A Simulation Study of Classification and Maximum Likelihood Estimators of the Stock Composition of Yukon River Chinook Salmon Harvests

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INTRODUCTION

The Yukon River flows over 2,000 miles from its headwaters in British Columbia, through the central interior of Alaska, to its mouth on the Bering Sea coast in western Alaska (Figure 1). All five species of Pacific salmon (*Oncorhynchus* spp.) occur in the Yukon River. Commercial fisheries are distributed throughout the mainstem Yukon River and in the lower portions of the Anvik and Tanana Rivers, while subsistence fisheries are distributed throughout the drainage. Commercial fisheries within the Yukon River target both chinook (*O. tshawytscha*) and chum (*O. keta*) salmon. The United States of America and Canada have been engaged in treaty negotiations regarding the management and conservation of transboundary Yukon River chinook and chum salmon stocks. Bergstrom et al. (1997) provides a detailed overview of the fisheries and salmon stocks of the Yukon River. Chinook salmon harvests have historically been the most economically valuable for commercial fishermen (Buklis, in press).

The Alaska Department of Fish and Game (Department) began to investigate the use of scale circuli distance measurements for stock identification of Yukon River chinook salmon in 1980 (McBride and Marshall, 1983). The investigations indicated stock identification was feasible on a broad geographic scale, and a stock identification program was developed to annually estimate the stock composition of chinook salmon harvests throughout the Yukon River drainage. Schneiderhan (1997) describes the development of the program and summarizes methods used from program inception through 1996.

The primary component of the stock identification program has been the classification of individual fish sampled from harvests to stock of origin (Schneiderhan, 1997). Stock groups are defined based on the geographic location of spawning streams. Three geographic regions, two in Alaska (Lower and Middle) and one in Canada (Upper), have been defined in most years. Stock standards used to characterize each stock group are obtained by sampling fish from within each geographic region. Sampled fish are aged, and distances between scale circuli are measured using digitizing equipment similar to the system described by Ryan and Christie (1976). These data are used to develop age-specific classification rules based on linear discriminant analysis (Hand, 1997) of important scale measurement variables. In most years, models were developed for the relatively abundant 1.3 and 1.4 age classes (European notation), with sample sizes usually being insufficient to develop classification rules for other age classes. Classification error rates are estimated by applying the classification rules to the stock standards, whose true stock identity is known, using a leave-one-out approach (Lachenbruch and Mickey, 1968). The stock composition of a fishery harvest is estimated by classifying fish sampled from the harvest to a stock of origin. The proportions classified to each of the stock groups are then adjusted according to

classification error rates using a procedure similar to that of Cook and Lord (1978), with estimates constrained to be non-negative and sum to unity (Hoenig and Heisey, 1987).

While the stock identification program has performed satisfactorily, in the spring of 1998 the Department decided to examine the program to determine if improvements could be made in the data analysis procedure. The data analysis procedure consists of a number of sequential steps, with manual manipulation of results between steps, and requires subjective decision making at several junctures. One of the primary motivations for the examination was to improve the efficiency of the analysis procedure, and reduce the need for subjective input. A second motivation was the importance of the Yukon River chinook salmon resource. Given their value in both commercial and non-commercial fisheries, and that stocks of Canadian origin continue to be a focal point in ongoing treaty negotiations, the Department wished to improve the statistical quality of the stock composition estimates to the extent feasible.

The central component of the stock identification program is the classification estimator that has been employed since the program's inception. When multiple estimates of a stock composition have been available, the classification estimator has generally produced estimates that are comparable to estimates obtained with other methods (JTC, 1997). However, the classification estimator does have some characteristics that are, at least conceptually, undesirable. The estimator is indirect in that the stock identity of individual fish, which are not of interest in themselves, must first be estimated. A related characteristic is that the estimator does not fully utilize information obtained in either a mixed-stock fishery sample or stock standard samples, which is inefficient and wasteful of information. Each sampled fish is assigned to the stock group for which its probability of membership is largest, and that assignment is the only information retained in the estimation process. No information about the absolute magnitude of membership probabilities across stocks for a given fish, or between fish, is utilized. An additional undesirable characteristic of the estimates produced by this method is that they are not continuous, but can vary only in steps of the inverse of the sample size, although the Cook and Lord adjustment partially masks this effect.

One potential alternative to the classification estimator is a maximum likelihood estimator (Stuart and Ord, 1991) based on a mixture model. A maximum likelihood estimator may share many of the underlying assumptions of the classification estimator, while largely avoiding the undesirable characteristics mentioned above. The absolute magnitudes of the stock membership probabilities are used directly in the likelihood function. The proportions of a harvest consisting of fish from each of the stock groups are parameters of the likelihood function, and estimates are thus obtained directly with no need to classify individual fish. In addition, estimates vary continuously over the interval (0.0, 1.0). One potential disadvantage of the maximum likelihood estimator is that it may be more sensitive to violations of distributional assumptions, in this case that data have multivariate normal distributions.

The statistical properties of the maximum likelihood estimator are superior to those of the classification estimator from a theoretical perspective. However, Millar (1990) found that the maximum likelihood estimator enjoys no practical advantage over a classification estimator when the number of stock groups is small. For that reason, we wished to compare the actual performance of the two estimators with respect to Yukon River chinook salmon applications. This report documents the design and conduct of the simulation study, and presents summaries of the results and our findings.

SIMULATION DESIGN

Stock Standard Data

Historic stock standard data were reviewed in order to select suitable data upon which to base the simulation study. Use of four data sets was judged sufficient to provide a meaningful evaluation of the statistical properties of the two estimators for Yukon River chinook applications. The primary criterion used to make a selection was the availability of relatively large stock standard samples for all stock groups. A secondary criterion for selection was that a three-stock classification model had been employed (Lower, Middle, and Upper), avoiding the occasional data set for which a more complicated four-stock model had been deemed necessary (Schneiderhan, 1996). Data from age classes 1.3 and 1.4 in 1992 and 1993 were selected. The stock standard sample sizes for these data sets are given in Table 1. The sample sizes in Table 1 differ somewhat from those given by Schneiderhan (1994a, 1994b), but we were unable to resolve the differences.

A large number of variables are computed from the circuli distance measurements obtained from each fish scale, and a subset of these variables is selected for use in the classification model (Schneiderhan, 1997). In order to provide the most straight-forward comparison of the estimators' performance, the variables selected for use in the original classification model from each of the four data sets (Schneiderhan, 1994a, 1994b) were also used in this simulation. These data were used to develop standards for each of the stock groups.

The assumptions made in developing the stock standards from each data set differed somewhat between the two estimators. For the classification estimator, the data were assumed to have a multivariate normal probability distribution function (pdf). Consistent with the original analysis of these data and the assumptions of linear discriminant analysis, the dispersion matrices of the three stock groups were assumed to be equal and an estimate of the pooled dispersion matrix was used for each stock

group. Although the data were also assumed to have a multivariate normal pdf for the maximum likelihood estimator, the dispersion matrices of the stock groups were not assumed to be equal. It was our objective assessment that the performance of the maximum likelihood estimator would not degrade with unequal dispersion matrices, as is often the case in discriminant analysis (Seber, 1984). However, because the maximum likelihood estimator may be more sensitive to violations of distributional assumptions, robust estimators of a mean vector and a dispersion matrix (Campbell, 1980) were employed to protect against the undue influence of outliers. These robust estimators are designed to reduce the influence of extreme observations on estimates of the mean vector and the dispersion matrix, producing estimates very similar to traditionally computed estimates when extreme observations are not overly prevalent in the data.

Construction of Mixture Samples

The performance of the classification and maximum likelihood estimators was examined under a variety of stock mixture proportions that cover the entire parameter space. Mixture proportions for each stock varied from 0.0 to 1.0 in steps of 0.10, and all possible combinations of proportions in those increments within the parameter space were considered. Figure 2 is a ternary plot of the stock mixtures considered in the simulation, with each intersection of the axes defining a single stock mixture.

Mixture samples of size 100 were constructed. This sample size was judged to be large enough to yield reliable results, and samples of approximately this size are routinely obtained from fishery harvests in the stock identification program. For each stock mixture, as displayed in Figure 2, the stock mixture proportions were multiplied by the sample size of 100 to determine the number of fish to include in the mixture from each stock group. Mixture samples were constructed by randomly selecting the appropriate number of fish from the stock standard data. All sampling was done with replacement.

Stock Composition Estimators

Each artificially constructed mixture sample was treated as a sample of unknown origin, and the stock composition of the sample was estimated using both the classification and maximum likelihood estimators. The classification estimator is based upon linear discriminant classification functions (Hand, 1997), with an adjusted Cook and Lord correction (Cook and Lord, 1978). The salient features of this estimator are summarized above, and the technique is sufficiently common that further description here is unnecessary. However, because the maximum likelihood mixture model may be less well known, we present it here in detail. Before describing the maximum likelihood mixture model, it is necessary to introduce some notation. Let

S = the number of stock groups in the model,

n = the number of fish in the mixture sample,

x_i = data vector of the ith fish in the mixture sample,

μ_i = the stock-standard mean vector of stock group i,

Σ_i = the stock-standard dispersion matrix of stock group i,

$f(x \mid i)$ = a multivariate normal pdf with mean μ_i and dispersion Σ_i evaluated at the data vector x, and

π_i = the proportion of a mixture composed of fish from stock group i.

With that notation, the likelihood function, L, can be expressed as

$$L = \prod_{i=1}^{n} \sum_{j=1}^{S} \pi_j f(x_i \mid j). \tag{1}$$

The maximum likelihood estimate of the vector $\pi = (\pi_i)$ is the value that maximizes L.

The Simulation

The simulation was performed using a computer program written in the FORTRAN programming language and compiled using the professional version of the Digital Equipment Corporation[1] Visual FORTRAN compiler. Since the maximum likelihood estimator corresponding to the likelihood function in equation (1) can not be expressed in closed form, the likelihood function was numerically maximized using the DLCONG subroutine of the Visual Numeric[1] IMSL library bundled with the DEC compiler.

The simulation study consisted of randomly constructing 500 mixture samples at each of the 66 stock mixtures considered (Figure 2) for each of the four data sets. For each of the 500 mixture samples, the estimated stock mixture proportions obtained with the classification estimator and the maximum likelihood estimator were written to an output file. Three summary statistics were computed from the 500 estimates of each stock group proportion; the average absolute bias, the standard deviation, and the root mean squared error (RMSE). The average absolute bias was computed as the average of the absolute value of the difference between the estimated and true stock proportion.

[1] Use of product names does not constitute endorsement by the Alaska Department of Fish and Game.

The standard deviation was computed as the standard deviation of the estimates. The RMSE is a summary statistic that combines the bias and standard deviation statistics; it is computed as the square root of the sum of the average absolute bias squared and the standard deviation squared.

SIMULATION RESULTS

The average absolute bias summary statistics are presented in Tables 2-5, the standard deviation summary statistics are presented in Tables 6-9, and the RMSE summary statistics are presented in Tables 10-13. Each set of four tables presents the summary statistics for the 1992 age 1.3, 1992 age 1.4, 1993 age 1.3, and 1993 age 1.4 simulations, respectively. Ternary plots comparing the summary statistics across estimators and stock groups are presented in Figures 3-14, corresponding to the data in Tables 2-13, respectively. In each of these figures, the summary statistic plotted corresponds to estimates of the mixture proportion for the stock group printed at the top of each column of ternary plots. In the ternary plots, the area of a circle is proportional to the magnitude of the summary statistic being plotted. Since large values of each of the summary statistics indicate poor performance, larger circles indicate poor performance throughout these figures.

The data in Tables 2-13, and the corresponding ternary plots in Figures 3-14, summarize a large quantity of data, comparing the performance of the estimators throughout the entire range of possible stock mixtures. While a detailed examination of these tables and figures is interesting and informative, a more concise summary is also of interest. The percentage of the simulations in which the measures of performance of the maximum likelihood estimator were superior to those of the classification estimator for each stock group in each data set are presented in Table 14.

CONCLUSIONS

A study of the simulation results reveals that the two estimators tend to perform similarly with given data sets and stock mixtures. When one of the estimators performs better or worse at a given stock mixture than at another, the other estimator tends perform similarly. The relatively few exceptions to this tendency generally involve the absolute bias summary statistic and occur near the boundary of the parameter space, i.e., when one of the stock groups is absent, or nearly absent. In these cases, the summary statistic of one of the estimators is substantially larger than the statistic of the other estimator. An example is provided by a comparison of the ternary plots for the

Lower stock group in Figure 4. The classification estimator performed poorly when the Upper stock group comprises, say, 30% or less of the mixture and the Lower stock group comprises from 10% to 40% of the mixture, whereas the maximum likelihood estimator performed well at those stock mixtures.

The selection of an estimator could conceivably depend on the stock mixture. If one estimator was consistently superior in one part of the parameter space, but the other estimator was superior elsewhere, it would be necessary to presuppose the true stock mixture to select the preferred estimator. Fortunately, no trend of one estimator being consistently superior at given stock mixtures across data sets is apparent in these results. This is advantageous in that an estimator can be selected based upon the summary results as presented in Table 14.

The maximum likelihood estimator was less biased than the classification estimator in 8 of the 12 combinations of data set and stock group (Table 14). However, the bias of both estimators was relatively small for most stock mixtures in all data sets (Tables 2-13), which implies that estimates from either estimator will be accurate on average. However, a substantial difference in the performance of the estimators is apparent when comparing the standard deviation and RMSE results, which are quite similar because of the relatively small average bias enjoyed by both estimators. The maximum likelihood estimator tends to be less variable than the classification estimator in a large proportion of the cases (Table 14). As a result, estimates produced by the maximum likelihood estimator can be expected to deviate less from the actual stock mixture than estimates produced by the classification estimator. The reduced variability of the maximum likelihood estimator is almost certainly due to the fact that the estimator fully utilizes all information contained in the sample.

In summary, the statistical properties of the maximum likelihood estimator appear to be superior to those of the classification estimator from both theoretical and practical perspectives for Yukon River chinook applications. It is likely that the performance of the estimator with the four data sets tested is indicative of the performance that can be expected with other similar data sets. The likelihood function (Equation 1) cleanly models the composition of a mixed stock fishery, with the parameters of the likelihood function being the proportions of direct interest. Perhaps more importantly, the information contained in both stock standard and mixed fishery samples is fully utilized. The simulated performance of the maximum likelihood estimator with observed Yukon River chinook salmon data also appears to be superior to that of the estimator currently employed. Overall, these results appear sufficient to recommend the adoption of the maximum likelihood estimator.

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Table 1. Stock standard sample sizes and the number with complete records for data sets used in the simulation.

Year	Age	Stock Group	Sample Size	Number Complete
		Lower	48	48
1992	1.3	Middle	67	65
		Upper	127	127
		Lower	62	62
1992	1.4	Middle	96	92
		Upper	118	118
		Lower	152	148
1993	1.3	Middle	132	132
		Upper	178	177
		Lower	185	183
1993	1.4	Middle	126	125
		Upper	113	113

Table 2. Average absolute bias observed over 500 simulations at each stock mixture. Mixture samples of 100 fish were constructed by sampling with replacement from stock standard data on fish of known stock origin; age 1.3 Yukon River chinook salmon in 1992.

Stock Mixture			Classification Estimator			Maximum Likelihood Estimator		
Lower	Middle	Upper	Lower	Middle	Upper	Lower	Middle	Upper
100.0%	0.0%	0.0%	0.0330	0.0178	0.0152	0.0008	0.0004	0.0003
90.0%	10.0%	0.0%	0.0227	0.0071	0.0156	0.0187	0.0259	0.0072
90.0%	0.0%	10.0%	0.0190	0.0171	0.0019	0.0158	0.0047	0.0204
80.0%	20.0%	0.0%	0.0262	0.0130	0.0131	0.0208	0.0304	0.0096
80.0%	10.0%	10.0%	0.0016	0.0076	0.0092	0.0199	0.0053	0.0145
80.0%	0.0%	20.0%	0.0162	0.0202	0.0040	0.0122	0.0098	0.0219
70.0%	30.0%	0.0%	0.0328	0.0232	0.0097	0.0207	0.0335	0.0128
70.0%	20.0%	10.0%	0.0009	0.0160	0.0151	0.0183	0.0065	0.0118
70.0%	10.0%	20.0%	0.0054	0.0018	0.0072	0.0148	0.0052	0.0200
70.0%	0.0%	30.0%	0.0186	0.0152	0.0034	0.0072	0.0124	0.0195
60.0%	40.0%	0.0%	0.0323	0.0209	0.0115	0.0180	0.0338	0.0158
60.0%	30.0%	10.0%	0.0017	0.0272	0.0255	0.0131	0.0091	0.0040
60.0%	20.0%	20.0%	0.0068	0.0048	0.0116	0.0119	0.0054	0.0173
60.0%	10.0%	30.0%	0.0088	0.0046	0.0042	0.0080	0.0129	0.0209
60.0%	0.0%	40.0%	0.0111	0.0212	0.0101	0.0049	0.0192	0.0240
50.0%	50.0%	0.0%	0.0386	0.0282	0.0104	0.0131	0.0321	0.0189
50.0%	40.0%	10.0%	0.0050	0.0353	0.0303	0.0111	0.0127	0.0016
50.0%	30.0%	20.0%	0.0065	0.0187	0.0252	0.0101	0.0043	0.0144
50.0%	20.0%	30.0%	0.0106	0.0007	0.0099	0.0060	0.0172	0.0232
50.0%	10.0%	40.0%	0.0136	0.0148	0.0012	0.0036	0.0189	0.0225
50.0%	0.0%	50.0%	0.0017	0.0164	0.0146	0.0029	0.0215	0.0244
40.0%	60.0%	0.0%	0.0318	0.0226	0.0092	0.0145	0.0385	0.0240
40.0%	50.0%	10.0%	0.0054	0.0497	0.0443	0.0079	0.0111	0.0032
40.0%	40.0%	20.0%	0.0039	0.0322	0.0361	0.0033	0.0003	0.0037
40.0%	30.0%	30.0%	0.0076	0.0083	0.0159	0.0007	0.0148	0.0141
40.0%	20.0%	40.0%	0.0125	0.0013	0.0112	0.0023	0.0282	0.0258
40.0%	10.0%	50.0%	0.0178	0.0133	0.0045	0.0000	0.0271	0.0271
40.0%	0.0%	60.0%	0.0058	0.0187	0.0244	0.0002	0.0251	0.0250
30.0%	70.0%	0.0%	0.0322	0.0217	0.0105	0.0081	0.0383	0.0302
30.0%	60.0%	10.0%	0.0086	0.0513	0.0428	0.0023	0.0185	0.0162
30.0%	50.0%	20.0%	0.0035	0.0398	0.0433	0.0007	0.0011	0.0004
30.0%	40.0%	30.0%	0.0104	0.0208	0.0313	0.0003	0.0127	0.0129
30.0%	30.0%	40.0%	0.0115	0.0060	0.0175	0.0035	0.0297	0.0262
30.0%	20.0%	50.0%	0.0194	0.0092	0.0102	0.0036	0.0315	0.0279
30.0%	10.0%	60.0%	0.0230	0.0091	0.0139	0.0018	0.0363	0.0345
30.0%	0.0%	70.0%	0.0134	0.0162	0.0297	0.0012	0.0284	0.0272
20.0%	80.0%	0.0%	0.0299	0.0222	0.0077	0.0027	0.0400	0.0373
20.0%	70.0%	10.0%	0.0098	0.0609	0.0510	0.0004	0.0242	0.0246
20.0%	60.0%	20.0%	0.0003	0.0532	0.0529	0.0045	0.0059	0.0104
20.0%	50.0%	30.0%	0.0068	0.0292	0.0359	0.0047	0.0101	0.0055
20.0%	40.0%	40.0%	0.0177	0.0115	0.0291	0.0008	0.0194	0.0186
20.0%	30.0%	50.0%	0.0203	0.0016	0.0187	0.0033	0.0347	0.0314
20.0%	20.0%	60.0%	0.0261	0.0145	0.0116	0.0007	0.0453	0.0446
20.0%	10.0%	70.0%	0.0314	0.0244	0.0070	0.0015	0.0411	0.0427
20.0%	0.0%	80.0%	0.0248	0.0174	0.0423	0.0014	0.0299	0.0313
10.0%	90.0%	0.0%	0.0253	0.0165	0.0088	0.0026	0.0504	0.0529
10.0%	80.0%	10.0%	0.0102	0.0650	0.0548	0.0045	0.0312	0.0357
10.0%	70.0%	20.0%	0.0033	0.0703	0.0670	0.0067	0.0107	0.0174
10.0%	60.0%	30.0%	0.0073	0.0528	0.0601	0.0028	0.0083	0.0055
10.0%	50.0%	40.0%	0.0111	0.0205	0.0317	0.0020	0.0174	0.0155
10.0%	40.0%	50.0%	0.0215	0.0132	0.0347	0.0006	0.0332	0.0326
10.0%	30.0%	60.0%	0.0293	0.0017	0.0310	0.0006	0.0437	0.0443
10.0%	20.0%	70.0%	0.0354	0.0246	0.0108	0.0016	0.0424	0.0440
10.0%	10.0%	80.0%	0.0420	0.0249	0.0171	0.0047	0.0456	0.0503
10.0%	0.0%	90.0%	0.0402	0.0172	0.0574	0.0065	0.0358	0.0423
0.0%	100.0%	0.0%	0.0032	0.0102	0.0069	0.0000	0.0643	0.0643
0.0%	90.0%	10.0%	0.0043	0.0527	0.0570	0.0019	0.0414	0.0396
0.0%	80.0%	20.0%	0.0086	0.0723	0.0809	0.0035	0.0244	0.0209
0.0%	70.0%	30.0%	0.0126	0.0550	0.0676	0.0045	0.0071	0.0026
0.0%	60.0%	40.0%	0.0187	0.0356	0.0543	0.0053	0.0086	0.0139
0.0%	50.0%	50.0%	0.0230	0.0158	0.0388	0.0054	0.0170	0.0224
0.0%	40.0%	60.0%	0.0298	0.0053	0.0351	0.0070	0.0385	0.0455
0.0%	30.0%	70.0%	0.0379	0.0149	0.0231	0.0069	0.0402	0.0470
0.0%	20.0%	80.0%	0.0452	0.0297	0.0155	0.0081	0.0385	0.0465
0.0%	10.0%	90.0%	0.0516	0.0263	0.0253	0.0078	0.0436	0.0514
0.0%	0.0%	100.0%	0.0547	0.0179	0.0726	0.0069	0.0295	0.0364

Table 3. Average absolute bias observed over 500 simulations at each stock mixture. Mixture samples of 100 fish were constructed by sampling with replacement from stock standard data on fish of known stock origin; age 1.4 Yukon River chinook salmon in 1992.

