MEMORANDUM

TO: Council and Board Members

FROM: David Witherell
Fishery Biologist

DATE: January 27, 1998

SUBJECT: Salmon Bycatch Management

ACTION REQUIRED

(a) Status report on salmon bycatch management in groundfish fisheries, and estimation procedures.
(b) Status of Salmon Retention Regulations.
(c) Public testimony on salmon issues.

BACKGROUND

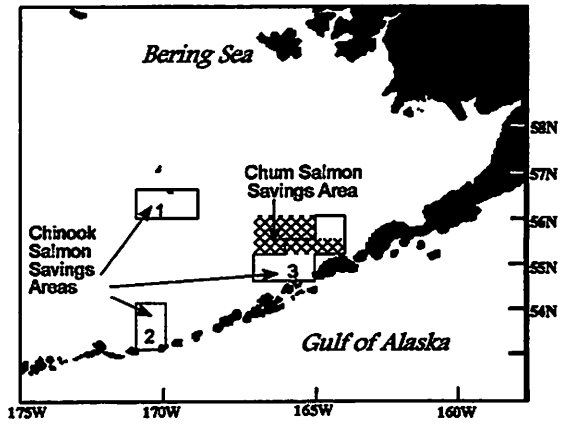
Salmon Bycatch in Groundfish Fisheries

Salmon are caught incidentally in groundfish fisheries. As discussed in the following sections, the Council has adopted many management measures to control this bycatch and reduce the impacts of groundfish fishing on salmon stocks. Bycatch is closely monitored through the fisheries observer program. Salmon bycatch from groundfish trawl fisheries is shown in the adjacent table. Bycatch of salmon in the BSAI has been somewhat variable in recent years. The 1997 bycatch of other salmon in the GOA was very low relative to previous years.

Number of salmon taken as bycatch in BSAI and GOA groundfish trawl fisheries 1993-1997 (preliminary data). Note that >95% of the 'other' salmon is chum salmon.

	Chinook Salmon		Other Salmon	
	BSAI	GOA	BSAI	GOA
1993	45,964	24,465	243,246	56,388
1994	43,636	13,613	94,508	37,226
1995	23,079	14,647	21,780	64,792
1996	63,179	15,761	77,926	4,176
1997	50,587	15,095	67,721	3,416

Time/area closures have been designed to control the bycatch of salmon in groundfish fisheries. The Chum Salmon Savings Area closes to all trawling from August 1 through August 31, and remains closed if a bycatch limit of 42,000 chum salmon is taken in the catcher vessel operational area (CVOA). Trawling is prohibited in the Chinook Salmon Savings Areas upon attainment of a bycatch limit of 48,000 chinook salmon in the BSAI. These areas are shown in the adjacent figure. The Council is currently preparing an analysis to reevaluate the chinook salmon bycatch program.



Salmon Bycatch Estimates and Salmon Retention Program

Prohibited species bycatch, including salmon, is estimated using observed bycatch rates and NMFS estimates of total groundfish catch, which are developed using a blend of observer data and industry reported catch. Although regulations were implemented several years ago that require vessel operators to sort salmon from their catch and retain those salmon until they are counted by a NMFS-certified observer, NMFS does not use these numbers for monitoring bycatch. These regulations were implemented at the request of industry and the North Pacific Fishery Management Council primarily to provide observed counts of salmon to support a voluntary fee collection program instigated by the Salmon Research Foundation. Collected funds were intended to support research on issues associated with salmon bycatch in the Bering Sea trawl fisheries. Subsequent actions by the Council to implement salmon bycatch limits for the Bering Sea trawl fisheries were perceived by the trawl industry to undermine the basic goals and objectives of the Salmon Research Foundation, and the voluntary fee collection was discontinued. However, the regulations requiring retention of salmon until counted by an observer still exist (Salmon Retention Program).

NMFS does not believe that the data collected under the Salmon Retention Program is useful for purposes of monitoring salmon bycatch in the groundfish trawl fisheries and has recommended that this program be discontinued. Estimates of salmon bycatch based on observed salmon bycatch rates and those based on retained counts always differ, with the latter consistently being lower. Because of this downward bias, NMFS prefers to use salmon bycatch estimates based on observed bycatch rates, although concerns do exist that these estimates are associated with high coefficients of variation under current sampling constraints (See attached report by Turnock and Karp, 1997)

NMFS intends to establish a panel of experts, including non-NMFS personnel, to assess current procedures used to collect fishery data and estimate fishery catch and bycatch estimates. The review of catch and bycatch estimation procedures, including those currently used to estimate salmon bycatch, will take time and results may not be available until 1999.

Estimation of Salmon Bycatch in the 1995 Pollock Fishery in the Bering Sea/Aleutian Islands - A Comparison of Methods Based on Observer Sampling and Counts of Salmon Retained by Fishing Vessel and Processing Plant Personnel

by

Jack Turnock and William A. Karp

Alaska Fisheries Science Center
National Marine Fisheries Service
7600 Sand Point Way NE
Seattle, WA 98115

June 3, 1997

Executive Summary

Data from the 1995 BSAI pollock A and B seasons were analyzed to allow comparison of vessel-specific and fleetwide estimates of salmon bycatch.

Data from catcher/processor trawlers, motherships, and shoreside plants were examined separately. Both seasons' data were combined for the shoreside plant analysis.

Five fleetwide estimators were applied. OS was based exclusively on observer samples. ROS utilized observer and industry retention data from observed hauls. RU utilized retention data from unobserved hauls. RO utilized retention data from observer sampled hauls when whole haul sampling did not occur. And OS>0.05 utilized the subset of OS which included within-haul sample fractions greater than .05. Since almost all shoreside plant sampling involved very large within-haul sample fractions, the OS>0.05 estimator was not applied to this data.

Within-haul variance was considered to be zero for all estimators except OS and OS>0.05. For these estimators, within haul variance was estimated by simulating sampling of Poisson-distributed salmon in pollock catches.

Vessel-specific and fleetwide bycatch rate and total bycatch estimates based exclusively on observer data were higher than estimates based on retained counts or observer-sampled data plus retained counts in almost all cases. Variability associated with estimates based exclusively on observer data was higher than for other estimation methods although it was generally lower for OS>0.05 than for OS because of the association between small with-haul sample size and high variance.

Comparison of fleetwide OS and ROS bycatch estimates at different within-haul sample fractions indicated much higher OS-based rates for some comparisons at low within-haul sample fractions. In most cases, however, estimates were similar at sample fractions of 0.2 and greater.

Simulations also indicated rapid decreases in bycatch rate CVs as the within-haul sample fraction increased to 0.2 (and

particularly marked improvement up to 0.02) under a range of between-haul sampling fractions typically employed by observers.

The consistently higher bycatch estimates obtained from exclusively observer data support the argument that independent observer sampling is an essential prerequisite to the collection of objective salmon bycatch data. High levels of uncertainty associated with estimates based on observer sampling is, however, of concern in fisheries were salmon bycatch may be limiting.

Even though observers are able to whole haul sample in some cases, universal recommendations regarding minimum within-haul sample sizes for observers are not currently supportable. This is because factory operating procedures and facilities often preclude taking of large samples and handling of modest sample fractions (0.1 - 0.2) would require observers to physically lift and weigh 10 - 30 t of fish in some cases. Some improvements may be achieved by consultation between NPGOP and industry personnel, assignment of crew members to assist observers, and provision of motion-compensated sampling scales.

Under current constraints, salmon bycatch estimates based on observer samples can be expected to be associated with high CVs. Management measures to control bycatch of salmon (and other infrequently-occurring species) should be designed with this concern in mind. However, current quota and PSC inseason management procedures do not utilize estimation procedures of the type discussed in this report. Rather, they employ *ad hoc* procedures for stratification, expansion, and blending of observer data with industry retained catch reports. Development of quota and PSC management strategies which take into account uncertainty associated with sampling and estimation would be a substantial task.

Continuation of the Salmon Retention Program is not recommended since it provides data which is not useful to NMFS in managing salmon bycatch. Furthermore, estimates based on observer data and those based on retained counts will always differ and may provide a basis for inappropriate arguments regarding the independence of observer sampling.

I. Introduction

Two sources of information are available for estimation of salmon bycatch in the Bering Sea-Aleutian Island (BSAI) groundfish trawl fisheries, observer sampling data and counts of salmon retained by industry personnel. Observer data is collected for all hauls and deliveries sampled by National Marines Fisheries- (NMFS) certified groundfish observers. Observers are present during all fishing days on vessels of 125' and greater length overall (LOA) and during 30% of the fishing days for vessels of 60' - 125' LOA; they sample up to 100% of the hauls taken while they are aboard these trawlers; however, for vessels delivering to shoreside plants, sampling of the whole delivery (consisting of several hauls) may occur at the plant. Federal regulations at 50 CFR '679.218 also require that vessel operators and shoreside plant managers fishing or receiving fish taken in directed BSAI trawl groundfish fisheries not discard salmon taken in these fisheries until they have been enumerated by a NMFS-certified observer. Thus, for observed hauls/deliveries, salmon bycatch can be estimated from observer samples, and for unobserved hauls/deliveries and unsampled portions of observed hauls/deliveries, counts of salmon retained by vessel or plant personnel are available.

