Concurrent air survey and weir counts provided information on catchability and its variation for the three weir streams, but the remaining 5 streams lacked these concurrent observations. Therefore we estimated catchability hierarchically such that catchability estimates across streams were assumed drawn from a common normal distribution with the mean and variance across streams informed primarily by the concurrent weir-air survey data from the three weir streams.

We obtained estimates of stock-recruitment parameters and used these results to run a management strategy evaluation (MSE) model to test a range of harvest policies. In this approach, a harvest policy is a combination of a minimum escapement target and a commercial harvest rate on the run in excess of the escapement target and expected subsistence harvest (Jones et al. 2011). The policy was assumed to be time-invariant. Details of this type of analysis can be found in Collie et al. (2012) and the Panel's Phase 1 final report. We tested 121 different harvest policies representing all possible combinations of a range of escapement targets from 0 to

50,000 salmon in increments of 5,000 and a range of commercial harvest rates from 0 to 1.0 in increments of 0.1. Implementation uncertainty, the variance between intended and realized harvest, was assumed to be 0.05 for the commercial fishery and 0.1 for the subsistence fishery. These assumed values were not well-informed by available data, but Phase 1 analyses suggested that the broad patterns in trade-offs in these types of analysis are not strongly related to the magnitude of implementation uncertainty (Jones et al. 2011). We ran the model 500 times, each time representing a different 50 year time-series of annual salmon runs and a different set of plausible population parameters as estimated from the stock recruitment analysis.

The run reconstruction and stock-recruitment analysis revealed relatively weak productivity at low stock sizes ($\alpha = 2.2$ recruits per spawner, 95%CI: 1.2 – 4.3); weak productivity has also been observed in the Yukon River fall chum salmon stock (Fleischman and Borba 2009). The equilibrium unfished stock size was 110,284 salmon (95%CI: 81,022 – 233,025). Few escapement observations were greater than the unfished equilibrium stock size. The majority of each year class matured at ages 4 (54%; 95%CI: 48 – 60%) and 5 (40%; 95%CI: 35 – 46%). Run abundance was highest in 1977-1981 (except 1979), 2005-2007, and 2010-2011 (Figure 1). The spawner-recruit relationship was uncertain over the range of observed data. Plausible spawner recruit curves ranged from classic dome-shaped Ricker curves, to asymptotic Beverton-Holt relationships, to nearly linear models (Figure 2).

Similar to other MSE models of this type (applied to other AYK chum and Chinook salmon stocks), we found that harvesting at MSY (commercial harvest rate of 1.0 and escapement target of 20,000 salmon) resulted in relatively high rates of commercial closure and frequent failure to meet minimum amounts necessary for subsistence (ANS; Figure 3). Maximum commercial harvest occurred at a harvest rate of 1.0 and an escapement target of

20,000 salmon. Commercial closures could be reduced and subsistence performance improved by simultaneously reducing the escapement target and the commercial harvest rate relative to the MSY policy. However, doing so would require tolerating a substantial drop in average commercial harvest (Figure 3). The probability of attaining a stock of concern designation (failure to meet the escapement goal in 4 of the last 5 years) was less than 0.1 if the escapement target was less than 25,000 and the commercial harvest rate was generally less than 0.8 (Figure 3).

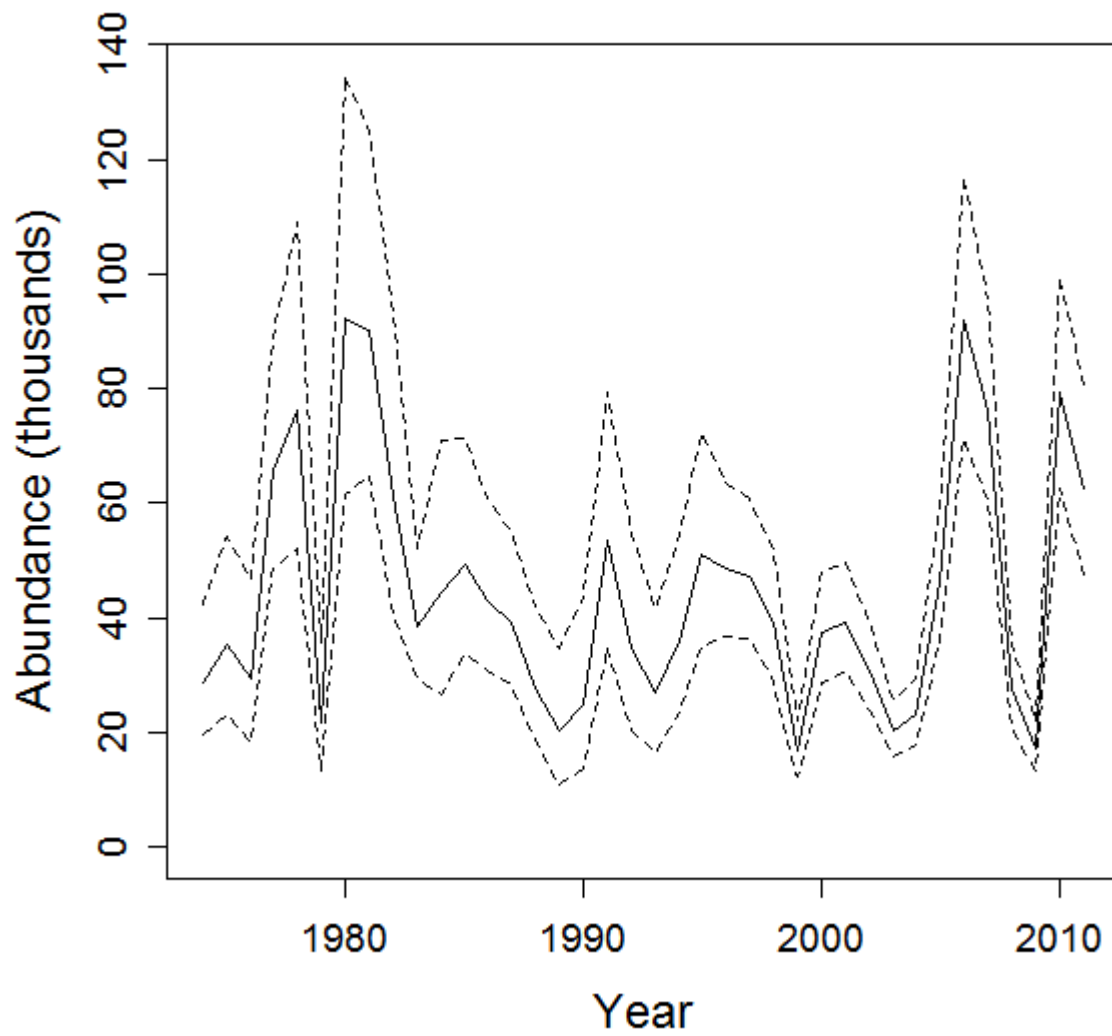


Figure 1. Median posterior (solid line) and 95% credible intervals (dashed lines) for reconstructed run abundance of Nome Subdistrict chum salmon, 1974-2011.

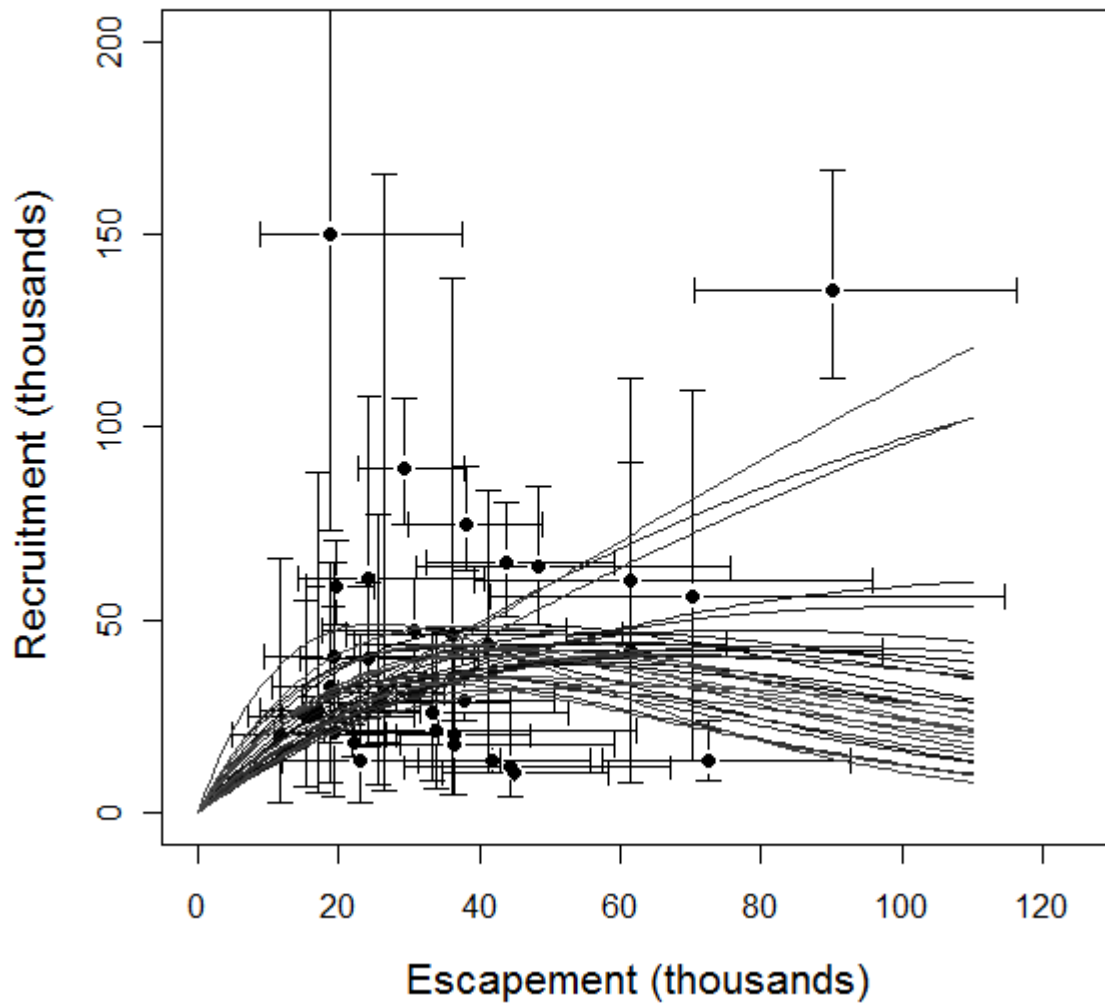


Figure 2. Brood year recruitment vs. escapement for Nome Subdistrict chum salmon, 1974-2011. The uncertainty in each recruitment and escapement pair is indicated by the error bars, which represent the 95% credible intervals from a Bayesian state-space age-structured model. Dashed lines represent 30 curves with parameters α and β drawn at random from the posterior distribution of the stock-recruitment parameters, depicting the uncertainty in the relationship between stock and recruitment for the stock.

