ANALYTICAL AND STATISTICAL REVIEW OF PROCEDURES FOR COLLECTION AND ANALYSIS OF COMMERCIAL FISHERY DATA USED FOR MANAGEMENT AND ASSESSMENT OF GROUNDFISH STOCKS IN THE U.S. EXCLUSIVE ECONOMIC ZONE OFF ALASKA

Versar INC.

ANALYTICAL AND STATISTICAL REVIEW OF PROCEDURES FOR COLLECTION AND ANALYSIS OF COMMERCIAL FISHERY DATA USED FOR MANAGEMENT AND ASSESSMENT OF GROUNDFISH STOCKS IN THE U.S. EXCLUSIVE ECONOMIC ZONE OFF ALASKA

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October 1997

EXECUTIVE SUMMARY

Effective management of multi-species fisheries requires reliable estimates of the amount and composition of catch and bycatch. In this report, we present the results of analyses of observer program data performed to compare several different estimators of catch and catch composition. Our analyses were applied to 1994 data collected in two fisheries selected based on data availability, representativeness, and economic importance: the walleye pollock and yellowfin sole fisheries in the USEEZ of the Eastern Bering Sea. We developed two statistical estimators of fleetwide total catch using data from the observer program and compared those estimates to three other estimators representative of the metrics currently used in managing these fisheries (WPR, OTC and blend). We evaluated the extent to which the precision of the catch and bycatch estimates as well as several biological population parameters would change in response to modifications of observer sampling protocol. In the pollock fishery, our adjusted OTC and WPR estimates of total groundfish landings for A and B seasons fell below the lower 95% confidence limits for our two statistical estimates, but our synthesized blend estimate fell within the 95% confidence limits of the statistical estimates. All five estimates were within 5% of each other in magnitude. In the yellowfin sole fishery, our adjusted OTC and WPR estimates of total groundfish catch, as well as our synthesized blend estimate, all fell below the lower 95% confidence limits of our two statistical estimates, with the statistical estimates being about 10% higher than the other estimates. Statistical estimates of individual species catch in both fisheries were, in most cases, higher than estimates derived from our synthesized blend estimates of total groundfish catch, with the largest differences among estimates occurring for the least abundant species. Results demonstrate the feasibility of the use of statistical estimation for the management of the fishery, suggest that its application would have resulted in attainment of TACs earlier than would have been the case using the blend procedure, but do not provide a basis for establishing the sources of bias that may be responsible for the observed differences among the five estimates. The use of the delta-distribution in conjunction with the ratio estimator yielded the most statistically efficient estimates of individual species catch for most species (i.e., estimates with the smallest coefficients of variation). Statistical estimates of individual species catch derived using the delta distribution were, in nearly all cases, higher than statistical estimates derived without the delta distribution and higher than estimates derived from blend estimates of total groundfish catch.

Substantial differences in haul variability exist among vessels participating in the fishery, such that the same magnitude increase in fraction of hauls sampled may result in substantially different magnitudes of decrease in coefficient of variation (cv) for different vessels. The precision of statistical estimates of fleetwide catch in both the pollock and yellowfin sole fisheries is more dependent on the proportion of vessels observed than on the fraction of hauls sampled. Precision of the estimates of prohibited species catch derived from observer data improved with increases in the fraction of hauls sampled. Most biological characteristics of catch in the pollock fishery could be estimated to an acceptable level of precision with fewer fish than are sampled under current protocols and, in the southeast region, with sampling of as few as 20% of the hauls. However, substantial differences exist among regions and biological characteristics in what would constitute an optimal sampling regime for all biological characteristics.

We offer the following recommendations:

- If it could be demonstrated that the 1994 data are typical for groundfish fisheries, our results suggest that statistical procedures should be used for catch estimation, in lieu of the current blend procedure. The advantage of statistical estimation of both total groundfish harvest as well as individual species catch is that the degree of uncertainty associated with the estimates could be taken into account in tracking cumulative harvest and addressing the need for season closures, a consideration not available to managers under the current estimation protocols. Fisheries managers should evaluate, based on these findings, whether the observer coverage of vessels is sufficiently high to yield levels of precision that satisfy management objectives, and modify coverage as necessary.

- Complete observer coverage of the CDQ pollock fishery should be maintained, since any reduction in observer coverage would result in substantial reduction in precision of estimates of total groundfish as well as individual species catches.

- Several statistical estimation procedures suggested in Section 5.0, should be considered by managers for their logistical feasibility. The suggested procedures would provide additional types of data for statistical estimation, and could enhance the optimization of the observer effort available to the program overall.

- Fisheries managers should consider the ratio estimator with delta as the preferred individual species catch estimation method because of its high efficiency; however, statistical estimates of individual species catch derived using the delta-distribution tended to be higher than those derived without the delta-distribution and those based on the blend estimate of total catch; our comparisons among estimation methods do not provide a basis for establishing biases inherent in any of the methods and thus their validity; the validity of the most efficient estimators of single species catch should be established through simulations, applying the individual estimation methods to a data with a known underlying distribution.

- Guidelines should be developed for sampling for biological characteristics of catch that take into account the differences that exist among regions and among biological characteristics. Our results illustrate that observer effort devoted to sampling for species population characteristics could be optimized in terms of fraction of hauls sampled and number of fish sampled per haul to achieve higher levels of precision in estimates of those characteristics than may presently be the case.

- It would be appropriate to repeat analyses such as these on data collected in different years, when stock abundance, composition and distribution might differ from that occurring in 1994. Such additional analyses would permit assessment of how robust these analytical approaches may be, given annual variability typical for the fisheries considered; the Fortran programs developed as part of this project would allow AFSC to conduct these analyses.

ACKNOWLEDGMENTS

The authors wish to express our appreciation to Dr. William Karp for his support, guidance, and understanding throughout the term of this project. Staff of the NMFS Alaska Fisheries Science Center were extremely helpful in providing all data and information requested and providing extensive insight to the manner in which the observer program is implemented. This work was funded under contract number NFFS2200599188 from the U.S. Department of Commerce.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT'D)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

Figure | Page

LIST OF FIGURES (Cont'd)

Figure | Page

LIST OF FIGURES (Cont'd)

LIST OF FIGURES (Cont'd)

LIST OF FIGURES (Cont'd)

LIST OF FIGURES (Cont'd)

Figure | Page

LIST OF FIGURES (Cont'd)

LIST OF ACRONYMS

AFSC	Alaska Fisheries Science Center
BSAI	Bering Sea and Aleutian Islands
CDQ	Community Development Quotas
cv	coefficient of variation
EBS	Eastern Bering Sea
EEZ	Exclusive Economic Zone
FMP	Fishery Management Plan
IPHC	International Pacific Halibut Commission
LOA	length overall
MFCMA	Magnuson Fishery Conservation and Management Act
mt	metric tons
NONA	non-allocated species catch
NPGOP	North Pacific Groundfish Observer Program
NW	North West
OTC	official total catch
PSC	prohibited species bycatch rates
RST	Random Sampling Table
SE	South East
srs wor	simple random sampling, without replacement
TAC	Total Allowable Catch
VIP	Vessel (Bycatch) Incentive Program
WPR	Weekly Production Reports
WOBS	Weekly Observer Reports

1.0 INTRODUCTION

1.1 THE ALASKA GROUNDFISH FISHERIES AND THE MAGNUSON ACT

The North Pacific Ocean is highly productive, supporting many of the world's largest populations of groundfish[1], salmon, crabs, marine mammals, and seabirds. Large-scale commercial fisheries for groundfish in Alaska waters were developed and dominated by foreign fleets from the early 1950's until the Magnuson Fishery Conservation and Management Act (MFCMA) was passed in 1976. The Magnuson Act, which went into effect on March 1, 1977, created federal authority to manage living marine resources in the Exclusive Economic Zone (EEZ), extending 200 miles off the U.S. coastline (see, e.g., French et al. 1982). Following the passage of the Magnuson Act, large-scale commercial fisheries in the EEZ, that were previously dominated by foreign vessels, were replaced by joint ventures between foreign factory ships and U.S. catcher vessels. Since the late 1980s, the fisheries have been almost exclusively domestic. The Alaska groundfish fishery is now a major industry with total 1992 groundfish catches generating ex-vessel revenues of $658 million.

