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Western Alaska Salmon Stock identification Program Technical Document 27: Sockeye Salmon Reporting Group Evaluations Using Simulated Fishery Mixtures

by

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and

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Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	\$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

REGIONAL INFORMATION REPORT 5J12-27

WESTERN ALASKA SALMON STOCK IDENTIFICATION PROGRAM TECHNICAL DOCUMENT 27: SOCKEYE SALMON REPORTING GROUP EVALUATIONS USING SIMULATED FISHERY MIXTURES

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ABSTRACT

Uncertainty about the magnitude, frequency, location, and timing of nonlocal harvest of sockeye and chum salmon in Western Alaska fisheries was the impetus for the Western Alaska Salmon Stock Identification Program (WASSIP), a program designed to use genetic data in mixed stock analysis (MSA) to reduce uncertainty. The purpose of WASSIP was to identify stock contributions of sockeye (*Oncorhynchus nerka*) and chum salmon (*O. keta*) to commercial and subsistence fisheries from Chignik northward to Kotzebue Sound. Draft stock composition estimates for sockeye salmon were released to the WASSIP Advisory Panel, Technical Committee, and Alaska Department of Fish and Game Regional Management Biologists as part of the Gene Conservation Laboratory quality control process and it was determined that a statistical reanalysis was not necessary. The Advisory Panel did request, however, that Gene Conservation Laboratory examine 3 specific questions using simulated fishery mixtures to investigate likely magnitudes of misallocation and biases of MSA of catch samples using the current genetic baseline for sockeye salmon. Mean stock composition estimates and 90% credibility intervals (CIs) for each of the 5 replicates for 4 simulations were visualized by plotting. For 96.8% of estimates, the known proportions were within the 90% CI. Additional statistical summaries of the results were calculated on the estimates including 1) the proportion of the 90% CIs that included the known proportions, 2) the absolute deviations between the means and the known values, 3) the widths of the 90% CIs, and 4) the width of the 90% CIs that were plotted against the known subregional stock proportions. Absolute deviations between the means and the known values ranged from 0.000 to 0.059 (5.9%) with half of the values below 0.001 (0.1%) and 90% of the values below 0.020 (2.0%). The widths of the 90% CIs ranged from 0.000 to 0.128 (12.8%) with half of the values below 0.001 (0.1%). The relationship between the width of the 90% CIs and the known subregional stock proportions showed that as the stock proportions increase, the width of the 90% CI increased quickly and reached an asymptote of about 12%. This 12% value represents a precision of approximately ±6% of the estimate. Many of the insights derived from the original 100% proof tests were apparent in these simulations. These simulations provide strong evidence that the MSA is performing well with this baseline and was able to provide answers to the questions posed by the Advisory Panel members who designed the tests.

Key words: Western Alaska Salmon Stock Identification Program, WASSIP, chum salmon, *Oncorhynchus nerka*, reporting groups, mixed stock analysis, MSA, stock composition estimates, simulations

INTRODUCTION

On May 29, 2012, draft stock composition estimates for sockeye salmon captured in fishery strata for the Western Alaska Salmon Stock Identification Program (WASSIP) were distributed to the regional research biologists for review. This review was designed to serve as part of the quality control process before distribution of estimates to the Advisory Panel (AP), Technical Committee (TC), and regional management biologists. Regional research biologists were asked to provide feedback to the Gene Conservation Laboratory (GCL) on estimates that appeared unexpected. The GCL committed to statistically reanalyzing a set of these fishery strata to look for analysis errors. This reanalysis involved rewriting R scripts as if the strata had never been analyzed before, pulling genotypes out of the database, compiling new input files for *BAYES* (using original priors and starting values; Pella and Masuda 2001), running the files through *BAYES*, and comparing the estimates to the released estimates.

The regional research biologists provided a list of area strata with unexpected stock composition estimates. The GCL selected 10 area strata (5% of the total) that represented strata spatially distributed throughout the WASSIP sampled fisheries and that contained estimates that were unexpected for a variety reasons (Table 1). Reanalysis of all 10 catch samples yielded almost identical results as those released. Small deviations were observed (<0.1% deviations in stock-specific estimates) for 1 catch sample and were attributed to using different versions of *BAYES*. Most estimates were analyzed using *BAYES* version 1, but some were analyzed on version 2, which uses an informative prior based on allele frequency variation within reporting groups rather than using allele frequency variation across the entire baseline, ignoring information among reporting groups. All estimates analyzed with version 2 were identified and re-analyzed with version 1. Only version 1 estimates will be released in final reports.

On July 6, 2012, draft stock composition estimates for sockeye salmon captured in fishery strata for WASSIP were distributed to the AP, TC, and regional management biologists for review. This review was a continuation of the quality control process before distribution of final estimates. Again, recipients were asked to provide feedback to the GCL on estimates that appeared unexpected. We received feedback from various AP members about unexpected proportions, but no responding AP members felt a statistical reanalysis was needed, given the results from the previous efforts. However, some AP members requested reporting group evaluations using simulated fishery mixtures similar to those done for chum salmon (Habicht et al. 2012). These simulations were requested to provide the AP with a better handle on likely misallocation magnitudes and biases of mixed stock analysis of catch samples using the baseline. Here we report the methods and results from these simulations.

METHODS

DEVELOPING MIXTURE COMPOSITIONS

Two AP members suggested 3 questions they wanted examined using simulated fishery mixtures to evaluate the magnitude and direction of biases. These AP members wanted to examine 2 simulated fishery mixtures to examine 1 of these questions in order to determine how the composition of the fishery might affect the magnitude and direction of biases. Final stock compositions for simulated fishery mixtures (simulations) were agreed to by these 2 AP members. Simulations were designed to provide insights into the following questions for the following simulated fisheries:

1) Are there misallocations to East of WASSIP (EOW), when EOW fish are not present in the sample?
    a. South Peninsula fishery with 0% EOW fish
    b. North Peninsula fishery with 0% EOW fish
2) Are allocations to EOW accurate when EOW fish are present in the sample?
    a. South Peninsula fishery with 20% EOW fish
3) Are small proportions of reporting groups accurately estimated and detectable?
    a. Bristol Bay fishery with 5% North Peninsula fish

ASSEMBLING SIMULATED FISHERY MIXTURES AND ESTIMATING MIXTURE COMPOSITIONS

A sample of 400 fish were randomly selected and removed from the baseline in proportion to the mixture compositions provided by the AP. The process was repeated 5 times (replicates) for each set of simulations. For each set, the known allocations were used as the priors in *BAYES* for the first replicate. A sequential-prior method was then used for the other 4 replicates, such that the *BAYES* estimate from the preceding analysis was used as the prior for the subsequent set. The sequential-prior method mirrors the method approved by the AP and TC for fishery strata (Jasper et al. 2012).