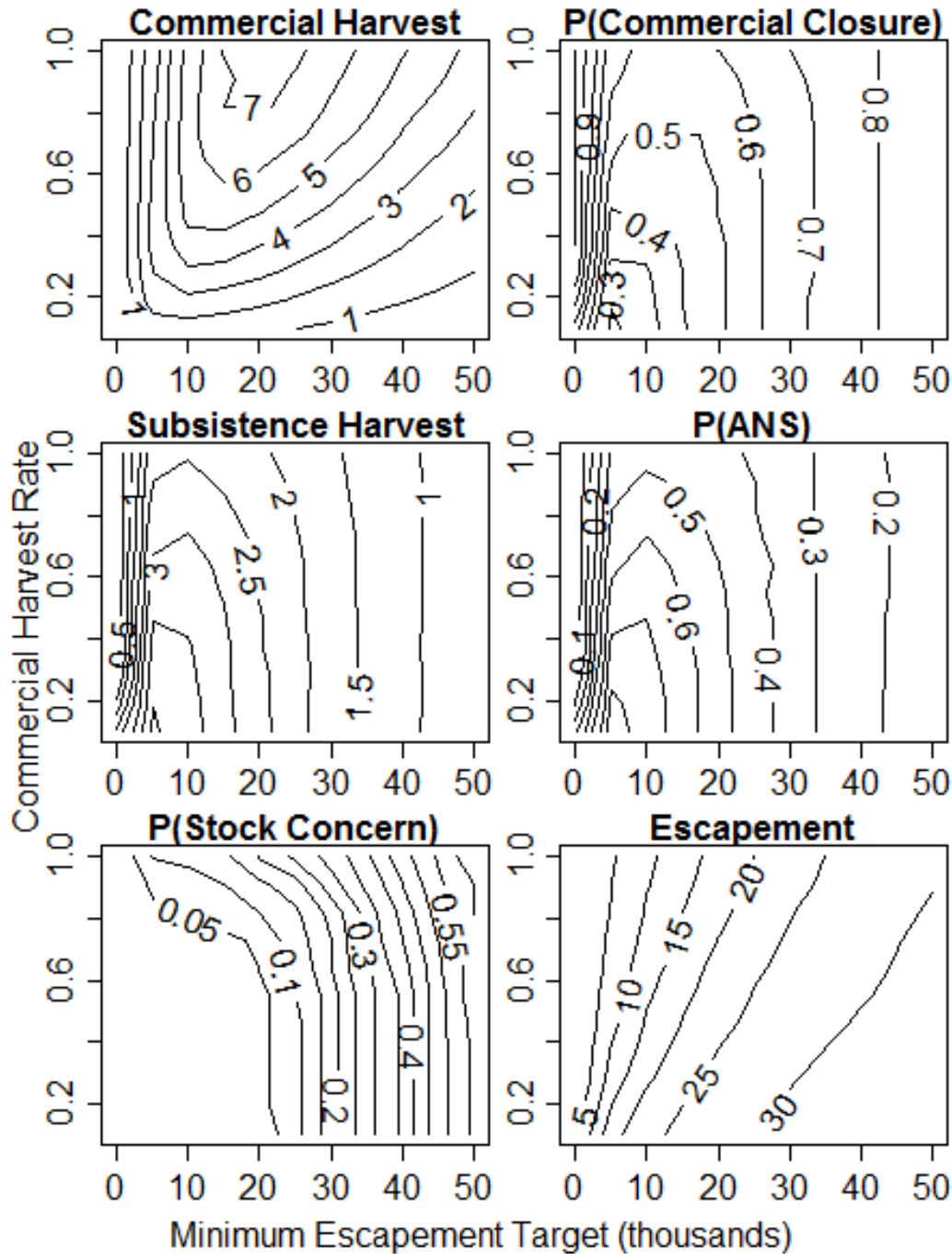


Figure 3. Contour plots for the Nome Subdistrict chum salmon stock showing the median values of performance indicators from 500 simulations across combinations of a minimum escapement target and commercial harvest rate. Performance indicators commercial harvest, subsistence harvest, and escapement represent the average values of these indicators over a 50-year simulated time horizon. P(commercial closure) is the proportion of simulated years in which there was no commercial harvest. P(ANS) is the proportion of simulated years in which the subsistence harvest exceeded the lower bound of the ADF&G published Amount Necessary for Subsistence (ANS) range (3,430 salmon), P(concern) represented the proportion of simulated years in which the escapement target was not met in four of the five previous years.

Yukon River Chinook salmon (mainstem Canadian stock)

We performed an MSE analysis for the Canadian portion of the mainstem Yukon River Chinook salmon stock. The MSE model was parameterized using estimates from a preliminary state-space stock-recruitment analysis that was conducted by Steve Fleischman (ADFG; personal communication). Similar to the Nome Subdistrict chum model, Fleischman's model contained an embedded escapement reconstruction sub-model that used all available mark-recapture border passage estimates, the Eagle sonar counts, telemetry studies, the Whitehorse Fishway counts, Blind Creek weir, Tatchum Creek foot survey, and air survey data from six Canadian tributaries. Harvest data were apportioned to the Canadian mainstem stock via scale pattern analysis (before 2005) and genetics samples (2006 and later). Age composition data were available mainly from fish wheel surveys upstream from the border and harvest subsamples. The structure of the population dynamics sub-model was consistent with the Nome Subdistrict chum model and Fleischman and Borba (2009). However, the observation sub-model was adapted to the particular data sets that were available for this stock.

We obtained estimates of stock-recruitment parameters and used these results to run a management strategy evaluation (MSE) model to test a range of harvest policies. The model was similar to the Nome Subdistrict chum model but contained some additional complexity associated with accounting for border passage and Canadian harvest, in addition to US commercial harvest, US subsistence harvest, and escapement. We tested 121 different harvest policies representing all possible combinations of a range of escapement targets from 0 to 100,000 salmon in increments of 10,000 and a range of US commercial harvest rates from 0 to 1.0 in increments of 0.1. The escapement target was applied in reference to spawning escapement in Canadian tributaries. US fisheries were managed to meet a border passage goal,

which was a function of a total allowable catch projection and a rule for allocation of harvest between US and Canadian fisheries. We implemented the harvest allocation rule that currently exists for the fishery as stated in the 2012 report of the Yukon River Joint Technical Committee. Implementation uncertainty was assumed to be 0.05 for the US commercial fishery, 0.1 for the US subsistence fishery, and 0.1 for the Canadian fishery. We made no distinction between the several different types of fisheries that occur in Canada. We ran the model 500 times, each time representing a different 50 year time-series of annual salmon runs and a different set of plausible population parameters as estimated from the stock recruitment analysis.

The run reconstruction and stock-recruitment analysis revealed high productivity at low stock sizes ($\alpha = 8.9$ recruits per spawner, 95%CI: 4.3 – 15.5); high productivity has also been observed for the Kuskokwim River Chinook salmon stock. The equilibrium unfished stock size was 85,764 salmon (95%CI: 67,558 – 121,866). Few escapement estimates were greater than the unfished equilibrium stock size. The spawner recruit estimates were weakly informative concerning the equilibrium stock size due to the lack of high escapements. The majority of each year class matured at ages 5 (28%; 95%CI: 24 – 31%) and 6 (57%; 95%CI: 53 – 61%). Run abundance was high in 1982-1997 and 2003 (Figure 4). Two periods of low abundance were observed since 1997 and the stock was at the second-lowest abundance on record in 2010 (Figure 4). The spawner-recruit relationship was uncertain over the range of observed data. Plausible spawner recruit curves ranged from classic dome-shaped Ricker curves, to asymptotic Beverton-Holt relationships (Figure 5).

Maximum sustained yield was obtained at a high commercial harvest rate and an escapement target of 20-30 thousand salmon (Figure 6). Unlike the Nome Subdistrict chum salmon analysis, tradeoffs between US commercial and subsistence fisheries were weak because

escapement goals were met by reducing Canadian harvest rather than US subsistence harvest if commercial harvest was too high. Therefore, tradeoffs were strong between US commercial and Canadian fisheries. For example, the probability of failing to meet the border passage agreement could be reduced from 0.35 to 0.1 by simultaneously reducing the commercial harvest rate from 1.0 to 0.4 and reducing the escapement target from 30 to 20 thousand salmon (Figure 6). However, doing so would require tolerating a substantial drop in average US commercial harvest (Figure 6).