The EEZ off Alaska extends 200 miles offshore, encompassing waters of the Gulf of Alaska and the eastern Bering Sea, otherwise known combined as the Bering Sea/Aleutian Islands (BSAI) region. Within the BSAI region, the pollock fishery occurs in three localized areas: eastern (Bering Sea); Aleutian Islands; and Central Bering Sea - Bogoslaf. Annual harvest of groundfish from these highly productive waters is about two million metric tons. The offshore fishery includes a mixed fleet of Seattle-based factory trawlers, motherships (i.e., seaborne processing plants), and their accompanying catcher vessels. The inshore fishery consists of Alaska-based vessels that deliver fish to processing plants on shore. Four basic types of fishing gears are used in the EEZ; (1) trawls, (2) hook-and-line, (3) pots and traps, and (4) jigs.

The fishery for walleye pollock (*Theragra chalcogramma*) accounts for about 70% of the total catch of all species in the EEZ (Herrick et al. 1994). Other commercially important fisheries include Pacific cod (*Gadus macrocephalus*), yellowfin sole (*Limanda aspera*) and several other species of sole, Pacific halibut (*Hippoglossus stenolepis*), Alaska plaice (*Pleuronectes quadrituberculatus*), sablefish (*Anoploma fimbria*), Pacific Ocean perch (*Sebastodes alutus*), and other rockfishes (Megrey and Wespestad 1990). The Magnuson Act brought fisheries for these species (except halibut) under the control of the U.S. government in 1977 (French et al. 1982).

[1]"Groundfish" are defined as fish that are subject to the Federal Groundfish Regulations for the U.S. off Alaska. Groundfish means pollock, cod, any species of flatfish, any species of flounder and sole, Pacific Ocean perch, thornyhead rockfish, other rockfish, sablefish, Atka mackerel, squid, octopus; all other marine invertebrates except shrimp, scallops, snails, king crab, Tanner crab, Dungeness crab, horsehair crab, lyre crab, coral, and clams; and all other finfish except salmonids, steelhead trout, Pacific herring, and Pacific halibut.

Alaska's groundfish are managed by two fishery management plans: one for the BSAI region and the other for the Gulf of Alaska. Thus, they are under constant watch by the North Pacific Fishery Management Council. Pacific halibut are not part of the groundfish fishery complex. They are managed by the International Pacific Halibut Commission (IPHC). While an important component of the bycatch in the groundfish fishery, halibut is designated as prohibited species catch (PSC) in that fishery.

1.2 THE NORTH PACIFIC GROUNDFISH OBSERVER PROGRAM

The North Pacific Groundfish Observer Program (NPGOP or Observer Program), a key component in effective management of fisheries in the Alaskan EEZ, started as a means of monitoring foreign fishing vessels during the mid 1970s. The primary objectives of the program (AFSC, 1995) are to:

- provide independent estimates of catch weight;
- determine the species composition of the catches;
- determine prohibited species catch (PSC) quantities;
- record incidental kills of marine mammals;
- collect biological data for estimation of critical parameters for target species, prohibited species, and other species of interest;
- monitor for compliance to fishery regulations.

The sampling protocol and measurements collected by the observers are described in the "Manual for Biologists Aboard Domestic Groundfish Vessels" (AFSC, 1995). The general instructions ask that observers collect random, unbiased samples from the catches so that data represent the vessel catches over time.

During the first year of the program, observers covered between 9% and 14% of the fishing days conducted by foreign vessels in the Bering Sea and Gulf of Alaska. Later, observers were also placed aboard domestic vessels. In 1990, 100% observer coverage became mandatory on vessels larger than 125 feet; ft (38 meters; m); vessels between 60 ft (18 m) and 125 ft (38 m) have observer coverage 30% of the fishing days; and vessels less than 60 ft (18 m) may be required to take observers if deemed necessary by the National Marine Fisheries Services regional director (Megrey and Wespestad 1990; NPFMC 1989a, 1989b). During 1994 observers also collected data at approximately 21 shoreside and 18 floating processors.

Data gathered by the Observer Program are used to estimate catch size by species, bycatch (the inadvertent capture of nontarget species), and population parameters that are crucial for managing and conserving the fisheries in the EEZ off Alaska. Regulatory discard occurs when species are in "bycatch only" status and the maximum retainable bycatch (MRB) percentage is reached (based only on weight, not size or age.) Economic discard occurs when the vessel operator chooses to discard fish, often small individuals, that cannot be processed or may take up hold space which he prefers to fill with more valuable products. The Observer Program provides data detailing catch location, duration of hauls, catches of target and nontarget species, discards, and biological measurements of target species and other species as necessary (Megrey and Wespestad 1990). The observers report sampling data to the inseason staff at the Alaska Fisheries Science Center (AFSC) on a weekly basis. The weekly observer reports (WOBS) include information on the total number of hauls or sets, the hauls sampled, and the weight of groundfish by species for the hauls sampled. The AFSC Resources Ecology and Fisheries Management Division uses the biological data collected by observers to construct age-length keys and estimate critical growth parameters.

1.3 INDUSTRY REPORTING REQUIREMENTS

Commercial fishing regulations for U.S. fishermen targeting groundfish in the BSAI region require that operators of processor vessels that conduct fishing or receive groundfish catches from any reporting area in the BSAI region anytime during the fishing year submit Weekly Production Reports (WPR) to the NMFS Regional Office in Juneau, Alaska. The managers of shoreside processors that receive catches from these areas also are required to submit WPRs. Processors are required to submit WPRs even during periods of zero catch. The reports include information on the reporting area, gear type, and weights of product and discarded groundfish in metric tons (mt). The shoreside processing plants are also required to report the weight of the groundfish landings for the State of Alaska fish ticket reporting system.

1.4 INSEASON MANAGEMENT

The management of groundfish fisheries in the BSAI region is based on various harvest limits, socioeconomic considerations, and time and area closures. Management measures based on harvest limits specify that:

- Total allowable catch (TAC) of all groundfish species combined must be within the optimum yield, ranging from 1.4 to 2.0 million mt in recent years;

- TACs for each target species and "other species" category are set for each calendar year by NMFS, after consultation with the North Pacific Management Council (Council);

- Limits for prohibited species bycatch quantities (PSC) may be in effect for any of the species of Pacific salmon (*Oncorhynchus* spp.), steelhead trout (*Oncorhynchus mykiss*), Pacific halibut, Pacific herring (*Clupea harengus pallasi*), king crab (*Paralithodes* spp. and *Lithodes* spp.), and Tanner (snow) crab (*Chionoecetes* spp.). Prohibited species bycatch quantities are defined as the ratio of total weight or total number of prohibited species to the total weight of all species (see Kappenman, 1992).

- The Vessel (Bycatch) Incentive Program (VIP) holds operators of individual trawl vessels accountable for their bycatch of halibut and red king crab (*Paralithodes camtschatica*) during their participation in specified groundfish fisheries. NOAA establishes an acceptable bycatch limit for each fishery monitored under the VIP; violations of bycatch limits for individual vessels are defined relative to these standards.

- Maximum retainable bycatch quantities are used to regulate the incidental harvest of species and species groups that are closed to direct fishing.

- The BSAI groundfish management plan establishes an annual 2 million metric ton cap on groundfish catches, which may prevent harvesting of the full TAC for some species.

Socioeconomic management measures include Community Development Quotas (CDQ). The Community Development Quota is federal program that was developed to enable residents of rural coastal communities in western Alaska to participate in the groundfish fishery off their shores in a way that will bring significant economic development to the Bering Sea region. The CDQ program is administered jointly by the Alaska Departments of Community and Regional Affairs (lead agency), Commerce and Economic Development, and Fish & Game.