The objectives of this analysis are to compare different methods of estimating salmon catch from the BSAI pollock trawl fishery, and to investigate the relationship between the coefficient of variation of the salmon bycatch estimate and within haul and between haul sampling fractions. Salmon bycatch estimates were obtained from observer samples (OS), counts of retained salmon for unobserved hauls (RU), counts of salmon retained from the unobserved portion of observed hauls (RO), and the sum of retained and observer-sampled salmon for observed hauls (ROS). OS, RU, and RO are mutually exclusive data sets but ROS includes data used for the OS and RO estimates. Data from the 1995 BSAI pollock fisheries were used in this analysis. Similar analyses were conducted to allow comparison between observer-sampled and retention-enumerated salmon bycatch estimates for shoreside deliveries of pollock in 1995. These analyses provide the basis for recommendations regarding future sampling and estimation of salmon bycatch in pollock trawl fisheries.

Results of this analysis are useful for comparing different estimation techniques and evaluating the benefits of the salmon retention program. The data sets and techniques used are different from those employed by the NMFS Alaska Region for inseason monitoring of prohibited species bycatch and the bycatch estimates are, therefore, different from those published by the Alaska Region.

II. Methods

Estimation of salmon bycatch and variance

Observer sampling is a three-stage process(Cochran 1977). The first stage is the vessel, the second the haul, and the third the sample within the haul. Most pollock trawlers in the BSAI require 100% observer coverage, so variance associated with the first stage is essentially zero; the sampling process can, therefore, be regarded as two-stage.

To draw inferences from the data, variances or confidence intervals must be estimated. Even though several discrete samples may be taken by observers from individual hauls, however, data are recorded as if only one sample is taken from each haul. Therefore, within-haul variances cannot be estimated directly and total variance cannot be determined for statistics based exclusively on observer sampling. An assumption regarding the distribution of salmon within hauls must be made to estimate the variance of salmon bycatch estimates by haul, vessel, and fishery. A range of possible distributions exists, from regular, (i.e. a constant number of salmon per unit weight of catch sampled) to clumped, where all salmon in the haul occur in a single aggregation which may be completely included in or excluded from the sample. For the purposes of this study, an assumption that salmon are randomly distributed within a haul has been made. However, within haul variance is assumed to be zero for the retained estimates of salmon for unobserved hauls (RU) and the retained plus observer estimate for observed hauls (ROS). Since vessel coverage is 100%, the only source of variability in the RU and ROS estimates is between hauls and depends on the fraction of hauls sampled within vessels.

Estimation of coefficient of variation by within-haul sample haul fraction

Since within-haul variance cannot be determined directly from observer data, a simulation model was developed. Observer data from whole-haul samples were used for this exercise because the total numbers of salmon per haul were known and sampling at different within-haul fractions of the catch could be simulated using the actual data. Based on the assumption that salmon were distributed randomly within each haul, sampling was simulated by drawing random numbers from a Poisson distribution with mean (and variance) equal to the sample fraction times the number of salmon occurring in the haul. The total number of whole-haul sampled hauls was resampled without replacement to obtain various fractions of hauls sampled. The simulation was carried out 100 times, and the mean and variance of the number of salmon per haul was calculated for each run.

Estimation of mean number of salmon per haul by vessel

The mean number of salmon per haul for each vessel and the 95% confidence interval were estimated to allow comparison of the results of the different sampling strategies. The distribution of salmon within hauls was assumed to be random as previously discussed. A bootstrap method for finite populations (Booth, Butler and Hall 1994) was employed to estimate means and confidence intervals by resampling observed hauls, and within those hauls, by sampling from a Poisson distribution with mean equal to the number of salmon in the sample. The bootstrap was done 1000 times and the percentile method was used to estimate the 95% C.I., using the 25th lowest value as the lower bound and the 976th value as the upper bound (Efron and Tibshirani 1993).

Estimates of 95% confidence intervals of the number of salmon per haul for retained counts from unobserved hauls (RU) and retained plus observed counts for observed hauls (ROS) (see below) contain only the variance associated with between hauls, since the number of salmon recorded is assumed to be the total in the haul and therefore has zero variance.

The data were analyzed by season (BSAI pollock A Season (January through March) and B Season(August through October)) and vessel type (motherships and catcher/processors).

Estimation of fleetwide salmon bycatch

The fleetwide total salmon bycatch was estimated by multiplying the mean number of salmon per haul by the total number of hauls within vessels and then summing for all vessels. A bootstrap was used to estimate the total and the 95% confidence interval as previously described. Five estimates were made, one from expanding the observed sample (OS), the second from the retained catch from unobserved hauls(RU), the third from the sum of the retained and observer sample from observed hauls,(ROS), the fourth from salmon retained from the unobserved portion of observed hauls (RO), and the fifth from observed data where the sampling fraction was greater than OS>0.05.

In order to estimate the total number of salmon caught by season and vessel type, the overall estimated mean number of salmon per haul in each of processor/season stratum was substituted as the mean number of salmon per haul for vessels with less than five hauls.

III. Results

Distribution of within-haul sample fraction

The number of hauls sampled and the within haul sample fractions varied by vessel(Table 1). There were 9,203 total hauls of which 6,159 were sampled. Although the fraction of hauls sampled varied by vessel from about 17% to 100%, it was 50% or greater for all but 5 of the 67 vessel/season data sets. Hauls with (within-haul) sample fractions of less than 0.1 made up about 37% of all hauls sampled(Figure 1). The sampled fraction was less than 0.05 for approximately 32% of all sampled hauls. For approximately 35% of the hauls sampled, the sample size was less than 5 t (Figure 2). Thirty-one percent and twenty-eight percent of the

hauls had sample weights less than 1 t and 0.5 t, respectively. Observers are required to sample a minimum of 0.3 t of catch. In many cases this is the maximum practicable sample size.

Estimated salmon bycatch rates by sample fraction, vessel type, and season

Comparison of mean salmon bycatch rates by within-haul sample fraction indicates that, in most cases, OS rates are higher than ROS rates for mothership and catcher/processors in both seasons(Figure 3). In general, salmon bycatch rates were lower in the A season (principally chinook salmon) than the B season (principally chum) and higher for motherships than catcher/processors. OS was generally markedly higher than ROS at low sampling fractions and the estimates become closer as sampling fractions increased. Large differences at low sampling fractions could be caused by rare large observations influencing the mean to a substantial degree.

Coefficient of variation and variance of estimated mean numbers of salmon per haul by within-haul sample fraction

The CV of the mean salmon bycatch rate declined markedly as the proportion of hauls sampled increased (Figures 4 a and b). At a between-haul fraction of 0.7, which is close to the fraction achieved by many observers, the CV decreased from approximately 0.2 to 0.1 as the within-haul fraction increased from less than 0.1 to approximately 0.2(Figure 4b). As the within-haul sample fraction increased from 0.0025 to 0.05, the CV declined from about 8 to 0.5 (Figure 4a). At low within-haul sample fractions (less than 0.05), changes in the between-haul sample fraction had little effect. The relationship between within-haul and between-haul variance components can be used to evaluate the impact on overall variance of alternative sampling strategies(Figure 5). For example, a larger decrease in CV can be obtained by increasing the within-haul sample fraction from 0.1 to 0.2 than can be obtained by increasing the between-haul fraction over the same range. However, practical considerations, such as vessel/factory layout and the quantity of fish which must be handled by observers must be taken into account when

considering such alternatives. For a 100 t haul, increasing the sample fraction from 0.1 to 0.2 would result in a doubling of the quantity of fish handled by the observer, from 10 t to 20 t. It is generally impossible for observers to handle samples of this magnitude.

Estimates of mean numbers of salmon per haul by vessel

Estimates of mean numbers of salmon per haul vary markedly by vessel (Figures 6 and 7). OS estimates were generally higher and confidence intervals were generally broader because within-haul variance was included in the computations. Confidence intervals for catcher/processors were generally greater than for motherships. RU estimates are generally lower than OS and ROS estimates. In the B Season data, only one haul was unobserved aboard vessel 35 but 18 salmon were retained from that haul; therefore the RU estimate for that vessel is considerably higher than the estimate obtained using the other methods.

Comparison of fleetwide estimates by season and vessel type

Estimates based on observer data were greater than estimates based on retained salmon for all vessel/season categories. In one case, however (motherships, A season), the OS estimate for sample fractions greater than 0.05 (OS>.05) was higher than the OS estimate based on data from all hauls (Table 2 and Figures 8 and 9). The RO estimate was lowest in all cases except B season catcher/processors where the RU estimate was lowest. Confidence intervals for the OS and RU estimates and the OS and RO estimates did not overlap for either season or vessel type. The largest difference between the OS estimate and the OS>0.05 estimate occurred in the catcher processor data set for the B season because it contained many hauls with small sample fractions. For motherships in the B season the OS, OS>0.05 and ROS estimates were similar because observers generally sampled larger fractions.