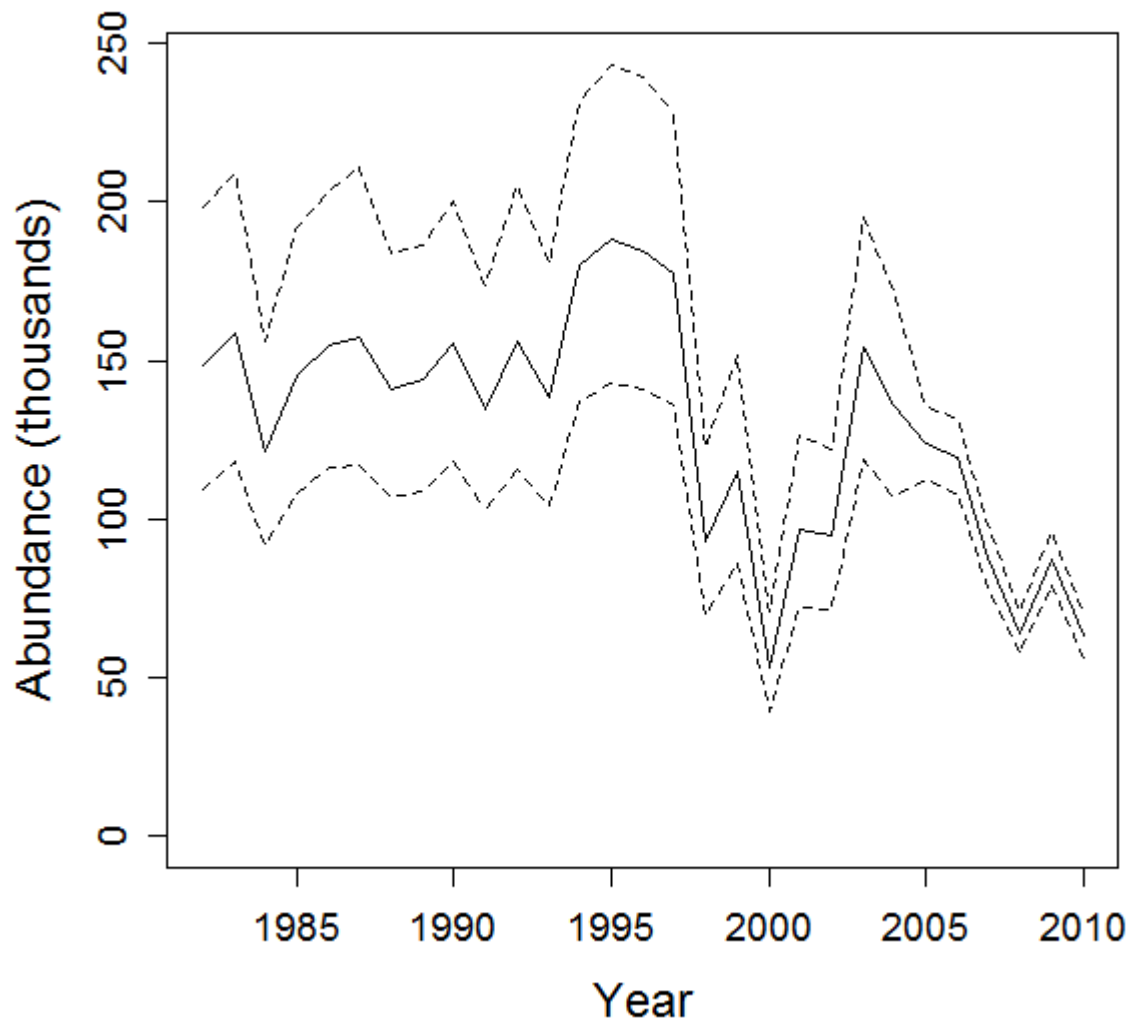


Figure 4. Median posterior (solid line) and 95% credible intervals (dashed lines) for reconstructed run abundance of the mainstem Canadian portion of the Yukon River Chinook salmon stock, 1982-2010.

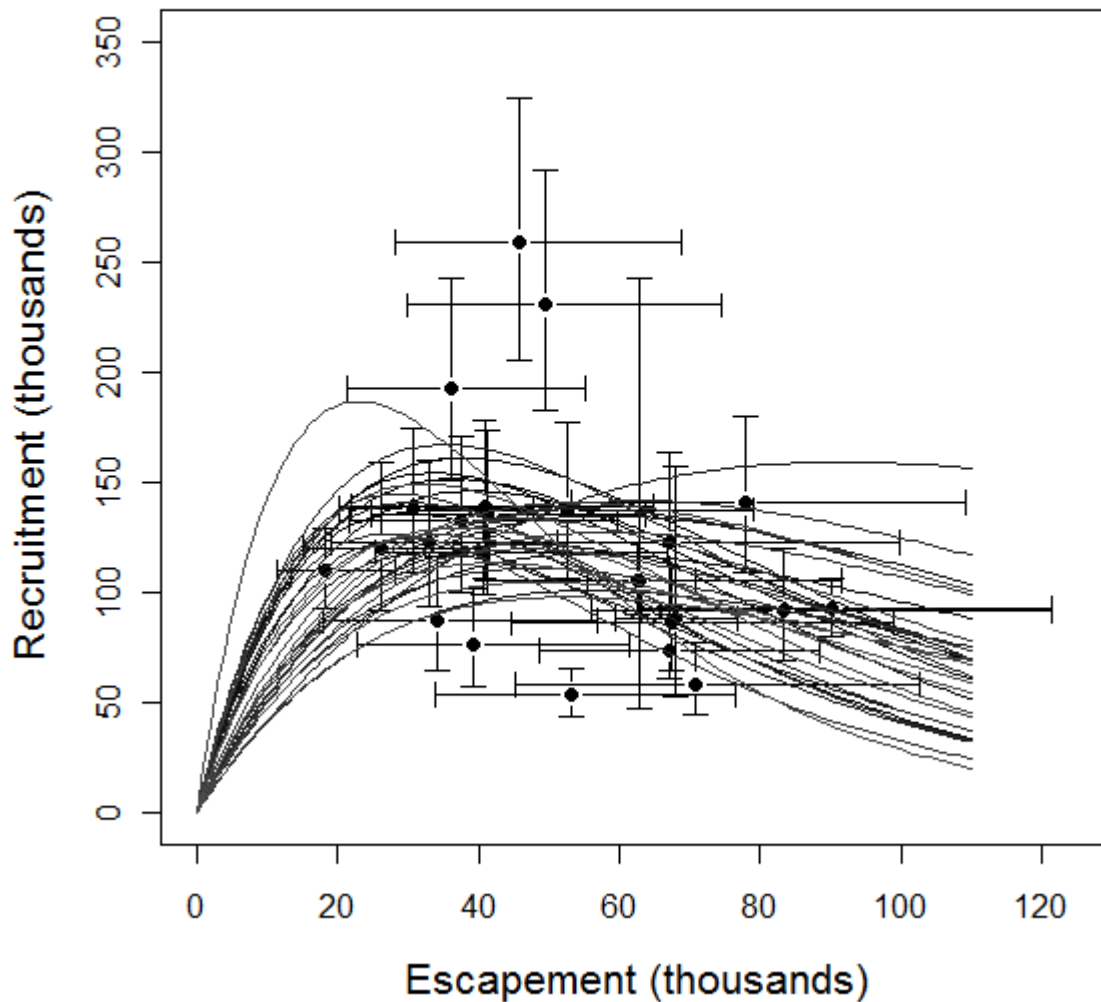


Figure 5. Brood year recruitment vs. escapement for the mainstem Canadian portion of the Yukon River Chinook salmon stock, 1982-2010. The uncertainty in each recruitment and escapement pair is indicated by the error bars, which represent the 95% credible intervals from a Bayesian state-space age-structured model. Dashed lines represent 30 curves with parameters α and β drawn at random from the posterior distribution of the stock-recruitment parameters, depicting the uncertainty in the relationship between stock and recruitment for the stock.