Stock Mixture			Classification Estimator			Maximum Likelihood Estimator		
Lower	Middle	Upper	Lower	Middle	Upper	Lower	Middle	Upper
100.0%	0.0%	0.0%	0.0428	0.0339	0.0089	0.0149	0.0149	0.0000
90.0%	10.0%	0.0%	0.0182	0.0067	0.0116	0.0106	0.0095	0.0011
90.0%	0.0%	10.0%	0.0284	0.0287	0.0003	0.0176	0.0245	0.0069
80.0%	20.0%	0.0%	0.0215	0.0081	0.0135	0.0103	0.0087	0.0016
80.0%	10.0%	10.0%	0.0089	0.0067	0.0021	0.0174	0.0208	0.0035
80.0%	0.0%	20.0%	0.0261	0.0281	0.0020	0.0200	0.0227	0.0027
70.0%	30.0%	0.0%	0.0245	0.0102	0.0143	0.0040	0.0019	0.0021
70.0%	20.0%	10.0%	0.0074	0.0045	0.0029	0.0122	0.0133	0.0011
70.0%	10.0%	20.0%	0.0080	0.0042	0.0038	0.0153	0.0163	0.0010
70.0%	0.0%	30.0%	0.0293	0.0328	0.0035	0.0230	0.0182	0.0047
60.0%	40.0%	0.0%	0.0293	0.0114	0.0179	0.0013	0.0011	0.0024
60.0%	30.0%	10.0%	0.0140	0.0113	0.0026	0.0061	0.0052	0.0009
60.0%	20.0%	20.0%	0.0071	0.0017	0.0088	0.0074	0.0042	0.0032
60.0%	10.0%	30.0%	0.0064	0.0010	0.0074	0.0106	0.0044	0.0062
60.0%	0.0%	40.0%	0.0224	0.0275	0.0050	0.0219	0.0120	0.0099
50.0%	50.0%	0.0%	0.0325	0.0129	0.0195	0.0004	0.0031	0.0027
50.0%	40.0%	10.0%	0.0197	0.0149	0.0048	0.0012	0.0007	0.0019
50.0%	30.0%	20.0%	0.0081	0.0019	0.0062	0.0019	0.0002	0.0021
50.0%	20.0%	30.0%	0.0035	0.0074	0.0110	0.0073	0.0008	0.0081
50.0%	10.0%	40.0%	0.0081	0.0011	0.0091	0.0149	0.0050	0.0099
50.0%	0.0%	50.0%	0.0177	0.0248	0.0072	0.0218	0.0090	0.0128
40.0%	60.0%	0.0%	0.0434	0.0224	0.0209	0.0027	0.0000	0.0027
40.0%	50.0%	10.0%	0.0275	0.0252	0.0024	0.0011	0.0053	0.0042
40.0%	50.0%	10.0%	0.0275	0.0252	0.0024	0.0011	0.0053	0.0042
40.0%	30.0%	30.0%	0.0188	0.0085	0.0103	0.0082	0.0007	0.0075
40.0%	20.0%	40.0%	0.0065	0.0085	0.0149	0.0075	0.0017	0.0092
40.0%	10.0%	50.0%	0.0095	0.0006	0.0100	0.0142	0.0008	0.0135
40.0%	0.0%	60.0%	0.0122	0.0213	0.0091	0.0188	0.0060	0.0128
30.0%	70.0%	0.0%	0.0488	0.0275	0.0213	0.0011	0.0035	0.0024
30.0%	60.0%	10.0%	0.0406	0.0396	0.0010	0.0037	0.0002	0.0039
30.0%	50.0%	20.0%	0.0295	0.0248	0.0047	0.0012	0.0046	0.0059
30.0%	40.0%	30.0%	0.0212	0.0102	0.0110	0.0039	0.0044	0.0083
30.0%	30.0%	40.0%	0.0111	0.0029	0.0140	0.0045	0.0049	0.0094
30.0%	20.0%	50.0%	0.0106	0.0037	0.0144	0.0104	0.0002	0.0102
30.0%	10.0%	60.0%	0.0014	0.0154	0.0168	0.0093	0.0066	0.0158
30.0%	0.0%	70.0%	0.0081	0.0213	0.0132	0.0159	0.0041	0.0118
20.0%	80.0%	0.0%	0.0569	0.0356	0.0213	0.0048	0.0068	0.0020
20.0%	70.0%	10.0%	0.0492	0.0494	0.0001	0.0005	0.0044	0.0049
20.0%	60.0%	20.0%	0.0373	0.0328	0.0045	0.0016	0.0071	0.0054
20.0%	50.0%	30.0%	0.0301	0.0147	0.0154	0.0004	0.0105	0.0109
20.0%	40.0%	40.0%	0.0236	0.0080	0.0156	0.0017	0.0075	0.0092
20.0%	30.0%	50.0%	0.0172	0.0022	0.0150	0.0068	0.0008	0.0077
20.0%	20.0%	60.0%	0.0069	0.0180	0.0249	0.0051	0.0086	0.0137
20.0%	10.0%	70.0%	0.0030	0.0148	0.0179	0.0099	0.0064	0.0163
20.0%	0.0%	80.0%	0.0023	0.0192	0.0168	0.0146	0.0043	0.0103
10.0%	90.0%	0.0%	0.0524	0.0299	0.0224	0.0075	0.0093	0.0018
10.0%	80.0%	10.0%	0.0494	0.0471	0.0023	0.0047	0.0094	0.0048
10.0%	70.0%	20.0%	0.0434	0.0364	0.0069	0.0031	0.0121	0.0090
10.0%	60.0%	30.0%	0.0348	0.0204	0.0144	0.0023	0.0124	0.0101
10.0%	50.0%	40.0%	0.0326	0.0216	0.0109	0.0009	0.0038	0.0047
10.0%	40.0%	50.0%	0.0210	0.0023	0.0187	0.0016	0.0073	0.0089
10.0%	30.0%	60.0%	0.0126	0.0084	0.0211	0.0023	0.0068	0.0090
10.0%	20.0%	70.0%	0.0094	0.0098	0.0192	0.0072	0.0008	0.0081
10.0%	10.0%	80.0%	0.0005	0.0188	0.0193	0.0072	0.0072	0.0144
10.0%	0.0%	90.0%	0.0010	0.0211	0.0221	0.0110	0.0039	0.0071
0.0%	100.0%	0.0%	0.0032	0.0245	0.0213	0.0309	0.0326	0.0017
0.0%	90.0%	10.0%	0.0034	0.0013	0.0021	0.0279	0.0383	0.0104
0.0%	80.0%	20.0%	0.0048	0.0049	0.0097	0.0232	0.0316	0.0083
0.0%	70.0%	30.0%	0.0056	0.0057	0.0000	0.0209	0.0324	0.0115
0.0%	60.0%	40.0%	0.0049	0.0068	0.0010	0.0177	0.0302	0.0125
0.0%	50.0%	50.0%	0.0068	0.0117	0.0049	0.0151	0.0268	0.0117
0.0%	40.0%	60.0%	0.0073	0.0111	0.0039	0.0107	0.0200	0.0093
0.0%	30.0%	70.0%	0.0096	0.0190	0.0094	0.0087	0.0210	0.0123
0.0%	20.0%	80.0%	0.0110	0.0142	0.0032	0.0067	0.0145	0.0078
0.0%	10.0%	90.0%	0.0125	0.0186	0.0061	0.0037	0.0188	0.0151
0.0%	0.0%	100.0%	0.0129	0.0191	0.0320	0.0000	0.0020	0.0020

Table 4. Average absolute bias observed over 500 simulations at each stock mixture. Mixture samples of 100 fish were constructed by sampling with replacement from stock standard data on fish of known stock origin; age 1.3 Yukon River chinook salmon in 1993.

Stock Mixture			Classification Estimator			Maximum Likelihood Estimator		
Lower	Middle	Upper	Lower	Middle	Upper	Lower	Middle	Upper
100.0%	0.0%	0.0%	0.0367	0.0165	0.0202	0.0174	0.0000	0.0174
90.0%	10.0%	0.0%	0.0224	0.0041	0.0183	0.0083	0.0160	0.0243
90.0%	0.0%	10.0%	0.0094	0.0225	0.0131	0.0136	0.0042	0.0094
80.0%	20.0%	0.0%	0.0151	0.0022	0.0174	0.0063	0.0191	0.0253
80.0%	10.0%	10.0%	0.0001	0.0124	0.0123	0.0098	0.0148	0.0246
80.0%	0.0%	20.0%	0.0150	0.0271	0.0121	0.0113	0.0068	0.0044
70.0%	30.0%	0.0%	0.0154	0.0037	0.0191	0.0069	0.0183	0.0252
70.0%	20.0%	10.0%	0.0018	0.0127	0.0145	0.0068	0.0151	0.0218
70.0%	10.0%	20.0%	0.0011	0.0156	0.0167	0.0041	0.0127	0.0167
70.0%	0.0%	30.0%	0.0148	0.0356	0.0209	0.0058	0.0107	0.0049
60.0%	40.0%	0.0%	0.0098	0.0043	0.0142	0.0033	0.0197	0.0229
60.0%	30.0%	10.0%	0.0069	0.0096	0.0164	0.0048	0.0126	0.0174
60.0%	20.0%	20.0%	0.0018	0.0227	0.0209	0.0046	0.0073	0.0119
60.0%	10.0%	30.0%	0.0004	0.0260	0.0256	0.0009	0.0067	0.0076
60.0%	0.0%	40.0%	0.0150	0.0430	0.0280	0.0040	0.0120	0.0080
50.0%	50.0%	0.0%	0.0087	0.0103	0.0190	0.0073	0.0222	0.0295
50.0%	40.0%	10.0%	0.0073	0.0095	0.0168	0.0041	0.0129	0.0170
50.0%	30.0%	20.0%	0.0045	0.0217	0.0262	0.0022	0.0062	0.0084
50.0%	20.0%	30.0%	0.0011	0.0252	0.0241	0.0040	0.0060	0.0099
50.0%	10.0%	40.0%	0.0048	0.0340	0.0292	0.0018	0.0031	0.0013
50.0%	0.0%	50.0%	0.0124	0.0462	0.0337	0.0001	0.0165	0.0166
40.0%	60.0%	0.0%	0.0018	0.0146	0.0164	0.0039	0.0247	0.0286
40.0%	50.0%	10.0%	0.0090	0.0122	0.0213	0.0052	0.0158	0.0210
40.0%	40.0%	20.0%	0.0125	0.0145	0.0270	0.0018	0.0071	0.0053
40.0%	30.0%	30.0%	0.0013	0.0262	0.0275	0.0020	0.0013	0.0034
40.0%	20.0%	40.0%	0.0002	0.0305	0.0303	0.0005	0.0002	0.0003
40.0%	10.0%	50.0%	0.0019	0.0372	0.0353	0.0025	0.0021	0.0046
40.0%	0.0%	60.0%	0.0036	0.0562	0.0527	0.0021	0.0202	0.0223
30.0%	70.0%	0.0%	0.0023	0.0187	0.0164	0.0027	0.0316	0.0343
30.0%	60.0%	10.0%	0.0149	0.0068	0.0217	0.0007	0.0165	0.0172
30.0%	50.0%	20.0%	0.0076	0.0148	0.0224	0.0029	0.0115	0.0143
30.0%	40.0%	30.0%	0.0104	0.0218	0.0321	0.0014	0.0024	0.0009
30.0%	30.0%	40.0%	0.0051	0.0264	0.0315	0.0014	0.0018	0.0004
30.0%	20.0%	50.0%	0.0033	0.0326	0.0359	0.0002	0.0042	0.0040
30.0%	10.0%	60.0%	0.0011	0.0397	0.0386	0.0002	0.0050	0.0049
30.0%	0.0%	70.0%	0.0028	0.0621	0.0593	0.0007	0.0253	0.0245
20.0%	80.0%	0.0%	0.0061	0.0221	0.0160	0.0037	0.0312	0.0349
20.0%	70.0%	10.0%	0.0139	0.0077	0.0216	0.0009	0.0162	0.0171
20.0%	60.0%	20.0%	0.0147	0.0140	0.0287	0.0001	0.0091	0.0091
20.0%	50.0%	30.0%	0.0121	0.0210	0.0331	0.0018	0.0014	0.0031
20.0%	40.0%	40.0%	0.0112	0.0306	0.0418	0.0004	0.0033	0.0029
20.0%	30.0%	50.0%	0.0133	0.0343	0.0476	0.0018	0.0062	0.0080
20.0%	20.0%	60.0%	0.0054	0.0401	0.0455	0.0014	0.0078	0.0064
20.0%	10.0%	70.0%	0.0049	0.0538	0.0587	0.0016	0.0150	0.0134
20.0%	0.0%	80.0%	0.0010	0.0674	0.0664	0.0047	0.0259	0.0212
10.0%	90.0%	0.0%	0.0156	0.0310	0.0154	0.0004	0.0365	0.0369
10.0%	80.0%	10.0%	0.0177	0.0076	0.0253	0.0010	0.0173	0.0163
10.0%	70.0%	20.0%	0.0181	0.0168	0.0349	0.0018	0.0093	0.0075
10.0%	60.0%	30.0%	0.0160	0.0146	0.0307	0.0008	0.0059	0.0068
10.0%	50.0%	40.0%	0.0199	0.0207	0.0407	0.0020	0.0009	0.0012
10.0%	40.0%	50.0%	0.0144	0.0295	0.0440	0.0030	0.0076	0.0046
10.0%	30.0%	60.0%	0.0110	0.0318	0.0428	0.0003	0.0085	0.0081
10.0%	20.0%	70.0%	0.0121	0.0481	0.0603	0.0030	0.0165	0.0135
10.0%	10.0%	80.0%	0.0154	0.0581	0.0734	0.0023	0.0169	0.0145
10.0%	0.0%	90.0%	0.0127	0.0727	0.0853	0.0045	0.0295	0.0250
0.0%	100.0%	0.0%	0.0249	0.0381	0.0133	0.0016	0.0307	0.0290
0.0%	90.0%	10.0%	0.0291	0.0013	0.0304	0.0033	0.0197	0.0165
0.0%	80.0%	20.0%	0.0275	0.0070	0.0345	0.0033	0.0105	0.0072
0.0%	70.0%	30.0%	0.0271	0.0069	0.0340	0.0040	0.0045	0.0005
0.0%	60.0%	40.0%	0.0308	0.0074	0.0383	0.0041	0.0041	0.0001
0.0%	50.0%	50.0%	0.0320	0.0231	0.0551	0.0042	0.0078	0.0120
0.0%	40.0%	60.0%	0.0329	0.0293	0.0622	0.0050	0.0120	0.0170
0.0%	30.0%	70.0%	0.0317	0.0400	0.0717	0.0048	0.0135	0.0182
0.0%	20.0%	80.0%	0.0328	0.0492	0.0820	0.0047	0.0162	0.0208
0.0%	10.0%	90.0%	0.0323	0.0615	0.0938	0.0032	0.0180	0.0212
0.0%	0.0%	100.0%	0.0334	0.0789	0.1123	0.0029	0.0316	0.0345

Table 5. Average absolute bias observed over 500 simulations at each stock mixture. Mixture samples of 100 fish were constructed by sampling with replacement from stock standard data on fish of known stock origin; age 1.4 Yukon River chinook salmon in 1993.