Further examination of the A season motherships data (in which the OS>0.05 estimate was greater than the OS estimate) revealed that all but one of the hauls with sample fractions less than 0.05 contained no salmon. Elimination of data from hauls with samples containing zero salmon resulted in an increase in the

estimate of the salmon bycatch. This illustrates the influence that small sampling fractions can have on estimates of bycatch quantity and variance when sampling rare events. Small numbers of salmon in small samples may result in large bycatch estimates, conversely, small sample fractions may result in salmon being missed with consequent underestimation if salmon are present in the catch. If a few samples where the sample fraction was small contain many salmon, a high estimate with high variance may result.

Estimates of salmon bycatch from deliveries to shoreside plants

The OS estimate of the total number of salmon (A and B seasons combined) from for shoreside deliveries in 1995 was 6,728, with a 95% CI of 5,980 - 7,477 (Figure 10). Five hundred out of a total of 893 deliveries were sampled. The RU estimate was 4,717 (95% CI, 4,186 - 5,248). The ROS estimate was 6,656 (95% CI 5,910 - 7,402). Within-delivery sampling fractions ranged from 0.15 to 1.0, however, 448 of 500 deliveries sampled had a sample fraction of 1.0. The RO estimate was 593 (95% CI, 167 - 1,018). Since only 52 of the 500 observed deliveries had sample fractions less than 1.0, and most of those had large sample fractions, the data set for the RO estimate was very sparse.

IV. Discussion and Recommendations

This analysis indicates that salmon bycatch estimates based exclusively on observer data are generally higher than those obtained using retained counts or a mixture of observer data and retained counts.. This pattern is apparent in both vessel-specific and fleetwide estimates. Fleetwide estimates based on observer and retained data were also consistently higher than those based exclusively on retained data. Differences between observer sample-based and other fleetwide estimates was greater for motherships and catcher/processors than shoreside plants. Working conditions are confined in fish processing plants, especially at sea, and industry personnel may find it difficult to keep track of salmon while maintaining demanding production responsibilities. The importance of independent, objective sampling by observers is, therefore, apparent.

The results also indicate high variances associated with estimates based exclusively upon observer data, especially when a high proportion of observer sample sizes are relatively small. Recall, however, that only the OS estimation process considered within-haul variance; it was assumed that all salmon within a haul were counted under the alternative schemes. However, the Poisson within-haul distribution assumption for the OS estimates likely resulted in unrealistically low estimates of within-haul variance. Regardless of these limitations, it is clear that observer sample size is of concern, especially if vessel-specific estimates are desired. A requirement that observers sample a minimum fraction of each observed haul would reduce estimated variances. This study suggests that a minimum sample fraction of .10 is required for fleetwide estimates and .20 for vessel-specific estimates. Under current operating conditions; these goals are not achievable in all situations.

Whole haul sampling for salmon can be accomplished by some observers aboard some vessels. To accommodate whole haul sampling, fish must flow slowly past the point of sampling and must not be so deep that salmon are hidden. Furthermore, the observer's sampling duties must allow him/her to monitor the whole catch. This may take several hours for large hauls. Taking large partial hauls may be even more difficult. The partial haul must be weighed to allow extrapolation from sample to haul and, in many cases, this can be achieved only by the observer placing the sample in 50 kg baskets and weighing them individually. The minimum recommended basket sample is 350 kg; this requires a lot of physical work on the part of the observer and yet the sample fraction may be quite small, especially in fisheries where 100 - 150 t hauls are not uncommon. In such situations, partial samples of 10 -15 t (fleetwide) and 20 - 30 t (vessel-specific) would be required to meet the criteria defined above. Under current working conditions, this is not realistic. Substantial changes in operating procedures would be required aboard many vessels including, in some cases, installation of flow scales and improved observer workstations, and provision of additional observers. More modest improvements, including assignment of vessel personnel to assist observers in handling and weighing samples, and installation of motion compensated sampling scales may provide for some modest improvements in sample sizes and associated reductions of salmon bycatch estimate

CVs . NPGOP and industry personnel should work together to identify alternatives to traditional sampling methods. Research to correctly characterize within-haul sampling variance should also be conducted.

Under current constraints, salmon bycatch estimates based on observer samples can be expected to be associated with high CVs. Management measures to control bycatch of salmon (and other infrequently-occurring species) should be designed with this concern in mind. However, current quota and PSC inseason management procedures do not utilize estimation procedures of the type discussed in this report. Rather, they employ *ad hoc* procedures for stratification, expansion, and blending of observer data with industry retained catch reports. Development of quota and PSC management strategies which take into account uncertainty associated with sampling and estimation would be a substantial task.

Continuation of the Salmon Retention Program is not recommended since it provides data which is not useful to NMFS in managing salmon bycatch. Furthermore, estimates based on observer data and those based on retained counts will always differ and may provide a basis for inappropriate arguments regarding the independence of observer sampling.

V. Literature Cited

Booth, J.G., R.W. Butler and P. Hall. 1994. Bootstrap methods for finite populations. Journal of the American Statistical Association 89, 1282-1289.

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Table 1a. Number of observed and unobserved hauls by vessel and within-haul sampling fraction for the 1995 BSAI pollock A season.

Vessel Type	Vessel Number*	Number of Hauls by Within - Haul Sample Fraction				Number of Hauls Unobserved	Proportion of Hauls Sampled
		0-0.05	0.05-0.3	0.3-0.99	1.00		
CP	1	48	65	19	4	3	0.98
MS	2	4	14	263	37	95	0.77
CP	3	18	1	0	0	16	0.54
CP	4	38	1	0	0	15	0.72
CP	5	0	24	12	0	0	1.00
CP	6	0	0	29	72	5	0.95
CP	7	34	1	0	0	18	0.66
CP	8	36	10	2	1	22	0.69
CP	9	3	44	26	0	14	0.84
CP	10	32	0	1	0	23	0.59
CP	11	20	35	0	0	29	0.65
CP	12	36	42	23	0	35	0.74
CP	13	48	0	0	0	18	0.73
CP	14	2	3	47	102	11	0.93
CP	15	0	30	16	0	23	0.67
CP	16	57	15	52	1	34	0.79
MS	17	0	0	0	14	1	0.93
CP	18	7	45	9	0	25	0.71
CP	19	42	1	41	15	12	0.89
CP	20	19	27	56	12	46	0.71
CP	21	17	5	0	0	76	0.22
CP	22	14	1	12	6	36	0.48
CP	23	14	57	1	0	47	0.61
CP	24	83	0	0	0	43	0.66
MS	25	75	0	0	1	360	0.17
CP	26	6	45	1	1	24	0.69
CP	27	11	45	1	0	40	0.59
CP	28	1	60	24	0	45	0.65
CP	29	125	0	0	0	13	0.91
CP	30	42	0	0	0	56	0.43
CP	31	5	45	41	1	48	0.66
MS	32	0	49	40	10	96	0.51

* Vessel numbers are arbitrary and cannot be compared between season A and B.

Table 1b. Number of observed and unobserved hauls by vessel and within-haul sampling fraction for 1995 BSAI pollock B season.

Vessel Type	Vessel Number	Number of Hauls by Within - Haul Sample Fraction				Number of Hauls Unobserved	Proportion of Hauls Sampled
		0-0.05	0.05-0.3	0.3-0.99	1.00		
CP	1	0	3	31	49	43	0.66
MS	2	0	30	160	32	90	0.71
CP	3	59	1	0	12	55	0.57
CP	4	40	6	0	0	18	0.72
CP	5	31	8	10	12	54	0.53
CP	6	5	11	77	32	7	0.95
CP	7	53	8	1	0	36	0.63
CP	8	9	2	0	0	4	0.73
CP	9	60	0	18	68	15	0.91
CP	10	9	46	5	8	58	0.54
CP	11	2	27	41	6	28	0.73
CP	12	1	58	12	0	35	0.67
CP	13	4	32	2	43	39	0.68
CP	14	58	3	2	3	63	0.51
CP	15	10	59	20	2	45	0.67
CP	16	77	1	0	0	54	0.59
CP	17	35	1	32	21	50	0.64
MS	18	1	38	22	2	63	0.50
CP	19	38	5	2	41	61	0.59
CP	20	80	3	11	17	52	0.68
CP	21	52	39	3	1	51	0.65
CP	22	133	1	0	0	2	0.99
CP	23	4	42	17	11	70	0.51
CP	24	94	2	0	1	53	0.65
CP	25	7	58	29	11	53	0.66
CP	26	2	76	1	1	86	0.48
CP	27	84	0	8	33	45	0.74
MS	28	10	0	0	283	203	0.59
CP	29	0	17	53	16	43	0.67
CP	30	0	75	29	0	43	0.71
CP	31	2	74	33	4	27	0.81
CP	32	97	0	0	1	47	0.68
CP	33	72	2	0	4	98	0.44
CP	34	3	113	12	2	21	0.86
MS	35	1	0	0	318	1	1.00

* Vessel numbers are arbitrary and cannot be compared between season A and B.