The CDQ program allocates 7.5% of the total-allowable catch (TAC) of the BSAI pollock fishery, as well as a portion of the halibut and sablefish quota, to eligible communities in that region. Full implementation of the CDQ pollock fishery began in December 1992, and in March 1995 for the CDQ halibut and sablefish fisheries. The halibut and sablefish CDQ program is granted in perpetuity, and the pollock program has been extended by the North Pacific Fisheries Management Council (NPFMC) until 1998. The State of Alaska is responsible for the administration and monitoring of the program.

For inseason management based on TACs and bycatch caps the fishery is closed once the estimated catch and bycatch equals the threshold values specified in the management plan. The incidental catch of Pacific halibut, king crabs and Tanner crabs off Alaska now restricts expansion of some groundfish fisheries. When halibut and crab bycatch limits are reached, some groundfish fisheries are closed before harvesting the quota of groundfish (currently set at 2 million mt). Bycatches of chinook (*Oncorhynchus tshawytscha*), chum (*Oncorhynchus keta*), and other salmon are also significant problems in the BSAI region.

1.5 OBJECTIVES OF THIS STUDY

Effective management requires reliable estimates of catch and bycatch. Imprecise estimates can result in actual harvest quantities exceeding biologically desirable limits or in fisheries being closed prematurely, resulting in adverse economic impact to the fishing industry. Each factor involved in estimating the threshold values (e.g., TACs) can affect the reliability of the estimates that provide the basis for decisions on closing fisheries. Also, the design and procedures for collecting data in the Observer Program should be optimized to meet the many possible uses of the data most cost effectively. Perhaps of greatest importance is that the current inseason management regime requires accurate fleetwide estimates of weekly catch and bycatch by species or species groups.

Our review of current procedures for collecting and analyzing observer data was instituted to use existing data to evaluate all factors that might impact the reliability and cost-effectiveness of data collection to support management decisions. It focused on:

(1) the effects of sampling strategy on the precision of catch and bycatch estimates, as measured by the coefficient of variation (cv);

(2) comparisons of current and alternative procedures for estimating total tonnage of groundfish; it should be noted that analyses were done for only two fisheries (pollock and yellowfin sole) because of their relative importance in the groundfish fishery; the data used was acquired from fisheries which were 100% observed catcher/processor fleets, and in which management was concerned with tracking catch of each species against the specified quota.

(3) the effects of sampling strategy on the precision (cv) in estimates of size, age, and sex composition in total catches of target species;

(4) potential cost-effectiveness of survey sampling procedures as reflected in the relationship between sampling effort and precision.

In developing recommendations, we have taken into account some obvious logistical considerations that might constrain modification of the survey design and procedures of the Observer Program. However, we have not attempted to account for all logistical factors. For example, any randomization scheme for collecting catch data from fishing operations must accommodate a workable schedule for the observers.

2.0 DESCRIPTION OF CURRENT SAMPLING AND ESTIMATION PROCEDURES

2.1 SAMPLING PROCEDURES FOR ESTIMATING CATCH AND BYCATCH

In 1991, Amendment 16 to the Fishery Management Plan (FMP) for the BSAI groundfish fishery and Amendment 21 to the FMP for the Gulf of Alaska groundfish fishery were implemented to enhance prohibited species bycatch management. These amendments created the VIP, which, as described earlier, holds operators of individual trawl vessels accountable for their bycatch of halibut and red king crab during their participation in specified groundfish fisheries.

As part of VIP, a rigorous statistical survey design for selecting hauls to be sampled by observers was implemented, following recommendations by Kappenman (1992). The most significant change from previous sampling protocol involved random selection of hauls following the "Random Sampling Table" (RST), as described in the Observer Manual. This randomization scheme was also implemented for all other fisheries in 1991. Before 1991, the sampling was largely ad-hoc; i.e., the probabilities by which individual hauls were selected for sampling by observers were unknown. Random selection of hauls is intended to eliminate bias in estimates of total catch, bycatch, and catch composition resulting from preferential selection by observers, and allows the estimation of associated confidence limits.

The species composition of any individual haul is generally determined by whole-haul sampling (i.e., by sampling the entire unsorted catch), or from a subsample of the catch using one of the following methods:

(1) *partial haul sampling*, in which a large portion of the catch is sorted and the weight of this subsample is determined based on volume and density estimates or other methods;

(2) *basket sampling*, which requires collection of weighed subsamples from different parts of the haul using baskets or other means.

Whole-haul sampling is commonly used for determining the bycatch of prohibited species in pure fisheries such as pollock, where non-target species typically make up less than 10% of the catch. However, for large hauls, sorting the entire catch may not be feasible because of the extended time required to process the entire catch, the presence of large numbers of non-target species, or for logistical reasons, such as difficult access to the catch as a result of the configuration of the processing plant. In such instances, partial haul or basket sampling is generally employed. When using partial haul and basket sampling, observers are instructed to collect the subsample from different parts of the holding bin to reduce any bias resulting from stratification of fish in the bin by size or species. In fisheries that are not part of the VIP, observers are allowed to use whole-haul, partial haul or basket sampling.

The VIP requires that bycatch quantities and their associated confidence limits be estimated based on weight of Pacific halibut and numbers of king crab along with associated weights of the observed sample from the catch. For most vessels these data can only be obtained by using "basket sampling" since weighing the total catch or large portions of the catch is generally not possible for the observers.

2.2 THE BLEND SYSTEM FOR ESTIMATING CATCH

NMFS' estimates of total annual removals and inseason weekly catches from the BSAI management areas for catcher/processors and motherships are currently based on a combination of data from the Observer Program and "weekly production reports" (WPR) from processors. The catch and bycatch information from the Observer Program along with WPRs is input to the NMFS' "blend" system, which produces weekly total estimates of the open-access groundfish catch for the combined inshore and offshore fishery. For each observed offshore processor (catcher/processor or mothership) in a management area:

W_{OBS} = weekly total catch of groundfish (mt) (retained catch plus discards) estimated from data from the Observer Program (in our analyses, equal to the sum of the OTC);

W_{WPR} = corresponding weight of total groundfish catch provided by the WPR[2] from the processors; and,

Δ = Absolute difference between W_{OBS} and W_{WPR}.

Currently, the W_{OBS} is estimated as a sum of the observer estimates of groundfish catch size (for the randomly sampled hauls), and the captain's eyeball estimates for the hauls not subject to observer catch estimation.[3] The weekly catch estimates (W_{OBS} and W_{WPR}) are combined for all reporting areas and gear-types within the BSAI. The *blend system* (Figure 2-1) is an algorithm for selecting either W_{OBS} or W_{WPR} as the data source for the estimation of total

[2]We note that WPRs are submitted by processors, not individual vessels; while factory trawlers are vessels, within this reporting system they are classified as processors.

[3]The observer data files provided by NMFS for these analyses contained records of both vessel estimates as well as observer estimates which sometimes disagreed. We were informed by NMFS that the observer may sometimes make an estimate that he/she believes is inaccurate or incorrect, in which case, he/she may choose the vessel estimate over his or her own. The observer's estimate cannot be a visual estimate because that is not an acceptable method of obtaining the observer derived figure. Some subsampled hauls may not have an observer estimate because the observer was unable to obtain it due to conflicting work/sleep demands, etc.

groundfish catch. If both WPR and Observer Reports are available, the blend selects one of them for incorporation into the catch database. If the vessel is unobserved, the total weekly catch estimate is based on W_{WPR}. Vessels participating in the CDQ fishery are required to have certified bins for volumetric catch size estimation, and they carry two observers for round the clock coverage (Galen Tromble, pers. com.). The blend system is not applied to the CDQ fishery; W_{OBS} is always selected for estimation of total catch in this fishery.