Stock Mixture			Classification Estimator			Maximum Likelihood Estimator		
Lower	Middle	Upper	Lower	Middle	Upper	Lower	Middle	Upper
100.0%	0.0%	0.0%	0.0334	0.0175	0.0159	0.0156	0.0142	0.0013
90.0%	10.0%	0.0%	0.0194	0.0009	0.0203	0.0235	0.0097	0.0138
90.0%	0.0%	10.0%	0.0191	0.0205	0.0014	0.0251	0.0319	0.0068
80.0%	20.0%	0.0%	0.0207	0.0028	0.0235	0.0243	0.0055	0.0188
80.0%	10.0%	10.0%	0.0011	0.0043	0.0054	0.0233	0.0197	0.0036
80.0%	0.0%	20.0%	0.0179	0.0197	0.0018	0.0228	0.0333	0.0105
70.0%	30.0%	0.0%	0.0192	0.0068	0.0259	0.0208	0.0013	0.0220
70.0%	20.0%	10.0%	0.0002	0.0054	0.0056	0.0198	0.0102	0.0096
70.0%	10.0%	20.0%	0.0053	0.0073	0.0126	0.0213	0.0220	0.0007
70.0%	0.0%	30.0%	0.0170	0.0208	0.0038	0.0226	0.0331	0.0105
60.0%	40.0%	0.0%	0.0213	0.0042	0.0255	0.0172	0.0064	0.0236
60.0%	30.0%	10.0%	0.0029	0.0014	0.0043	0.0122	0.0060	0.0061
60.0%	20.0%	20.0%	0.0001	0.0010	0.0011	0.0160	0.0171	0.0011
60.0%	10.0%	30.0%	0.0057	0.0036	0.0092	0.0190	0.0219	0.0029
60.0%	0.0%	40.0%	0.0214	0.0221	0.0007	0.0227	0.0324	0.0097
50.0%	50.0%	0.0%	0.0202	0.0091	0.0293	0.0128	0.0140	0.0268
50.0%	40.0%	10.0%	0.0067	0.0011	0.0055	0.0122	0.0002	0.0120
50.0%	30.0%	20.0%	0.0027	0.0060	0.0087	0.0110	0.0070	0.0040
50.0%	20.0%	30.0%	0.0042	0.0073	0.0115	0.0143	0.0166	0.0023
50.0%	10.0%	40.0%	0.0029	0.0013	0.0042	0.0152	0.0253	0.0101
50.0%	0.0%	50.0%	0.0143	0.0224	0.0082	0.0172	0.0324	0.0152
40.0%	60.0%	0.0%	0.0204	0.0088	0.0293	0.0063	0.0191	0.0254
40.0%	50.0%	10.0%	0.0107	0.0047	0.0060	0.0076	0.0057	0.0133
40.0%	40.0%	20.0%	0.0086	0.0034	0.0120	0.0085	0.0017	0.0102
40.0%	30.0%	30.0%	0.0011	0.0067	0.0077	0.0072	0.0055	0.0017
40.0%	20.0%	40.0%	0.0030	0.0074	0.0104	0.0126	0.0171	0.0044
40.0%	10.0%	50.0%	0.0012	0.0030	0.0018	0.0125	0.0247	0.0122
40.0%	0.0%	60.0%	0.0099	0.0221	0.0122	0.0193	0.0297	0.0104
30.0%	70.0%	0.0%	0.0192	0.0105	0.0296	0.0004	0.0280	0.0283
30.0%	60.0%	10.0%	0.0124	0.0070	0.0053	0.0034	0.0108	0.0142
30.0%	50.0%	20.0%	0.0059	0.0021	0.0079	0.0023	0.0076	0.0099
30.0%	40.0%	30.0%	0.0026	0.0054	0.0080	0.0030	0.0026	0.0056
30.0%	30.0%	40.0%	0.0008	0.0053	0.0061	0.0082	0.0130	0.0048
30.0%	20.0%	50.0%	0.0005	0.0144	0.0149	0.0087	0.0107	0.0020
30.0%	10.0%	60.0%	0.0029	0.0077	0.0047	0.0110	0.0165	0.0056
30.0%	0.0%	70.0%	0.0025	0.0230	0.0205	0.0145	0.0266	0.0121
20.0%	80.0%	0.0%	0.0221	0.0094	0.0315	0.0011	0.0290	0.0279
20.0%	70.0%	10.0%	0.0115	0.0024	0.0091	0.0044	0.0214	0.0170
20.0%	60.0%	20.0%	0.0080	0.0027	0.0053	0.0005	0.0130	0.0125
20.0%	50.0%	30.0%	0.0068	0.0025	0.0094	0.0031	0.0034	0.0065
20.0%	40.0%	40.0%	0.0036	0.0046	0.0082	0.0051	0.0018	0.0033
20.0%	30.0%	50.0%	0.0018	0.0090	0.0109	0.0079	0.0085	0.0007
20.0%	20.0%	60.0%	0.0008	0.0112	0.0103	0.0109	0.0136	0.0026
20.0%	10.0%	70.0%	0.0024	0.0034	0.0010	0.0126	0.0165	0.0039
20.0%	0.0%	80.0%	0.0040	0.0211	0.0250	0.0135	0.0206	0.0071
10.0%	90.0%	0.0%	0.0203	0.0097	0.0300	0.0082	0.0364	0.0282
10.0%	80.0%	10.0%	0.0135	0.0023	0.0112	0.0080	0.0318	0.0237
10.0%	70.0%	20.0%	0.0142	0.0038	0.0104	0.0005	0.0173	0.0168
10.0%	60.0%	30.0%	0.0083	0.0039	0.0122	0.0006	0.0128	0.0134
10.0%	50.0%	40.0%	0.0047	0.0063	0.0111	0.0030	0.0079	0.0109
10.0%	40.0%	50.0%	0.0027	0.0084	0.0111	0.0061	0.0050	0.0011
10.0%	30.0%	60.0%	0.0016	0.0153	0.0137	0.0069	0.0066	0.0003
10.0%	20.0%	70.0%	0.0030	0.0086	0.0056	0.0106	0.0142	0.0036
10.0%	10.0%	80.0%	0.0064	0.0136	0.0072	0.0134	0.0123	0.0011
10.0%	0.0%	90.0%	0.0038	0.0235	0.0272	0.0159	0.0218	0.0060
0.0%	100.0%	0.0%	0.0046	0.0391	0.0345	0.0128	0.0509	0.0380
0.0%	90.0%	10.0%	0.0057	0.0196	0.0139	0.0096	0.0421	0.0325
0.0%	80.0%	20.0%	0.0082	0.0088	0.0006	0.0090	0.0280	0.0190
0.0%	70.0%	30.0%	0.0081	0.0172	0.0091	0.0069	0.0254	0.0185
0.0%	60.0%	40.0%	0.0097	0.0161	0.0064	0.0057	0.0145	0.0088
0.0%	50.0%	50.0%	0.0113	0.0199	0.0085	0.0049	0.0114	0.0065
0.0%	40.0%	60.0%	0.0137	0.0185	0.0048	0.0040	0.0066	0.0026
0.0%	30.0%	70.0%	0.0142	0.0131	0.0012	0.0032	0.0033	0.0065
0.0%	20.0%	80.0%	0.0174	0.0167	0.0007	0.0022	0.0070	0.0091
0.0%	10.0%	90.0%	0.0206	0.0052	0.0154	0.0012	0.0118	0.0130
0.0%	0.0%	100.0%	0.0215	0.0227	0.0442	0.0000	0.0141	0.0141

Table 6. Standard deviation observed over 500 simulations at each stock mixture. Mixture samples of 100 fish were constructed by sampling with replacement from stock standard data on fish of known stock origin; age 1.3 Yukon River chinook salmon in 1992.

Stock Mixture			Classification Estimator			Maximum Likelihood Estimator		
Lower	Middle	Upper	Lower	Middle	Upper	Lower	Middle	Upper
100.0%	0.0%	0.0%	0.0299	0.0275	0.0241	0.0029	0.0022	0.0020
90.0%	10.0%	0.0%	0.0406	0.0506	0.0272	0.0150	0.0182	0.0124
90.0%	0.0%	10.0%	0.0382	0.0280	0.0463	0.0154	0.0114	0.0195
80.0%	20.0%	0.0%	0.0397	0.0521	0.0262	0.0181	0.0228	0.0143
80.0%	10.0%	10.0%	0.0333	0.0564	0.0562	0.0210	0.0336	0.0347
80.0%	0.0%	20.0%	0.0389	0.0327	0.0524	0.0190	0.0181	0.0254
70.0%	30.0%	0.0%	0.0396	0.0507	0.0235	0.0220	0.0264	0.0177
70.0%	20.0%	10.0%	0.0347	0.0667	0.0618	0.0228	0.0401	0.0388
70.0%	10.0%	20.0%	0.0347	0.0646	0.0681	0.0234	0.0409	0.0434
70.0%	0.0%	30.0%	0.0383	0.0280	0.0504	0.0215	0.0202	0.0286
60.0%	40.0%	0.0%	0.0408	0.0554	0.0283	0.0238	0.0319	0.0225
60.0%	30.0%	10.0%	0.0342	0.0691	0.0621	0.0230	0.0407	0.0395
60.0%	20.0%	20.0%	0.0331	0.0742	0.0721	0.0228	0.0427	0.0452
60.0%	10.0%	30.0%	0.0341	0.0649	0.0682	0.0233	0.0430	0.0446
60.0%	0.0%	40.0%	0.0389	0.0401	0.0593	0.0236	0.0283	0.0353
50.0%	50.0%	0.0%	0.0392	0.0522	0.0278	0.0251	0.0338	0.0271
50.0%	40.0%	10.0%	0.0335	0.0751	0.0667	0.0248	0.0452	0.0435
50.0%	30.0%	20.0%	0.0319	0.0783	0.0748	0.0255	0.0475	0.0469
50.0%	20.0%	30.0%	0.0350	0.0761	0.0756	0.0249	0.0502	0.0517
50.0%	10.0%	40.0%	0.0331	0.0668	0.0705	0.0262	0.0492	0.0517
50.0%	0.0%	50.0%	0.0368	0.0336	0.0544	0.0242	0.0289	0.0360
40.0%	60.0%	0.0%	0.0350	0.0491	0.0267	0.0252	0.0356	0.0277
40.0%	50.0%	10.0%	0.0321	0.0653	0.0580	0.0252	0.0437	0.0439
40.0%	40.0%	20.0%	0.0299	0.0872	0.0857	0.0242	0.0510	0.0525
40.0%	30.0%	30.0%	0.0323	0.0845	0.0858	0.0261	0.0522	0.0531
40.0%	20.0%	40.0%	0.0344	0.0827	0.0834	0.0275	0.0545	0.0583
40.0%	10.0%	50.0%	0.0357	0.0739	0.0786	0.0281	0.0525	0.0555
40.0%	0.0%	60.0%	0.0370	0.0374	0.0584	0.0278	0.0343	0.0431
30.0%	70.0%	0.0%	0.0331	0.0493	0.0306	0.0236	0.0406	0.0340
30.0%	60.0%	10.0%	0.0310	0.0739	0.0649	0.0234	0.0482	0.0481
30.0%	50.0%	20.0%	0.0322	0.0864	0.0835	0.0256	0.0519	0.0523
30.0%	40.0%	30.0%	0.0313	0.0930	0.0905	0.0255	0.0551	0.0542
30.0%	30.0%	40.0%	0.0314	0.0930	0.0913	0.0259	0.0562	0.0578
30.0%	20.0%	50.0%	0.0330	0.0867	0.0874	0.0264	0.0562	0.0603
30.0%	10.0%	60.0%	0.0341	0.0778	0.0839	0.0270	0.0546	0.0591
30.0%	0.0%	70.0%	0.0360	0.0333	0.0549	0.0261	0.0377	0.0452
20.0%	80.0%	0.0%	0.0280	0.0421	0.0263	0.0211	0.0403	0.0380
20.0%	70.0%	10.0%	0.0303	0.0717	0.0623	0.0228	0.0516	0.0517
20.0%	60.0%	20.0%	0.0304	0.0878	0.0851	0.0226	0.0507	0.0521
20.0%	50.0%	30.0%	0.0311	0.0973	0.0971	0.0247	0.0575	0.0606
20.0%	40.0%	40.0%	0.0310	0.0899	0.0899	0.0260	0.0569	0.0594
20.0%	30.0%	50.0%	0.0311	0.0877	0.0902	0.0237	0.0549	0.0583
20.0%	20.0%	60.0%	0.0332	0.0856	0.0881	0.0265	0.0592	0.0618
20.0%	10.0%	70.0%	0.0331	0.0740	0.0810	0.0258	0.0556	0.0575
20.0%	0.0%	80.0%	0.0323	0.0380	0.0520	0.0280	0.0378	0.0432
10.0%	90.0%	0.0%	0.0267	0.0437	0.0306	0.0182	0.0442	0.0436
10.0%	80.0%	10.0%	0.0267	0.0673	0.0610	0.0187	0.0513	0.0536
10.0%	70.0%	20.0%	0.0280	0.0976	0.0933	0.0195	0.0554	0.0575
10.0%	60.0%	30.0%	0.0302	0.1052	0.1011	0.0216	0.0573	0.0590
10.0%	50.0%	40.0%	0.0296	0.0998	0.0965	0.0239	0.0577	0.0587
10.0%	40.0%	50.0%	0.0313	0.0946	0.0953	0.0229	0.0582	0.0606
10.0%	30.0%	60.0%	0.0331	0.0920	0.0952	0.0248	0.0576	0.0617
10.0%	20.0%	70.0%	0.0320	0.0921	0.0946	0.0242	0.0569	0.0578
10.0%	10.0%	80.0%	0.0309	0.0731	0.0785	0.0236	0.0546	0.0591
10.0%	0.0%	90.0%	0.0307	0.0375	0.0470	0.0240	0.0395	0.0446
0.0%	100.0%	0.0%	0.0085	0.0290	0.0274	0.0000	0.0446	0.0446
0.0%	90.0%	10.0%	0.0116	0.0634	0.0618	0.0051	0.0509	0.0515
0.0%	80.0%	20.0%	0.0154	0.0929	0.0923	0.0068	0.0548	0.0556
0.0%	70.0%	30.0%	0.0178	0.0981	0.0983	0.0077	0.0564	0.0573
0.0%	60.0%	40.0%	0.0220	0.0988	0.0980	0.0090	0.0591	0.0596
0.0%	50.0%	50.0%	0.0240	0.0995	0.0998	0.0091	0.0596	0.0603
0.0%	40.0%	60.0%	0.0270	0.0997	0.1011	0.0114	0.0580	0.0595
0.0%	30.0%	70.0%	0.0286	0.0986	0.0971	0.0112	0.0615	0.0621
0.0%	20.0%	80.0%	0.0296	0.1018	0.1015	0.0126	0.0604	0.0621
0.0%	10.0%	90.0%	0.0309	0.0749	0.0796	0.0122	0.0567	0.0572
0.0%	0.0%	100.0%	0.0315	0.0406	0.0510	0.0115	0.0388	0.0410

Table 7. Standard deviation observed over 500 simulations at each stock mixture. Mixture samples of 100 fish were constructed by sampling with replacement from stock standard data on fish of known stock origin; age 1.4 Yukon River chinook salmon in 1992.

Stock Mixture			Classification Estimator			Maximum Likelihood Estimator		
Lower	Middle	Upper	Lower	Middle	Upper	Lower	Middle	Upper
100.0%	0.0%	0.0%	0.0498	0.0528	0.0133	0.0244	0.0244	0.0000
90.0%	10.0%	0.0%	0.0663	0.0742	0.0179	0.0379	0.0387	0.0045
90.0%	0.0%	10.0%	0.0401	0.0485	0.0273	0.0282	0.0303	0.0190
80.0%	20.0%	0.0%	0.0765	0.0853	0.0198	0.0467	0.0472	0.0057
80.0%	10.0%	10.0%	0.0625	0.0847	0.0364	0.0388	0.0479	0.0246
80.0%	0.0%	20.0%	0.0361	0.0473	0.0306	0.0293	0.0331	0.0242
70.0%	30.0%	0.0%	0.0752	0.0863	0.0232	0.0476	0.0488	0.0074
70.0%	20.0%	10.0%	0.0652	0.0877	0.0412	0.0449	0.0545	0.0279
70.0%	10.0%	20.0%	0.0577	0.0804	0.0407	0.0392	0.0527	0.0308
70.0%	0.0%	30.0%	0.0405	0.0530	0.0332	0.0284	0.0304	0.0241
60.0%	40.0%	0.0%	0.0699	0.0830	0.0281	0.0457	0.0468	0.0071
60.0%	30.0%	10.0%	0.0646	0.0920	0.0462	0.0460	0.0573	0.0301
60.0%	20.0%	20.0%	0.0579	0.0843	0.0464	0.0416	0.0542	0.0334
60.0%	10.0%	30.0%	0.0540	0.0778	0.0423	0.0373	0.0525	0.0347
60.0%	0.0%	40.0%	0.0383	0.0453	0.0347	0.0285	0.0254	0.0266
50.0%	50.0%	0.0%	0.0666	0.0820	0.0310	0.0421	0.0431	0.0091
50.0%	40.0%	10.0%	0.0626	0.0948	0.0512	0.0474	0.0612	0.0330
50.0%	30.0%	20.0%	0.0607	0.0939	0.0522	0.0438	0.0593	0.0368
50.0%	20.0%	30.0%	0.0566	0.0870	0.0487	0.0394	0.0554	0.0364
50.0%	10.0%	40.0%	0.0524	0.0749	0.0438	0.0360	0.0506	0.0357
50.0%	0.0%	50.0%	0.0369	0.0464	0.0370	0.0275	0.0219	0.0280
40.0%	60.0%	0.0%	0.0679	0.0851	0.0337	0.0465	0.0480	0.0098
40.0%	50.0%	10.0%	0.0653	0.0967	0.0524	0.0459	0.0592	0.0337
40.0%	50.0%	10.0%	0.0653	0.0967	0.0524	0.0459	0.0592	0.0337
40.0%	30.0%	30.0%	0.0579	0.0919	0.0532	0.0399	0.0575	0.0393
40.0%	20.0%	40.0%	0.0544	0.0916	0.0576	0.0391	0.0580	0.0424
40.0%	10.0%	50.0%	0.0483	0.0796	0.0482	0.0331	0.0535	0.0385
40.0%	0.0%	60.0%	0.0343	0.0372	0.0327	0.0248	0.0169	0.0251
30.0%	70.0%	0.0%	0.0671	0.0843	0.0328	0.0462	0.0478	0.0088
30.0%	60.0%	10.0%	0.0606	0.0952	0.0545	0.0434	0.0575	0.0323
30.0%	50.0%	20.0%	0.0584	0.0916	0.0543	0.0403	0.0585	0.0380
30.0%	40.0%	30.0%	0.0568	0.0932	0.0569	0.0404	0.0620	0.0436
30.0%	30.0%	40.0%	0.0526	0.0879	0.0556	0.0375	0.0611	0.0417
30.0%	20.0%	50.0%	0.0476	0.0835	0.0571	0.0356	0.0551	0.0419
30.0%	10.0%	60.0%	0.0423	0.0702	0.0463	0.0316	0.0520	0.0390
30.0%	0.0%	70.0%	0.0336	0.0384	0.0322	0.0247	0.0154	0.0250
20.0%	80.0%	0.0%	0.0671	0.0850	0.0360	0.0440	0.0450	0.0075
20.0%	70.0%	10.0%	0.0660	0.1062	0.0612	0.0438	0.0612	0.0382
20.0%	60.0%	20.0%	0.0582	0.0974	0.0614	0.0399	0.0611	0.0422
20.0%	50.0%	30.0%	0.0546	0.0902	0.0580	0.0376	0.0576	0.0412
20.0%	40.0%	40.0%	0.0534	0.0893	0.0549	0.0374	0.0593	0.0405
20.0%	30.0%	50.0%	0.0480	0.0888	0.0604	0.0330	0.0584	0.0456
20.0%	20.0%	60.0%	0.0461	0.0836	0.0555	0.0331	0.0575	0.0439
20.0%	10.0%	70.0%	0.0408	0.0750	0.0515	0.0309	0.0525	0.0420
20.0%	0.0%	80.0%	0.0303	0.0391	0.0325	0.0217	0.0164	0.0220
10.0%	90.0%	0.0%	0.0507	0.0718	0.0359	0.0411	0.0417	0.0072
10.0%	80.0%	10.0%	0.0492	0.0908	0.0643	0.0371	0.0526	0.0361
10.0%	70.0%	20.0%	0.0512	0.0959	0.0645	0.0347	0.0528	0.0391
10.0%	60.0%	30.0%	0.0485	0.0954	0.0661	0.0339	0.0592	0.0448
10.0%	50.0%	40.0%	0.0468	0.0952	0.0662	0.0324	0.0620	0.0476
10.0%	40.0%	50.0%	0.0490	0.0950	0.0656	0.0317	0.0596	0.0472
10.0%	30.0%	60.0%	0.0442	0.0901	0.0637	0.0286	0.0589	0.0489
10.0%	20.0%	70.0%	0.0396	0.0864	0.0629	0.0261	0.0573	0.0475
10.0%	10.0%	80.0%	0.0351	0.0686	0.0523	0.0242	0.0471	0.0405
10.0%	0.0%	90.0%	0.0270	0.0418	0.0342	0.0167	0.0153	0.0192
0.0%	100.0%	0.0%	0.0112	0.0393	0.0363	0.0267	0.0272	0.0063
0.0%	90.0%	10.0%	0.0140	0.0676	0.0640	0.0256	0.0470	0.0375
0.0%	80.0%	20.0%	0.0165	0.0736	0.0687	0.0244	0.0489	0.0439
0.0%	70.0%	30.0%	0.0168	0.0743	0.0678	0.0211	0.0527	0.0475
0.0%	60.0%	40.0%	0.0148	0.0768	0.0723	0.0202	0.0527	0.0484
0.0%	50.0%	50.0%	0.0167	0.0766	0.0707	0.0181	0.0539	0.0495
0.0%	40.0%	60.0%	0.0165	0.0831	0.0746	0.0146	0.0521	0.0486
0.0%	30.0%	70.0%	0.0193	0.0857	0.0774	0.0129	0.0501	0.0482
0.0%	20.0%	80.0%	0.0196	0.0816	0.0726	0.0106	0.0459	0.0438
0.0%	10.0%	90.0%	0.0184	0.0698	0.0614	0.0077	0.0408	0.0397
0.0%	0.0%	100.0%	0.0155	0.0376	0.0349	0.0000	0.0076	0.0076

Table 8. Standard deviation observed over 500 simulations at each stock mixture. Mixture samples of 100 fish were constructed by sampling with replacement from stock standard data on fish of known stock origin; age 1.3 Yukon River chinook salmon in 1993.