Table 2. Estimated total catch of salmon by season and processor type.

Estimation Method	Total Number of Salmon	95% Confidence Interval	CV
A Season			
Catcher/processor			
Observer	3,351	1,982 - 5,210	0.241
Observer + Retained	1,490	1,412 - 1,569	0.026
Retained unobs	1,152	792 - 1,540	0.162
Retained obs	1,065	977 - 1,152	0.041
Observer sample fraction>.05	3,010	2,510 - 3,536	0.085
Mothership			
Observer	1,022	768 - 1,377	0.149
Observer + Retained	485	427 - 544	0.060
Retained unobs	340	188 - 506	0.234
Retained obs	158	112 - 203	0.144
Observer sample fraction >.05	1,477	1,252 - 1,721	0.079
B Season			
Catcher/processor			
Observer	6,512	4,069 - 9,174	0.196
Observer + Retained	3,479	3,026 - 3,865	0.060
Retained unobs	1,646	1,084 - 2,241	0.176
Retained obs	2,519	2,035 - 2,964	0.092
Observer sample fraction >.05	4,352	3,704 - 4,976	0.073
Mothership			
Observer	4,077	3,454 - 4,736	0.079
Observer + Retained	3,614	3,140 - 4,066	0.064
Retained unobs	1,228	890 - 1,559	0.136
Retained obs	289	197 - 372	0.151
Observer sample fraction >.05	4,012	3,507 - 4,514	0.063

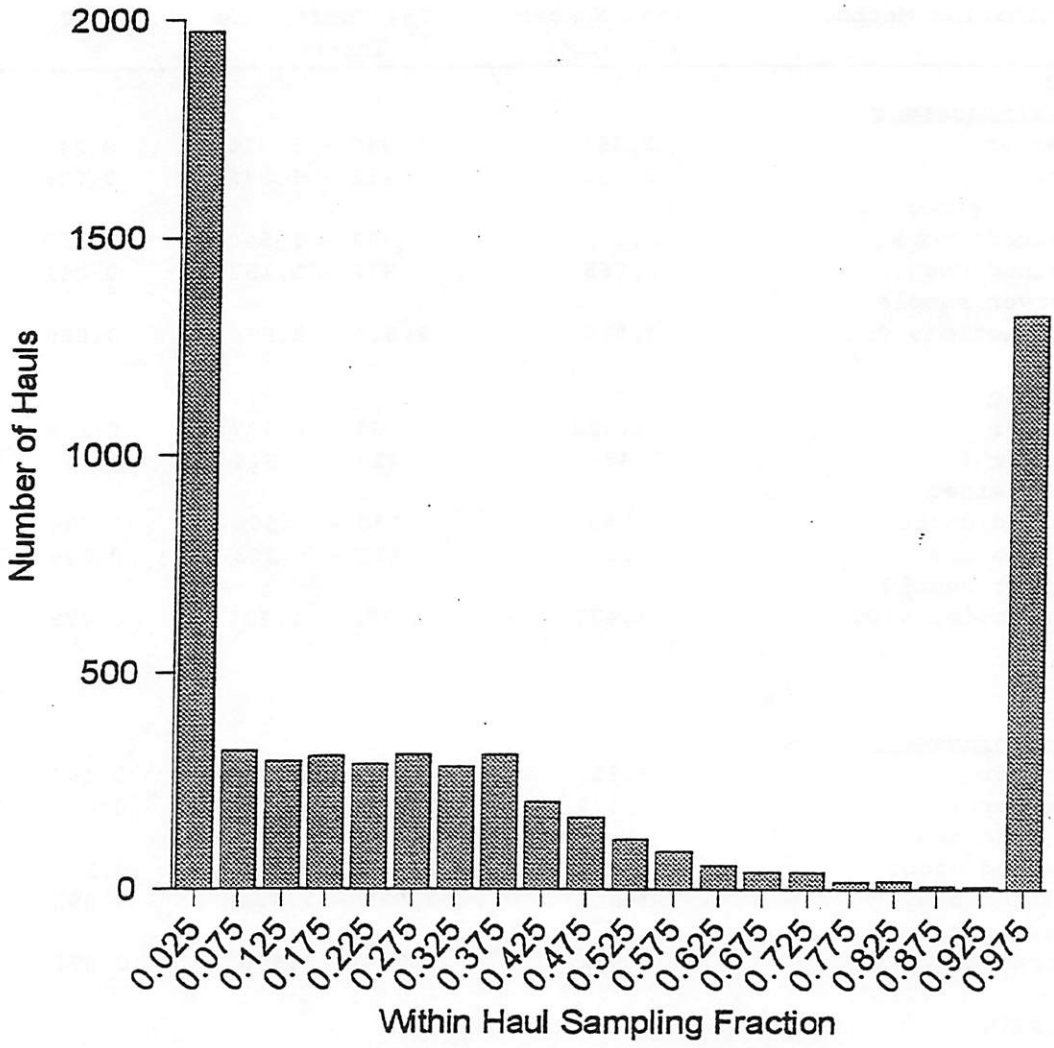

Figure 1. Distribution of within-haul sample fractions for all sampled hauls.

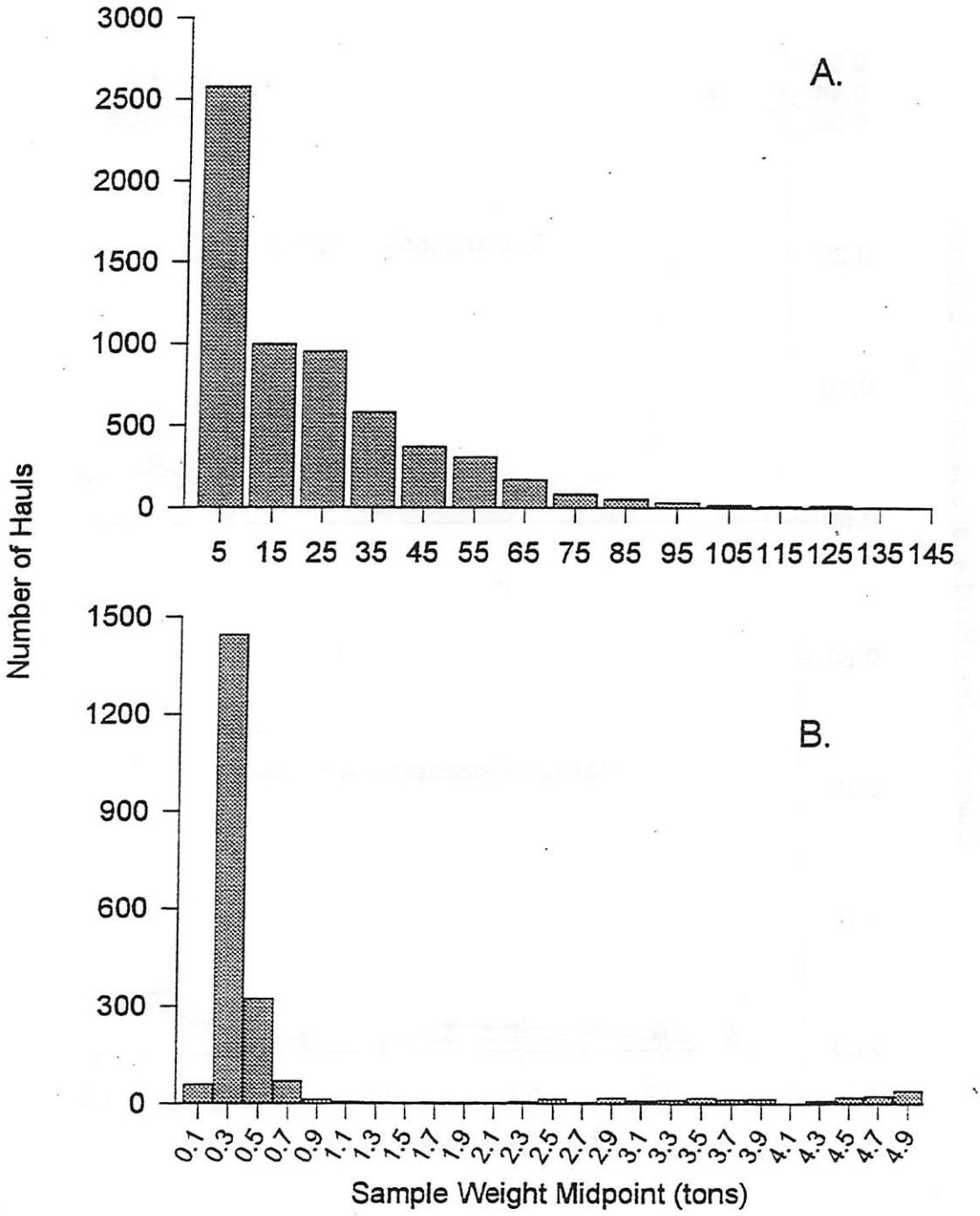

Figure 2. (A.) Distribution of within haul sample weights for all sampled hauls. (B.) Distribution of within haul sample weights between 0.1 and 5 tons.