For each replicate within each set, we ran 5 independent Markov Chain Monte Carlo (MCMC) chains of 40,000 iterations with different starting values and discarded the first 20,000 iterations to remove the influences of the initial start values. We defined the starting values for the first chain such that the first 1/5 of the baseline populations summed to 0.9 and the remaining populations summed to 0.1. Each chain had a different 1/5 of baseline populations sum to 0.9. We combined the second half of each chain to form the posterior distribution and tabulated mean estimates and 90% credibility intervals from a total of 100,000 iterations. We also assessed the within- and among-chain convergence of these estimates using the Raftery-Lewis (Raftery and Lewis 1996) and Gelman-Rubin (Gelman and Rubin 1992) diagnostics, respectively. Gelman-Rubin diagnostic measures below 1.2 were interpreted as indicating convergence among chains (Dann et al. 2012). If the Gelman-Rubin diagnostic for any stock group estimate was greater than 1.2 and/or the Raftery-Lewis diagnostic suggested each chain had not converged to stable estimates, we reanalyzed the mixture with 80,000-iteration chains following the same protocol.

VISUALIZING AND DESCRIBING MAGNITUDE AND DIRECTION OF BIASES AND PRECISION OF ESTIMATES

Mean stock composition estimates and 90% credibility intervals (CIs) for each of the 5 replicates for the 4 simulations were plotted by subregional reporting groups (5 replicates, 4 simulations, 24 subregional reporting groups = 480 estimates). Correct allocations were indicated within each plot for each subregional reporting group. We provided interpretation of these plots to answer the questions posed by the AP.

To provide additional statistical summaries of the results and to further examine relationships between estimate precision and known proportions in mixtures, 4 additional analyses were conducted on the 480 estimates.

1) The proportion of the 90% CIs that included the known proportions was calculated.
2) The absolute deviations between the means and the known values were calculated. These values were ranked from lowest to highest and plotted. The values for the median and 90% quantile were identified.
3) The widths of the 90% CIs were calculated, values were ranked from lowest to highest and plotted, and the value for the median was identified.
4) The width of the 90% CIs was plotted against the known subregional stock proportions.

RESULTS

DEVELOPING MIXTURE COMPOSITIONS

Stock compositions of the simulated fisheries are shown in Table 2 and follow the number/letter combination for the questions/fisheries shown above in the methods section.

ESTIMATING MIXTURE COMPOSITIONS

For all but 1 set of estimates, Raftery-Lewis diagnostics indicated convergence within chains and Gelman-Rubin diagnostics fell below 1.2, indicating convergence among chains. The third replicate of the simulated Bristol Bay fishery with 5% North Peninsula fish had a Gelman-Rubin of 1.32 for Kuskokwim River (mean=0.05%; 90% CI=0–0.01%) due to 1 slightly divergent chain and very little variation within chains. In the interest of presenting results at the August

30, 2012 meeting of the AP, and the mild departure from convergence among chains, we used these estimates as the priors for the fourth replicate in these simulations. All estimates did converge after reanalysis of the replicate with 80,000 iterations, and the Kuskokwim River estimates were similar between the 2 analyses (80,000 iteration mean = 0.01%).

VISUALIZING AND DESCRIBING MAGNITUDE AND DIRECTION OF BIASES AND PRECISION OF ESTIMATES

Mean stock composition estimates and 90% CIs for each of the 5 replicates for the 4 simulations plotted by subregional reporting group are shown in Figures 1–4 and tabulated results are found in Appendices A–D. The following answers can be provided for the questions posed by the AP based on these results:

1) Are there misallocations to East of WASSIP (EOW), when EOW fish are not present in the sample?

    a. South Peninsula fishery with 0.0% EOW fish

Answer: No; estimates are all zero (Figure 1, Appendix A).

    b. North Peninsula fishery with 0.0% EOW fish

Answer: No; estimates are all zero (Figure 2, Appendix B)

2) Are allocations to EOW accurate when EOW fish are present in the sample?

    a. South Peninsula fishery with 20% EOW fish

Answer: Allocations were within 1.8% for all replicates but there was a 1.3% negative bias across all 5 replicates (average allocation to EOW was 18.7%). The 90% CIs included the correct proportion in all 5 replicates (Figure 3, Appendix C).

3) Are small proportions of reporting groups accurately estimated and detectable?

    a. Bristol Bay fishery with 5% North Peninsula fish

Answer: The average summed allocation to all North Peninsula reporting groups across all 5 replicates was 4.2% (Figure 4; Appendix D). Cinder was biased low (average allocation=0.3%; known allocation=1.0%), while Meshik (1.1%; 1.0%), Ilnik (0.8%; 1.0%), Sandy (0.1%; 0.0%), and Bear (1.9%; 2.0%) were within 0.2% of the correct allocations. The 90% CI's for 4 of the 5 replicates did not include 0.0% for Bear (known 2%, the most highly represented North Peninsula reporting group).

For 96.8% of estimates, the known proportions were within the 90% CI, indicating that the 90% CIs are conservative. Absolute deviations between the means and the known values ranged from 0.000 to 0.059 (5.9%) with half of the values below 0.001 (0.1%) and 90% of the values below 0.020 (2.0%; Figure 5). The widths of the 90% CIs ranged from 0.000 to 0.128 (12.8%) with half of the values below 0.001 (0.1%; Figure 6). The relationship between the width of the 90% CIs and the known subregional stock proportions showed that as the stock proportions increase, the width of the 90% CI increased quickly and reached an asymptote of about 12% (Figure 7). This 12% value represents a precision of approximately ±6% of the estimate.

DISCUSSION

This exercise was designed to provide a better sense of the potential magnitude and direction of biases in stock composition estimates for mixed stock analysis of real-world fisheries mixtures using the WASSIP baseline for sockeye salmon. Clearly, an examination of all possible stock compositions likely to occur among the fisheries sampled for WASSIP is not possible. However, this set of analyses sheds some light on the magnitude and direction of biases for a wide range of stock compositions. These results provide a better sense of how well the MSA methods work for real-world stock compositions than the 100% stock proportions used in the original proof tests (Dann et al. 2012). The 100% proof tests are more stringent than these tests because any misallocation is detected, whereas in the fishery-based simulations, some misallocation was undetected because the reporting group that received the misallocation may have been present in the mixture. For example, if the mixture contained fish from both Egegik and Ugashik, and fish misallocated back and forth between these reporting groups, some of the misallocation signal was lost because they canceled each other out. As a result, the 100% proof tests show much higher misallocations and wider 90% CIs than the fisheries-based simulations.

These simulations provide strong evidence that the MSA is performing well with this baseline and was able to provide answers to the questions posed by the AP members who designed the tests. When no EOW fish were represented in the simulated fisheries, the mean estimates of EOW were 0.0000 for all 5 replicates for all 3 simulated fishery mixtures. The high end of the 90% CI included 0.0006 (0.06%) in 1 replicate, 0.0001 in 2 replicates and 0.0000 in the remaining 12 replicates. When EOW fish were represented in a simulated fishery mixture, the mean estimates for EOW were underestimated by 1.3% (known 20.0%; average estimate 18.7%) and the 90% CIs included the known value in all replicates. This bias was in the opposite direction from that expected based on AP concerns that the model may be overestimating EOW contributions to WASSIP fisheries. Finally, the simulations demonstrated that even fairly small contribution to fisheries from reporting groups can be both detected and estimated with high accuracy. For example, simulated Bristol Bay fishery with 5% North Peninsula fish allocated an average of 4.2% to North Peninsula reporting groups with individual replicate estimates of 5.0%, 5.0%, 2.7%, 4.3%, and 4.0%. The 90% CIs included 0 for the stock most represented in these simulations (Bear) in only 1 of the 5 replicates.