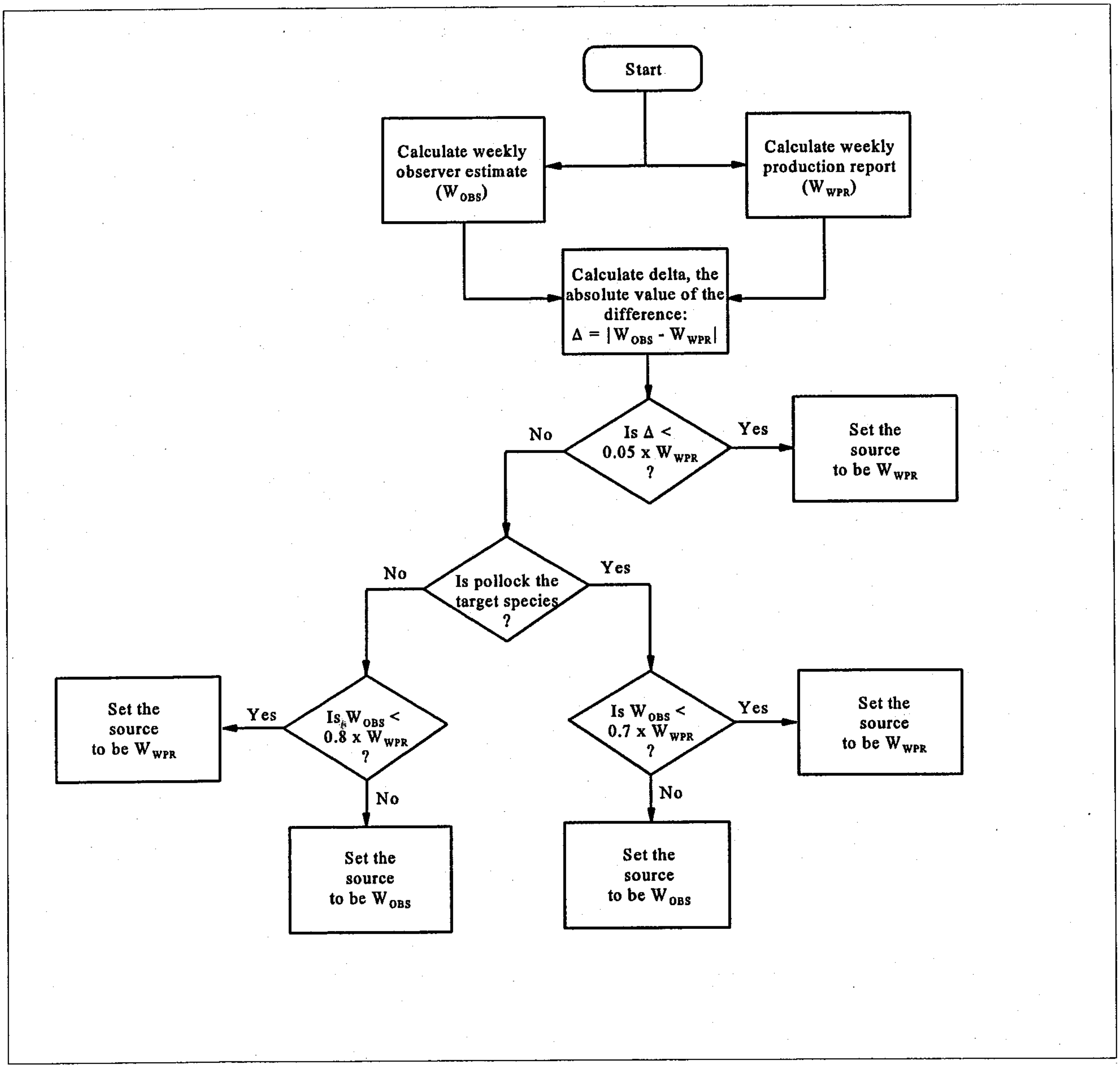

Figure 2-1. Flowchart detailing the blend system algorithm

The blend algorithm used before 1995 specified that the W_{OBS} be selected as input for estimations of total catch when both W_{OBS} and W_{WPR} are provided, with the following exceptions:

- W_{WPR} is selected if $\Delta < 0.05 x W_{WPR}$
- W_{WPR} is selected if $W_{OBS} < 0.8 x W_{WPR}$

The fleetwide estimate of total weekly catch is obtained by choosing one of the two sources of total groundfish catch for each processor, and summing across all processors. In 1995 the blend algorithm was modified in recognition of the high degree of variability in pollock product recovery rates which are used in the WPRs and, thus, increase cases for which observer data were selected. The following algorithm currently applies:

- when the target fish is pollock, W_{WPR} is now selected as source if $W_{OBS} < 0.7 x W_{WPR}$
- for target species different from pollock, W_{WPR} is still selected as source if $W_{OBS} < 0.8 x W_{WPR}$.

Partitioning of total weekly catches among gear types and reporting areas is based on the data source selected by the blend analysis and is done after the total catch is estimated using the blend system.

In general, the blend procedure is designed to provide weekly estimates of catch for each quota species (or species group) by week, area, and gear type, and estimates of prohibited species catches (PSC) by these same strata. The procedure employed for estimating quota species differs from that employed for estimating PSC.

As indicated, above, for the quota species, the blend compares and combines observer and processor reports by processor and week. The product is stratified by processor, week, area, and gear type. The PSC estimation procedure differs in that observer data are used as the sole basis to calculate a catch proportion by processor, week, area, and gear type. This proportion is then applied to the stratified product of the blend to estimate PSC. These procedural steps are employed for catch and bycatch management.

We used five data sets to estimate total species catch: blend (described above), WPR, adjusted OTC, adjusted observer (all hauls), and adjusted observer (subsampled). The WPR data set consists of weekly production reports from shoreside processors and factory trawlers of total groundfish catch (i.e. excludes non-allocated and prohibited species catch). The OTC data set provided by NMFS for use in this project contains total species catch estimates (observed and captain's "eyeball" estimates for unobserved hauls) that include non-allocated and prohibited species. In order to make the OTC data comparable to the WPR data, we created an adjusted OTC data set by multiplying the OTC data by the proportion of groundfish measured in hauls subsampled by observers. For the purpose of our analyses, the adjusted OTC data set is essentially the same as the W_{OBS} data set described above.

Observer estimates of total catch (OBS) are similar to the OTC data in that they include non-allocated and prohibited species. We adjusted the OBS data to account for non-allocated and prohibited species using the same technique as described above for the adjusted OTC data set. Some of the hauls included in the adjusted OBS data set were subsampled by observers and provide catch composition data in addition to providing total groundfish catch estimates. The remaining hauls (unsubsampled hauls) within the adjusted OBS data set only provide estimates of total groundfish catch. We estimated total seasonal or annual groundfish catch from the adjusted OBS data using both the entire data set [i.e. adjusted OBS (all hauls)] and a subset of the data consisting of only the hauls that were subsampled [i.e. adjusted OBS (subsampled)] excluding data from hauls not subsampled. For the pollock fishery, 16 percent, 1 percent, and 11 percent of the observed hauls were excluded from the A Season, CDQ Fishery, and B Season data sets, respectively. In the yellowfin sole fishery, 11 percent of the observed hauls were excluded. As described earlier, observers have a list of random hauls designated to be sampled for species composition as well as for total catch weight, but may record only total catch weight from other non-listed hauls if time permits. We included in our analyses the adjusted total OBS data set as well as the adjusted OBS subsampled-only data set to evaluate whether the inclusion of non-random hauls in the data created any bias in the statistical catch estimates. All catch estimates of individual species were derived from the catch composition data included in the adjusted OBS (subsampled) data set.