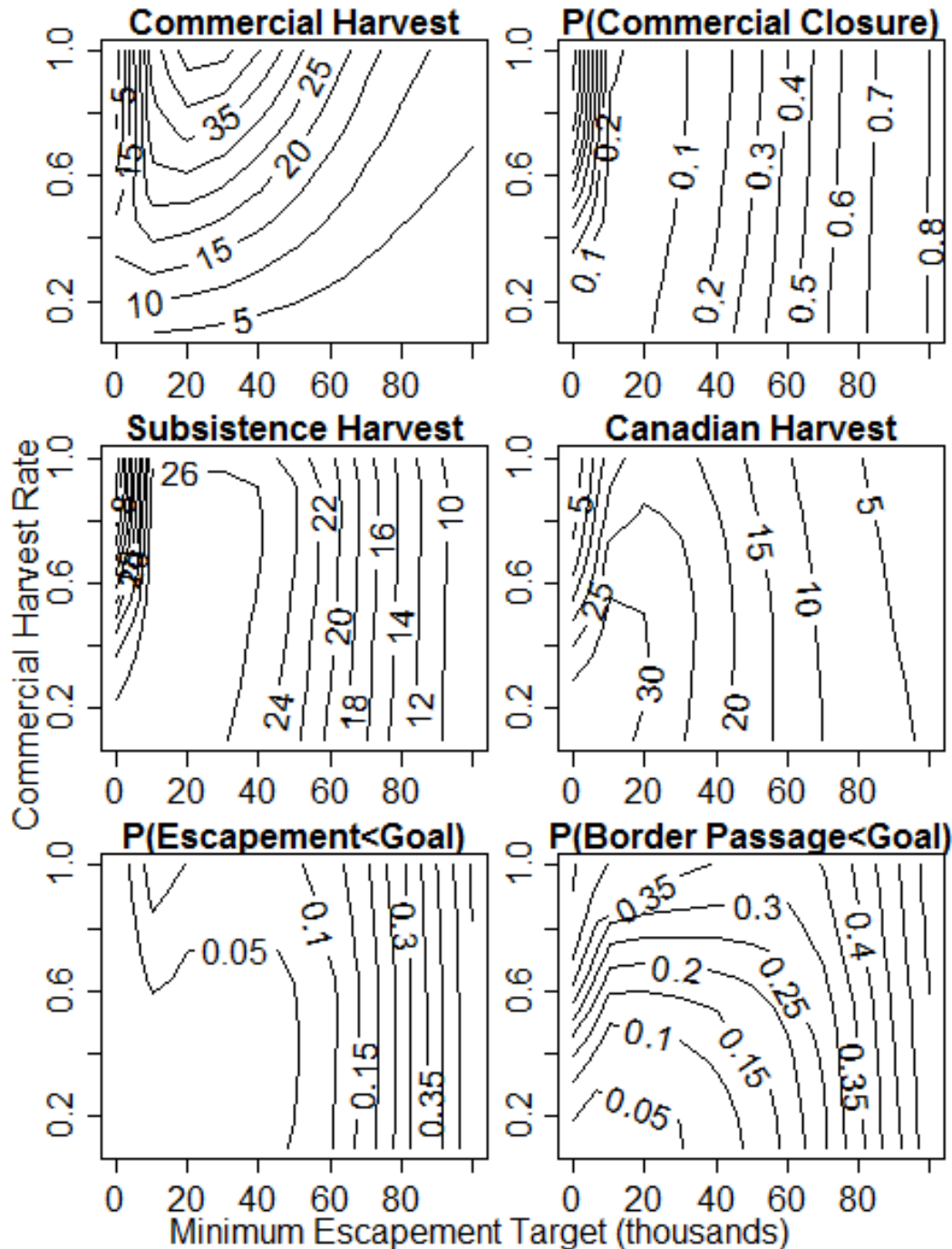


Figure 6. Contour plots for the mainstem Canadian Yukon River Chinook salmon stock showing the median values of performance indicators from 500 simulations across combinations of a minimum escapement target and commercial harvest rate. Performance indicators commercial harvest, subsistence harvest, and Canadian harvest are the average values of these indicators over a 50-year simulated time horizon. P(commercial closure) is the proportion of simulated years in which there was no commercial harvest. P(escapement < goal) is the proportion of simulated years in which the escapement target was not met, P(border passage < goal) represented the proportion of simulated years in which the border passage obligation to Canada was not met.

Yukon Fall Chum Multi-stock In-season Analysis

Meeting border passage agreements with Canada is a critical aspect of Yukon River salmon management in Alaska. To consider this issue, the Panel refined the Yukon River fall chum in-season analysis (Phase 1, Activity 3) to include an analysis of decision rules and performance indicators related to border passage. The Yukon fall chum run is composed of four main genetically-distinct stocks: summer chum, Tanana, mainstem Canadian, and US Border stocks. We were interested in the performance of management strategies aimed at reducing harvest rates on the mainstem Canadian stock.

Genetics data collected at Pilot Station sonar from 2004-2011 were analyzed to estimate run timing of the four stocks. A multinomial logit model (Agresti 2007) was fit to these data to estimate temporal trends in the proportional stock composition. Thirty years (1982-2011) of run timing data from Pilot station sonar and test fisheries were assembled to assess the timing of the aggregate run. Estimates of total run abundance and population dynamics parameters were obtained from a basin-wide stock recruitment analysis (Fleischman and Borba 2009, Jones et al. 2011).

A simulation model, similar to the one developed in Phase 1 of the Panel, was used to generate time series of salmon returns and fisheries that operated on a daily time step (Jones et al. 2011). Daily run abundance was obtained by multiplying the total run abundance for the year by the proportion of the run entering each day. Run proportions were iteratively re-sampled with replacement from the existing thirty years of observed run timings. Abundance of each stock was then computed by multiplying the daily abundance by the stock proportion for that day. Stock proportions (i.e., proportion of the salmon entering the river each day that were of a particular stock) were generated from the estimated mean and variance of the annual stock

composition time series estimates (estimated from genetics samples via multinomial logit model).

We adopted a more sophisticated approach to propagating the upstream movement of salmon than was used in the Phase 1 in-season model. In that analysis, a simple “boxcar” approach was used. This approach failed to account for variability in swimming speed among individuals, which resulted in a mismatch between observed and predicted upstream run timing. Therefore, instead of the simple boxcar approach, we divided the river into management districts that were consistent with ADFG management districts. In each district we computed the probability that a salmon that has resided in that district for x days and is travelling upstream at z km per day (\pm sigma km/day) would enter the next upstream district by the beginning of the next day. The upstream progression of the fall chum run was propagated by applying these transition probabilities on a daily basis using an assumed swimming speed of 48 km/day and standard deviation of 1.0. The standard deviation value was chosen such that simulated run timing patterns were qualitatively consistent with observed run timing at Eagle Sonar.

Each day of the run, upstream subsistence (management districts 4-6) and downstream commercial (districts 1-3) fisheries were opened based on whether the projected run size on each day exceeded management thresholds. The run size thresholds were consistent with current ADFG management thresholds: <300,000, no harvest; 300,000 – 500,000, restricted subsistence fishing; >500,000, restricted commercial fishing, unlimited subsistence fishing. Daily run projections were a weighted average (weighted by the precision) of an uncertain pre-season forecast, and an in-season run estimate (Walters and Buckingham 1975). Uncertainty in the in-season run estimate declined over time within a season due to data accumulation. Therefore, reliance on the pre-season forecast in the run projection computation declined over the course of

the run. A particular fishery was allowed on a given day if the point estimate of the run projection (i.e., weighted average) exceeded the appropriate management threshold. The harvest rate that was allowed on a given day was set such that the desired harvest would be achieved if that rate were applied for the entire run and the run projection was in fact the true run abundance.

We tested a management strategy aimed at reducing harvest rates on the mainstem Canadian portion of the run. The specific strategy that we tested was a weighting scheme that was applied to daily harvest rates. To reduce harvest rates on the mainstem Canadian stock, daily harvest rates were weighted inversely proportional to the expected daily proportion of the stock that was of mainstem Canadian origin. We refer to this management strategy as the avoidance policy. The alternative management strategy that we tested did not employ this weighting scheme. We will refer to this strategy as the status quo policy.

There were clear differences in run timing among stocks but the US border and Canadian stocks overlapped substantially (Figure 7). Summer chum salmon comprised the majority of the Yukon fall chum run for approximately the first 15-20 days of the run. The mainstem Canadian and US border stocks represented the middle of the run with US border stocks arriving 5-10 earlier than the Canadian portion. There was substantial overlap in run timing for these two stocks. The Tanana portion of the run generally comprised the majority of the fall chum run after day 50.

The results of the simulation model suggested that there was little to be gained by attempting to avoid the mainstem Canadian stock by concentrating fishing effort early and late in the run. The avoidance policy resulted in a small increase in average border passage from 117 thousand to 122 thousand salmon (Figure 8). The probability of meeting border passage obligations increased from 0.66 to 0.77 under the avoidance policy. It is important to note that these results

apply only to our simulated avoidance policy in which harvest rate adjustments were inversely proportional to the expected proportion of the run that was of mainstem Canadian origin. Other avoidance schemes might produce larger increases in border passage when compared to the status quo policy but might also result in undesirably high harvest rates on summer and Tanana River stocks.

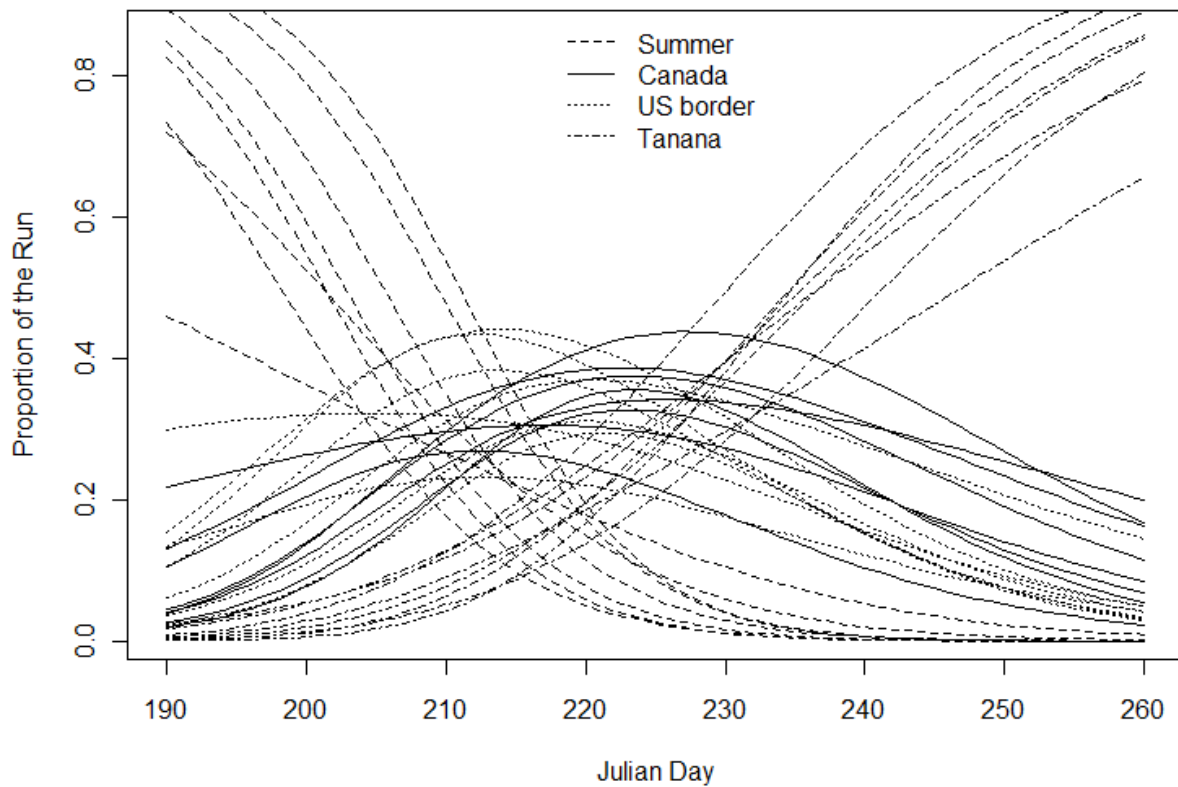


Figure 7. Daily estimates of the proportion of Yukon River fall chum salmon passing Pilot station that are of one of four stocks: summer, mainstem Canadian, US border stocks, and Tanana stocks. The estimates are predictions from a multinomial logit model relating the stock proportions to Julian day. For each stock, the eight different curves depict eight different years (2004-2011) of stock proportions. The model was fit to stock proportions that were obtained from genetics analysis.