Many of the insights derived from the original 100% proof tests were apparent in these simulations. For example, the wider 90% CIs and the mirror pattern in estimated stock contributions among replicates between Ugashik and Egegik reporting groups in the simulated North Peninsula fishery with no EOW (Figure 2) might have been predicted by the 100% proof tests that show misallocations from Ugashik to Egegik and from Egegik to Ugashik. Similar patterns can be seen for the Cinder and Meshik for the same simulation (Figure 2) and for Black and Chignik in the 2 South Peninsula simulations (Figures 1 and 3). Fortunately, in all these cases, the misallocations are going back and forth between 2 subregional reporting groups within regional reporting groups. The results from the simulated fisheries corroborated the previous 100% proof tests that indicate that the Goodnews and Togiak reporting groups are potentially problematic: when both reporting groups were represented in simulated mixtures, misallocation back and forth canceled out and they both showed little bias (Figure 2), but when only 1 of these reporting groups was represented in the mixture (Togiak), misallocations to the other reporting group (Goodnews) were observed (Figure 4).

CAVEATS FOR APPLYING THESE RESULTS TO REAL CATCH SAMPLE MIXTURES

How well these results predict what will happen with real catch sample mixtures depends on how robust the MSA model is to 2 assumptions made in the simulations: 1) the baseline completely characterizes genetic variation of all populations likely to contribute to catch samples, and 2) each population in the baseline within a reporting group will have representation in a catch sample equal to its representation in the baseline. Both assumptions are unlikely to be met, but the MSA model is likely to be robust to most of the deviations from these assumptions, which means that the simulations are likely to provide meaningful insights into performance of the MSA model for catch samples.

The MSA model is likely to be robust to the first assumption because the baseline is likely to represent the vast majority of population structure. Such representation results in individuals from catch samples that come from populations not represented in the baseline allocating to the correct reporting group. Evidence for this can be found in the tree (Baseline report; Dann et al. 2012) which shows clustering of populations within reporting groups. Additional evidence that this assumption is met is in the escapement tests where high proportions of fish captured in lower river reaches allocated to the correct reporting group. The fish used in escapement tests may have come from populations not in the baseline. Finally, for areas where populations do not cluster and where escapement test samples were not available, such as the Alaska Peninsula, concerted effort was made to collect samples from all known spawning aggregates and the area biologists agree that 99% of the production of sockeye salmon from the area is represented in the baseline (Mark Witteveen and Robert Murphy, Commercial Fisheries Biologists, ADF&G, Kodiak, personal communication).

The MSA model is likely to be robust to the second assumption in most, but not all, cases. Again, the high performance of the proof tests in most cases provides evidence that the MSA model is robust to this assumption. The proof tests samples not only included fish that came from populations not represented in the baseline, but these samples also likely contained fish that represent some populations at much higher proportions than others. This would be expected because the number of spawning fish and the run timing varies among populations.

However, there are some cases where the model is not as robust to the second assumption. This is likely to be the case where reporting groups have large populations of sea/river-ecotype sockeye salmon. Sea/river-ecotype sockeye salmon are less genetically divergent among drainages than the lake-ecotype sockeye salmon (Dann et al. 2012). If, in the wild, populations representing the sea/river ecotype contain larger numbers of fish than populations representing lake ecotype, then the simulations may be optimistic. Sea/river-ecotype populations are concentrated in western Bristol Bay and Kuskokwim Bay drainages. Evidence that the MSA model is not robust to this assumption can be seen in the divergence in performance between the proof tests and some escapement tests within the Kuskokwim, Goodnews, Togiak, Igushik, and Nushagak rivers. Here the proof tests hit the 90% correct allocation mark in all but Togiak, but the escapement tests were much more variable, with most above the 90% correct allocation mark but some falling considerably below the mark (Figures 18 and 19 in Dann et al. 2012).

Taken together, these simulations provide useful insights into how the MSA model used for WASSIP is likely to perform for real-world catch samples. Extra care will need to be exercised when interpreting results from catch samples that contain sea/river ecotype sockeye salmon, which are more concentrated in western Bristol Bay and Kuskokwim Bay drainages.

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QUESTIONS FOR TECHNICAL COMMITTEE

1) Do these fishery-based simulations provide useful insight into likely performance of the mixed stock analysis methods for sockeye salmon captured in WASSIP fishery strata?

2) Do the caveats adequately capture the assumptions required for these simulations to provide performance that might be expected from harvest sample mixtures?

3) Do you recommend other analyses or other summaries or interpretation of these data?

Technical Committee comments regarding reporting group evaluations using simulated fisheries are documented on Page 6 of Habicht et al. (2012) for chum salmon. No further comments were provided for this report.

TABLES

Table 1.–Catch strata with unexpected stock composition estimates identified by Area Research Biologists (ARBs) and selected for statistical reanalysis as part of the quality control measures. These strata and names correspond to Tables 3, 5, 7, 9, 11, 14, and 17 of the sampling report (Eggers et al. 2011). For each catch strata, the reason for unexpected stock composition was provided by the ARBs.

Catch strata	Reason
WestPerry08.3_Jul21_Jul31	Only 25% Chignik, 35% Bristol Bay, >10% both North and South Pen
SWStepovak08.3_Jul26_Aug20	62% East of WASSIP, 37% Chignik
Shumagin08.P4_Aug1_Aug21	41% East of WASSIP
Dolgoi06.J1_Jun7_Jun13	55% Chignik, 39% East of WASSIP
Unimak06.J1_Jun7_Jun13	51% Chignik
IlnikN07.3_Jul16_Jul31	20% East of WASSIP
OPHeiden08.3_Jul14_Jul15	90% Bristol Bay
Egegik07.4_Jul9_Jul14	Non-local estimates changed from Dann et al. (2009)
Togiak07.1_Jun18_Jul6	Highest non-local proportion of all Togiak mixtures
W5Comm07.3_Jul18_Aug31	Highest non-local proportion of all Kuskokwim mixtures

Table 2.–Percent stock compositions for fishery-based simulations to investigate magnitude and direction of biases of mixed stock analysis methods. The question/fishery number/letter designations are described in the methods.