For shoreside processors, WPRs are considered by fisheries managers to be the most accurate source of data for estimating retained groundfish landings. All fish delivered to shoreside processors are weighed on scales, and these weights are used to account for retained catch. Observer data from catcher vessels provide the best data on at-sea discards of groundfish by vessels delivering to shoreside processors. Discard rates from these observer data are applied to the shoreside groundfish landings to estimate total at-sea discards from both observed and unobserved catcher vessels.

3.0 ANALYTICAL APPROACH

3.1 DESCRIPTION OF DEMONSTRATION FISHERIES

We selected two major fisheries for examination in this study. In cooperation with AFSC, we considered the following factors in our selection: (1) availability of data, (2) representativeness, and (3) economic importance.

The walleye pollock fishery was selected because of its economic importance as a large-scale offshore fishery. This fishery consists of bottom and semipelagic trawling, with the latter being dominant. Individual catches in the pollock fishery generally have a pure species composition, typically with more than 90% pollock. The stock structure of Bering Sea pollock is not well defined (Wespestad, 1996). In the U.S. EEZ, the population is divided into three stocks for management purposes: (1) Eastern Bering Sea (EBS), consisting of pollock inhabiting the shelf from Unimak to the U.S. — Russia Convention line; (2) Aleutian Islands, encompassing the shelf region from 170° W to the Russia Convention line; and (3) the Central Bering Sea-Bogolov Island pollock. The latter component of the population is considered to be a mixture of pollock that migrate from the U.S. and Russian shelves to the Aleutian Islands around the time of maturity (Wespestad, 1996).

The yellowfin sole fishery in the BSAI region was the second demonstration fishery selected. The yellowfin sole population is considered one stock, and inhabits the EBS shelf. This stock is the target of the largest flatfish fishery in the United States (Wilderbuer 1996). The yellowfin sole fishery is demersal, and the species composition of catches are generally highly mixed.

For both fisheries, catch statistics from 1994 were the most recent complete observer data available for analysis:

(1) Data for the offshore fishery for pollock in the BSAI region, was obtained for management areas 509, 513, 514, 516, 517, 518, 519, 521, 523, 524, 541, 542, 550 (Figure 3-1). The offshore fishery includes catcher/processors and motherships, each generally having 100% observer coverage.

(2) Data for the offshore fishery for yellowfin sole in the BSAI region, was obtained for management areas 509, 513, 514, 516, and 517. The study includes catcher/processors that participate in the bottom trawl fishery; the catcher vessels which deliver to shore-based processing plants are not part of this study. Observers collect catch samples from 30% of the fishing-days for vessels with length overall (LOA) between 60 and 125 ft (or 18 to 38 m), and 100% of the fishing-days for vessels with LOA greater or equal to 125 ft (or 38 m).

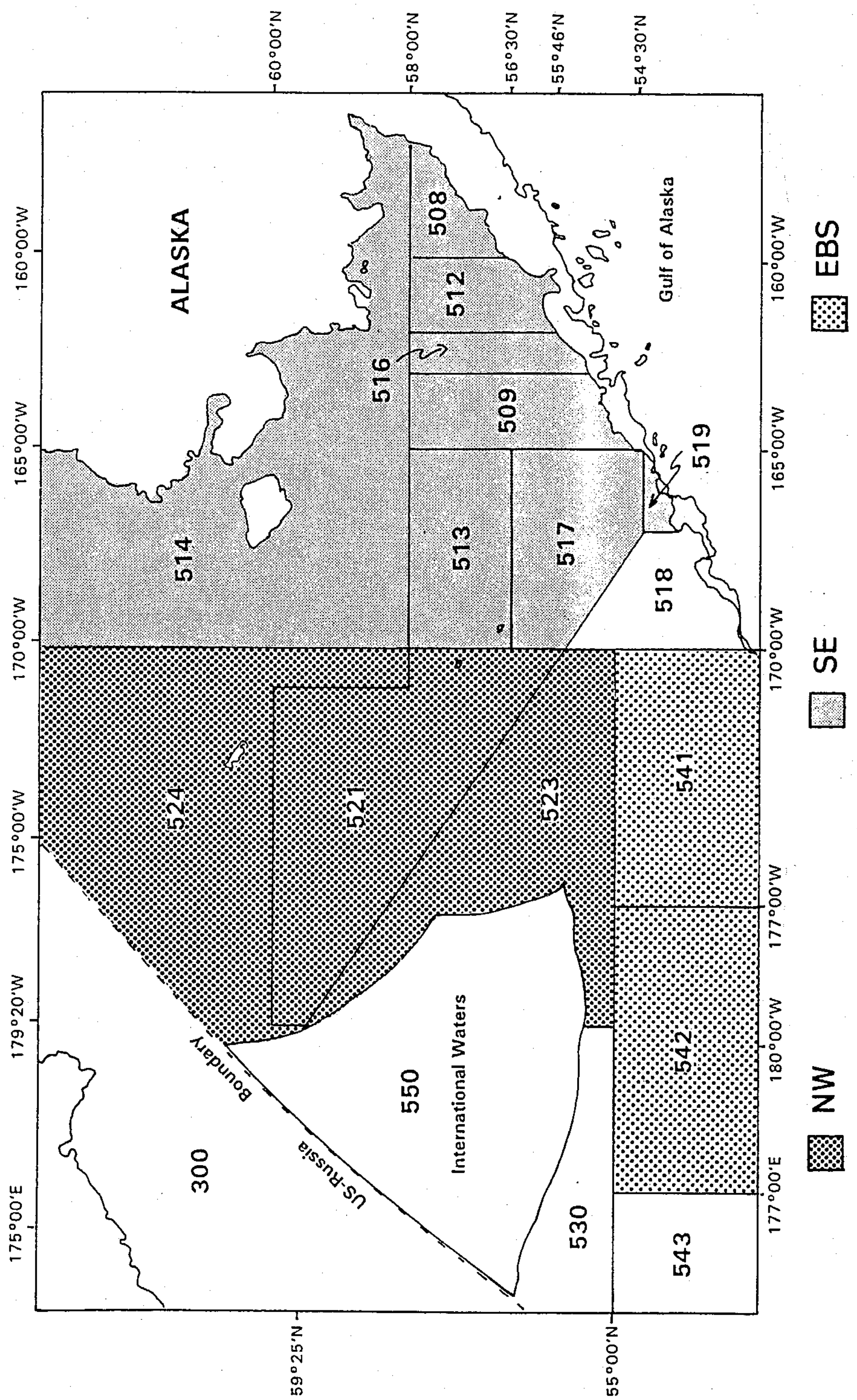

Figure 3-1. 1995 reporting areas of the BSAI region

We note that the data files provided by NMFS for these analyses contained only entries for which the target species had already been identified by NMFS as pollock or yellowfin sole. As has already been described, Weekly Production Report (WPR) data files contain only groundfish catch. In order to compare total groundfish catch estimates based on WPR data to those derived from observer total catch data, the observer total catch data had to be adjusted by eliminating the contribution of non-allocated (NONA) and prohibited species catch (PSC). This adjustment made datasets comparable in our analysis and was done by developing a proportion of NONA and PSC in observer total catch estimates for tows that were subsampled (species composition data was available only for those tows subsampled), and reducing observer total catch by that proportion.

Since the implementation of the MFCMA in 1977, yearly catch quotas for pollock in the BSAI region have ranged from 950,000 to 1.3 million mt (Wespestad 1996). The total yearly catches have ranged from 0.9 million mt in 1987 to 1.6 million in 1991, averaging 1.2 million. Prohibited bycatch of salmon is currently of concern for this fishery; the PSC in 1995 was close to the cap.

Total catches of yellowfin sole in the period from 1977 to 1994 have ranged from 58,373 mt in 1977 to 227,107 mt in 1985, averaging 135,423 mt (Wilderbuer 1996). This fishery is generally closed before the TAC for yellowfin sole is reached because the cap for bycatch of Pacific halibut is reached.