Stock Mixture			Classification Estimator			Maximum Likelihood Estimator		
Lower	Middle	Upper	Lower	Middle	Upper	Lower	Middle	Upper
100.0%	0.0%	0.0%	0.0392	0.0247	0.0356	0.0204	0.0001	0.0204
90.0%	10.0%	0.0%	0.0423	0.0387	0.0320	0.0256	0.0253	0.0304
90.0%	0.0%	10.0%	0.0534	0.0285	0.0593	0.0321	0.0093	0.0340
80.0%	20.0%	0.0%	0.0406	0.0395	0.0320	0.0288	0.0306	0.0324
80.0%	10.0%	10.0%	0.0528	0.0476	0.0609	0.0356	0.0327	0.0464
80.0%	0.0%	20.0%	0.0575	0.0333	0.0634	0.0340	0.0132	0.0368
70.0%	30.0%	0.0%	0.0411	0.0442	0.0340	0.0318	0.0339	0.0327
70.0%	20.0%	10.0%	0.0508	0.0474	0.0602	0.0364	0.0410	0.0510
70.0%	10.0%	20.0%	0.0577	0.0513	0.0666	0.0378	0.0379	0.0505
70.0%	0.0%	30.0%	0.0545	0.0376	0.0650	0.0389	0.0179	0.0424
60.0%	40.0%	0.0%	0.0431	0.0451	0.0283	0.0327	0.0366	0.0305
60.0%	30.0%	10.0%	0.0497	0.0506	0.0592	0.0365	0.0420	0.0477
60.0%	20.0%	20.0%	0.0522	0.0516	0.0655	0.0378	0.0423	0.0513
60.0%	10.0%	30.0%	0.0530	0.0526	0.0726	0.0372	0.0439	0.0568
60.0%	0.0%	40.0%	0.0561	0.0438	0.0728	0.0405	0.0200	0.0460
50.0%	50.0%	0.0%	0.0426	0.0472	0.0351	0.0351	0.0411	0.0365
50.0%	40.0%	10.0%	0.0447	0.0542	0.0595	0.0357	0.0457	0.0521
50.0%	30.0%	20.0%	0.0481	0.0595	0.0720	0.0374	0.0487	0.0563
50.0%	20.0%	30.0%	0.0535	0.0563	0.0705	0.0399	0.0473	0.0558
50.0%	10.0%	40.0%	0.0514	0.0533	0.0708	0.0402	0.0434	0.0585
50.0%	0.0%	50.0%	0.0516	0.0462	0.0713	0.0388	0.0242	0.0455
40.0%	60.0%	0.0%	0.0380	0.0434	0.0320	0.0323	0.0389	0.0357
40.0%	50.0%	10.0%	0.0435	0.0546	0.0597	0.0344	0.0472	0.0514
40.0%	40.0%	20.0%	0.0486	0.0608	0.0691	0.0379	0.0518	0.0563
40.0%	30.0%	30.0%	0.0490	0.0596	0.0754	0.0372	0.0524	0.0608
40.0%	20.0%	40.0%	0.0513	0.0642	0.0779	0.0378	0.0541	0.0609
40.0%	10.0%	50.0%	0.0489	0.0562	0.0751	0.0374	0.0437	0.0565
40.0%	0.0%	60.0%	0.0486	0.0501	0.0686	0.0369	0.0284	0.0457
30.0%	70.0%	0.0%	0.0384	0.0468	0.0324	0.0309	0.0420	0.0355
30.0%	60.0%	10.0%	0.0427	0.0594	0.0663	0.0345	0.0486	0.0539
30.0%	50.0%	20.0%	0.0436	0.0610	0.0704	0.0352	0.0528	0.0586
30.0%	40.0%	30.0%	0.0494	0.0598	0.0720	0.0373	0.0557	0.0617
30.0%	30.0%	40.0%	0.0482	0.0604	0.0733	0.0382	0.0553	0.0624
30.0%	20.0%	50.0%	0.0458	0.0593	0.0720	0.0361	0.0535	0.0600
30.0%	10.0%	60.0%	0.0465	0.0574	0.0749	0.0362	0.0491	0.0597
30.0%	0.0%	70.0%	0.0469	0.0531	0.0710	0.0360	0.0298	0.0461
20.0%	80.0%	0.0%	0.0361	0.0434	0.0310	0.0307	0.0412	0.0378
20.0%	70.0%	10.0%	0.0393	0.0628	0.0633	0.0317	0.0488	0.0526
20.0%	60.0%	20.0%	0.0426	0.0685	0.0745	0.0340	0.0533	0.0563
20.0%	50.0%	30.0%	0.0470	0.0629	0.0719	0.0348	0.0557	0.0586
20.0%	40.0%	40.0%	0.0439	0.0663	0.0792	0.0338	0.0583	0.0638
20.0%	30.0%	50.0%	0.0454	0.0663	0.0814	0.0347	0.0548	0.0639
20.0%	20.0%	60.0%	0.0464	0.0623	0.0745	0.0363	0.0549	0.0622
20.0%	10.0%	70.0%	0.0494	0.0614	0.0782	0.0340	0.0511	0.0595
20.0%	0.0%	80.0%	0.0463	0.0573	0.0763	0.0340	0.0317	0.0458
10.0%	90.0%	0.0%	0.0380	0.0440	0.0312	0.0261	0.0420	0.0375
10.0%	80.0%	10.0%	0.0391	0.0627	0.0632	0.0291	0.0487	0.0512
10.0%	70.0%	20.0%	0.0428	0.0682	0.0717	0.0308	0.0516	0.0558
10.0%	60.0%	30.0%	0.0425	0.0723	0.0791	0.0299	0.0588	0.0633
10.0%	50.0%	40.0%	0.0436	0.0661	0.0745	0.0306	0.0589	0.0617
10.0%	40.0%	50.0%	0.0446	0.0662	0.0788	0.0322	0.0572	0.0620
10.0%	30.0%	60.0%	0.0437	0.0648	0.0773	0.0305	0.0561	0.0613
10.0%	20.0%	70.0%	0.0453	0.0664	0.0764	0.0311	0.0582	0.0629
10.0%	10.0%	80.0%	0.0469	0.0624	0.0791	0.0311	0.0510	0.0588
10.0%	0.0%	90.0%	0.0478	0.0583	0.0782	0.0319	0.0353	0.0483
0.0%	100.0%	0.0%	0.0266	0.0391	0.0291	0.0053	0.0319	0.0317
0.0%	90.0%	10.0%	0.0308	0.0617	0.0606	0.0090	0.0470	0.0469
0.0%	80.0%	20.0%	0.0308	0.0748	0.0786	0.0089	0.0555	0.0563
0.0%	70.0%	30.0%	0.0325	0.0693	0.0724	0.0104	0.0563	0.0566
0.0%	60.0%	40.0%	0.0322	0.0673	0.0729	0.0095	0.0574	0.0574
0.0%	50.0%	50.0%	0.0335	0.0675	0.0751	0.0104	0.0600	0.0604
0.0%	40.0%	60.0%	0.0346	0.0693	0.0755	0.0113	0.0610	0.0612
0.0%	30.0%	70.0%	0.0333	0.0667	0.0715	0.0109	0.0588	0.0586
0.0%	20.0%	80.0%	0.0350	0.0656	0.0769	0.0115	0.0546	0.0545
0.0%	10.0%	90.0%	0.0341	0.0655	0.0742	0.0087	0.0507	0.0510
0.0%	0.0%	100.0%	0.0377	0.0600	0.0734	0.0081	0.0361	0.0367

Table 9. Standard deviation observed over 500 simulations at each stock mixture. Mixture samples of 100 fish were constructed by sampling with replacement from stock standard data on fish of known stock origin; age 1.4 Yukon River chinook salmon in 1993.

Stock Mixture			Classification Estimator			Maximum Likelihood Estimator		
Lower	Middle	Upper	Lower	Middle	Upper	Lower	Middle	Upper
100.0%	0.0%	0.0%	0.0329	0.0276	0.0257	0.0186	0.0181	0.0058
90.0%	10.0%	0.0%	0.0417	0.0475	0.0310	0.0271	0.0305	0.0203
90.0%	0.0%	10.0%	0.0430	0.0300	0.0489	0.0288	0.0302	0.0306
80.0%	20.0%	0.0%	0.0400	0.0497	0.0358	0.0300	0.0354	0.0251
80.0%	10.0%	10.0%	0.0450	0.0514	0.0571	0.0320	0.0415	0.0378
80.0%	0.0%	20.0%	0.0439	0.0310	0.0522	0.0313	0.0325	0.0343
70.0%	30.0%	0.0%	0.0430	0.0542	0.0391	0.0316	0.0379	0.0277
70.0%	20.0%	10.0%	0.0436	0.0571	0.0566	0.0339	0.0437	0.0408
70.0%	10.0%	20.0%	0.0449	0.0559	0.0600	0.0335	0.0440	0.0413
70.0%	0.0%	30.0%	0.0473	0.0329	0.0574	0.0335	0.0344	0.0387
60.0%	40.0%	0.0%	0.0403	0.0540	0.0377	0.0332	0.0413	0.0291
60.0%	30.0%	10.0%	0.0434	0.0648	0.0610	0.0348	0.0488	0.0430
60.0%	20.0%	20.0%	0.0420	0.0615	0.0661	0.0355	0.0497	0.0472
60.0%	10.0%	30.0%	0.0416	0.0598	0.0631	0.0346	0.0507	0.0487
60.0%	0.0%	40.0%	0.0437	0.0330	0.0537	0.0343	0.0346	0.0401
50.0%	50.0%	0.0%	0.0422	0.0606	0.0421	0.0327	0.0439	0.0311
50.0%	40.0%	10.0%	0.0403	0.0662	0.0635	0.0345	0.0524	0.0469
50.0%	30.0%	20.0%	0.0439	0.0640	0.0649	0.0371	0.0555	0.0512
50.0%	20.0%	30.0%	0.0411	0.0633	0.0671	0.0327	0.0550	0.0516
50.0%	10.0%	40.0%	0.0422	0.0637	0.0666	0.0338	0.0522	0.0497
50.0%	0.0%	50.0%	0.0427	0.0367	0.0564	0.0319	0.0357	0.0394
40.0%	60.0%	0.0%	0.0384	0.0548	0.0420	0.0343	0.0428	0.0309
40.0%	50.0%	10.0%	0.0384	0.0678	0.0660	0.0343	0.0510	0.0478
40.0%	40.0%	20.0%	0.0421	0.0694	0.0707	0.0347	0.0511	0.0485
40.0%	30.0%	30.0%	0.0416	0.0694	0.0709	0.0349	0.0551	0.0522
40.0%	20.0%	40.0%	0.0400	0.0657	0.0714	0.0313	0.0533	0.0532
40.0%	10.0%	50.0%	0.0434	0.0637	0.0722	0.0333	0.0487	0.0520
40.0%	0.0%	60.0%	0.0416	0.0364	0.0555	0.0313	0.0349	0.0392
30.0%	70.0%	0.0%	0.0375	0.0596	0.0440	0.0324	0.0447	0.0353
30.0%	60.0%	10.0%	0.0393	0.0714	0.0688	0.0327	0.0554	0.0510
30.0%	50.0%	20.0%	0.0402	0.0756	0.0737	0.0349	0.0588	0.0551
30.0%	40.0%	30.0%	0.0382	0.0736	0.0737	0.0329	0.0577	0.0555
30.0%	30.0%	40.0%	0.0403	0.0713	0.0730	0.0326	0.0565	0.0539
30.0%	20.0%	50.0%	0.0400	0.0719	0.0771	0.0312	0.0571	0.0571
30.0%	10.0%	60.0%	0.0411	0.0629	0.0716	0.0302	0.0514	0.0529
30.0%	0.0%	70.0%	0.0389	0.0372	0.0565	0.0273	0.0329	0.0361
20.0%	80.0%	0.0%	0.0358	0.0567	0.0459	0.0305	0.0412	0.0341
20.0%	70.0%	10.0%	0.0364	0.0748	0.0725	0.0313	0.0564	0.0504
20.0%	60.0%	20.0%	0.0362	0.0826	0.0789	0.0301	0.0600	0.0555
20.0%	50.0%	30.0%	0.0385	0.0757	0.0781	0.0319	0.0607	0.0596
20.0%	40.0%	40.0%	0.0368	0.0749	0.0760	0.0289	0.0555	0.0548
20.0%	30.0%	50.0%	0.0386	0.0726	0.0733	0.0294	0.0578	0.0557
20.0%	20.0%	60.0%	0.0386	0.0736	0.0778	0.0268	0.0575	0.0552
20.0%	10.0%	70.0%	0.0374	0.0674	0.0725	0.0259	0.0528	0.0507
20.0%	0.0%	80.0%	0.0377	0.0373	0.0534	0.0248	0.0296	0.0344
10.0%	90.0%	0.0%	0.0329	0.0568	0.0467	0.0273	0.0424	0.0336
10.0%	80.0%	10.0%	0.0358	0.0772	0.0713	0.0285	0.0532	0.0499
10.0%	70.0%	20.0%	0.0360	0.0853	0.0819	0.0270	0.0610	0.0586
10.0%	60.0%	30.0%	0.0349	0.0803	0.0790	0.0261	0.0588	0.0563
10.0%	50.0%	40.0%	0.0357	0.0804	0.0804	0.0256	0.0618	0.0600
10.0%	40.0%	50.0%	0.0341	0.0808	0.0791	0.0242	0.0614	0.0579
10.0%	30.0%	60.0%	0.0358	0.0731	0.0758	0.0243	0.0569	0.0568
10.0%	20.0%	70.0%	0.0352	0.0772	0.0794	0.0228	0.0579	0.0556
10.0%	10.0%	80.0%	0.0370	0.0684	0.0751	0.0209	0.0506	0.0509
10.0%	0.0%	90.0%	0.0338	0.0396	0.0500	0.0200	0.0310	0.0336
0.0%	100.0%	0.0%	0.0122	0.0512	0.0506	0.0163	0.0394	0.0381
0.0%	90.0%	10.0%	0.0132	0.0758	0.0743	0.0141	0.0559	0.0539
0.0%	80.0%	20.0%	0.0172	0.0785	0.0774	0.0136	0.0570	0.0555
0.0%	70.0%	30.0%	0.0165	0.0804	0.0801	0.0112	0.0598	0.0592
0.0%	60.0%	40.0%	0.0181	0.0774	0.0779	0.0094	0.0611	0.0607
0.0%	50.0%	50.0%	0.0189	0.0773	0.0763	0.0084	0.0605	0.0592
0.0%	40.0%	60.0%	0.0218	0.0809	0.0813	0.0076	0.0598	0.0593
0.0%	30.0%	70.0%	0.0214	0.0799	0.0827	0.0068	0.0604	0.0601
0.0%	20.0%	80.0%	0.0240	0.0747	0.0767	0.0057	0.0534	0.0531
0.0%	10.0%	90.0%	0.0263	0.0700	0.0742	0.0047	0.0509	0.0510
0.0%	0.0%	100.0%	0.0273	0.0380	0.0474	0.0000	0.0241	0.0241

Table 10. Root mean squared error observed over 500 simulations at each stock mixture. Mixture samples of 100 fish were constructed by sampling with replacement from stock standard data on fish of known stock origin; age 1.3 Yukon River chinook salmon in 1992.

Stock Mixture			Classification Estimator			Maximum Likelihood Estimator		
Lower	Middle	Upper	Lower	Middle	Upper	Lower	Middle	Upper
100.0%	0.0%	0.0%	0.0445	0.0327	0.0285	0.0030	0.0022	0.0020
90.0%	10.0%	0.0%	0.0465	0.0511	0.0314	0.0240	0.0316	0.0143
90.0%	0.0%	10.0%	0.0427	0.0328	0.0464	0.0221	0.0124	0.0282
80.0%	20.0%	0.0%	0.0475	0.0537	0.0293	0.0276	0.0380	0.0172
80.0%	10.0%	10.0%	0.0333	0.0569	0.0570	0.0289	0.0340	0.0377
80.0%	0.0%	20.0%	0.0422	0.0384	0.0526	0.0226	0.0205	0.0336
70.0%	30.0%	0.0%	0.0515	0.0557	0.0254	0.0302	0.0427	0.0219
70.0%	20.0%	10.0%	0.0347	0.0686	0.0636	0.0292	0.0406	0.0405
70.0%	10.0%	20.0%	0.0351	0.0646	0.0684	0.0277	0.0412	0.0478
70.0%	0.0%	30.0%	0.0426	0.0319	0.0505	0.0226	0.0237	0.0347
60.0%	40.0%	0.0%	0.0521	0.0592	0.0306	0.0298	0.0464	0.0275
60.0%	30.0%	10.0%	0.0343	0.0742	0.0671	0.0264	0.0417	0.0397
60.0%	20.0%	20.0%	0.0338	0.0743	0.0730	0.0257	0.0431	0.0484
60.0%	10.0%	30.0%	0.0352	0.0650	0.0684	0.0246	0.0449	0.0493
60.0%	0.0%	40.0%	0.0405	0.0453	0.0602	0.0241	0.0342	0.0427
50.0%	50.0%	0.0%	0.0550	0.0593	0.0297	0.0283	0.0466	0.0331
50.0%	40.0%	10.0%	0.0338	0.0830	0.0733	0.0271	0.0469	0.0435
50.0%	30.0%	20.0%	0.0326	0.0805	0.0790	0.0274	0.0477	0.0490
50.0%	20.0%	30.0%	0.0366	0.0762	0.0763	0.0256	0.0531	0.0567
50.0%	10.0%	40.0%	0.0357	0.0685	0.0706	0.0263	0.0528	0.0564
50.0%	0.0%	50.0%	0.0368	0.0374	0.0563	0.0244	0.0360	0.0435
40.0%	60.0%	0.0%	0.0473	0.0541	0.0282	0.0290	0.0524	0.0367
40.0%	50.0%	10.0%	0.0325	0.0821	0.0729	0.0264	0.0450	0.0440
40.0%	40.0%	20.0%	0.0302	0.0929	0.0930	0.0244	0.0510	0.0526
40.0%	30.0%	30.0%	0.0332	0.0849	0.0873	0.0261	0.0542	0.0549
40.0%	20.0%	40.0%	0.0366	0.0827	0.0841	0.0276	0.0614	0.0637
40.0%	10.0%	50.0%	0.0399	0.0750	0.0787	0.0281	0.0591	0.0618
40.0%	0.0%	60.0%	0.0374	0.0418	0.0633	0.0278	0.0425	0.0498
30.0%	70.0%	0.0%	0.0462	0.0539	0.0324	0.0250	0.0558	0.0455
30.0%	60.0%	10.0%	0.0322	0.0899	0.0777	0.0235	0.0516	0.0507
30.0%	50.0%	20.0%	0.0324	0.0952	0.0941	0.0256	0.0519	0.0523
30.0%	40.0%	30.0%	0.0330	0.0953	0.0958	0.0255	0.0566	0.0557
30.0%	30.0%	40.0%	0.0334	0.0931	0.0929	0.0262	0.0636	0.0635
30.0%	20.0%	50.0%	0.0383	0.0872	0.0880	0.0267	0.0645	0.0664
30.0%	10.0%	60.0%	0.0412	0.0783	0.0851	0.0271	0.0655	0.0685
30.0%	0.0%	70.0%	0.0385	0.0371	0.0624	0.0262	0.0472	0.0528
20.0%	80.0%	0.0%	0.0409	0.0476	0.0274	0.0213	0.0568	0.0532
20.0%	70.0%	10.0%	0.0319	0.0940	0.0805	0.0228	0.0570	0.0572
20.0%	60.0%	20.0%	0.0304	0.1026	0.1002	0.0230	0.0510	0.0531
20.0%	50.0%	30.0%	0.0318	0.1016	0.1035	0.0251	0.0584	0.0609
20.0%	40.0%	40.0%	0.0356	0.0906	0.0945	0.0260	0.0601	0.0622
20.0%	30.0%	50.0%	0.0371	0.0877	0.0921	0.0240	0.0649	0.0662
20.0%	20.0%	60.0%	0.0422	0.0868	0.0889	0.0265	0.0746	0.0762
20.0%	10.0%	70.0%	0.0456	0.0779	0.0813	0.0259	0.0692	0.0716
20.0%	0.0%	80.0%	0.0407	0.0418	0.0670	0.0280	0.0482	0.0534
10.0%	90.0%	0.0%	0.0368	0.0467	0.0319	0.0184	0.0670	0.0686
10.0%	80.0%	10.0%	0.0285	0.0936	0.0820	0.0192	0.0601	0.0644
10.0%	70.0%	20.0%	0.0282	0.1203	0.1148	0.0206	0.0564	0.0601
10.0%	60.0%	30.0%	0.0311	0.1177	0.1176	0.0217	0.0579	0.0592
10.0%	50.0%	40.0%	0.0317	0.1019	0.1015	0.0240	0.0603	0.0607
10.0%	40.0%	50.0%	0.0380	0.0955	0.1014	0.0229	0.0670	0.0688
10.0%	30.0%	60.0%	0.0442	0.0921	0.1001	0.0248	0.0723	0.0759
10.0%	20.0%	70.0%	0.0477	0.0954	0.0952	0.0243	0.0710	0.0727
10.0%	10.0%	80.0%	0.0522	0.0772	0.0803	0.0241	0.0712	0.0776
10.0%	0.0%	90.0%	0.0506	0.0412	0.0742	0.0244	0.0533	0.0614
0.0%	100.0%	0.0%	0.0091	0.0308	0.0283	0.0000	0.0782	0.0782
0.0%	90.0%	10.0%	0.0124	0.0824	0.0842	0.0054	0.0656	0.0649
0.0%	80.0%	20.0%	0.0176	0.1177	0.1227	0.0077	0.0600	0.0594
0.0%	70.0%	30.0%	0.0218	0.1125	0.1193	0.0089	0.0569	0.0575
0.0%	60.0%	40.0%	0.0289	0.1051	0.1120	0.0104	0.0598	0.0612
0.0%	50.0%	50.0%	0.0335	0.1008	0.1071	0.0106	0.0620	0.0643
0.0%	40.0%	60.0%	0.0402	0.0999	0.1070	0.0134	0.0696	0.0749
0.0%	30.0%	70.0%	0.0475	0.0997	0.0998	0.0131	0.0735	0.0779
0.0%	20.0%	80.0%	0.0540	0.1061	0.1027	0.0150	0.0716	0.0776
0.0%	10.0%	90.0%	0.0602	0.0794	0.0835	0.0145	0.0715	0.0769
0.0%	0.0%	100.0%	0.0631	0.0443	0.0887	0.0134	0.0487	0.0548

Table 11. Root mean squared error observed over 500 simulations at each stock mixture. Mixture samples of 100 fish were constructed by sampling with replacement from stock standard data on fish of known stock origin; age 1.4 Yukon River chinook salmon in 1992.