Reporting Group		Question/fishery			
Regional	Subregional	1.a.	1.b.	2.a.	3.a.
Norton Sound		0.0	0.0	0.0	0.0
Kuskokwim Bay					
	Kuskokwim R.	0.0	0.0	0.0	0.0
	Kanektok	0.0	0.0	0.0	0.0
	Goodnews	0.0	1.0	0.0	0.0
Bristol Bay					
	Togiak	0.0	0.5	0.0	1.0
	Igushik	0.0	4.0	0.0	1.0
	Wood	0.0	13.0	0.0	21.0
	Nushagak	0.0	2.0	0.0	6.0
	Kvichak	0.0	5.0	0.0	9.0
	Alagnak	0.0	1.5	0.0	7.0
	Naknek	0.0	8.0	0.0	17.0
	Egegik	0.0	7.0	0.0	22.0
	Ugashik	0.0	18.0	0.0	11.0
North Peninsula					
	Cinder	0.0	6.0	0.0	1.0
	Meshik	0.0	9.0	0.0	1.0
	Ilnik	0.0	9.0	0.0	1.0
	Sandy	0.0	2.0	0.0	0.0
	Bear	0.0	9.0	0.0	2.0
	Nelson	0.0	5.0	0.0	0.0
	NW Dist.-BH	0.0	0.0	0.0	0.0
South Peninsula		2.0	0.0	2.0	0.0
Chignik					
	Black Lake	44.0	0.0	35.0	0.0
	Chignik Lake	54.0	0.0	43.0	0.0
East of WASSIP		0.0	0.0	20.0	0.0

FIGURES

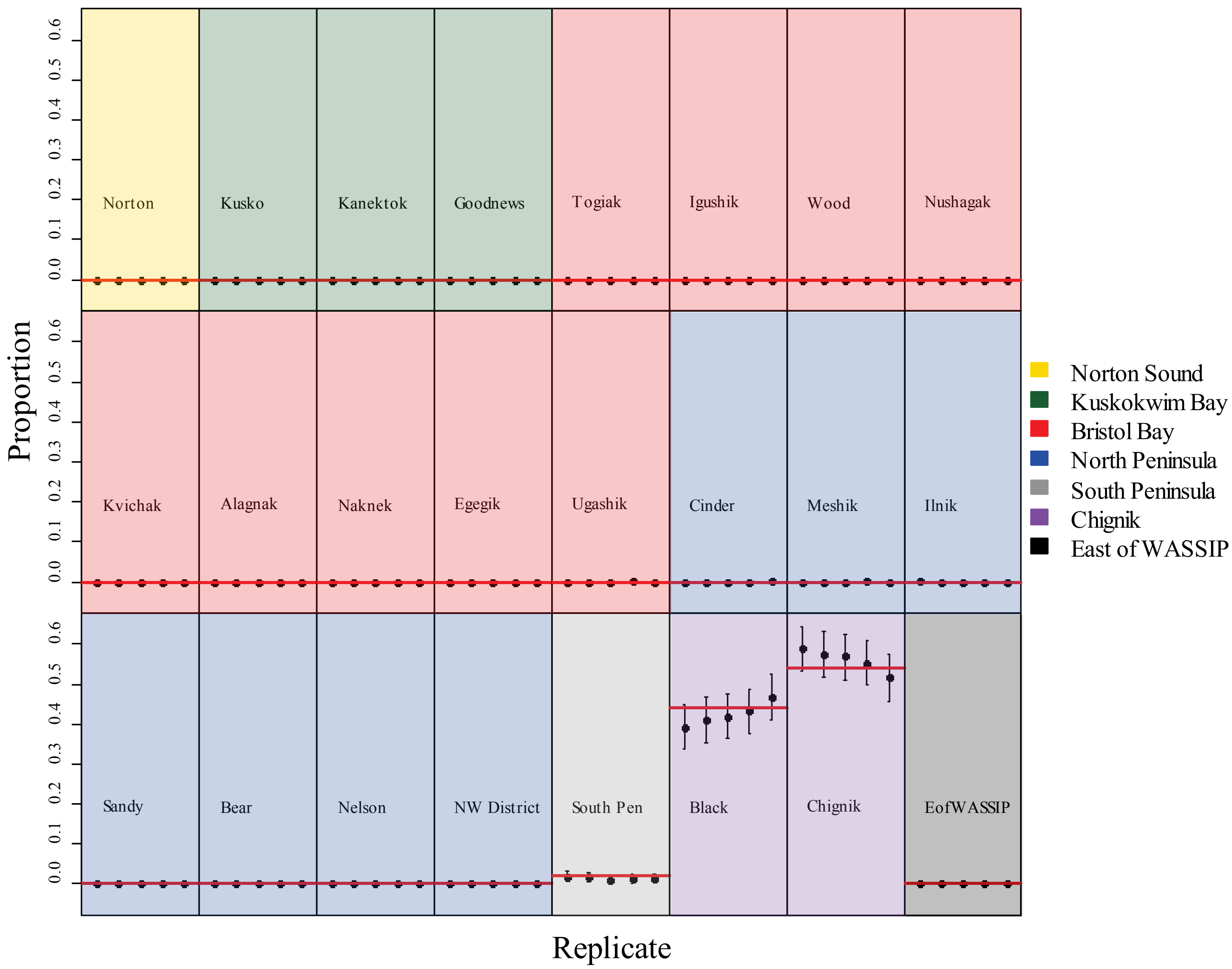

Figure 1.–Mean (black points) and 90% credibility interval (vertical black lines) estimates for 5 replicates of a simulated South Peninsula fishery with no East of WASSIP fish (Table 2: Question/fishery 1.a.). Each cell represents a subregional reporting group; ordered geographically from north to south and colored by regional reporting group (legend). Red line shows the known stock composition of the simulation. Deviations from the red line show magnitude and direction of biases for each replicate.