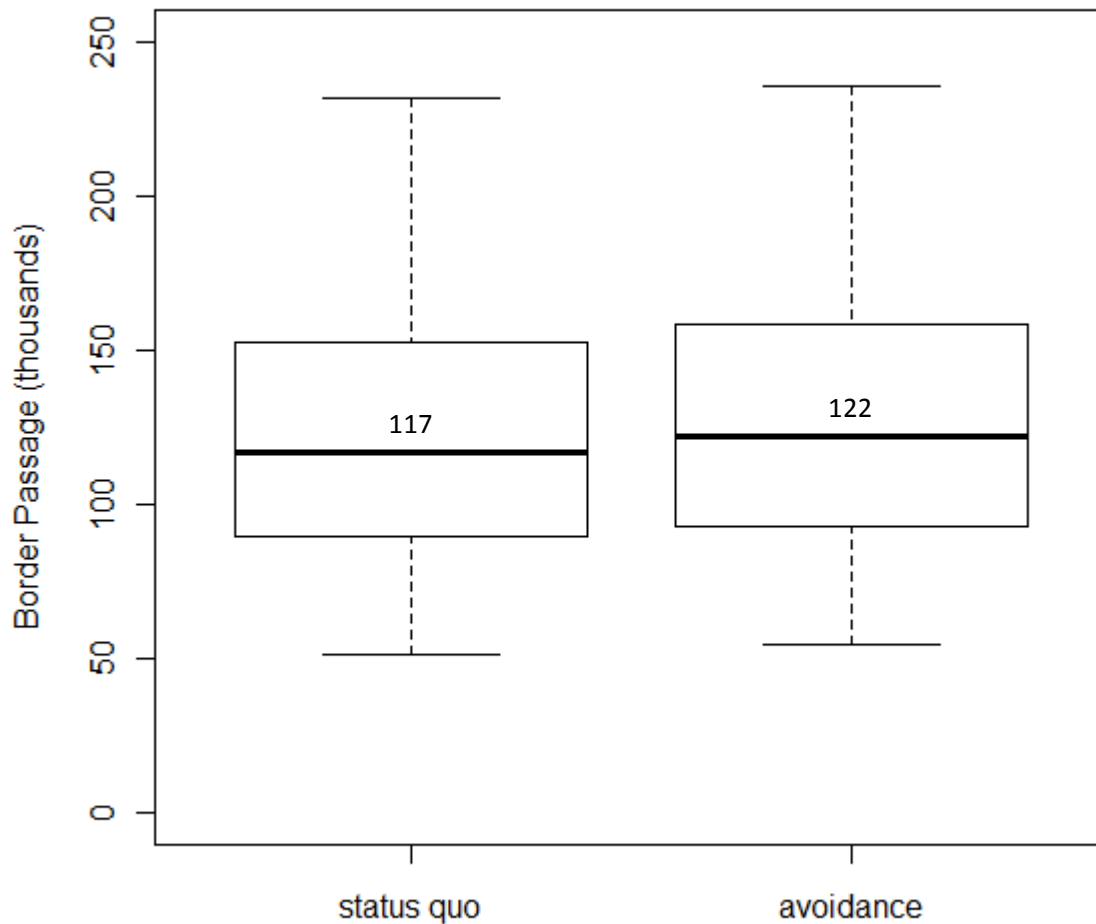


Figure 8. Box and whisker plot of mean border passage for Yukon River fall chum salmon under two in-season management strategies. The status quo strategy represents a management approach that makes no attempt to avoid capturing Canada-bound salmon. The avoidance strategy represents a policy that reduces harvest rates during the days of the run that are expected to have the highest percentages of Canada-bound salmon.

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APPENDIX A. Participant list for MSE training workshop 1, April 9-11, 2012.

Last Name	First Name	Role	Affiliation	Workshops Attended
Anderson	Jeffrey	student	USFWS	1
Bell	Jen	student	ADFG	1
Bergstrom	Dan	student	ADFG	1
Borba	Bonnie	student	ADFG	1
Brazil	Charles	student	ADFG	1
Clark	Bob	student	ADFG	1
Conitz	Jan	student	ADFG	1 & 2
Elison	Travis	student	ADFG	1
Estensen	Jeff	student	ADFG	1
Evenson	Matt	student	ADFG	1
Fleischman	Steve	student	ADFG	1
Gillikin	Dan	student	USFWS	1 & 2
Hamazaki	Hamachan	student	ADFG	1 & 2
Harper	Ken	student	USFWS	1 & 2
Harris	Frank	student	USFWS	1
Howard	Katie	student	ADFG	1
Kent	Scott	student	ADFG	1
Linderman	John	student	ADFG	1
McCaffery	Brian	student	USFWS	1
Mears	Jeremy	student	USFWS	1
Munro	Andrew	student	ADFG	1
Rivard	Donald	student	USFWS	1
Schaberg	Kevin	student	ADFG	1 & 2
Sethi	Suresh	student	USFWS	1
Spaeder	Joe	observer	BSFA	1
Stockdale	Casie	student	AVCP	1 & 2
Volk	Eric	observer	ADFG	1
Catalano	Matt	instructor	MSU	1 & 2
Jones	Mike	instructor	MSU	1 & 2

APPENDIX B. Agenda and outline for MSE training workshop 1, April 9-11, 2012.

Management Strategy Evaluation I: Harvest Policy Trade-offs

Day 1

- 1:00 Introductions
- 1:15 MSE Overview [mostly the standard MSE talk; **Powerpoint lecture #1**]
History, motivation, rationale, concepts, contrast with MSY/BEG
Steps of MSE: problem definition, objectives, options, outcomes, trade-offs, decision
Types of uncertainty: process, observation, structural, outcome
- 2:00 Model Building: getting started [Excel exercise]
Forward simulation: build simple example population with no process uncertainty and no fishing
Incorporating process uncertainty: add recruitment variation
Briefly explore the distribution of outcomes by hitting F9 key to recalculate the sheet
Modeling Activity #1: create a stock-recruitment plot
- 3:00 Specifying Objectives and Options [**Powerpoint lecture #2**; class discussion – small groups]
Lecture on specifying objectives: generate performance indicators
Lecture on options: define and discuss an escapement goal and harvest rate policy
Introduce case studies and form groups around them
Small Group Activity #1: generate list of objectives, performance indicators, and options for each case study
- 4:00 Model Building: incorporating performance indicators and management options [Excel exercise]
Add harvesting component and harvest policy (E goal and harvest rate policy)
Generate performance indicators
Modeling Activity #2: set the harvest rate (U) = 1 and evaluate commercial catch outcomes under three different escapement goals (E). Run the model 10 times for each goal. Copy and paste each of the results to a new worksheet to assess the expected outcome and its uncertainty.

Day 2

- 8:00 Incorporating Uncertainty [**Powerpoint lecture #3**; class discussion – small groups]
Lecture on different types of uncertainty: observation, implementation, process, structural
Small Group Activity #2: identify multiple sources of uncertainty for each case study stock and categorize them
- 9:00 Model Building: incorporating additional uncertainties
Observation – generate observed abundance from true
Implementation – generate true catch from target catch
Process – maturity variation, autocorrelated AR(1) recruitment residuals
Structural – simulate parameter uncertainty then demonstrate the use of posterior samples
- 10:00 Simulating a Distribution of Outcomes [Excel exercise]
For a single policy, run the model multiple times, once for each posterior sample [Excel]
Modeling Activity #3: Repeat the 3-policy analysis from Day 1 (Modeling Activity #2). Have the results changed now that we have incorporated more uncertainties?
- 10:30 Using VBA to Simulate a Range of Policies [Excel exercise]
Run VBA code to iterate the 50-year model over parameters and policies [Excel with VBA]
- 11:00 Visualization of Results [Excel exercise]
Create plots in Excel from the results of a short VBA run with only a few policies
- 12:00 Lunch Break
- 1:00 Real-World Examples [small group model-building in Excel]
Provide posterior parameter sets for:
Yukon fall chum, Kuskokwim Chinook, Nome Subdistrict chum, Karluk Chinook
Modeling Activity #4: Small groups amend the model template to fit their case studies.
Iterate the models many times over a range of policies using the built-in VBA code (Matt will run the models in the evening/overnight)

Day 3

- 8:00 Vismon Tutorial [lecture and Vismon exercise]
Vismon is a software package developed at Simon Fraser University to assist with visualization of trade-offs.
Vismon tutorial using results from example stock
Demonstration of trade-offs and how to visualize them
- 9:00 Exploring Trade-offs [small group exercise using Vismon]
Modeling Activity #5: small groups import MSE results for their stock into Vismon and explore trade-offs. Find a set of “good” policies for the stock and be ready to explain why.
- 11:00 Small Group Presentations (4 groups - 10 min each)
Groups will present their findings and recommended policy to the group in a short oral presentation.
Brief discussion and concluding remarks

Appendix C. An outline of the narrated slideshow.

Module 1: Introduction

AYK SSI Background

How do we make good management decisions?