Stock Mixture			Classification Estimator			Maximum Likelihood Estimator		
Lower	Middle	Upper	Lower	Middle	Upper	Lower	Middle	Upper
100.0%	0.0%	0.0%	0.0657	0.0628	0.0160	0.0286	0.0286	0.0000
90.0%	10.0%	0.0%	0.0688	0.0745	0.0213	0.0393	0.0399	0.0046
90.0%	0.0%	10.0%	0.0491	0.0563	0.0273	0.0332	0.0390	0.0202
80.0%	20.0%	0.0%	0.0795	0.0857	0.0239	0.0478	0.0480	0.0059
80.0%	10.0%	10.0%	0.0631	0.0850	0.0365	0.0425	0.0523	0.0248
80.0%	0.0%	20.0%	0.0446	0.0550	0.0306	0.0355	0.0401	0.0243
70.0%	30.0%	0.0%	0.0790	0.0869	0.0272	0.0478	0.0489	0.0076
70.0%	20.0%	10.0%	0.0657	0.0878	0.0413	0.0465	0.0561	0.0279
70.0%	10.0%	20.0%	0.0583	0.0805	0.0409	0.0421	0.0552	0.0308
70.0%	0.0%	30.0%	0.0500	0.0623	0.0334	0.0365	0.0355	0.0245
60.0%	40.0%	0.0%	0.0758	0.0837	0.0333	0.0457	0.0468	0.0075
60.0%	30.0%	10.0%	0.0661	0.0927	0.0463	0.0464	0.0575	0.0301
60.0%	20.0%	20.0%	0.0583	0.0843	0.0472	0.0423	0.0543	0.0336
60.0%	10.0%	30.0%	0.0544	0.0778	0.0429	0.0388	0.0527	0.0352
60.0%	0.0%	40.0%	0.0444	0.0529	0.0350	0.0360	0.0281	0.0284
50.0%	50.0%	0.0%	0.0741	0.0830	0.0366	0.0421	0.0432	0.0095
50.0%	40.0%	10.0%	0.0656	0.0960	0.0515	0.0474	0.0612	0.0330
50.0%	30.0%	20.0%	0.0613	0.0939	0.0525	0.0439	0.0593	0.0368
50.0%	20.0%	30.0%	0.0567	0.0873	0.0499	0.0400	0.0555	0.0373
50.0%	10.0%	40.0%	0.0530	0.0749	0.0447	0.0390	0.0508	0.0370
50.0%	0.0%	50.0%	0.0409	0.0527	0.0377	0.0351	0.0237	0.0308
40.0%	60.0%	0.0%	0.0806	0.0880	0.0397	0.0466	0.0480	0.0101
40.0%	50.0%	10.0%	0.0709	0.0999	0.0524	0.0459	0.0595	0.0339
40.0%	50.0%	10.0%	0.0709	0.0999	0.0524	0.0459	0.0595	0.0339
40.0%	30.0%	30.0%	0.0609	0.0923	0.0542	0.0408	0.0575	0.0400
40.0%	20.0%	40.0%	0.0548	0.0920	0.0595	0.0399	0.0580	0.0433
40.0%	10.0%	50.0%	0.0493	0.0796	0.0492	0.0360	0.0535	0.0407
40.0%	0.0%	60.0%	0.0364	0.0428	0.0339	0.0311	0.0179	0.0282
30.0%	70.0%	0.0%	0.0830	0.0887	0.0391	0.0462	0.0479	0.0091
30.0%	60.0%	10.0%	0.0730	0.1031	0.0545	0.0436	0.0575	0.0325
30.0%	50.0%	20.0%	0.0654	0.0949	0.0545	0.0403	0.0587	0.0384
30.0%	40.0%	30.0%	0.0606	0.0938	0.0580	0.0406	0.0621	0.0444
30.0%	30.0%	40.0%	0.0537	0.0879	0.0573	0.0378	0.0613	0.0427
30.0%	20.0%	50.0%	0.0488	0.0835	0.0589	0.0371	0.0551	0.0431
30.0%	10.0%	60.0%	0.0423	0.0718	0.0493	0.0329	0.0524	0.0421
30.0%	0.0%	70.0%	0.0345	0.0439	0.0348	0.0294	0.0159	0.0277
20.0%	80.0%	0.0%	0.0880	0.0922	0.0418	0.0442	0.0455	0.0078
20.0%	70.0%	10.0%	0.0823	0.1171	0.0612	0.0438	0.0613	0.0386
20.0%	60.0%	20.0%	0.0691	0.1028	0.0616	0.0399	0.0615	0.0425
20.0%	50.0%	30.0%	0.0623	0.0914	0.0600	0.0376	0.0585	0.0426
20.0%	40.0%	40.0%	0.0584	0.0897	0.0571	0.0375	0.0597	0.0415
20.0%	30.0%	50.0%	0.0510	0.0888	0.0622	0.0337	0.0584	0.0462
20.0%	20.0%	60.0%	0.0466	0.0855	0.0608	0.0335	0.0581	0.0460
20.0%	10.0%	70.0%	0.0409	0.0765	0.0545	0.0324	0.0529	0.0450
20.0%	0.0%	80.0%	0.0304	0.0435	0.0366	0.0262	0.0170	0.0243
10.0%	90.0%	0.0%	0.0729	0.0778	0.0424	0.0418	0.0427	0.0075
10.0%	80.0%	10.0%	0.0697	0.1023	0.0644	0.0374	0.0535	0.0364
10.0%	70.0%	20.0%	0.0671	0.1026	0.0648	0.0349	0.0542	0.0401
10.0%	60.0%	30.0%	0.0597	0.0976	0.0676	0.0340	0.0605	0.0459
10.0%	50.0%	40.0%	0.0571	0.0976	0.0671	0.0324	0.0621	0.0478
10.0%	40.0%	50.0%	0.0533	0.0950	0.0682	0.0317	0.0601	0.0480
10.0%	30.0%	60.0%	0.0460	0.0905	0.0671	0.0287	0.0593	0.0498
10.0%	20.0%	70.0%	0.0407	0.0870	0.0658	0.0271	0.0573	0.0482
10.0%	10.0%	80.0%	0.0351	0.0712	0.0558	0.0252	0.0476	0.0429
10.0%	0.0%	90.0%	0.0270	0.0468	0.0407	0.0201	0.0158	0.0205
0.0%	100.0%	0.0%	0.0117	0.0463	0.0421	0.0408	0.0425	0.0066
0.0%	90.0%	10.0%	0.0144	0.0676	0.0640	0.0379	0.0606	0.0389
0.0%	80.0%	20.0%	0.0172	0.0738	0.0694	0.0337	0.0582	0.0447
0.0%	70.0%	30.0%	0.0177	0.0745	0.0678	0.0297	0.0619	0.0486
0.0%	60.0%	40.0%	0.0156	0.0771	0.0723	0.0268	0.0607	0.0500
0.0%	50.0%	50.0%	0.0181	0.0775	0.0709	0.0235	0.0602	0.0508
0.0%	40.0%	60.0%	0.0180	0.0838	0.0747	0.0181	0.0558	0.0495
0.0%	30.0%	70.0%	0.0216	0.0878	0.0780	0.0155	0.0543	0.0498
0.0%	20.0%	80.0%	0.0225	0.0829	0.0727	0.0125	0.0482	0.0445
0.0%	10.0%	90.0%	0.0222	0.0722	0.0617	0.0086	0.0449	0.0425
0.0%	0.0%	100.0%	0.0202	0.0422	0.0474	0.0000	0.0078	0.0078

Table 12. Root mean squared error observed over 500 simulations at each stock mixture. Mixture samples of 100 fish were constructed by sampling with replacement from stock standard data on fish of known stock origin; age 1.3 Yukon River chinook salmon in 1993.

Stock Mixture			Classification Estimator			Maximum Likelihood Estimator		
Lower	Middle	Upper	Lower	Middle	Upper	Lower	Middle	Upper
100.0%	0.0%	0.0%	0.0537	0.0297	0.0409	0.0268	0.0001	0.0268
90.0%	10.0%	0.0%	0.0479	0.0389	0.0369	0.0269	0.0299	0.0389
90.0%	0.0%	10.0%	0.0542	0.0363	0.0608	0.0348	0.0102	0.0353
80.0%	20.0%	0.0%	0.0433	0.0395	0.0364	0.0294	0.0361	0.0411
80.0%	10.0%	10.0%	0.0528	0.0491	0.0622	0.0369	0.0359	0.0525
80.0%	0.0%	20.0%	0.0594	0.0429	0.0646	0.0358	0.0149	0.0371
70.0%	30.0%	0.0%	0.0439	0.0443	0.0390	0.0325	0.0386	0.0413
70.0%	20.0%	10.0%	0.0509	0.0491	0.0619	0.0370	0.0437	0.0555
70.0%	10.0%	20.0%	0.0577	0.0536	0.0687	0.0380	0.0400	0.0532
70.0%	0.0%	30.0%	0.0565	0.0518	0.0683	0.0393	0.0209	0.0427
60.0%	40.0%	0.0%	0.0442	0.0453	0.0317	0.0329	0.0416	0.0382
60.0%	30.0%	10.0%	0.0502	0.0515	0.0614	0.0368	0.0438	0.0508
60.0%	20.0%	20.0%	0.0523	0.0564	0.0688	0.0381	0.0429	0.0527
60.0%	10.0%	30.0%	0.0530	0.0587	0.0770	0.0372	0.0444	0.0573
60.0%	0.0%	40.0%	0.0581	0.0614	0.0780	0.0407	0.0234	0.0467
50.0%	50.0%	0.0%	0.0435	0.0483	0.0400	0.0359	0.0467	0.0469
50.0%	40.0%	10.0%	0.0453	0.0550	0.0619	0.0360	0.0475	0.0548
50.0%	30.0%	20.0%	0.0483	0.0633	0.0766	0.0374	0.0491	0.0569
50.0%	20.0%	30.0%	0.0535	0.0617	0.0746	0.0401	0.0477	0.0567
50.0%	10.0%	40.0%	0.0517	0.0632	0.0766	0.0402	0.0435	0.0585
50.0%	0.0%	50.0%	0.0531	0.0653	0.0789	0.0388	0.0293	0.0484
40.0%	60.0%	0.0%	0.0380	0.0458	0.0360	0.0325	0.0460	0.0458
40.0%	50.0%	10.0%	0.0444	0.0560	0.0634	0.0348	0.0498	0.0555
40.0%	40.0%	20.0%	0.0502	0.0625	0.0742	0.0379	0.0523	0.0565
40.0%	30.0%	30.0%	0.0490	0.0651	0.0803	0.0372	0.0525	0.0609
40.0%	20.0%	40.0%	0.0513	0.0710	0.0836	0.0378	0.0541	0.0609
40.0%	10.0%	50.0%	0.0489	0.0674	0.0830	0.0375	0.0437	0.0567
40.0%	0.0%	60.0%	0.0487	0.0753	0.0865	0.0369	0.0349	0.0509
30.0%	70.0%	0.0%	0.0384	0.0504	0.0363	0.0310	0.0525	0.0494
30.0%	60.0%	10.0%	0.0452	0.0598	0.0698	0.0345	0.0513	0.0566
30.0%	50.0%	20.0%	0.0442	0.0628	0.0739	0.0353	0.0540	0.0603
30.0%	40.0%	30.0%	0.0505	0.0636	0.0789	0.0373	0.0557	0.0617
30.0%	30.0%	40.0%	0.0484	0.0659	0.0798	0.0382	0.0553	0.0624
30.0%	20.0%	50.0%	0.0459	0.0676	0.0804	0.0361	0.0537	0.0602
30.0%	10.0%	60.0%	0.0465	0.0698	0.0843	0.0362	0.0494	0.0599
30.0%	0.0%	70.0%	0.0470	0.0817	0.0925	0.0360	0.0391	0.0522
20.0%	80.0%	0.0%	0.0367	0.0488	0.0349	0.0309	0.0517	0.0514
20.0%	70.0%	10.0%	0.0417	0.0633	0.0669	0.0317	0.0514	0.0553
20.0%	60.0%	20.0%	0.0450	0.0699	0.0798	0.0340	0.0541	0.0570
20.0%	50.0%	30.0%	0.0486	0.0663	0.0792	0.0348	0.0557	0.0587
20.0%	40.0%	40.0%	0.0453	0.0730	0.0895	0.0338	0.0584	0.0638
20.0%	30.0%	50.0%	0.0473	0.0747	0.0942	0.0347	0.0551	0.0643
20.0%	20.0%	60.0%	0.0467	0.0741	0.0873	0.0364	0.0554	0.0625
20.0%	10.0%	70.0%	0.0496	0.0816	0.0978	0.0340	0.0532	0.0610
20.0%	0.0%	80.0%	0.0463	0.0884	0.1011	0.0344	0.0410	0.0505
10.0%	90.0%	0.0%	0.0410	0.0539	0.0348	0.0261	0.0557	0.0526
10.0%	80.0%	10.0%	0.0429	0.0631	0.0681	0.0291	0.0516	0.0537
10.0%	70.0%	20.0%	0.0465	0.0702	0.0797	0.0309	0.0524	0.0563
10.0%	60.0%	30.0%	0.0454	0.0737	0.0848	0.0300	0.0591	0.0636
10.0%	50.0%	40.0%	0.0479	0.0693	0.0849	0.0307	0.0589	0.0617
10.0%	40.0%	50.0%	0.0468	0.0725	0.0902	0.0323	0.0577	0.0622
10.0%	30.0%	60.0%	0.0451	0.0722	0.0884	0.0305	0.0568	0.0618
10.0%	20.0%	70.0%	0.0469	0.0820	0.0973	0.0313	0.0605	0.0643
10.0%	10.0%	80.0%	0.0494	0.0852	0.1079	0.0312	0.0537	0.0605
10.0%	0.0%	90.0%	0.0494	0.0931	0.1157	0.0322	0.0460	0.0544
0.0%	100.0%	0.0%	0.0364	0.0546	0.0328	0.0056	0.0442	0.0430
0.0%	90.0%	10.0%	0.0424	0.0617	0.0678	0.0096	0.0510	0.0497
0.0%	80.0%	20.0%	0.0413	0.0751	0.0859	0.0095	0.0565	0.0568
0.0%	70.0%	30.0%	0.0423	0.0696	0.0808	0.0111	0.0565	0.0566
0.0%	60.0%	40.0%	0.0446	0.0677	0.0823	0.0104	0.0575	0.0574
0.0%	50.0%	50.0%	0.0464	0.0713	0.0932	0.0112	0.0605	0.0616
0.0%	40.0%	60.0%	0.0477	0.0753	0.0978	0.0124	0.0622	0.0635
0.0%	30.0%	70.0%	0.0460	0.0778	0.1013	0.0119	0.0603	0.0614
0.0%	20.0%	80.0%	0.0480	0.0820	0.1124	0.0124	0.0570	0.0583
0.0%	10.0%	90.0%	0.0470	0.0898	0.1196	0.0092	0.0538	0.0552
0.0%	0.0%	100.0%	0.0504	0.0991	0.1342	0.0086	0.0480	0.0503

Table 13. Root mean squared error observed over 500 simulations at each stock mixture. Mixture samples of 100 fish were constructed by sampling with replacement from stock standard data on fish of known stock origin; age 1.4 Yukon River chinook salmon in 1993.

Stock Mixture			Classification Estimator			Maximum Likelihood Estimator		
Lower	Middle	Upper	Lower	Middle	Upper	Lower	Middle	Upper
100.0%	0.0%	0.0%	0.0468	0.0326	0.0303	0.0243	0.0230	0.0059
90.0%	10.0%	0.0%	0.0460	0.0475	0.0371	0.0358	0.0320	0.0245
90.0%	0.0%	10.0%	0.0470	0.0363	0.0490	0.0382	0.0439	0.0313
80.0%	20.0%	0.0%	0.0451	0.0498	0.0428	0.0386	0.0359	0.0314
80.0%	10.0%	10.0%	0.0450	0.0516	0.0573	0.0396	0.0459	0.0380
80.0%	0.0%	20.0%	0.0474	0.0367	0.0522	0.0387	0.0465	0.0358
70.0%	30.0%	0.0%	0.0471	0.0547	0.0469	0.0378	0.0380	0.0354
70.0%	20.0%	10.0%	0.0436	0.0574	0.0568	0.0393	0.0449	0.0419
70.0%	10.0%	20.0%	0.0452	0.0564	0.0613	0.0397	0.0492	0.0413
70.0%	0.0%	30.0%	0.0503	0.0389	0.0575	0.0404	0.0477	0.0401
60.0%	40.0%	0.0%	0.0456	0.0542	0.0455	0.0374	0.0418	0.0374
60.0%	30.0%	10.0%	0.0435	0.0649	0.0612	0.0368	0.0492	0.0435
60.0%	20.0%	20.0%	0.0420	0.0615	0.0661	0.0389	0.0525	0.0473
60.0%	10.0%	30.0%	0.0420	0.0599	0.0638	0.0394	0.0552	0.0488
60.0%	0.0%	40.0%	0.0487	0.0397	0.0537	0.0411	0.0474	0.0413
50.0%	50.0%	0.0%	0.0468	0.0613	0.0513	0.0351	0.0461	0.0410
50.0%	40.0%	10.0%	0.0409	0.0662	0.0638	0.0366	0.0524	0.0484
50.0%	30.0%	20.0%	0.0440	0.0643	0.0655	0.0387	0.0559	0.0514
50.0%	20.0%	30.0%	0.0413	0.0637	0.0681	0.0357	0.0574	0.0517
50.0%	10.0%	40.0%	0.0423	0.0637	0.0667	0.0370	0.0580	0.0507
50.0%	0.0%	50.0%	0.0450	0.0430	0.0569	0.0362	0.0482	0.0422
40.0%	60.0%	0.0%	0.0435	0.0556	0.0512	0.0349	0.0469	0.0400
40.0%	50.0%	10.0%	0.0398	0.0680	0.0662	0.0351	0.0513	0.0496
40.0%	40.0%	20.0%	0.0430	0.0695	0.0717	0.0358	0.0512	0.0495
40.0%	30.0%	30.0%	0.0416	0.0697	0.0713	0.0356	0.0554	0.0523
40.0%	20.0%	40.0%	0.0401	0.0661	0.0722	0.0337	0.0560	0.0533
40.0%	10.0%	50.0%	0.0434	0.0637	0.0722	0.0356	0.0546	0.0534
40.0%	0.0%	60.0%	0.0428	0.0426	0.0568	0.0368	0.0458	0.0405
30.0%	70.0%	0.0%	0.0421	0.0605	0.0531	0.0324	0.0528	0.0452
30.0%	60.0%	10.0%	0.0412	0.0718	0.0690	0.0329	0.0565	0.0529
30.0%	50.0%	20.0%	0.0406	0.0756	0.0741	0.0350	0.0593	0.0560
30.0%	40.0%	30.0%	0.0383	0.0738	0.0742	0.0330	0.0577	0.0557
30.0%	30.0%	40.0%	0.0403	0.0715	0.0733	0.0336	0.0579	0.0541
30.0%	20.0%	50.0%	0.0400	0.0734	0.0785	0.0324	0.0581	0.0571
30.0%	10.0%	60.0%	0.0412	0.0633	0.0718	0.0321	0.0540	0.0531
30.0%	0.0%	70.0%	0.0390	0.0437	0.0601	0.0309	0.0423	0.0381
20.0%	80.0%	0.0%	0.0421	0.0575	0.0556	0.0305	0.0504	0.0441
20.0%	70.0%	10.0%	0.0382	0.0749	0.0730	0.0316	0.0603	0.0532
20.0%	60.0%	20.0%	0.0370	0.0827	0.0791	0.0301	0.0613	0.0569
20.0%	50.0%	30.0%	0.0391	0.0758	0.0787	0.0320	0.0608	0.0599
20.0%	40.0%	40.0%	0.0369	0.0750	0.0765	0.0293	0.0556	0.0549
20.0%	30.0%	50.0%	0.0387	0.0732	0.0741	0.0304	0.0585	0.0557
20.0%	20.0%	60.0%	0.0386	0.0744	0.0785	0.0290	0.0590	0.0553
20.0%	10.0%	70.0%	0.0375	0.0675	0.0725	0.0288	0.0553	0.0508
20.0%	0.0%	80.0%	0.0380	0.0428	0.0590	0.0282	0.0360	0.0351
10.0%	90.0%	0.0%	0.0387	0.0576	0.0555	0.0285	0.0559	0.0438
10.0%	80.0%	10.0%	0.0383	0.0772	0.0722	0.0296	0.0620	0.0553
10.0%	70.0%	20.0%	0.0387	0.0853	0.0825	0.0270	0.0634	0.0609
10.0%	60.0%	30.0%	0.0359	0.0804	0.0799	0.0261	0.0602	0.0579
10.0%	50.0%	40.0%	0.0360	0.0806	0.0812	0.0257	0.0623	0.0609
10.0%	40.0%	50.0%	0.0342	0.0813	0.0799	0.0249	0.0616	0.0580
10.0%	30.0%	60.0%	0.0358	0.0747	0.0770	0.0253	0.0573	0.0568
10.0%	20.0%	70.0%	0.0354	0.0777	0.0795	0.0251	0.0596	0.0558
10.0%	10.0%	80.0%	0.0375	0.0697	0.0755	0.0248	0.0521	0.0509
10.0%	0.0%	90.0%	0.0340	0.0460	0.0569	0.0255	0.0380	0.0341
0.0%	100.0%	0.0%	0.0130	0.0645	0.0612	0.0207	0.0643	0.0538
0.0%	90.0%	10.0%	0.0143	0.0783	0.0756	0.0171	0.0700	0.0630
0.0%	80.0%	20.0%	0.0190	0.0790	0.0774	0.0163	0.0635	0.0587
0.0%	70.0%	30.0%	0.0184	0.0822	0.0806	0.0132	0.0650	0.0620
0.0%	60.0%	40.0%	0.0205	0.0791	0.0782	0.0110	0.0628	0.0613
0.0%	50.0%	50.0%	0.0220	0.0798	0.0768	0.0097	0.0616	0.0596
0.0%	40.0%	60.0%	0.0258	0.0830	0.0814	0.0086	0.0601	0.0594
0.0%	30.0%	70.0%	0.0257	0.0810	0.0828	0.0075	0.0605	0.0604
0.0%	20.0%	80.0%	0.0296	0.0765	0.0767	0.0061	0.0539	0.0539
0.0%	10.0%	90.0%	0.0334	0.0702	0.0758	0.0048	0.0523	0.0526
0.0%	0.0%	100.0%	0.0348	0.0442	0.0649	0.0000	0.0279	0.0279