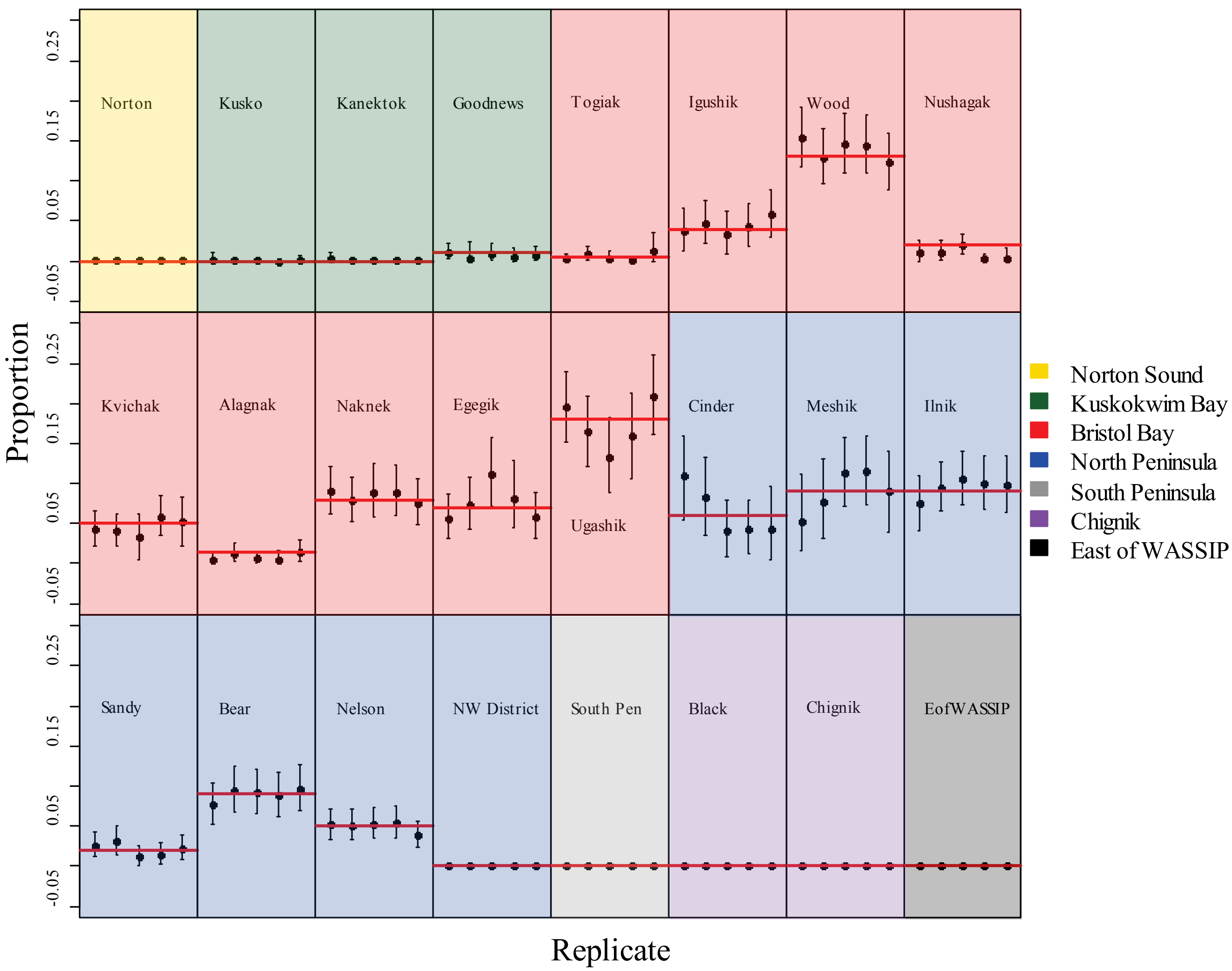

Figure 2.–Mean (black points) and 90% credibility interval (vertical black lines) estimates for 5 replicates of a simulated North Peninsula fishery with no East of WASSIP fish (Table 2: Question/fishery 1.b.). Each cell represents a subregional reporting group; ordered geographically from north to south and colored by regional reporting group (legend). Red line shows the known stock composition of the simulation. Deviations from the red line show magnitude and direction of biases for each replicate.

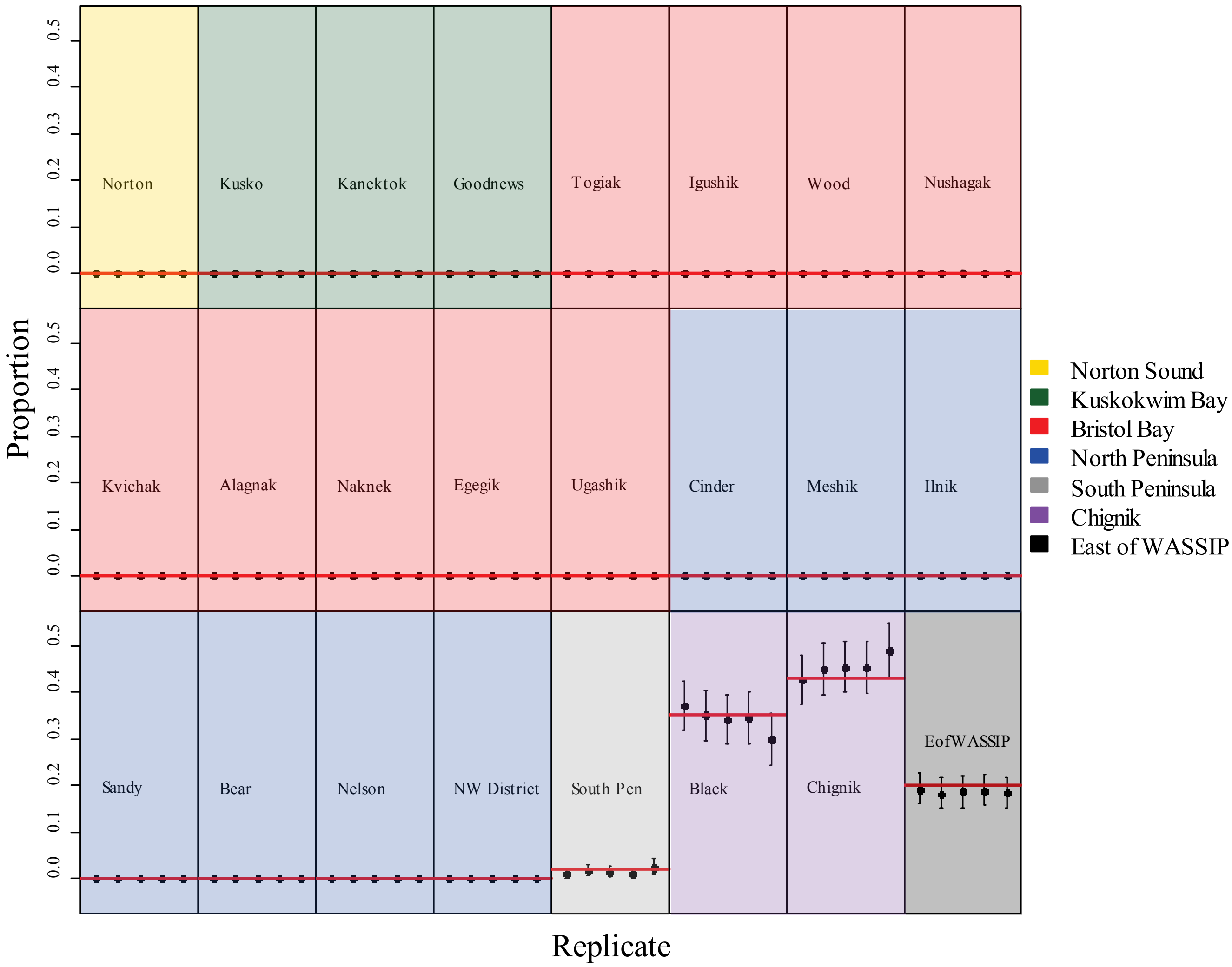

Figure 3.–Mean (black points) and 90% credibility interval (vertical black lines) estimates for 5 replicates of a simulated South Peninsula fishery with 20% East of WASSIP fish (Table 2: Question/fishery 2.a.). Each cell represents a subregional reporting group; ordered geographically from north to south and colored by regional reporting group (legend). Red line shows the known stock composition of the simulation. Deviations from the red line show magnitude and direction of biases for each replicate.