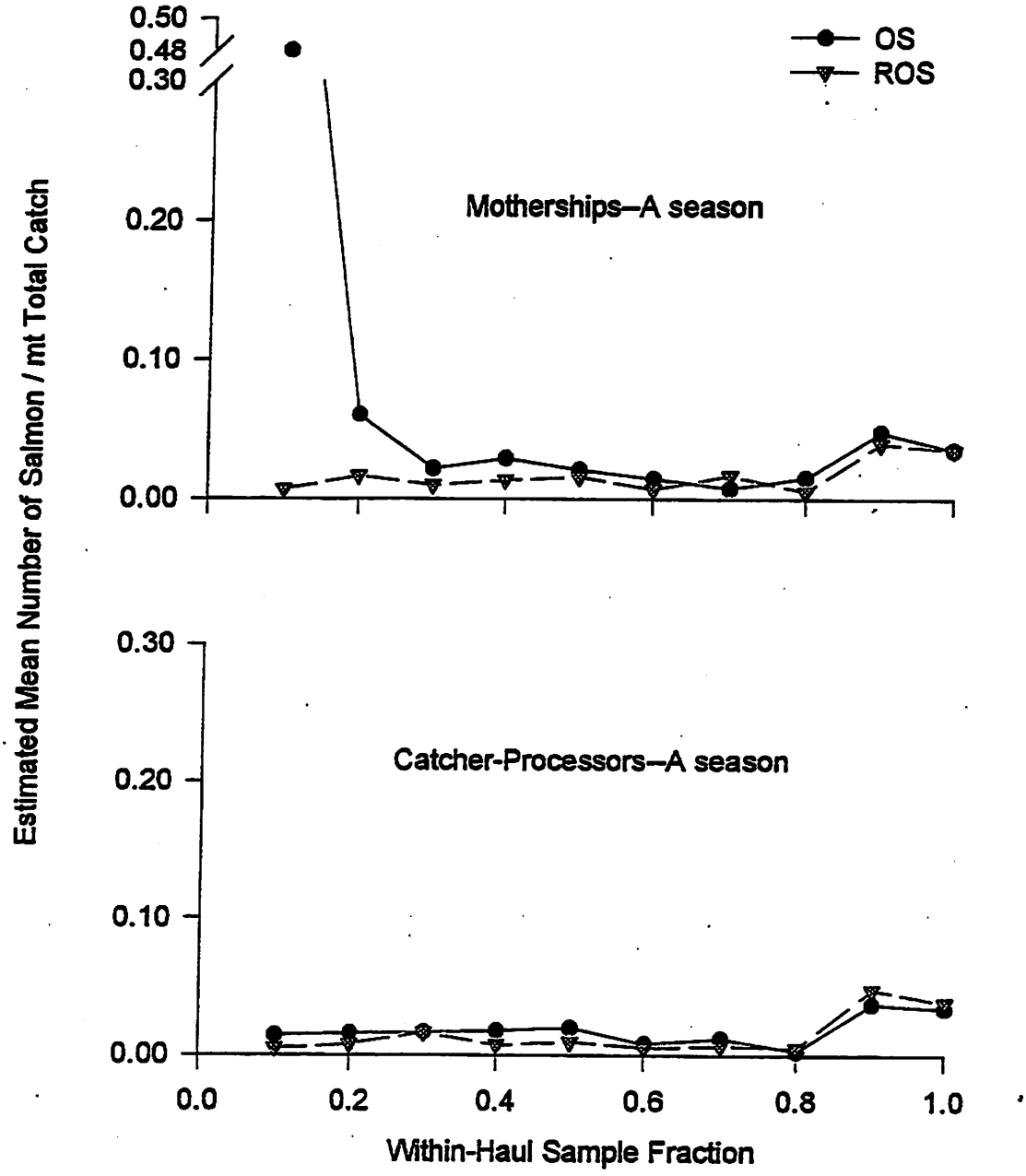

Figure 3. Comparison of estimated mean salmon bycatch rates over increasing within-haul sample fractions. Estimates are from observer samples (OS) and retained plus observer data (ROS) for observed hauls.

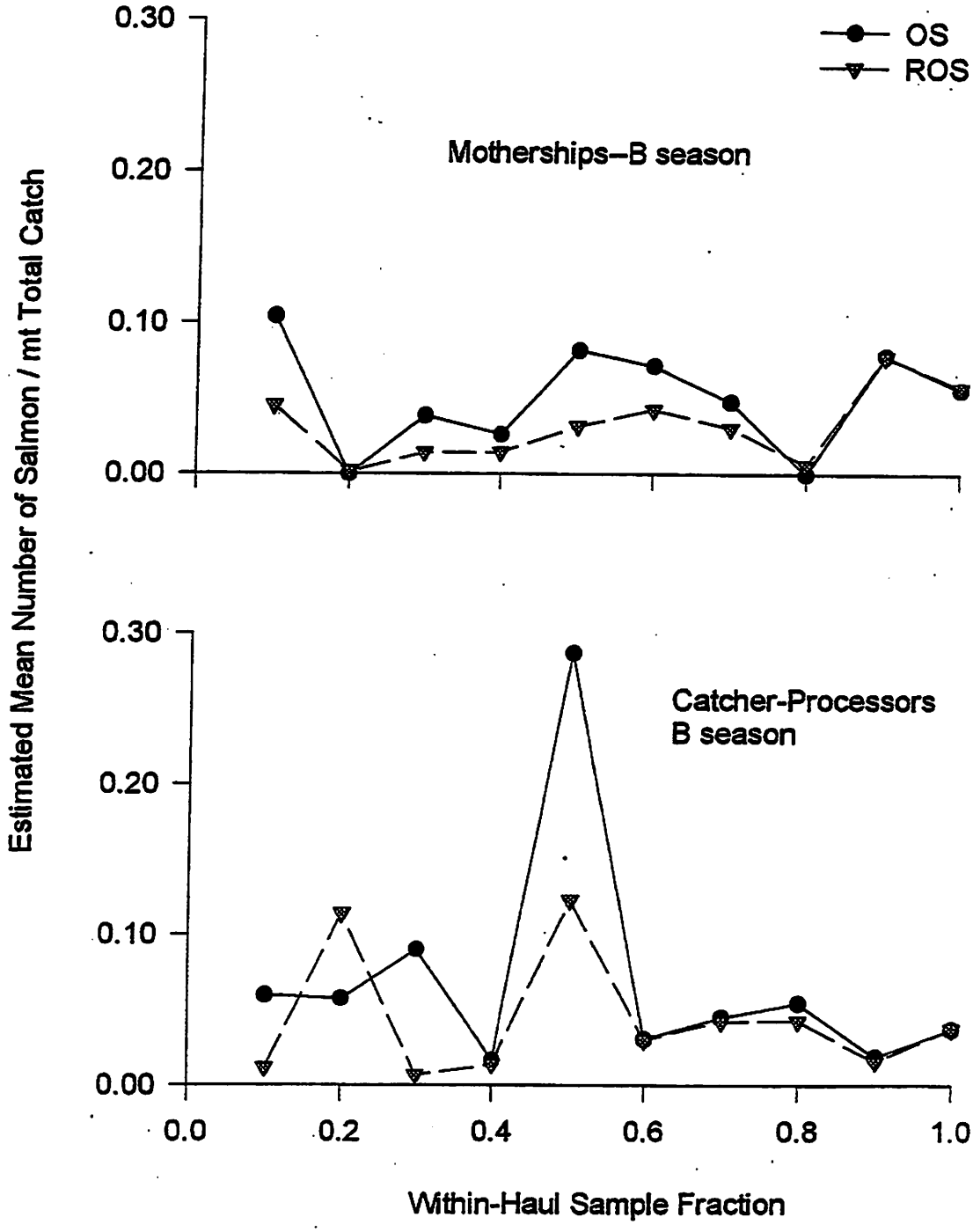

Figure 3, continued. Comparison of estimated mean salmon bycatch rates over increasing within-haul sample fractions. Estimates are from observer samples (OS) and retained plus observer data (ROS) for observed hauls.