Table 14. Percent of the stock group mixtures for which the average absolute bias (Bias), standard deviation (S. D.), and root mean squared error (RMSE) of the maximum likelihood estimator were superior to those of the classification estimator.

Year	Age	Stock Group	Bias	S. D.	RMSE
		Lower	83.3%	100.0%	100.0%
1992	1.3	Middle	39.4%	93.9%	86.4%
		Upper	47.0%	92.4%	90.9%
		Lower	63.6%	90.9%	89.4%
1992	1.4	Middle	68.2%	100.0%	100.0%
		Upper	62.1%	100.0%	100.0%
		Lower	80.3%	100.0%	100.0%
1993	1.3	Middle	71.2%	100.0%	93.9%
		Upper	77.3%	87.9%	84.8%
		Lower	39.4%	97.0%	97.0%
1993	1.4	Middle	30.3%	93.9%	90.9%
		Upper	57.6%	100.0%	100.0%

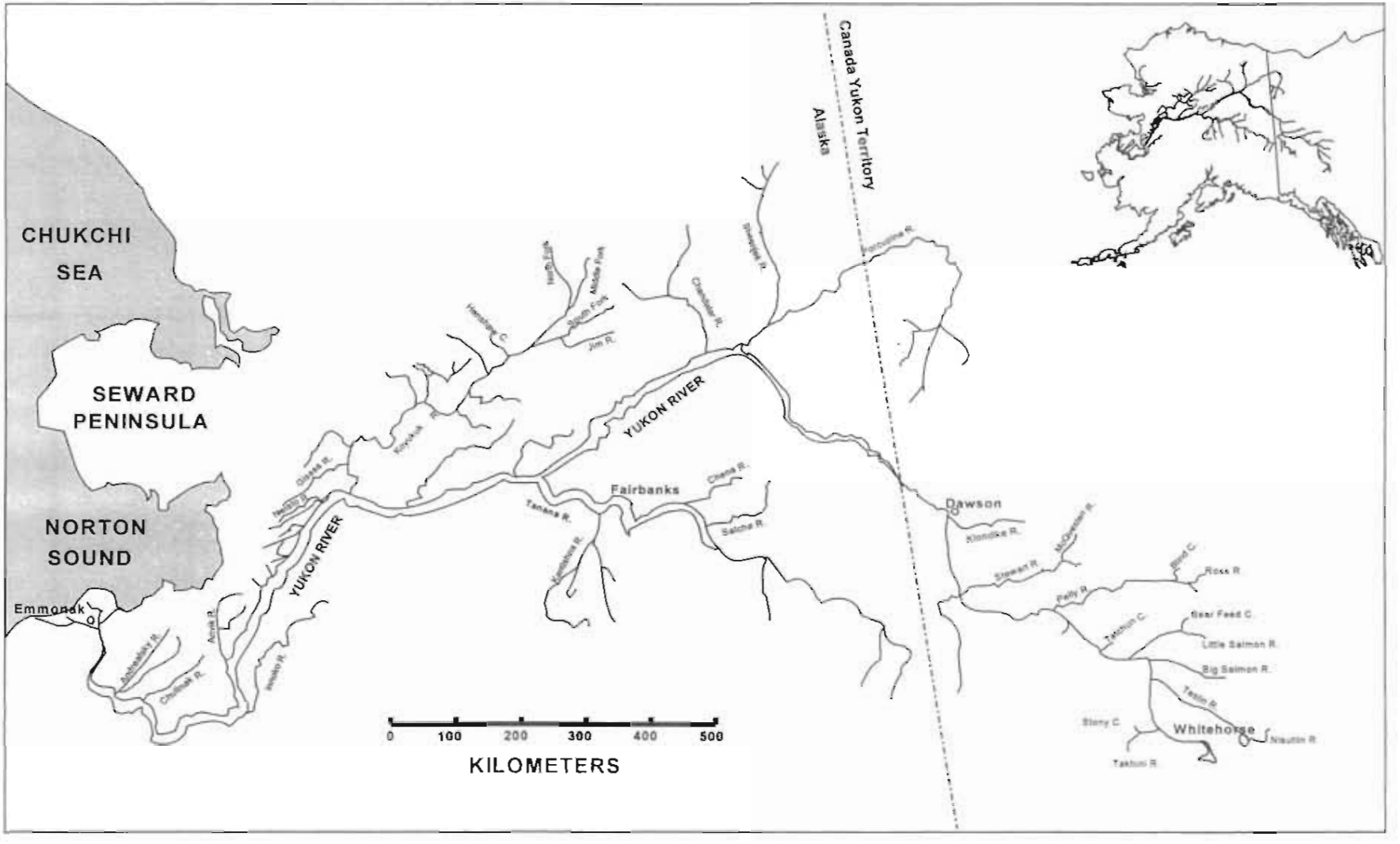

Figure 1. Map of the Yukon River drainage.

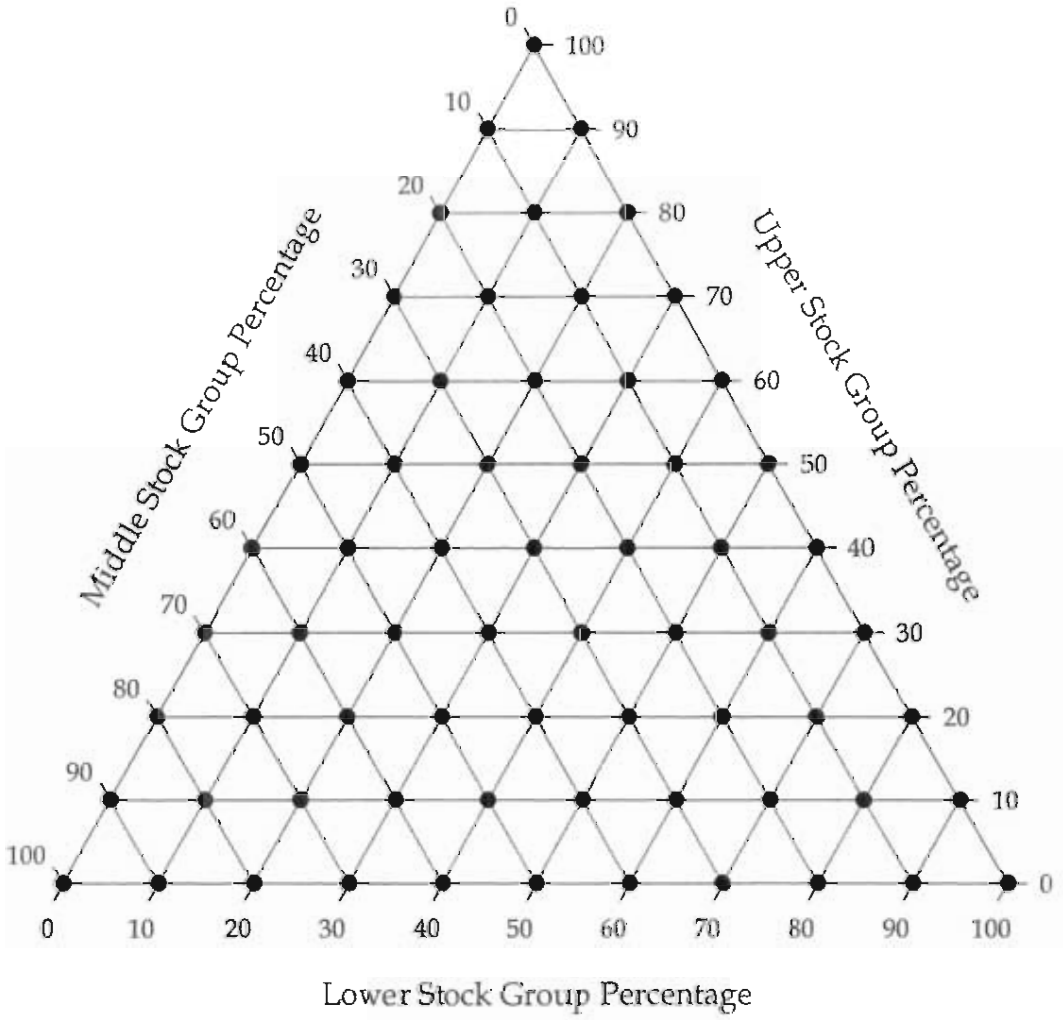

Figure 2. The stock group mixtures used in the simulation.

1992 Age 1.3 Yukon River Chinook Salmon - Average Absolute Bias

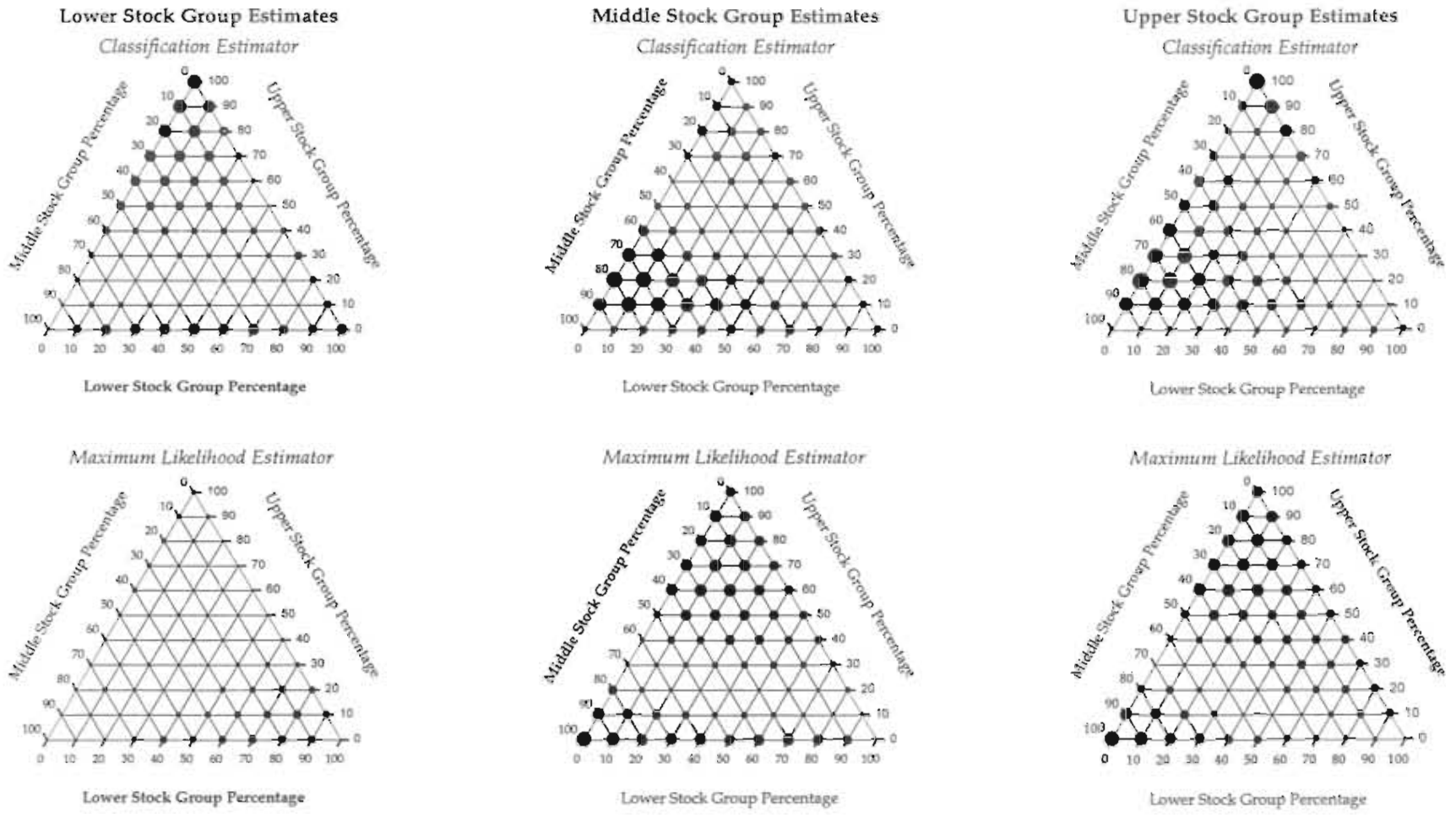

Figure 3. Average absolute bias of classification and maximum likelihood stock composition estimators. Each data point represents the average observed during 500 simulations with the stock mixture defined by each intersection of the three axes. The area of each circle is proportional to average absolute bias. Stock standard data were collected from age 1.3 Yukon River chinook salmon in 1992.

1992 Age 1.4 Yukon River Chinook Salmon - Average Absolute Bias

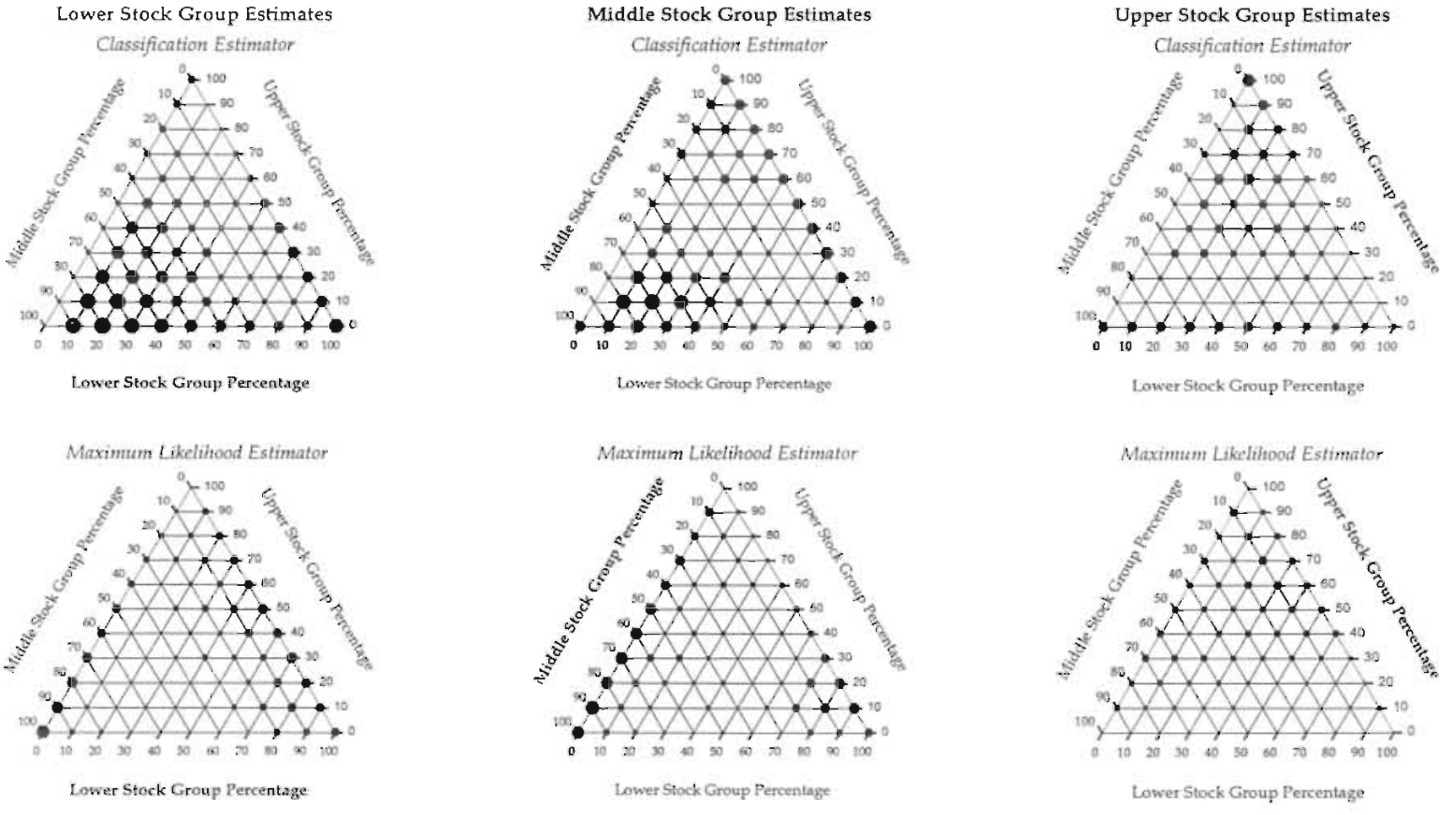

Figure 4. Average absolute bias of classification and maximum likelihood stock composition estimators. Each data point represents the average observed during 500 simulations with the stock mixture defined by each intersection of the three axes. The area of each circle is proportional to average absolute bias. Stock standard data were collected from age 1.4 Yukon River chinook salmon in 1992.