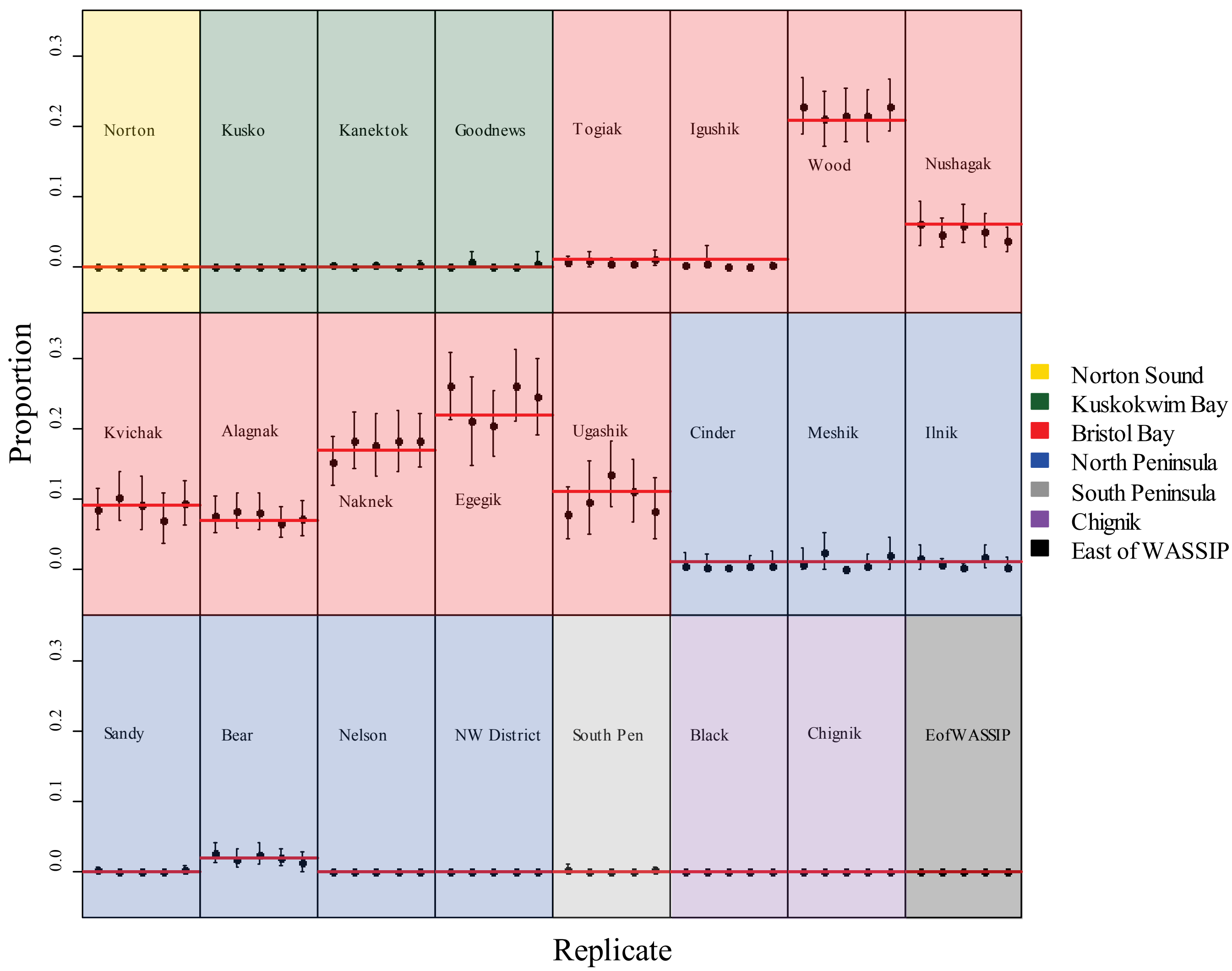

Figure 4.–Mean (black points) and 90% credibility interval (vertical black lines) estimates for 5 replicates of a simulated Bristol Bay fishery with 5% North Peninsula fish (Table 2: Question/fishery 3.a.). Each cell represents a subregional reporting group; ordered geographically from north to south and colored by regional reporting group (legend). Red line shows the known stock composition of the simulation. Deviations from the red line show magnitude and direction of biases for each replicate.

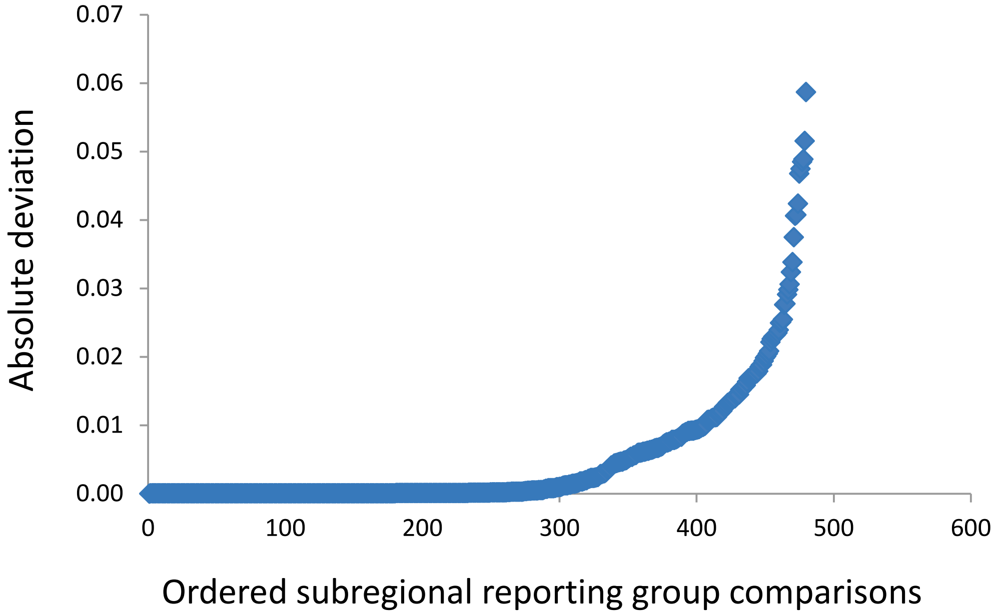

Figure 5.–Absolute deviations between mean allocations and true stock composition estimates to subregional reporting groups (24), ordered from smallest to largest, for 5 replicates of 4 simulated fisheries. Total number of deviations is 24 × 5 × 4 = 480. Half the deviations were at or below 0.0001 (0.01%), and 90% were below 0.02 (2%).