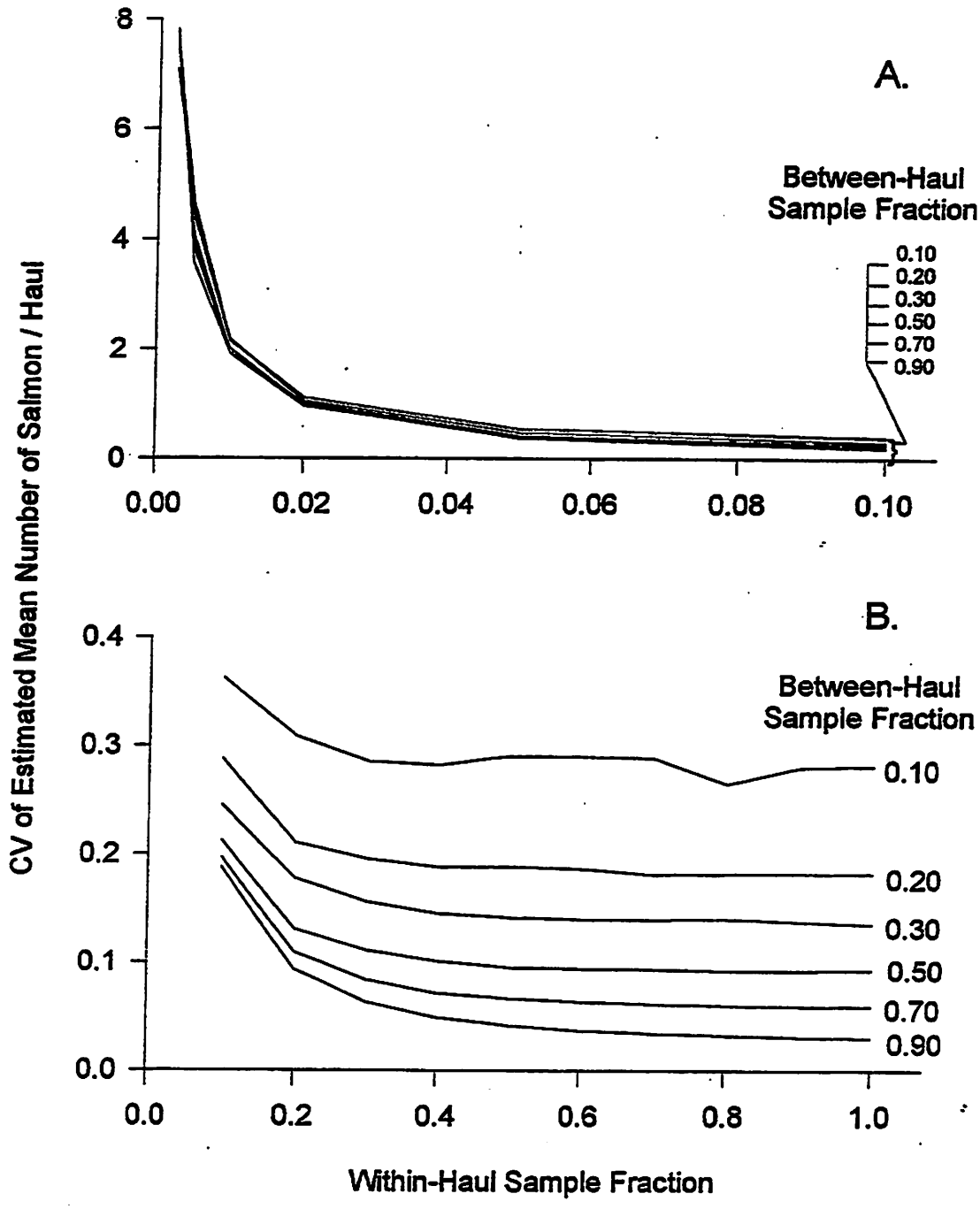

Figure 4. CV of estimated mean number of salmon per haul for different between-haul sample fractions over within-haul sample fractions (A.) 0.0025 to 0.1, and (B.) 0.1 to 1.0.

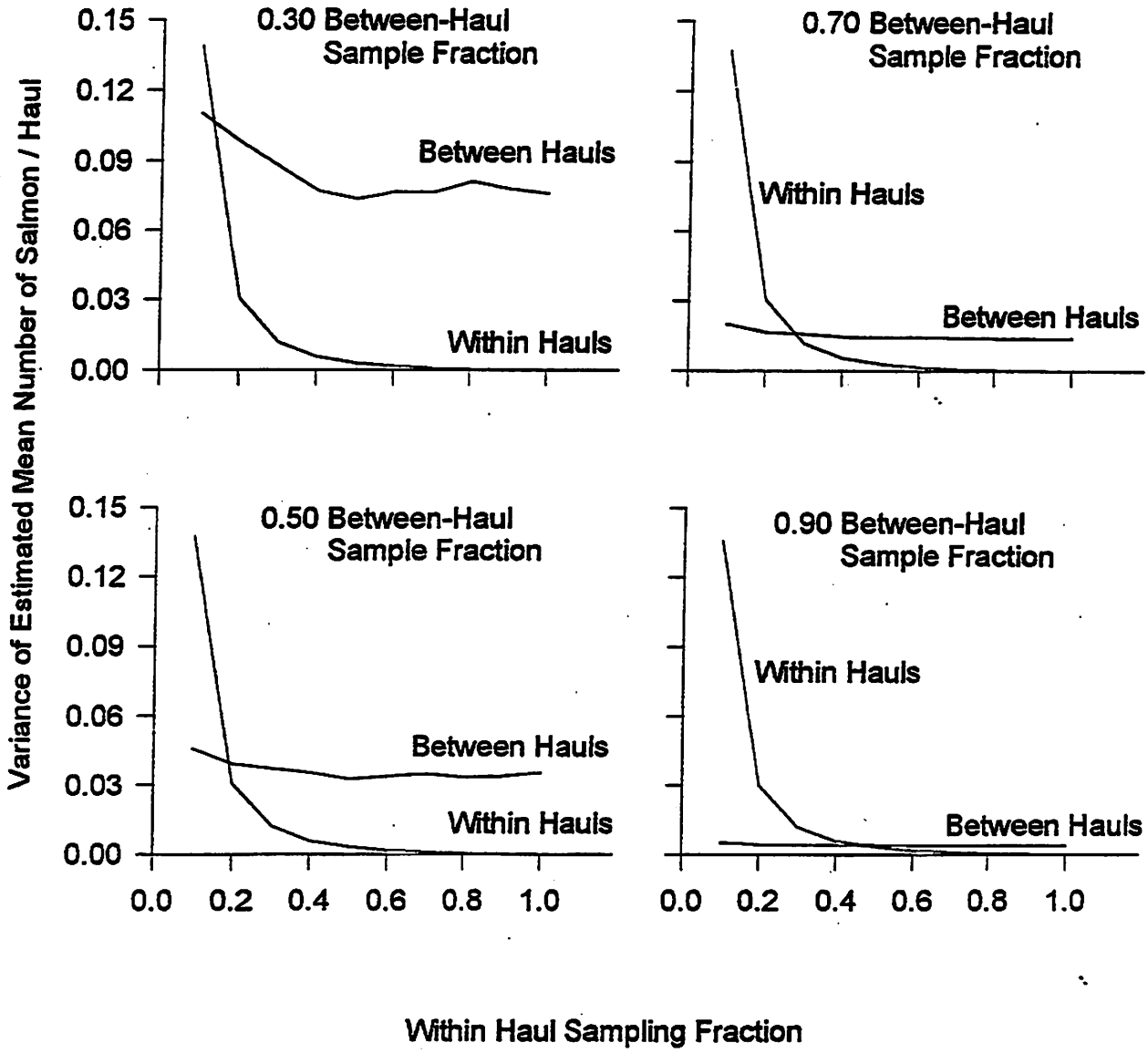

Figure 5. Variance between and within hauls of the estimated mean number of salmon per haul for different between- and within-haul sampling fractions.