3.2 SAMPLE BASED ESTIMATION TECHNIQUES

We evaluated the factors contributing to precision of estimates of catch and biological parameters generated from the Observer Program by establishing the coefficient of variation (cv) in estimates of:

(1) total catch based on the observer data for randomly selected hauls;

(2) estimates of bycatch (i.e., crabs, salmon, and Pacific halibut); and

(3) biological characteristics (mean length, proportions at age, proportions of females) of the target species catches.

In evaluating the benefits of any modifications of the program, we assessed the relative influence of each component of the sampling program on the precision (cv) of the estimates and defined how uncertainty propagates through the system to affect the estimates of threshold values and population characteristics. This approach enabled us to illustrate how changes in the allocation of resources and sampling routines could enhance precision.

We evaluated how the sampling procedures and estimation methods might be improved under the current level of observer effort, and if the precision (cv) of the catch and bycatch estimates can be improved by adjusting the sampling protocol.

3.2.1 Estimation of Catch

The Official Total Catch (OTC) of all species, including NONA and PSC, is the sum of observer catch estimates for observer-sampled hauls and skipper or observer catch estimates for unsampled hauls.[4] We could not determine the precision of the blend estimate because it is based on a mixture of observer estimates and WPRs.

A statistical estimation of total catch of all species which takes advantage of the random selection of hauls observed from each vessel is an alternative to using W_{OBS} and/or W_{WPR} in the blend system. Such an alternative would allow for an estimation of precision not possible using the blend system.

In the Observer Program, sampling from a certain fleet generally involves three stages of selection: (1) selection of vessels (primary sampling units); (2) selection of hauls (secondary sampling units) from each vessel; and (3) subsampling of the catches from each selected haul. The third stage of selection involves the use of whole-haul sampling, partial haul sampling, or basket sampling to determine the composition of the catch. In our analyses, we defined the primary sampling unit as a 'vessel'. The selection of a primary sampling unit (vessel) from a fleet is signified by an observer being onboard. The sampling fraction of primary units (f_1), refers to the observer coverage for the fleet. The overall variance in estimates of fleetwide total catch and bycatch rates can be broken into three components, corresponding to the three sampling stages. If every vessel in a fleet has an observer onboard for all fishing days, we say that the fleet has 100% coverage.

The current observer data generally do not include information about weight and species composition for individual subsamples from the catches (e.g., by individual baskets or partial haul samples). For each haul sampled by the observers, the species composition based on subsampling was assumed to accurately represent the composition in the entire catch. We have assumed for the purposes of this analysis that the catch and bycatch data collected by observers come from a two-stage sampling scheme. For the experimental studies conducted in 1995 and 1996, data exist for all three stages of sampling, but the catch subsampling data was not incorporated into this specific analysis. Given that about 8 baskets are subsampled from each selected haul, about 50% of hauls are sampled, and there are about 50 vessels in

[4]In some cases observer estimates of catch are not available for subsampled hauls because of conflicting demands on the observer's time. Captain's estimates are used for such hauls, since observer's are precluded from making "eyeball" estimates of catch. Under current regulations, the captains are not required to follow a standardized method to estimate haul weights and therefore, the ad-hoc eyeball method may result in significant variability of estimates among captains.

the fishery, the number of third stage units is so large that it is not likely to affect the standard error. For very rare species, the third component of the variance may become significant. This could be further investigated through experimental studies. Salmon are sampled by whole-haul or partial hauls; basket sampling is not appropriate for this species.

3.2.1.1 Two-stage Cluster Sampling

We assume here that simple random sampling, without replacement (srs wor) is employed in the first and second stage when sampling catches from a fleet. This implies that the observers are deployed on a random sample of vessels from a fleet, and that each observer collects data on catch and bycatch from a random sample of hauls from each of these vessels. We further assume that the species composition data from observed hauls are obtained by whole-haul sampling, or that the subsampling of hauls produce perfect estimates of composition for each catch. The current database for the observer program does not contain observations for individual subsampling units from each sampled haul and we thus are not able to verify this assumption. Species composition from partial haul or basket samples from each haul are expanded to the entire catch of that haul in the data sets. Hence, the estimation of total catch and bycatch is based on a two-stage cluster sampling design.

The following table summarizes the notation used in the estimation of catch and bycatch. The method is general, and can be used for fleets with less than 100% sampling coverage of fishing days. The two demonstration fisheries analyzed in this study generally have 100% observer coverage. The sample of hauls, hence, could also be analyzed as a stratified random sample, where each vessel in a fleet (or cruise) constitutes a stratum. However, to evaluate the effects of changes in observer coverage on the precision in catch and bycatch estimates we have employed standard estimators for two-stage cluster sampling (Cochran, 1977).

Table 3-1. Notation used in two-stage cluster sampling

Population (Fleet)	Sample	Defined As
N	n	# of vessels
M_i	m_i	# of tows for vessel *i*; *i*=1,2,...,n (sample)
X_{ij}	x_{ij}	weight of a species of interest for haul j, $j=1,2,\ldots,m_i$
Y_{ij}	y_{ij}	total weight of haul j; $j=1,2,\ldots,m_i$

An estimator for total catch is:

$$\hat{Y}_{..} = \frac{N}{n} \sum_{i=1}^{n} M_i \bar{y}_{i.} \tag{1.1}$$

where

$$\bar{y}_{i\cdot} = \frac{1}{m_i} \sum_{j=1}^{m_i} y_{ij} \tag{1.2}$$

is an estimate of the mean catch per haul for vessel *i.* Following the notation in Wolter (1985), the subscript ".." signifies that the estimate is based on units selected in two stages, while the subscript *i.* denotes that the estimate (of means or totals) applies to the *i*th unit, based on observations from the m_i second stage units. An estimator for the variance of (1) is:

$$v\left(\hat{Y}_{..}\right) = \left\{\frac{N^2}{n} (1-f_1) \sum_{i=1}^{n} \left(M_i \bar{y}_{i.} - \frac{\hat{y}_{..}}{N}\right)^2 /(n-1)\right\} + \frac{N}{n} \sum_{i=1}^{n} M_i^2 (1-f_{2i}) \frac{s_{2i}^2}{m_i} \tag{1.3}$$

where

$$s_{2i}^2 = \sum_{j=1}^{n} \left(y_{ij} - \bar{y}_{i.}\right)^2/(m_i-1) \tag{1.4}$$

is the estimated (population) variance in catch per haul for vessel *i*, $f_1 = n/N$ is the fraction of vessels sampled from a fleet, and $f_{2i} = m_i/M_i$ is the fraction of hauls sampled from vessel *i*. The standard error of the estimated total catch is $(v(\hat{y}_{..}))^{1/2}$. The coefficient of variation, cv = $se(\hat{y}_{..})/\hat{y}_{..}$, is used as a measure of the precision of the estimated total catch. For a fleet with 100% observer coverage, $f_1 = 1$, and the first component of the variance in eq. 1.3 is zero. The variability in catch and bycatch estimates, hence, results from the second stage of sampling (i.e., the sample of hauls from each vessel).

We also estimated the expected coefficient of variation in estimates of catch and bycatch for various sampling strategies:

(1) the fraction of vessels from a fleet (f_1) with observers onboard was varied from 0.2 to 1.0 in increments of 0.2,

(2) the fraction of hauls sampled from each observed vessel (f_2) was varied from 0.1 to 1.0, in increments of 0.1.

This method allowed us to evaluate the expected effects on precision in catch and bycatch estimates resulting from changing sampling effort.

3.2.1.2 Three-stage Cluster Sampling

The variance component resulting from the subsampling of hauls can be estimated if data on catch by species are collected for individual subsampling units by haul. We assume in this analysis that simple random sampling, without replacement (srs wor) is employed in the first, second, and third stage of sampling from a fleet. The following table summarizes the notation used in the estimation of catch and bycatch using data from three-stage cluster sampling.