1993 Age 1.3 Yukon River Chinook Salmon - Average Absolute Bias

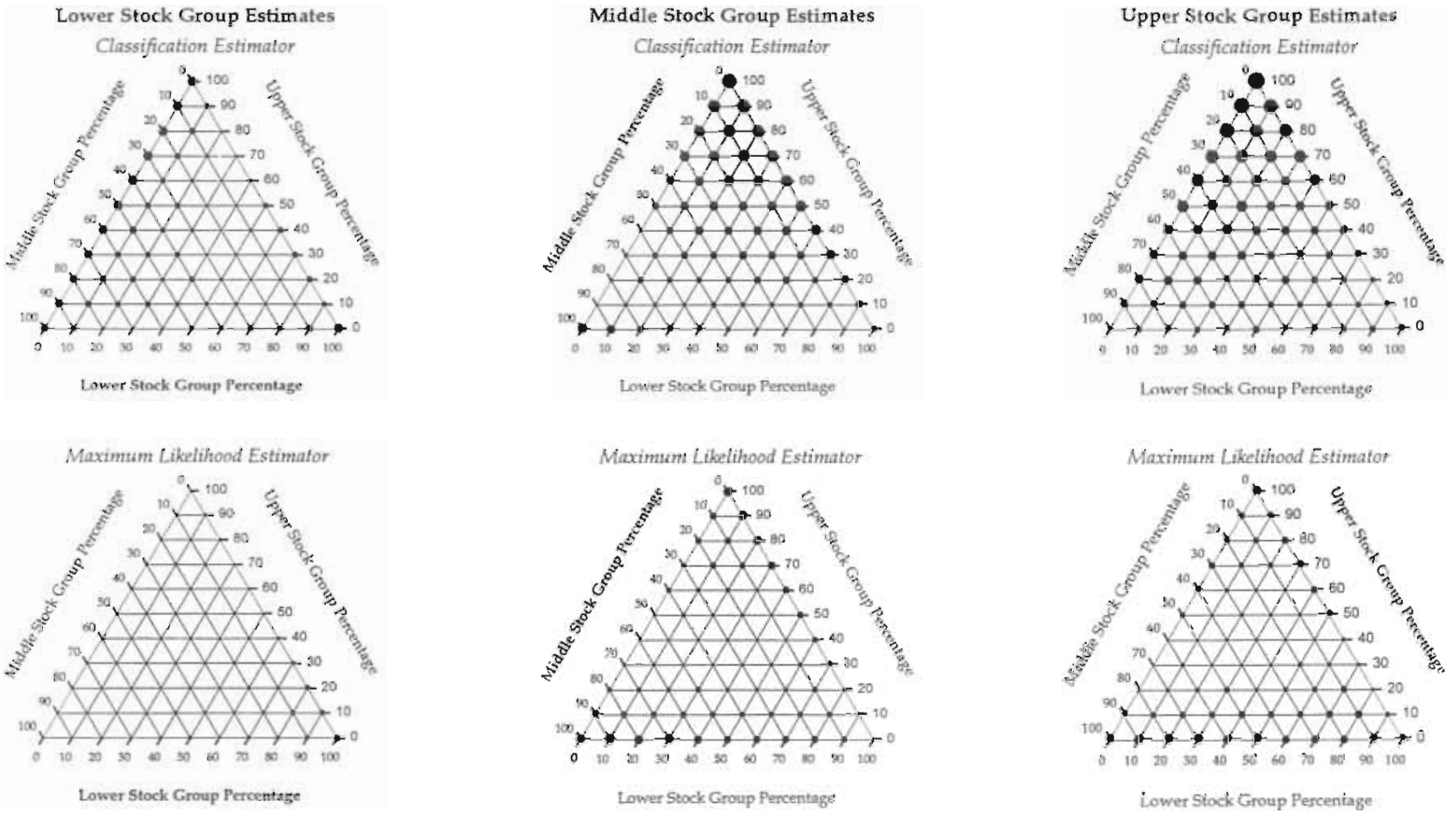

Figure 5. Average absolute bias of classification and maximum likelihood stock composition estimators. Each data point represents the average observed during 500 simulations with the stock mixture defined by each intersection of the three axes. The area of each circle is proportional to average absolute bias. Stock standard data were collected from age 1.3 Yukon River chinook salmon in 1993.

1993 Age 1.4 Yukon River Chinook Salmon - Average Absolute Bias

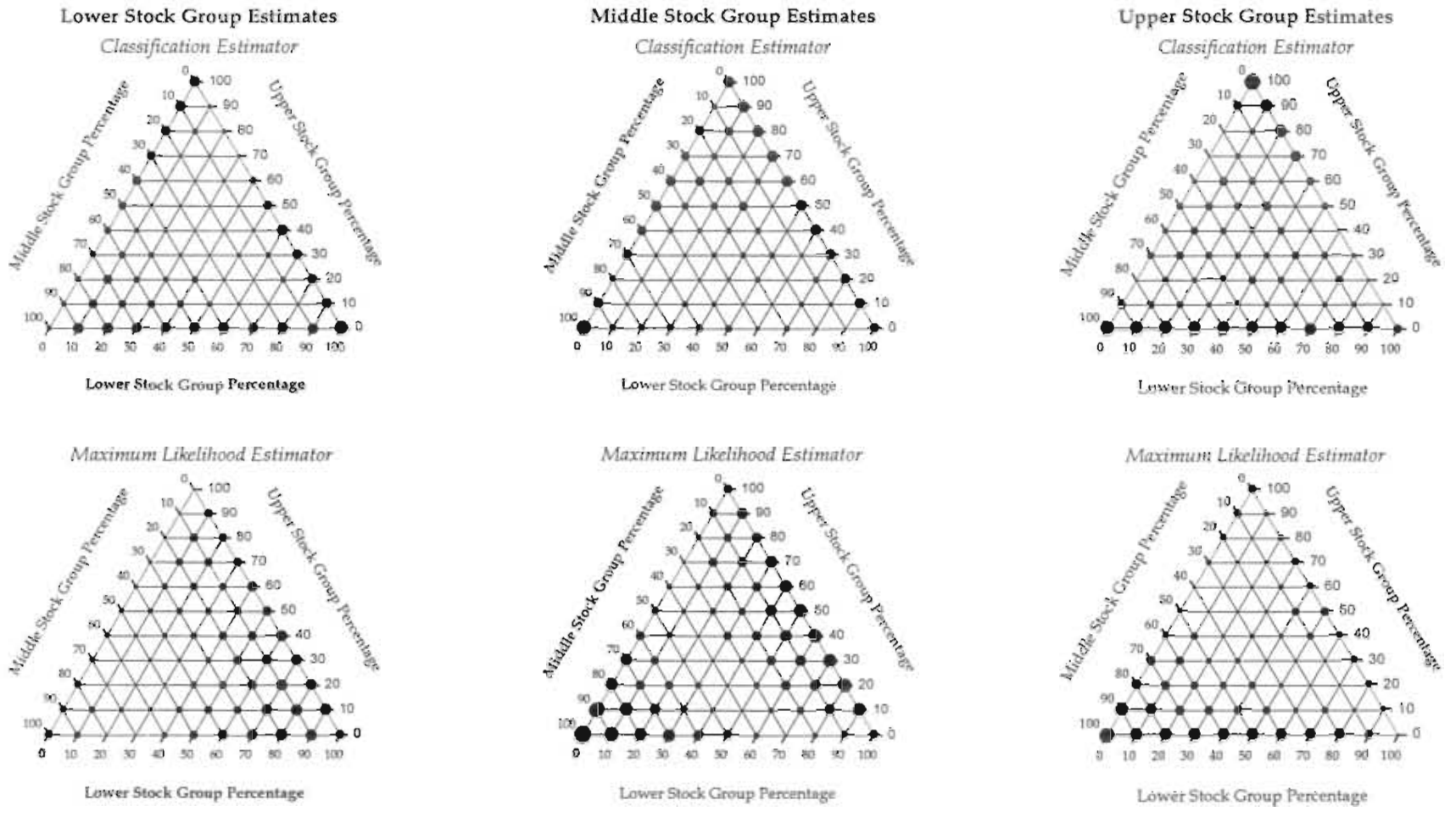

Figure 6. Average absolute bias of classification and maximum likelihood stock composition estimators. Each data point represents the average observed during 500 simulations with the stock mixture defined by each intersection of the three axes. The area of each circle is proportional to average absolute bias. Stock standard data were collected from age 1.4 Yukon River chinook salmon in 1993.

1992 Age 1.3 Yukon River Chinook Salmon - Standard Deviation

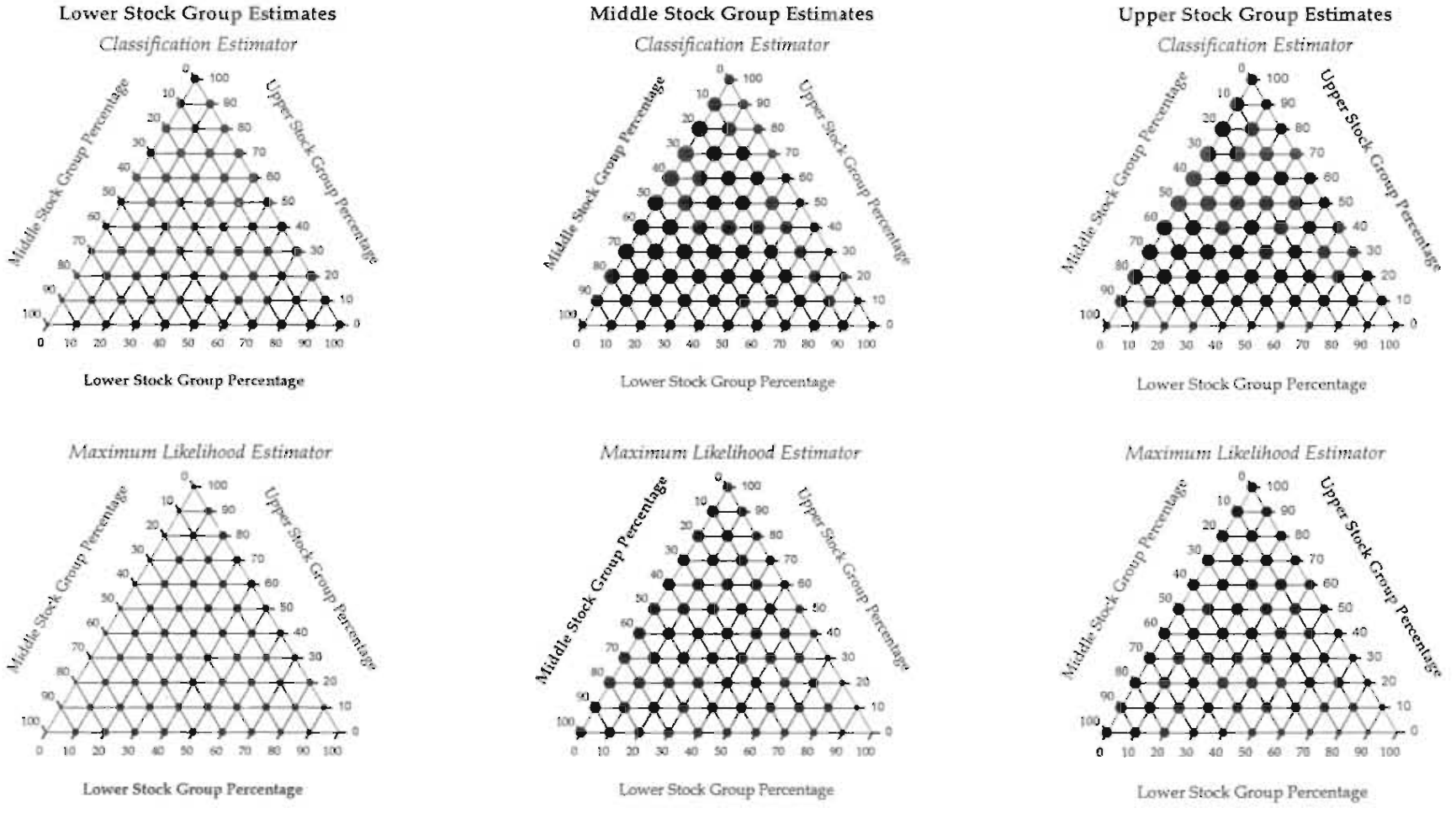

Figure 7. Standard deviation of classification and maximum likelihood stock composition estimators. Each data point represents the standard deviation observed during 500 simulations with the stock mixture defined by each intersection of the three axes. The area of each circle is proportional to standard deviation. Stock standard data were collected from age 1.3 Yukon River chinook salmon in 1992.

1992 Age 1.4 Yukon River Chinook Salmon - Standard Deviation

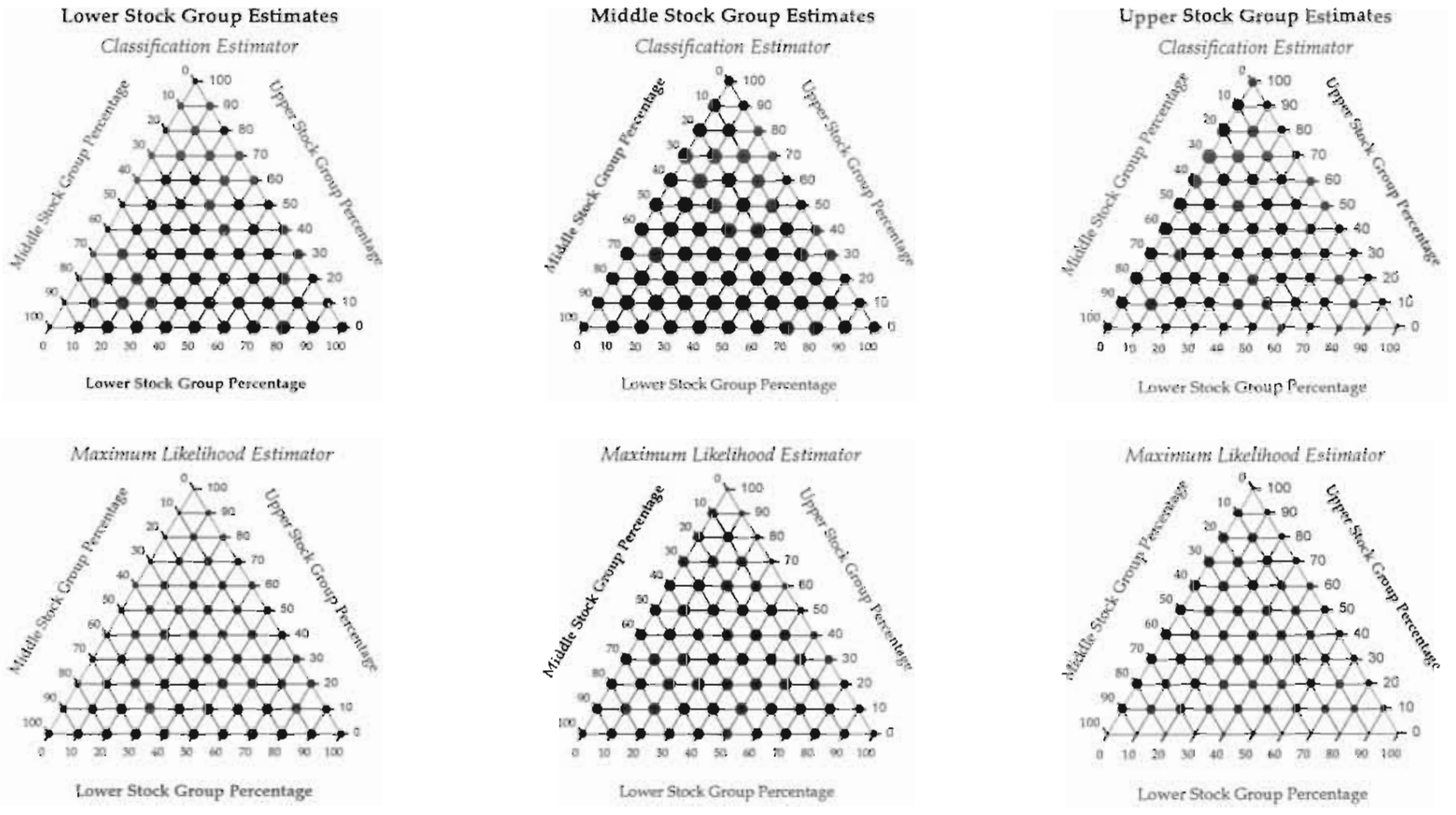

Figure 8. Standard deviation of classification and maximum likelihood stock composition estimators. Each data point represents the standard deviation observed during 500 simulations with the stock mixture defined by each intersection of the three axes. The area of each circle is proportional to standard deviation. Stock standard data were collected from age 1.4 Yukon River chinook salmon in 1992.

1993 Age 1.3 Yukon River Chinook Salmon - Standard Deviation

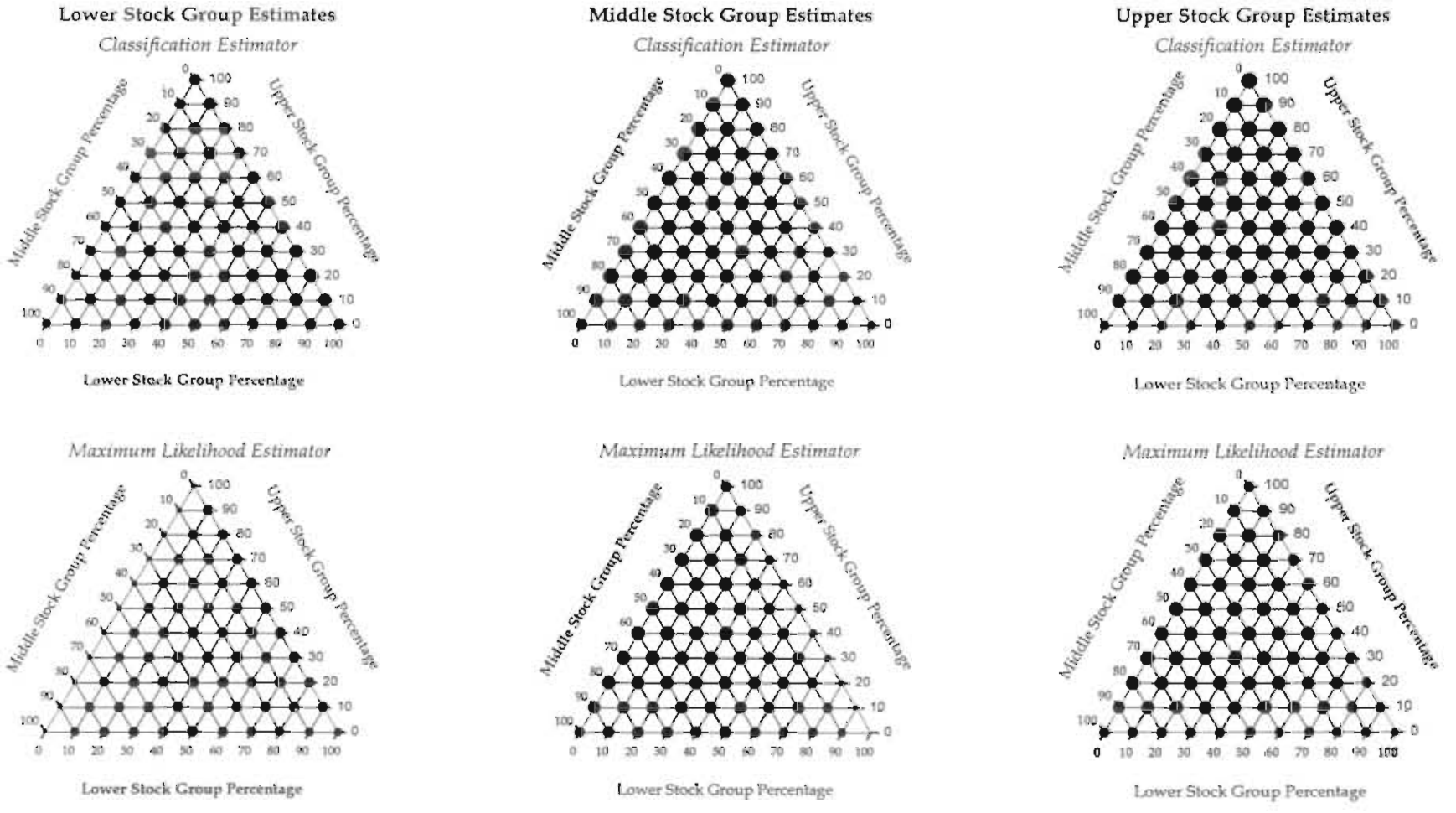

Figure 9. Standard deviation of classification and maximum likelihood stock composition estimators. Each data point represents the standard deviation observed during 500 simulations with the stock mixture defined by each intersection of the three axes. The area of each circle is proportional to standard deviation. Stock standard data were collected from age 1.3 Yukon River chinook salmon in 1993.