Decision Analysis

- Define the problem

- Specify objectives

- Identify options

- Evaluate outcomes

- Explore trade-offs

- Decide and implement

Module 2: A Model to Evaluate Outcomes

What is a model and how can it be useful?

Review of salmon life history

Dynamics of salmon fisheries and assessment programs

Stock and recruitment

Accounting for uncertainty

- Observation uncertainty

- Process uncertainty

- Structural uncertainty

- Implementation uncertainty

Module 3: Evaluating Outcomes

Testing the performance of management options

Stochastic simulation

Evaluating trade-offs

Module 4: Advanced Topics I - Uncertainty and Two-dimensional Policies

Risk analysis

Assigning probabilities to outcomes

Two-dimensional policies

- Escapement target

- Harvest rate

Visualization of expected outcomes

Module 5: Advanced Topics II – Yukon Fall Chum Analysis

An MSE for Yukon Fall chum salmon results

Evaluating trade-offs in two-dimensional policy space

Visualizing uncertainty

APPENDIX D. Supplementary figures for the Nome subdistrict chum salmon analysis.

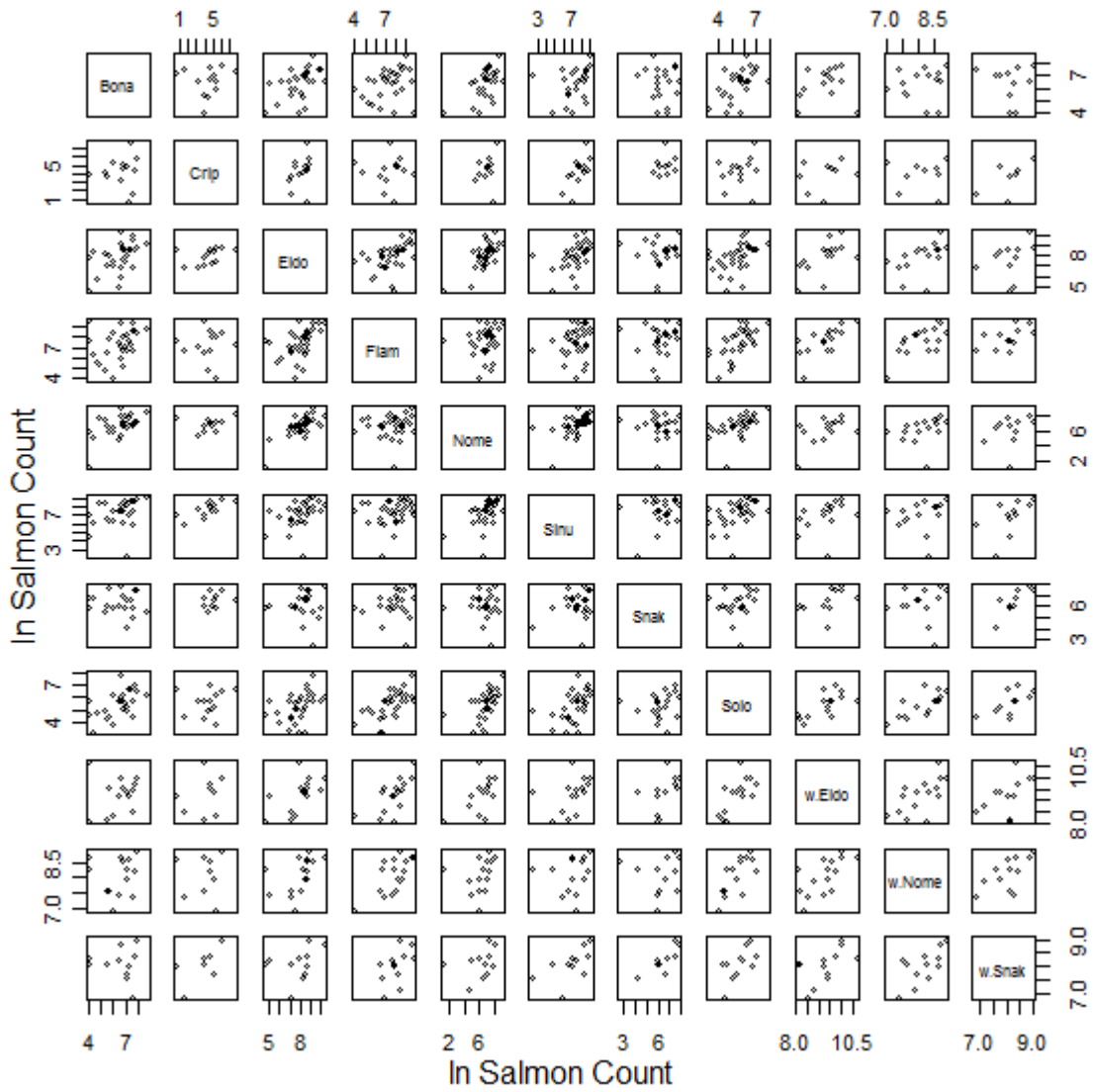


Figure D-1. Scatter plots of annual chum salmon counts (natural log scale) from air surveys (rows 1-8) and weirs (rows 9-11) from eight tributaries of the Nome Subdistrict.

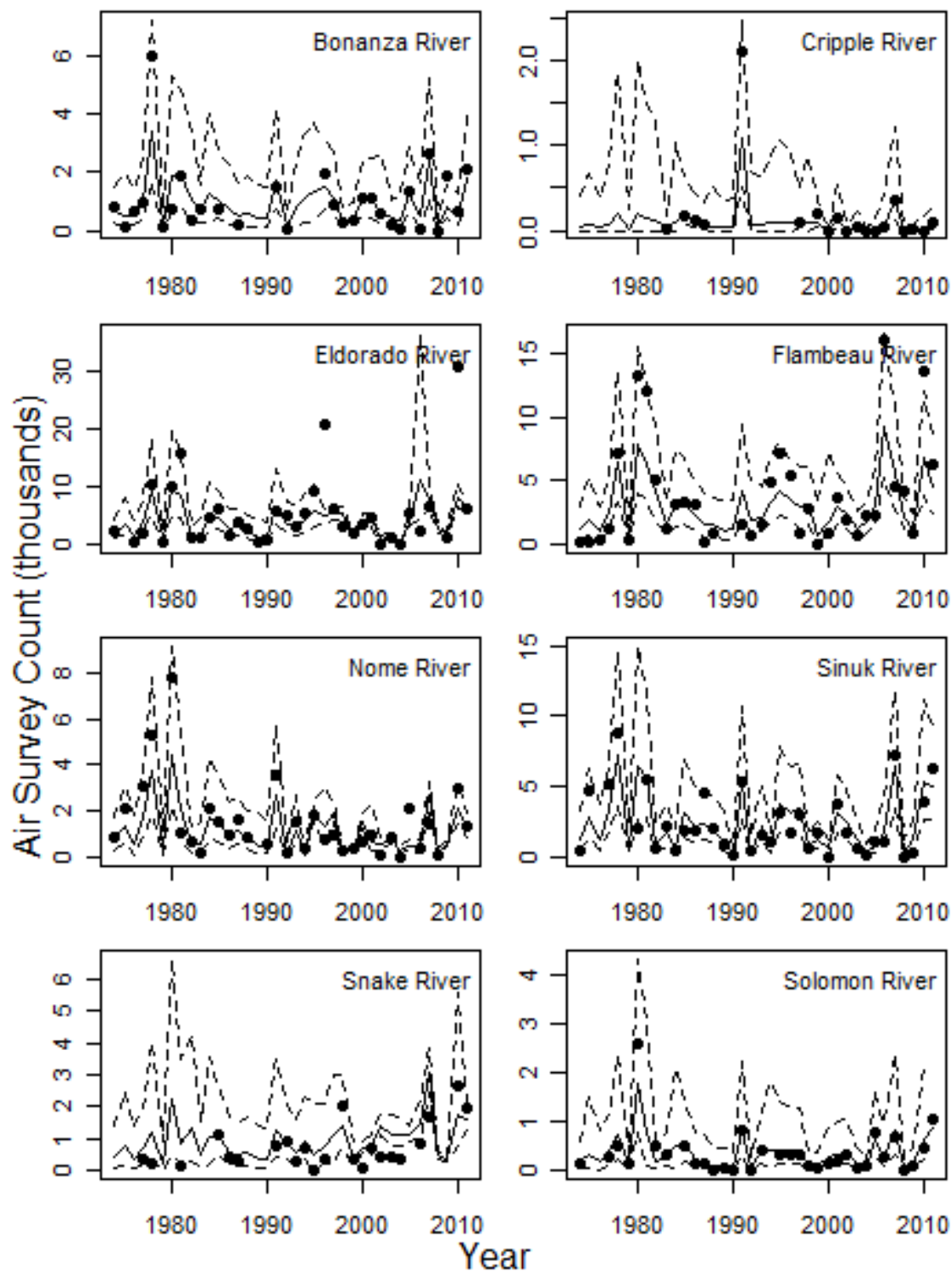


Figure D-2. Observed (solid circles) and posterior median (solid lines; 95%CI dashed lines) air survey counts of chum salmon from eight tributaries of the Nome Subdistrict.