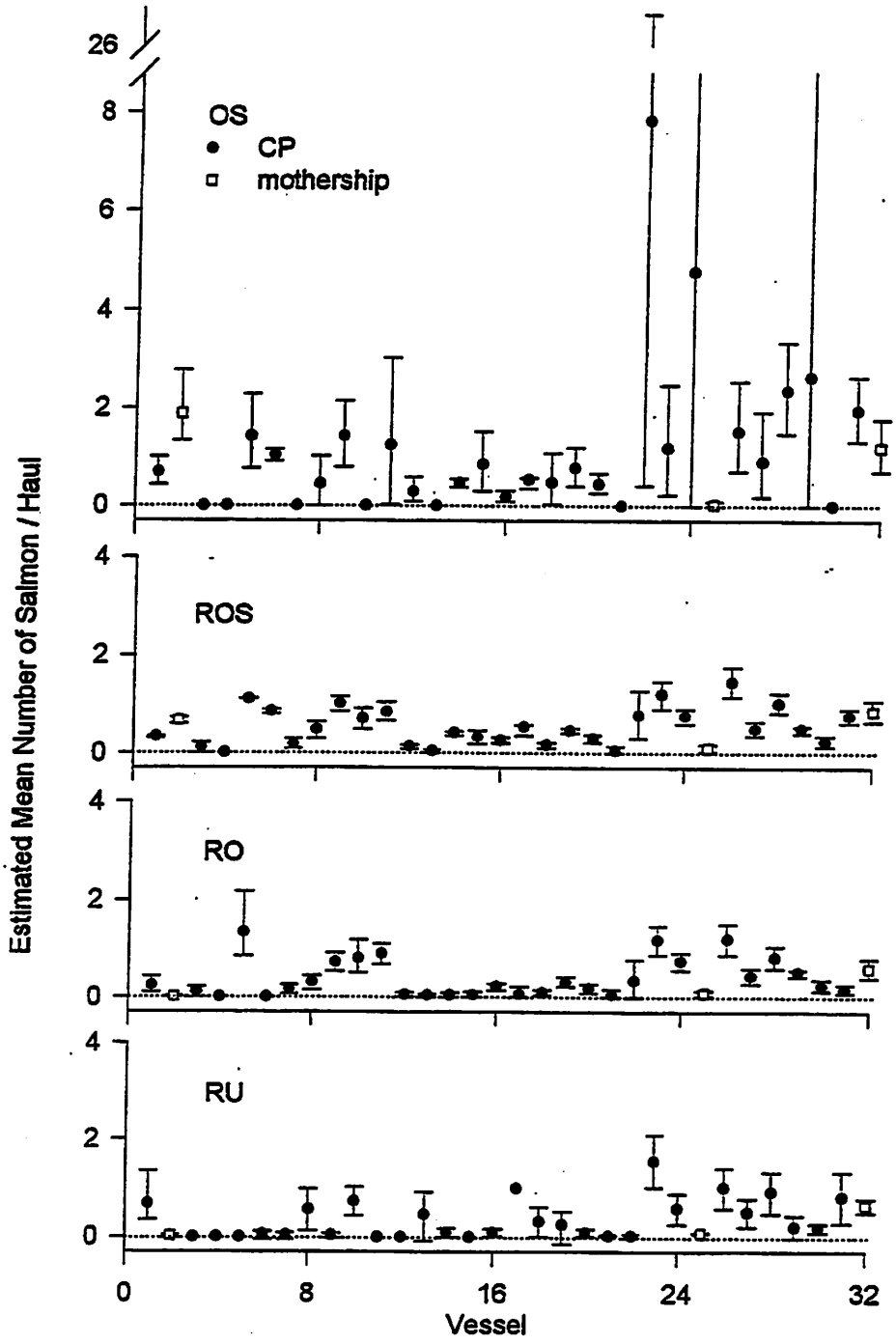

Figure 6. Estimated mean numbers of salmon per haul by vessel for 1995 BSAI A season. Estimates are from observer samples(OS), observed plus retained for observed hauls (ROS), retained from observed hauls (RO), and retained salmon from unobserved hauls (RU).

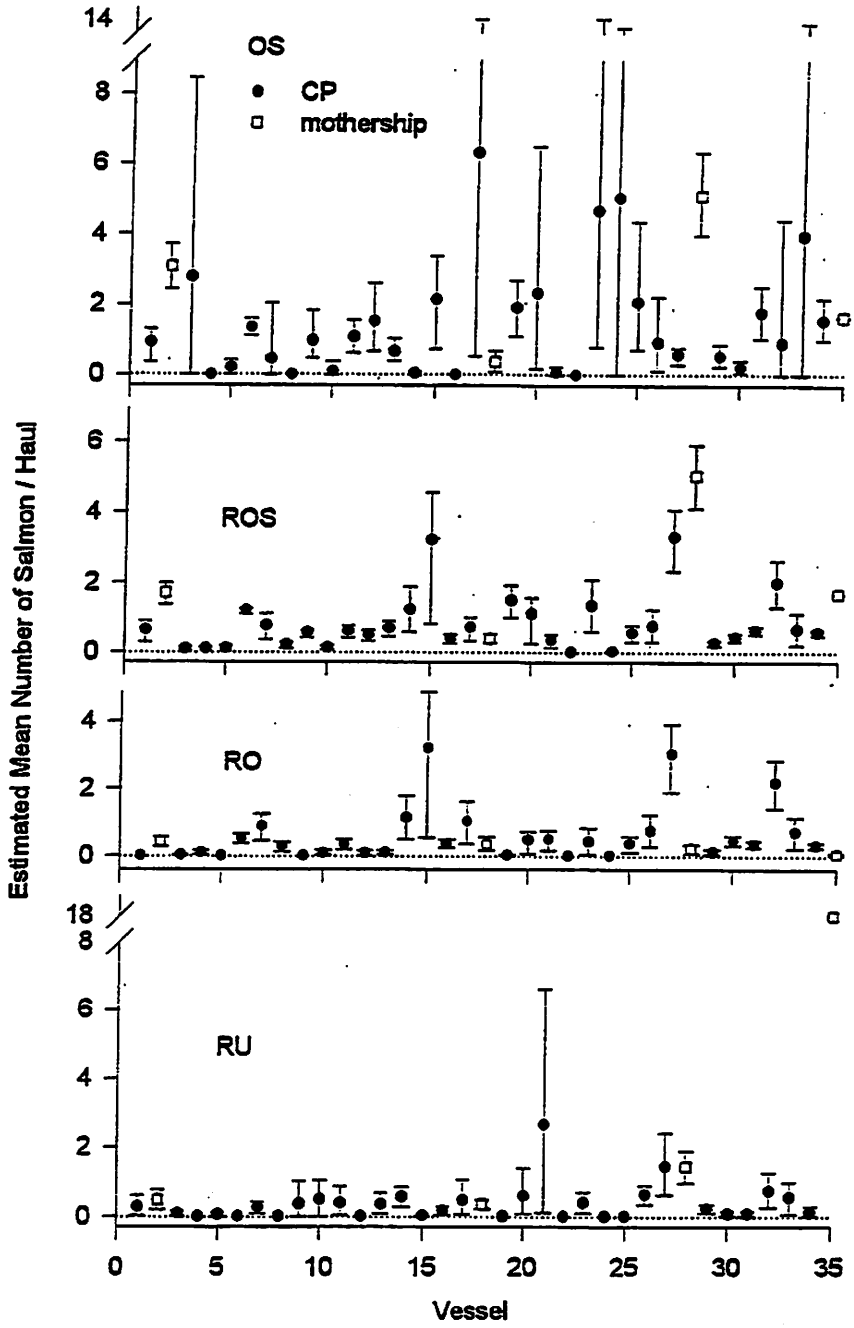

Figure 7. Estimated mean numbers of salmon per haul by vessel for 1995 BSAI B season. Estimates are from observer samples(OS), observed plus retained for observed hauls (ROS), retained from observed hauls (RO), and retained salmon from unobserved hauls (RU).