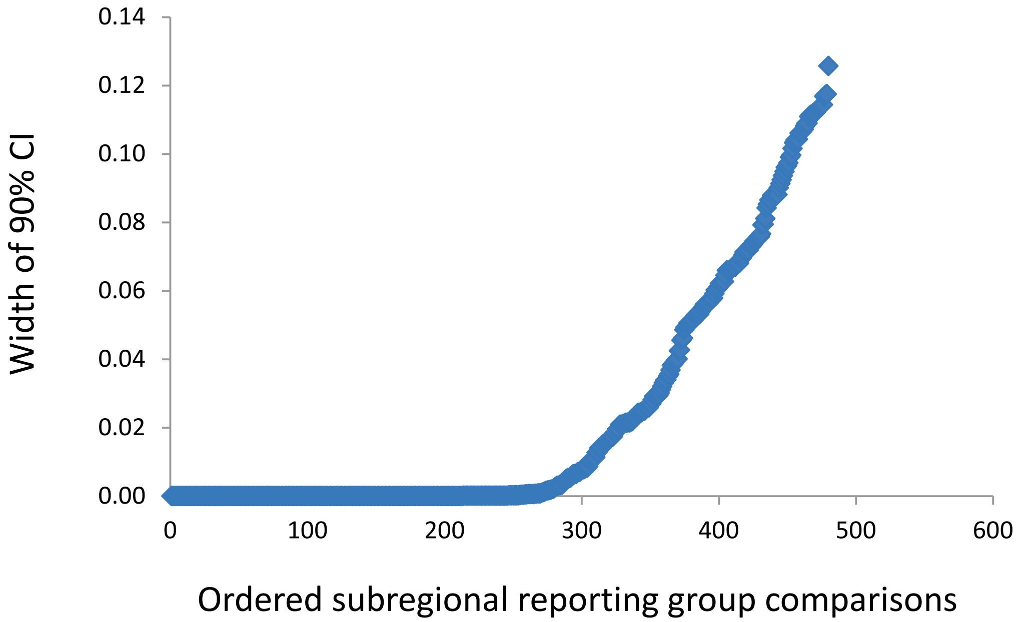

Figure 6.–Width of 90% credibility intervals (CIs) for mean allocations to subregional reporting groups (24), ordered from smallest to largest, for 5 replicates of 4 simulated fisheries. Total number of allocations is 24 × 5 × 4 = 480. Half the 90% CIs were at or below 0.0001 (0.01%), and the remainder were distributed fairly evenly up to 12.6%.

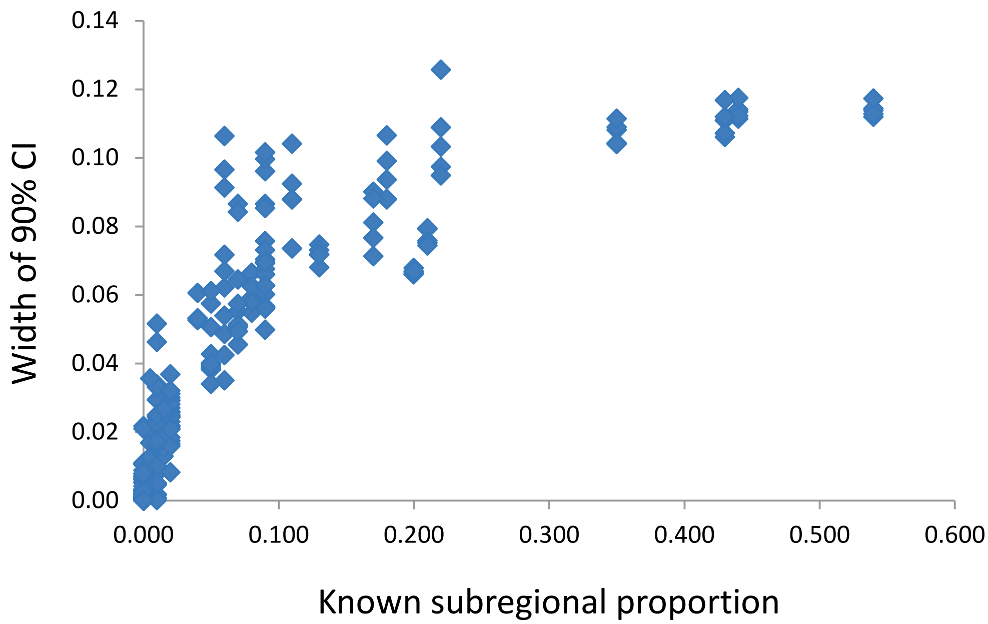

Figure 7.–Relationship between the known subregional stock proportions (24) and the width of the 90% credibility intervals (CIs) for 5 replicates of 4 simulated fisheries. Total number of points is 24 × 5 × 4 = 480. As the known stock proportions increased, the width of the 90% CIs increased quickly and reached an asymptote of about 12%.

APPENDICES

Appendix A.–Mean and 90% credibility interval estimates for allocations to subregional reporting groups for 5 replicates of a simulated sockeye salmon South Peninsula fishery with no East of WASSIP fish (Table 2: Question/fishery 1.a.).

		Proof 1			Proof 2			Proof 3			Proof 4			Proof 5			
Reporting Group	Known	Mean	5%	95%	Mean	5%	95%	Mean	5%	95%	Mean	5%	95%	Mean	5%	95%	Average
NortonSound	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
KuskokwimRiver	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Kanektok	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Goodnews	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Togiak	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Igushik	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Wood	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Nushagak	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Kvichak	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Alagnak	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Naknek	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Egegik	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ugashik	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Cinder	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
Meshik	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.007	0.000	0.000	0.000	0.000
Ilnik	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sandy	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bear	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.005	0.000
Nelson	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NWDistrict	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.003	0.000
SouthPeninsula	0.020	0.018	0.008	0.031	0.016	0.006	0.028	0.010	0.003	0.020	0.012	0.003	0.024	0.013	0.005	0.025	0.014
BlackLake	0.440	0.393	0.337	0.448	0.409	0.353	0.466	0.420	0.363	0.477	0.433	0.377	0.489	0.468	0.409	0.527	0.424
ChignikLake	0.540	0.588	0.532	0.644	0.574	0.517	0.630	0.569	0.512	0.626	0.553	0.497	0.609	0.517	0.458	0.575	0.560
EastofWASSIP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Appendix B.–Mean and 90% credibility interval estimates for allocations to subregional reporting groups for 5 replicates of a simulated sockeye salmon North Peninsula fishery with no East of WASSIP fish (Table 2: Question/fishery 1.b.).