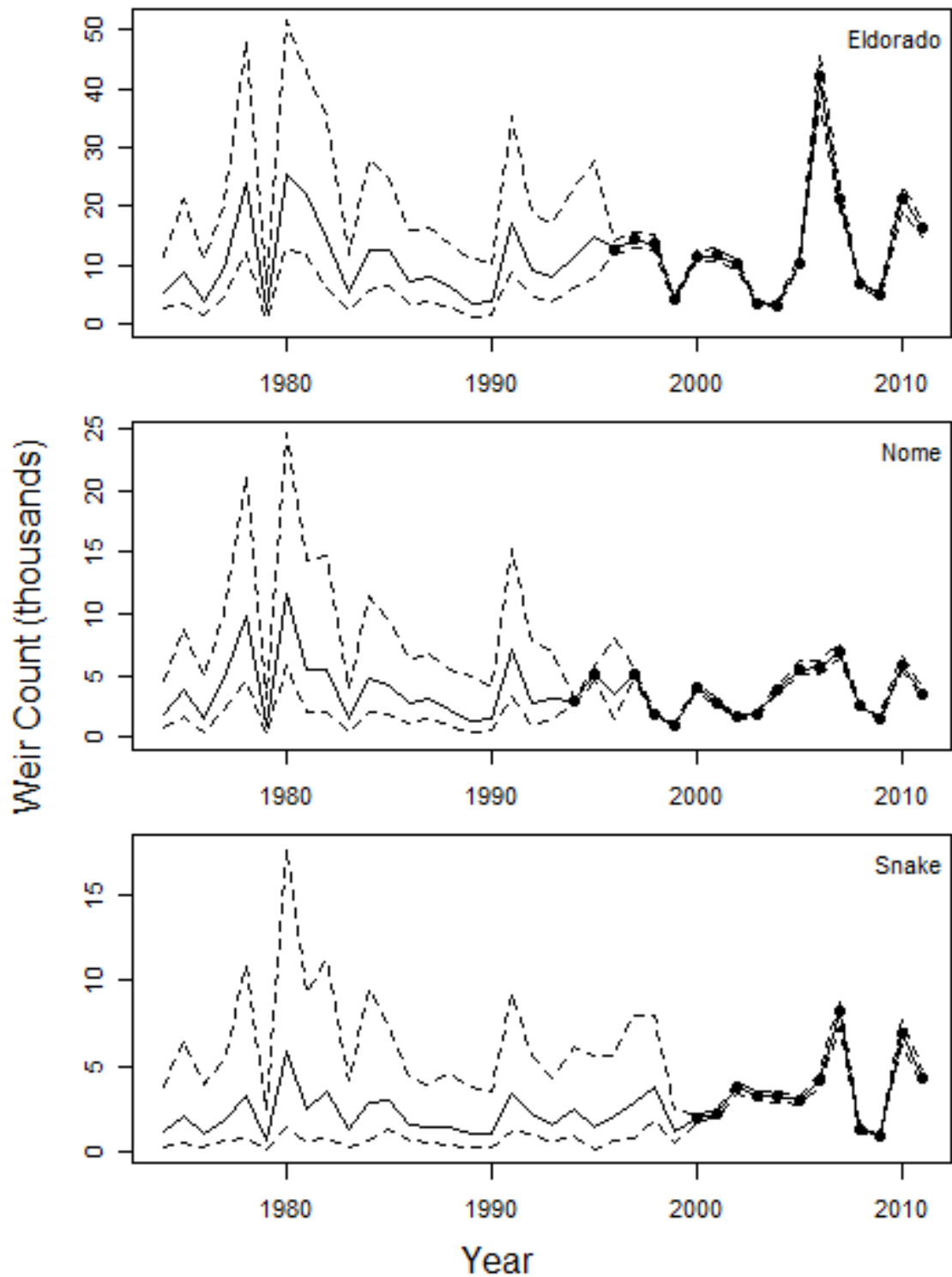


Figure D-3. Observed (solid circles) and posterior median (solid lines; 95%CI dashed lines) weir counts of chum salmon from three tributaries of the Nome Subdistrict.

APPENDIX E. Supplementary figures for the mainstem Canadian Yukon River Chinook salmon analysis.

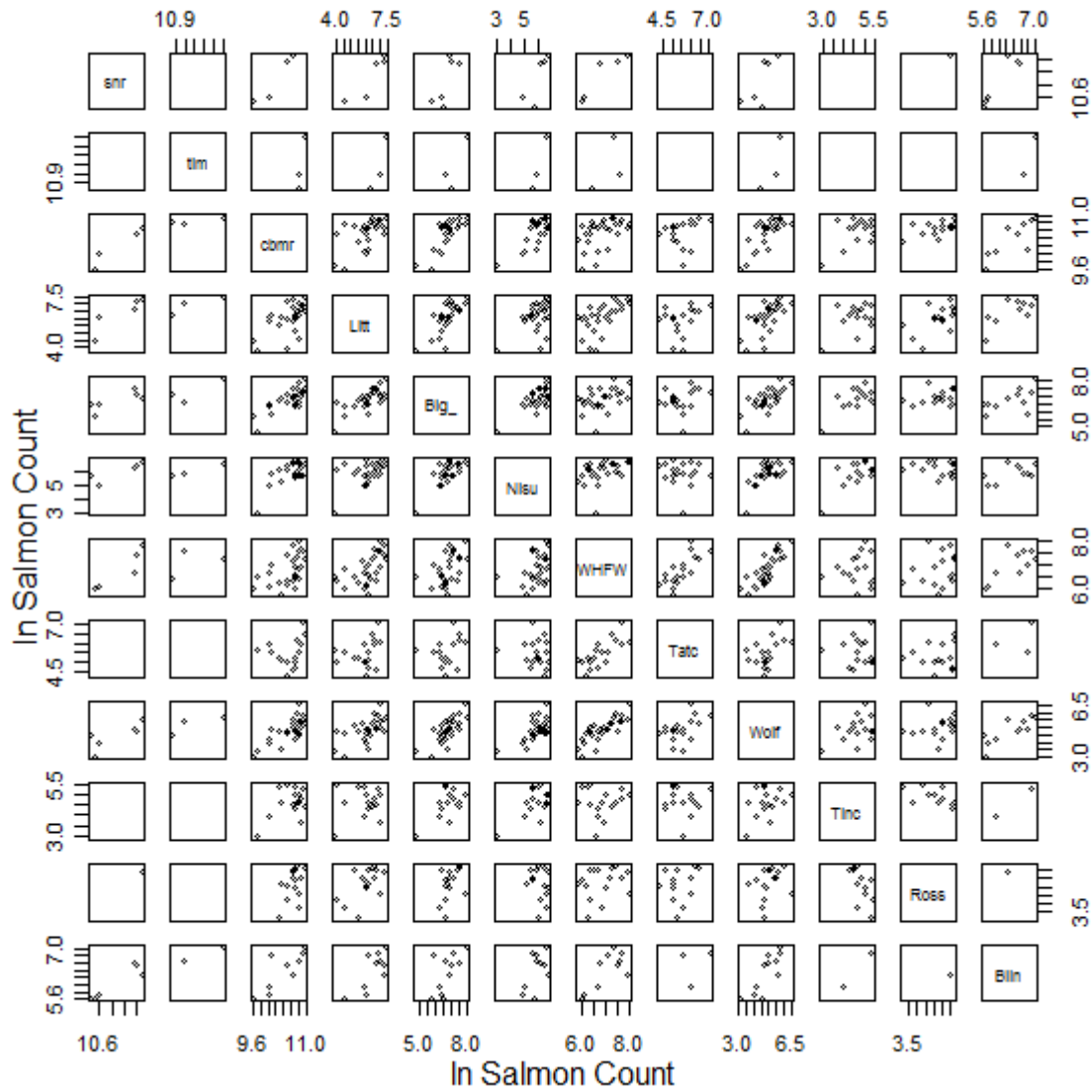


Figure E-1. Scatter plots of annual Chinook salmon counts (natural log scale) from Eagle sonar (snr), telemetry studies (tlm), border mark-recapture studies (cmbr), Whitehorse Fishway (WHFW), Tatchum Creek foot survey (Talc), Blind River weir (Blin) and air surveys from six Canadian tributary streams to the Yukon River: Little Salmon River (Litt), Big Salmon River (Big), Nisutlin River (Nisu), Wolf River (Wolf), Tincup River (Tinc), Ross River (Ross).