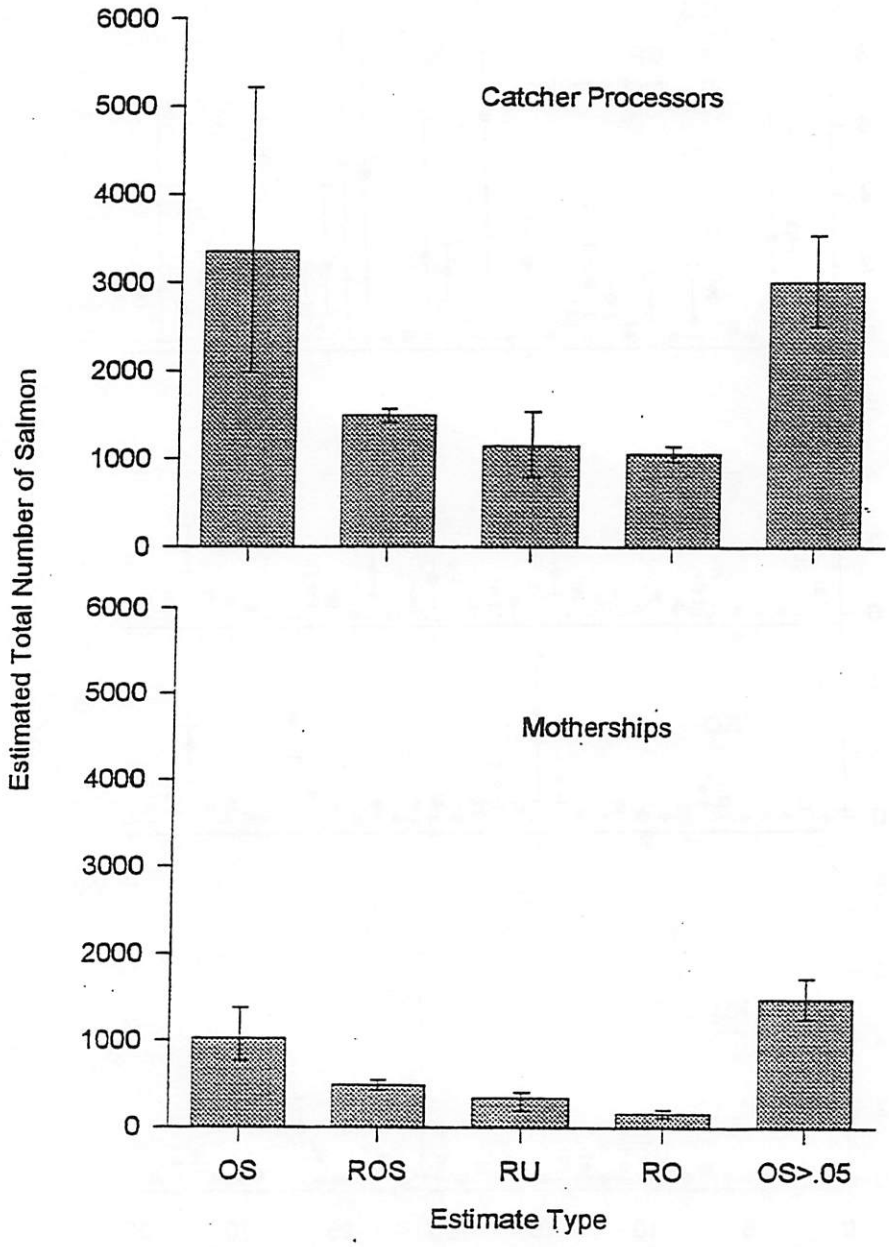

Figure 8. Estimated total catch of salmon by processor type for 1995 BSAI A season. Estimates are from observer samples (OS), observed plus retained (ROS), retained from unobserved hauls (RU), retained from observed hauls (RO), and observer sample fractions > 0.05 (OS>.05).

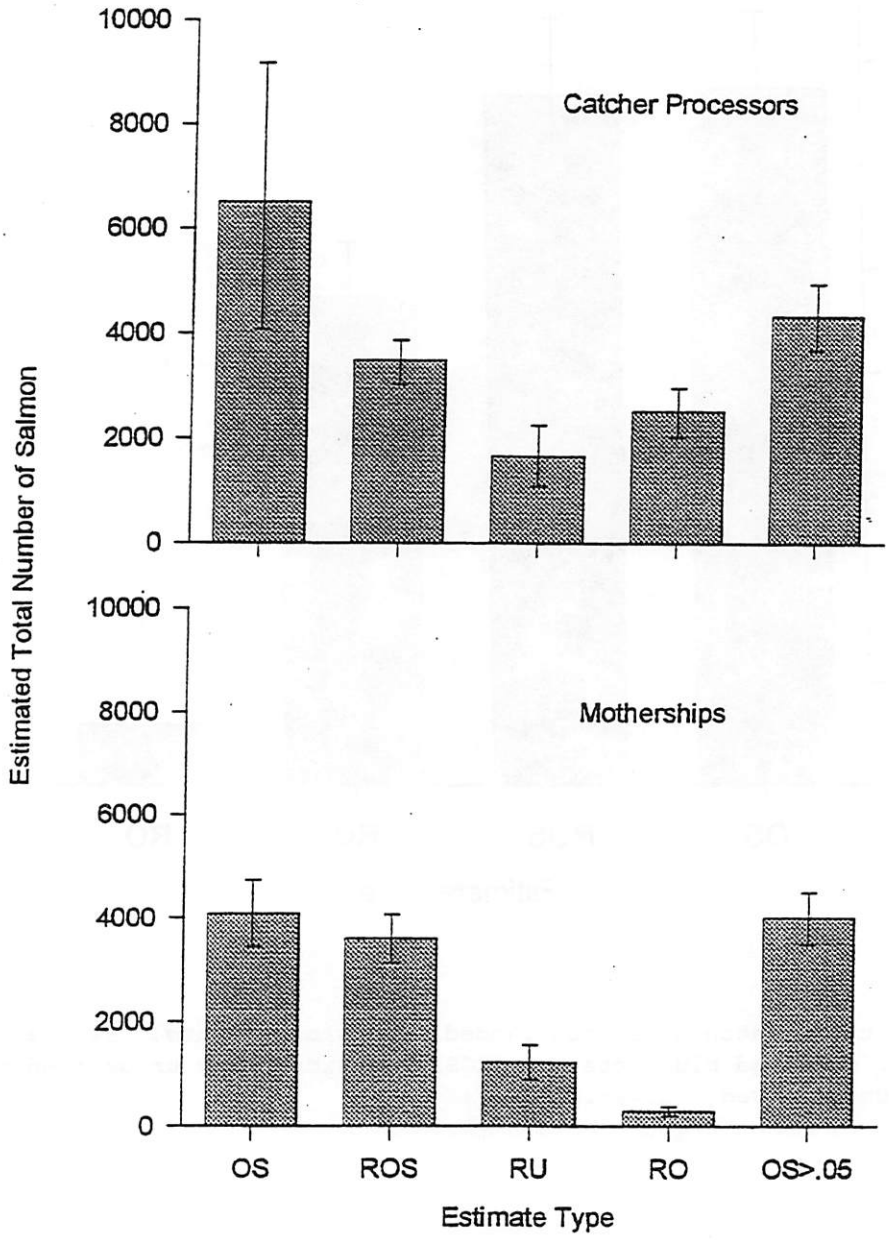

Figure 9. Estimated total catch of salmon by processor type for 1995 BSAI B season. Estimates are from observer samples (OS), observed plus retained (ROS), retained from unobserved hauls (RU), retained from observed hauls (RO), and observer sample fractions > 0.05 (OS>.05).

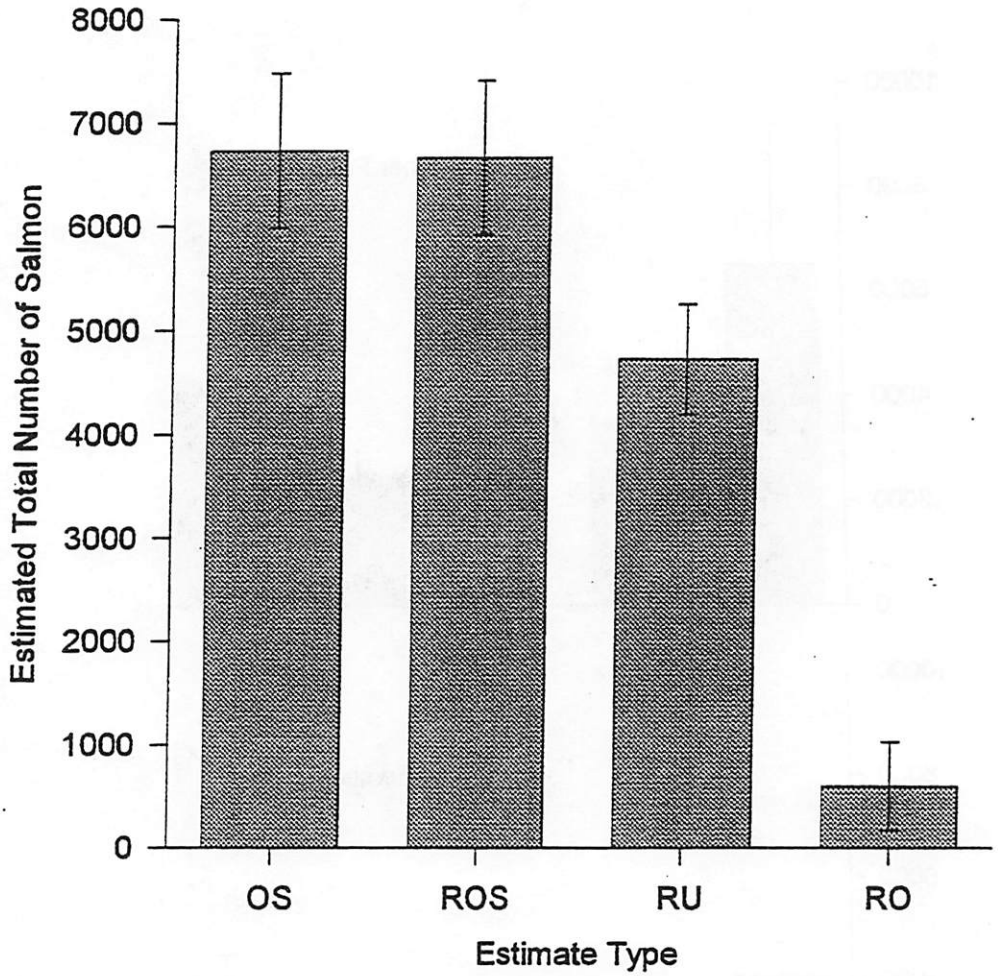

Figure 10. Estimated total catch of salmon landed at onshore plants. Estimates are from observer samples (OS), observed plus retained (ROS), retained from unobserved deliveries (RU), and retained from observed deliveries (RO).