Table 3-2. Notation used in three-stage cluster sampling

Population (Fleet)	Sample	Defined as
N	n	# of vessels
M_i	m_i	# of tows for vessel *i*; *i*=1,2,...,n (sample)
B_{ij}	b_{ij}	# subsamples from haul j, for vessel *i*; j=1,2,...,m_i (sample)
X_{ijk}	x_{ijk}	weight of a species of interest in subsample k from haul j and vessel *i*, k=1,2,...,b_{ij}
Y_{ijk}	y_{ijk}	total weight of subsample k from haul j and vessel *i*, k=1,2,...,b_{ij}

An estimator for total catch based on data from three stages of sampling is

$$\hat{Y}_{...} = \frac{N}{n} \sum_{i=1}^{n} \frac{M_i}{m_i} \sum_{j=1}^{M_i} \frac{B_{ij}}{b_{ij}} \cdot \bar{y}_{ij.} \tag{1.5}$$

where

$$\bar{y}_{ij.} = \frac{1}{b_{ijk}} \sum_{k=1}^{b_{ijk}} y_{ijk} \tag{1.6}$$

is the estimated mean weight of the subsamples from vessel *i* and haul *j*. The subscript "..." signifies that the estimate is based on units from three stages of selection (see Wolter, 1985). An estimator for the variance of the total catch estimate is:

$$v\left(\hat{y}_{...}\right) = \left(\sum_{i=1}^{N} \sum_{j=1}^{M_i} B_{ij}\right)^2 \cdot v\left(\bar{y}_{...}\right) \tag{1.7}$$

Other estimators used in our analysis, as described below, are as follows:

$$\bar{y}_{...} = \frac{1}{n} \sum_{i=1}^{n} w_i \, \bar{y}_{i.} \tag{1.8}$$

where

$$\bar{y}_{i..} = \frac{1}{m_i} \sum_{j=1}^{m_i} v_{ij} \, \bar{y}_{ij.}$$

$$v\left(\bar{y}_{...}\right) = \left(1 - f_1\right) \frac{s_1^2}{n} + \frac{f_1}{n^2} \sum_{i=1}^{n} w_1^2 \left(1 - f_{2i}\right) \frac{s_{2i}^2}{m_i} + \frac{f_1}{n^2} \sum_{i=1}^{n} w_i^2 \frac{f_{2i}}{m_i^2} \sum_{j=1}^{m_i} v_{ij}^2 \left(1 - f_{3ij}\right) \frac{s_{3ij}^2}{b_{ij}} \tag{1.9}$$

$$s_1^2 = \frac{1}{n-1} \sum_{i=1}^{n} \left(w_i \bar{y}_{i.} - \bar{y}_{...}\right)^2 \tag{1.10}$$

$$s_{2i}^2 = \frac{1}{m_i - 1} \sum_{j=1}^{m_i} (v_{ij}\bar{y}_{ij.} - \bar{y}_{i.})^2 \tag{1.11}$$

$$s_{3i}^2 = \frac{1}{b_{ij} - 1} \sum_{k=1}^{b_{ij}} (y_{ijk} - \bar{y}_{ij.})^2 \tag{1.13}$$

$$w_i = \frac{\sum_{j=1}^{M_i} M_{ij}}{\frac{1}{N} \sum_{i=1}^{N} \sum_{j=1}^{M_i} B_{ij}} \tag{1.14}$$

$$v_{ij} = \frac{B_{ij}}{\sum_{j=1}^{M_i} B_{ij} / M_i} \tag{1.15}$$

If data on weight and species composition are collected from individual third-stage subsampling units (baskets or partial hauls), then the effects of changes in sampling strategy can be assessed using the above equations. Variances in each stage can be estimated using equations 1.10, 1.11, and 1.13. Using the above equations, the expected cv for estimated total catch and bycatch can be calculated for different observer coverage for vessels (f_1), different fractions of hauls sampled (f_2), and for changes in the number of subsamples taken from each haul(b).

By examining equation 1.9 we see that the sampling of all hauls from all vessels in a fleet (i.e., $f_1 = f_2 = 1$) would eliminate the first two components of the variance in catch estimates. However, the third component resulting from the subsampling of catches would remain unless whole-haul sampling was employed for all hauls (i.e., each haul would be censussed rather than sampled). For fleetwide estimation of catch and bycatch the third component of the variance is likely to be small because a very large number of third-stage units are observed, as was noted earlier.

3.2.2 Estimating Catch of Individual Species and Variance of the Estimate

We used four methods to estimate the total fleetwide catch of individual species and the variance of each. In method 1a we used the standard estimator for two-stage sampling. In method 1b we use the delta-estimator to estimate the mean catch per vessel in the second stage. Methods 2a and 2b are based on ratio-estimates of the catch rates for individual species. Total number or weights in catches of individual species for a fleet can then be estimated by applying the ratio-based catch rate estimate to fleetwide total catch.

3.2.2.1 Method 1a: Regular Two-stage Estimator

An estimator for total catch of a species of interest is:

$$\hat{X}_{..} = \frac{N}{n} \sum_{i=1}^{n} M_i \, \bar{x}_{i.} \tag{1.16}$$

where

$$\bar{x}_{i\cdot} = \frac{1}{m_i} \sum_{j=1}^{m_i} x_{ij} \tag{1.17}$$

is an estimate of the mean catch per haul of the species of interest for vessel *i.* An estimator for the variance of $\hat{X}_{..}$ is:

$$v\left(\hat{X}_{..}\right) = \left\{\frac{N^2}{n} (1-f_1) \sum_{i=1}^{n} \left(M_i \, \bar{x}_{i.} - \frac{\hat{X}_{..}}{N}\right)^2 / (n-1)\right\} + \frac{N}{n} \sum_{i=1}^{n} M_i^2 \, (1-f_{2i}) \frac{s_{2i}^2}{m_i} \tag{1.18}$$

where

$$s_{2i}^2 = \sum_{j=1}^{n} \left(x_{ij} - \bar{x}_{i.}\right)^2 / (m_i - 1) \tag{1.19}$$

is the sample estimate of the (population) variance in catch per haul for vessel *i*, $f_1 = n/N$ is the fraction of vessels sampled from a fleet, and $f_{2i} = m_i/M_i$ is the fraction of hauls sampled from vessel *i.*

3.2.2.2 Method 1b: Regular Two-stage estimator, With Delta Estimator in Second Stage

Data on number or weight of individual species by haul often contain a large proportion of zero values. The distribution of PSC per tow for each vessel sampled by the observers is generally highly skewed, and as a result the ordinary sampling estimates of the mean prohibited species catch per vessel ($\bar{x}_{i.}$) may not be statistically efficient. More efficient[5] estimates of the mean catch of rare species for each vessel may be obtained based on the delta-distribution (Pennington 1983, 1986 and Smith 1981, 1988). By definition, a delta-distribution is a log-normal distribution with a spike at zero (Conquest et al. 1996). An unbiased estimate of the mean catch per haul of a species of interest for each vessel *i* ($\bar{x}_{i.}$) is

$$\bar{x}_{\Delta}=\begin{bmatrix}(m/n)\exp(\bar{z})G_m(s^2/2), & m>1\\ x_1/n, & m=1\\ 0, & m=0\end{bmatrix} \tag{1.20}$$

and the estimate of total catch is obtained from equation (1.16), substituting (1.20) for equation (1.17). The overall variance in estimated total catch is obtained from equation (1.18), but the large sample estimate of the variance of the estimated mean catch per haul for vessel *i* (s_{2i}^2/m_i) is estimated by (eq. 1.21):

$$v(\bar{x}_{\Delta})=\begin{bmatrix}(\frac{m}{n})\exp(2\bar{z})(\frac{m}{n})G_m^2(s^2/2)-[\frac{(m-2)}{(n-1)}]G_m[\frac{s^2(m-2)}{(m-1)}], & m>1\\ (x_1/n)^2, & m=1\\ 0, & m=0\end{bmatrix} \tag{1.21}$$

(Pennington, 1983), where n_i is the total number of observed hauls for vessel *i*, m is the number of samples with positive catches, z and s^2 are the sample mean and sample variance, respectively, of the log of observed values for the species of interest and

$$G_n(t)=1+\frac{(n-1)}{n}t+\sum_{j=2}^{\infty}\frac{(n-1)^{2j-1}}{(n+1)(n+3)...(n+2j-3)}x\frac{t^j}{j!}$$

[5]An estimator is considered efficient if it produces an estimate with a smaller standard error than other estimators.