		Proof 1			Proof 2			Proof 3			Proof 4			Proof 5			
Reporting Group	Known	Mean	5%	95%	Mean	5%	95%	Mean	5%	95%	Mean	5%	95%	Mean	5%	95%	Average
NortonSound	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
KuskokwimRiver	0.000	0.001	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.006	0.000
Kanektok	0.000	0.002	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Goodnews	0.010	0.010	0.003	0.021	0.004	0.000	0.023	0.009	0.001	0.021	0.004	0.000	0.015	0.007	0.001	0.018	0.007
Togiak	0.005	0.002	0.000	0.008	0.008	0.001	0.018	0.003	0.000	0.013	0.000	0.000	0.003	0.012	0.000	0.036	0.005
Igushik	0.040	0.038	0.013	0.066	0.047	0.022	0.075	0.034	0.009	0.062	0.042	0.019	0.072	0.058	0.029	0.090	0.044
Wood	0.130	0.153	0.118	0.192	0.130	0.097	0.165	0.146	0.111	0.184	0.145	0.110	0.182	0.122	0.088	0.160	0.139
Nushagak	0.020	0.011	0.000	0.026	0.011	0.001	0.026	0.020	0.009	0.033	0.003	0.000	0.008	0.004	0.000	0.016	0.010
Kvichak	0.050	0.042	0.023	0.065	0.041	0.022	0.063	0.033	0.005	0.062	0.058	0.035	0.085	0.052	0.023	0.084	0.045
Alagnak	0.015	0.005	0.000	0.014	0.013	0.004	0.025	0.006	0.001	0.014	0.004	0.000	0.015	0.014	0.002	0.029	0.008
Naknek	0.080	0.091	0.063	0.122	0.079	0.053	0.108	0.088	0.058	0.124	0.089	0.060	0.122	0.075	0.048	0.106	0.084
Egegik	0.070	0.057	0.031	0.087	0.073	0.043	0.108	0.112	0.071	0.158	0.081	0.044	0.128	0.059	0.032	0.090	0.076
Ugashik	0.180	0.196	0.153	0.240	0.165	0.122	0.210	0.133	0.089	0.183	0.159	0.105	0.212	0.210	0.162	0.261	0.173
Cinder	0.060	0.109	0.054	0.160	0.082	0.036	0.133	0.041	0.008	0.080	0.043	0.012	0.079	0.042	0.005	0.096	0.063
Meshik	0.090	0.053	0.016	0.112	0.076	0.031	0.130	0.113	0.071	0.158	0.115	0.074	0.159	0.091	0.039	0.140	0.090
Ilnik	0.090	0.076	0.040	0.110	0.095	0.065	0.128	0.106	0.073	0.141	0.099	0.068	0.134	0.097	0.064	0.134	0.095
Sandy	0.020	0.026	0.012	0.042	0.031	0.015	0.051	0.012	0.002	0.026	0.014	0.002	0.029	0.022	0.008	0.039	0.021
Bear	0.090	0.077	0.053	0.103	0.095	0.068	0.124	0.092	0.065	0.122	0.088	0.062	0.118	0.097	0.070	0.126	0.090
Nelson	0.050	0.052	0.034	0.072	0.050	0.032	0.071	0.052	0.034	0.073	0.054	0.036	0.075	0.038	0.023	0.057	0.049
NWDistrict	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SouthPeninsula	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BlackLake	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ChignikLake	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EastofWASSIP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Appendix C.–Mean and 90% credibility interval estimates for allocations to subregional reporting groups for 5 replicates of a simulated sockeye salmon South Peninsula fishery with 20% East of WASSIP fish (Table 2: Question/fishery 2.a.).

		Proof 1			Proof 2			Proof 3			Proof 4			Proof 5			
Reporting Group	Known	Mean	5%	95%	Mean	5%	95%	Mean	5%	95%	Mean	5%	95%	Mean	5%	95%	Average
NortonSound	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
KuskokwimRiver	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Kanektok	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Goodnews	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Togiak	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.002	0.000
Igushik	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Wood	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Nushagak	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Kvichak	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Alagnak	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Naknek	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Egegik	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ugashik	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.003	0.001	0.000	0.004	0.000
Cinder	0.000	0.001	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.007	0.000
Meshik	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.003	0.000
Ilnik	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.008	0.000
Sandy	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bear	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Nelson	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NWDistrict	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SouthPeninsula	0.020	0.009	0.002	0.020	0.017	0.008	0.030	0.014	0.003	0.028	0.011	0.004	0.022	0.025	0.011	0.043	0.015
BlackLake	0.350	0.370	0.318	0.423	0.351	0.297	0.405	0.342	0.290	0.394	0.344	0.290	0.399	0.298	0.244	0.355	0.341
ChignikLake	0.430	0.427	0.374	0.480	0.448	0.393	0.504	0.453	0.400	0.507	0.454	0.398	0.510	0.489	0.430	0.547	0.454
EastofWASSIP	0.200	0.192	0.160	0.226	0.182	0.150	0.216	0.186	0.153	0.221	0.189	0.157	0.223	0.183	0.151	0.217	0.187

Appendix D.–Mean and 90% credibility interval estimates for allocations to subregional reporting groups for 5 replicates of a simulated sockeye salmon Bristol Bay fishery with 5% North Peninsula fish (Table 2: Question/fishery 3.a.).

		Proof 1			Proof 2			Proof 3			Proof 4			Proof 5			
Reporting Group	Known	Mean	5%	95%	Mean	5%	95%	Mean	5%	95%	Mean	5%	95%	Mean	5%	95%	Average
NortonSound	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
KuskokwimRiver	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Kanektok	0.000	0.001	0.000	0.002	0.000	0.000	0.000	0.001	0.000	0.005	0.000	0.000	0.000	0.001	0.000	0.008	0.001
Goodnews	0.000	0.000	0.000	0.001	0.006	0.000	0.022	0.000	0.000	0.001	0.000	0.000	0.000	0.005	0.000	0.021	0.002
Togiak	0.010	0.006	0.001	0.015	0.009	0.000	0.021	0.005	0.001	0.012	0.004	0.000	0.010	0.011	0.002	0.024	0.007
Igushik	0.010	0.001	0.000	0.002	0.005	0.000	0.029	0.001	0.000	0.002	0.000	0.000	0.000	0.001	0.000	0.005	0.001
Wood	0.210	0.229	0.190	0.269	0.211	0.171	0.251	0.217	0.179	0.255	0.215	0.178	0.254	0.229	0.193	0.267	0.220
Nushagak	0.060	0.060	0.031	0.093	0.046	0.027	0.070	0.059	0.034	0.088	0.051	0.028	0.077	0.037	0.022	0.057	0.051
Kvichak	0.090	0.084	0.055	0.115	0.103	0.070	0.139	0.092	0.057	0.132	0.070	0.036	0.109	0.092	0.063	0.125	0.088
Alagnak	0.070	0.077	0.053	0.103	0.082	0.058	0.109	0.081	0.057	0.108	0.066	0.044	0.090	0.071	0.048	0.098	0.075
Naknek	0.170	0.153	0.119	0.190	0.182	0.143	0.224	0.176	0.132	0.222	0.182	0.139	0.227	0.183	0.146	0.222	0.175
Egegik	0.220	0.261	0.213	0.310	0.211	0.148	0.273	0.206	0.160	0.255	0.261	0.211	0.314	0.245	0.191	0.300	0.237
Ugashik	0.110	0.078	0.043	0.117	0.096	0.049	0.153	0.135	0.090	0.182	0.110	0.068	0.155	0.082	0.043	0.131	0.100
Cinder	0.010	0.004	0.000	0.024	0.003	0.000	0.021	0.001	0.000	0.005	0.004	0.000	0.019	0.003	0.000	0.025	0.003
Meshik	0.010	0.005	0.000	0.029	0.023	0.000	0.052	0.000	0.000	0.001	0.004	0.000	0.021	0.020	0.000	0.046	0.011
Ilnik	0.010	0.014	0.000	0.034	0.006	0.001	0.015	0.002	0.000	0.008	0.016	0.002	0.035	0.002	0.000	0.016	0.008
Sandy	0.000	0.001	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.009	0.001
Bear	0.020	0.025	0.012	0.041	0.017	0.006	0.031	0.024	0.011	0.040	0.018	0.007	0.033	0.013	0.000	0.028	0.019
Nelson	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NWDistrict	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SouthPeninsula	0.000	0.001	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.006	0.001
BlackLake	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ChignikLake	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EastofWASSIP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000