1993 Age 1.4 Yukon River Chinook Salmon - Standard Deviation

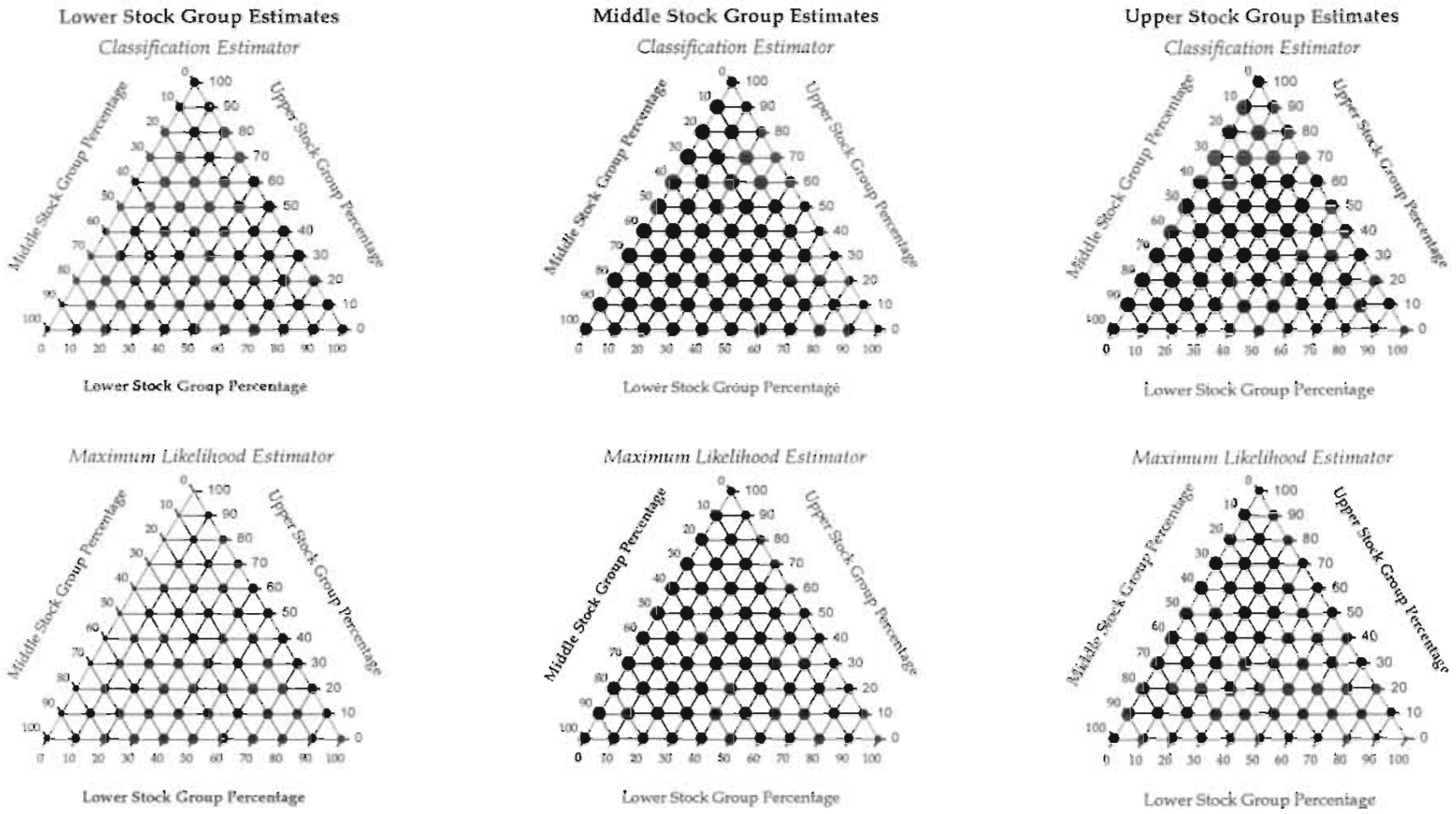

Figure 10. Standard deviation of classification and maximum likelihood stock composition estimators. Each data point represents the standard deviation observed during 500 simulations with the stock mixture defined by each intersection of the three axes. The area of each circle is proportional to standard deviation. Stock standard data were collected from age 1.4 Yukon River chinook salmon in 1993.

1992 Age 1.3 Yukon River Chinook Salmon - Root Mean Squared Error

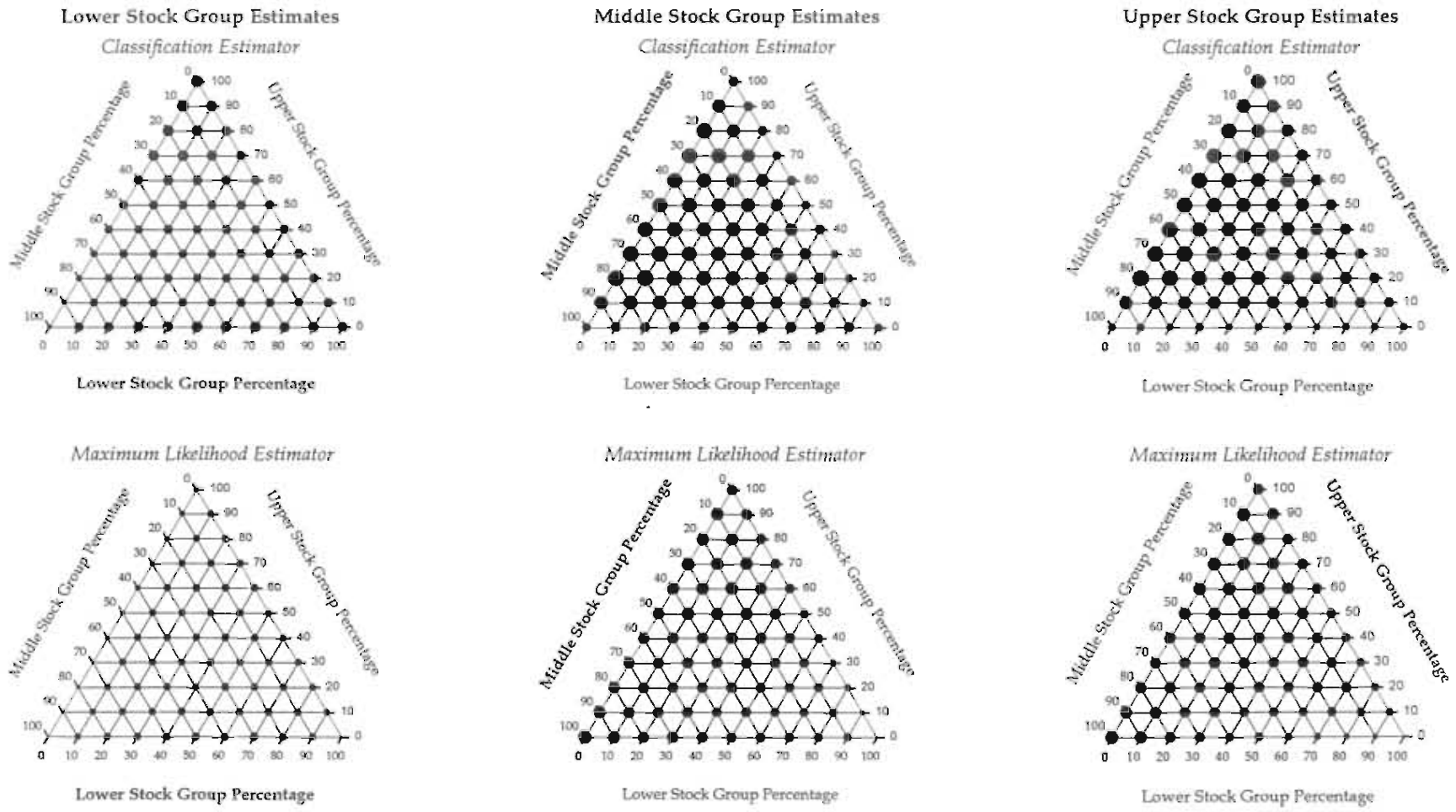

Figure 11. Root mean squared error (RMSE) of classification and maximum likelihood stock composition estimators. Each data point represents the RMSE observed during 500 simulations with the stock mixture defined by each intersection of the three axes. The area of each circle is proportional to RMSE. Stock standard data were collected from age 1.3 Yukon River chinook salmon in 1992.

1992 Age 1.4 Yukon River Chinook Salmon - Root Mean Squared Error

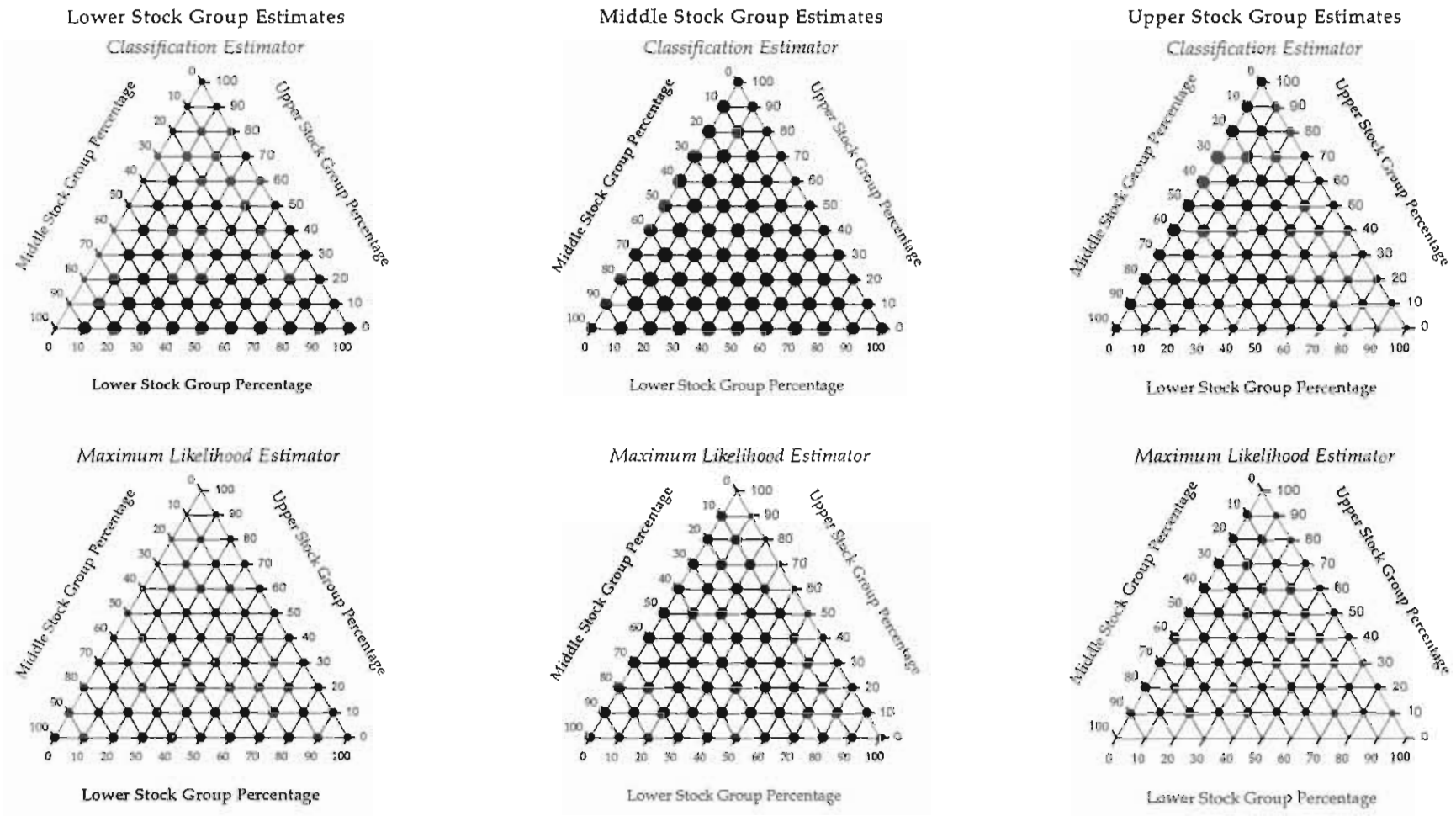

Figure 12. Root mean squared error (RMSE) of classification and maximum likelihood stock composition estimators. Each data point represents the RMSE observed during 500 simulations with the stock mixture defined by each intersection of the three axes. The area of each circle is proportional to RMSE. Stock standard data were collected from age 1.4 Yukon River chinook salmon in 1992.

1993 Age 1.3 Yukon River Chinook Salmon - Root Mean Squared Error

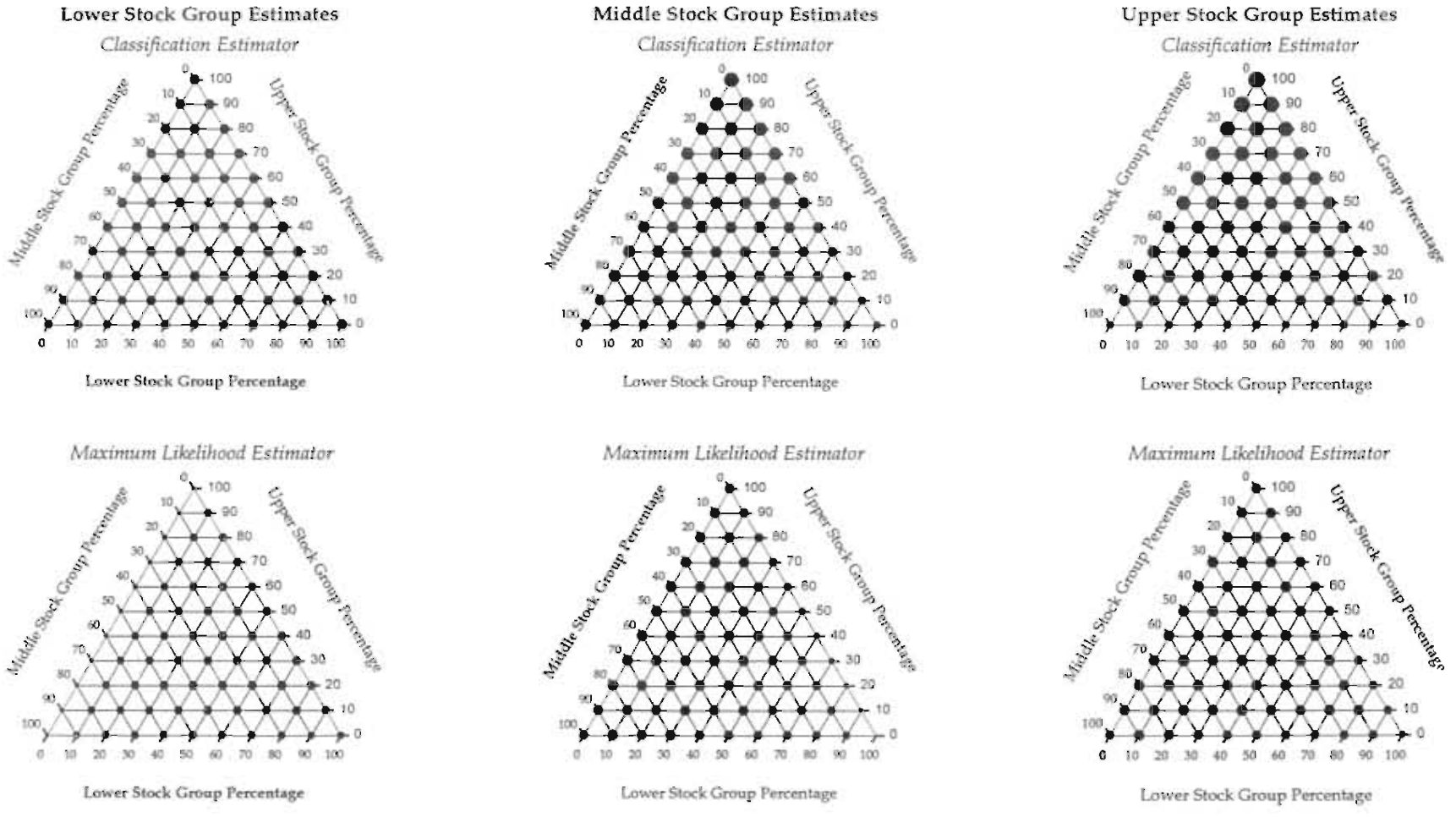

Figure 13. Root mean squared error (RMSE) of classification and maximum likelihood stock composition estimators. Each data point represents the RMSE observed during 500 simulations with the stock mixture defined by each intersection of the three axes. The area of each circle is proportional to RMSE. Stock standard data were collected from age 1.3 Yukon River chinook salmon in 1993.

1993 Age 1.4 Yukon River Chinook Salmon - Root Mean Squared Error

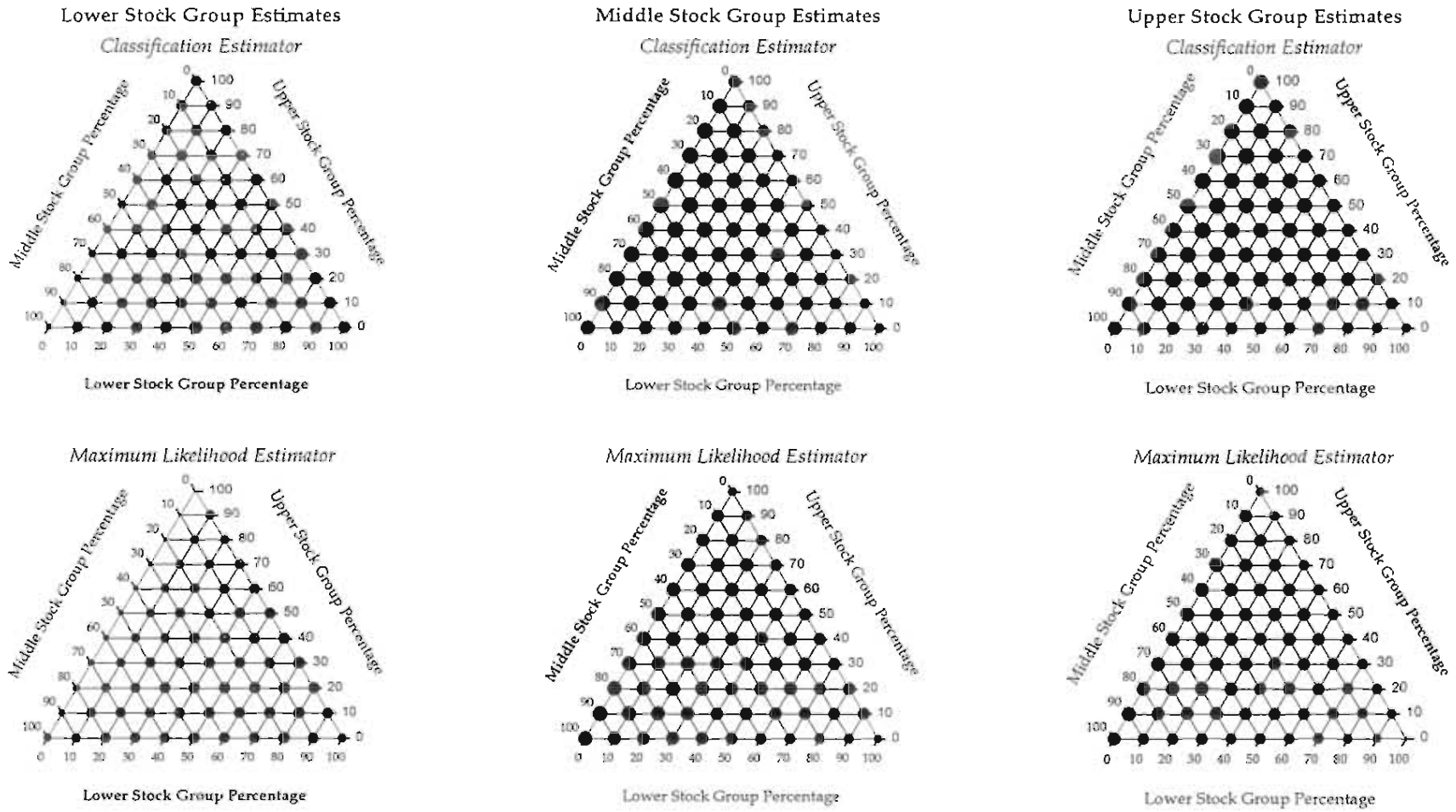

Figure 14. Root mean squared error (RMSE) of classification and maximum likelihood stock composition estimators. Each data point represents the RMSE observed during 500 simulations with the stock mixture defined by each intersection of the three axes. The area of each circle is proportional to RMSE. Stock standard data were collected from age 1.4 Yukon River chinook salmon in 1993.