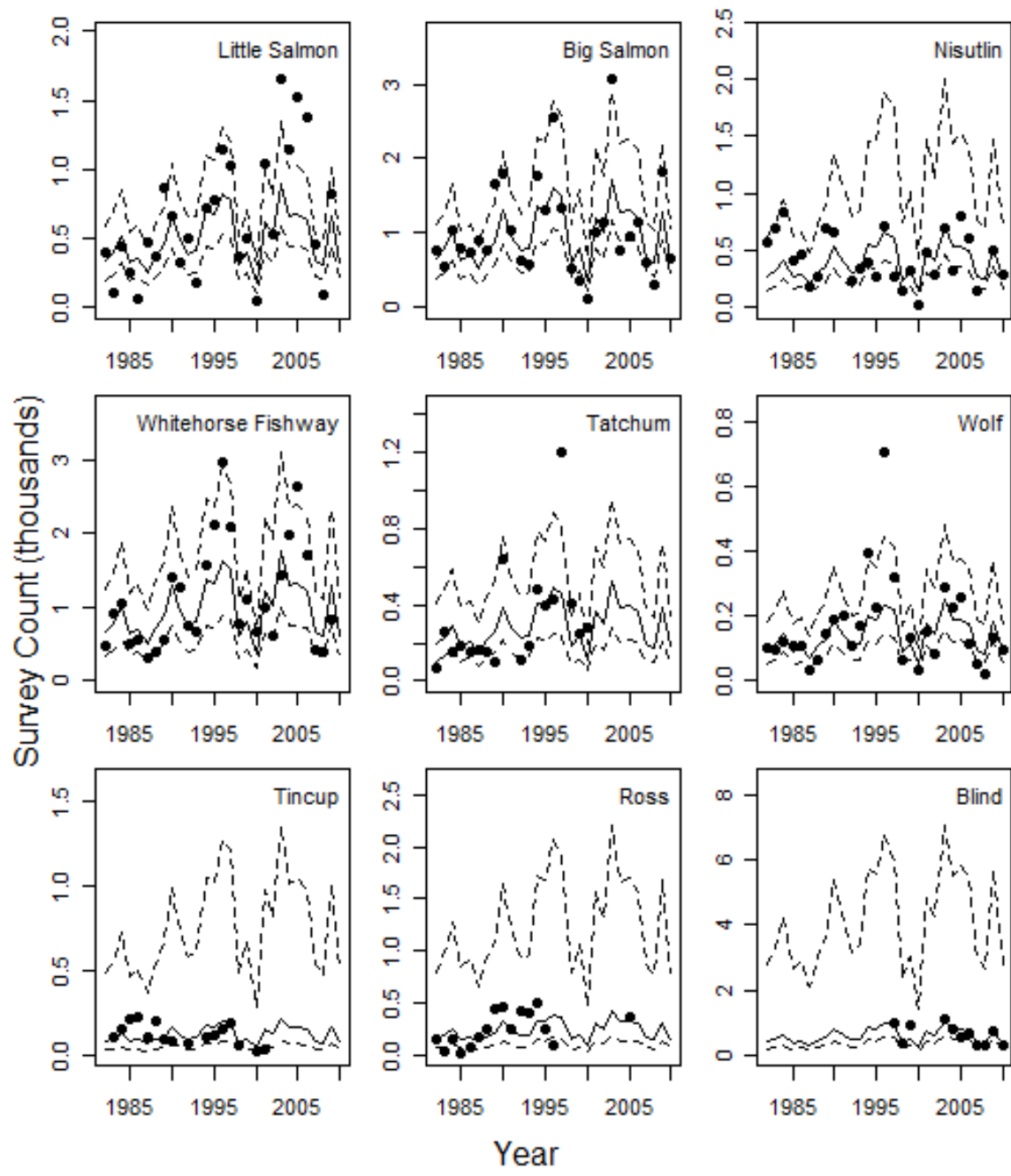


Figure E-2. Observed (solid circles) and posterior median (solid lines; 95%CI dashed lines) counts of Chinook salmon at eight enumeration projects in the Canadian portion of the Yukon River basin. The Tatchum Creek project was a foot survey and Blind Creek was a weir. All other projects were air surveys except the Whitehorse Fishway (WHFW).

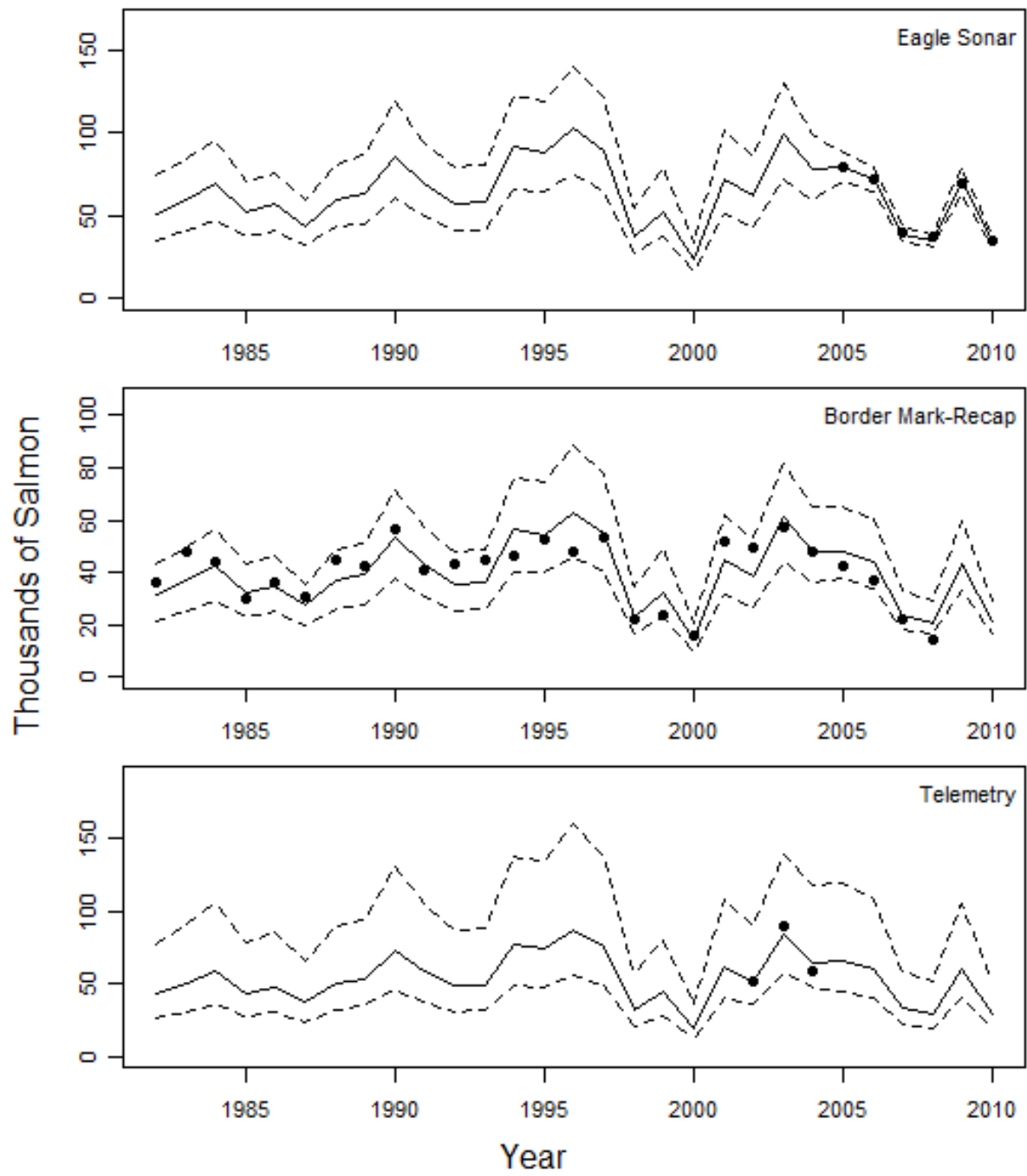


Figure E-3. Observed (solid circles) and posterior median (solid lines; 95%CI dashed lines) counts of Chinook salmon from Eagle sonar, border mark-recapture studies, and telemetry studies in the Canadian portion of the Yukon River basin.

APPENDIX F. Supplemental figures for the multi-stock in-season analysis of Yukon River fall chum salmon.

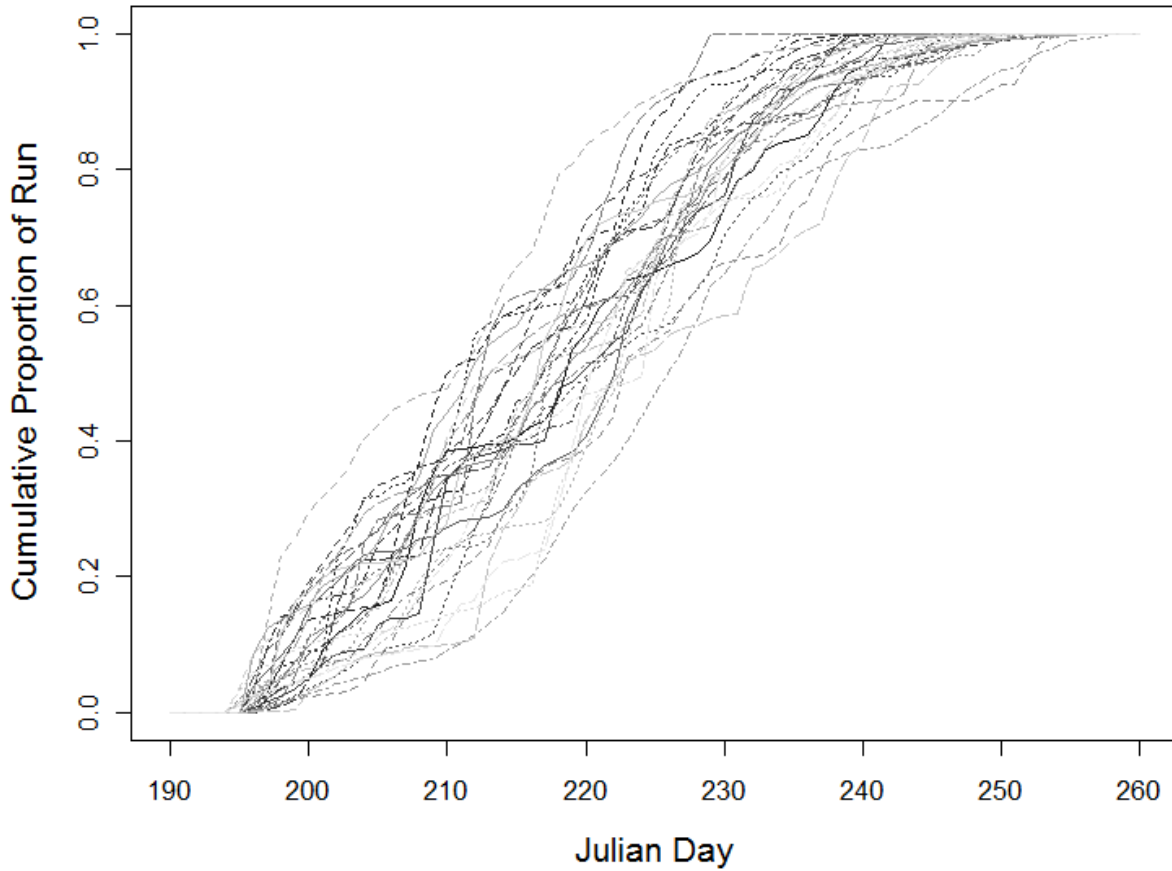


Figure F-1. Daily cumulative run proportions for Yukon River fall chum salmon, 1982-2011. Each year is represented by a different combination of grayscale and line type. The proportions were calculated by averaging all available run timing data from Pilot Station sonar, Middle Mouth/Big Eddy test fishery, and Mountain Village test fishery.