We follow the methods of Conquest et al. (1996) and refer to equations 1.20 and 1.21 as the Pennington Delta-distribution estimates for catch data (Conquest et al. 1996). Pennington (1983, 1986, 1996) has shown that for small sample sizes, the performance of the ordinary sample mean estimator is much worse than other estimators (see also Conquest et al. 1996).

3.2.2.3 Method 2a: The Ratio Estimator of Catch Rate

For this analysis, Y and X denote the unknown total catch and catch of an individual species for a fleet. The catch rate (R) of a species of interest is then defined as:

$$R = X/Y$$

and a natural estimator for R is

$$\hat{R} = \hat{X}/\hat{Y} \tag{1.22}$$

where $\hat{X}$ and Y are estimated using the standard two-stage estimator (method 1a). The variance can be estimated by (Cochran, 1977):

$$v\left(\hat{R}\right) = \frac{1}{\hat{Y}^2}\left\{\frac{N^2}{n}(1-f_1)\sum_{i=1}^{n}\left(M_i\,\bar{d}_{i.} - \frac{\hat{x}_{..}}{N}\right)^2/(n-1)\right\} + \frac{N}{n}\sum_{i=1}^{n} M_i^2\,(1-f_{2i})\,\frac{s_i^2}{m_i} \tag{1.23}$$

where

$$s_i^2 = \sum_{j=1}^{n}\left(d_{ij} - \bar{d}_{i.}\right)^2/(m_i-1) \tag{1.24}$$

and

$$d_{ij} = x_{ij} - \hat{R}y_{ij}. \tag{1.25}$$

Ratios are currently used by NOAA to estimate prohibited species bycatch (PSC), but their application is not as presented here.

3.2.2.4 Method 2b: The Ratio Estimator, With the Delta-estimate of X

An alternative method for estimating the catch ratio R is to use the delta method for estimating the total weight or number of species catch X (Method 1b). The variance of the ratio R can also be estimated by the Taylor series:

$$v(\hat{R}) = \hat{R}^2 \left[\frac{v(\hat{Y})}{\hat{Y}^2} + \frac{v(\hat{X})}{\hat{X}^2} - 2\,\frac{c(\hat{Y},\hat{X})}{\hat{X}\hat{Y}} \right], \qquad (1.26)$$

where $v(\hat{Y})$, $v(\hat{X})$, and $c(\hat{Y}, \hat{X})$, denote estimators of Var{ $\hat{Y}$ }, Var{ $\hat{X}$ }, and Cov{ $\hat{Y}, \hat{X}$ } respectively. The estimators of $v(\hat{Y})$, $v(\hat{X})$, and $c(\hat{Y}, \hat{X})$ should take into account both the sampling design and the form of the estimators $\hat{Y}$ and $\hat{X}$ (Wolter, 1985, p. 236). If the delta estimator reduces the coefficient of variation in estimated bycatch, then the variance in the bycatch ratio will also be reduced.

3.2.3 Estimating Biological Characteristics of Target Species

Biological assessments of fisheries resources require information on: (1) landings; (2) fishing effort; and (3) biological characteristics (length frequencies, age, and sex) of commercial catches by species. The Observer Program collects data on length, age, and sex of the target species. The observers are instructed to collect measurements from a sample of 150 fish each day (Observer Manual, p. 5-15), and these fish may be taken from a number of hauls over the course of the day. To evaluate the efficiency of current sampling strategies for collecting biological data for target species, we estimated the coefficient of variation (cv) of the mean length, proportions at age, and proportions of females in fleetwide catches of pollock and yellowfin sole. We then assessed the effects on cv of changes in: (1) the fraction of hauls sampled; and (2) the number of fish sampled from each haul. Because the two demonstration fisheries evaluated in this study generally had 100% observer coverage, we treated each vessel in a fleet as a stratum, and used methods from two stage cluster sampling within vessels to estimate key biological parameters for fleetwide catches. For each fishery, we estimated the mean length, proportions by age, and proportions of females in fleetwide catches of the target species.

We assumed that data on length, age, and sex are collected from individual fish sampled from n randomly selected hauls from each vessel. We assumed that the total hauls sampled for biological characteristics (age, length, sex composition) from a vessel form a random sample from all hauls taken by this vessel. In practice, it is not feasible to obtain random samples of fish from the entire catch of a haul. However, observers are instructed to spread out the sampling of fish within each haul, and we assumed in this study that the individual measurements (length, age, sex) come from a simple random sample of individual fish from each haul. Within each vessel, the sampling procedure is a two-stage sampling scheme, where the hauls are the primary units, and the fish sampled are the secondary units.

Since the catches from each haul vary in size, the population estimator $\bar{x}_k$ for mean length of fish in the entire catch from all hauls for vessel k is:

$$\bar{x}_k = \sum_{i=1}^{n} M_{ik}\, \bar{x}_{ik} / \sum_{i=1}^{n} M_{ik} \tag{1.27}$$

where M_{ik} is the number of fish caught in haul i from vessel k, and $\bar{x}_{ik}$ is the average length of the m_{ik} fish in the subsample (see, e.g., Cochran, 1977). An estimator for the variance of $\bar{x}_k$ is:

$$v\left\{\bar{X}_k\right\} = \left\{\frac{1 - f_{1k}}{M_k^2 n_k} \sum_{i=1}^{n_k} \frac{M_{ik}^2 \left(\bar{x}_{ik} - \bar{x}_k\right)^2}{(n_k - 1)}\right\} + \frac{1}{n_k N_k \bar{M}_k^2} \sum_{i=1}^{n_k} M_{ik}^2 \left(1 - f_{2ik}\right) \frac{s_{2ik}^2}{m_{ik}} \tag{1.28}$$

where

$$s_{2ik}^2 = \sum_{j=1}^{m_{ik}} \left(x_{ijk} - \bar{x}_{ik}\right)^2 / (m_{ik} - 1) \tag{1.29}$$

is an estimate of the within haul variance of the variable of interest (e.g., individual lengths) based on the measurements of m_{ik} fish in the subsample from haul i. Ratio estimates of this type were also used to estimate the proportion of fish in total catches that fall into a certain category. This is done by introducing an indicator variable (I) which takes the value 1 when the measurement is falling in the category of interest, and 0 otherwise (see Cochran, 1977). As an example, let I_{ik} = 1 for any pollock of age 7, and 0 otherwise. Using the equations 1.27 and 1.28, substituting I_{ijk} for x_{ijk}, an estimate of the proportion of age 7 pollock in the total catch by vessel k is simply $\bar{I}_k$, and an estimate of the standard error is obtained by taking the square root of var $\bar{I}_k$. The sample estimate used for means and proportions for the population of fish in the fleetwide catch of a species by V vessels is where C_k is the total catch by vessel k. The variance of the estimate $\bar{x}_{st}$ is

$$\bar{x}_{st} = \frac{\sum_{k=1}^{v} c_k \bar{x}_k}{\sum_{k=1}^{v} c_k}, \tag{1.30}$$

$$v(\bar{x}_{st}) = \sum_{k=1}^{v} w_k^2 v(\bar{x}_k), \tag{1.31}$$

where the stratum weight for vessel k,

$$W_k = \frac{c_k}{\sum_{k=1}^{v} c_k} \tag{1.32}$$

is the proportion of the fleetwide catch taken by vessel k.

The coefficient of variation in estimates of mean length, proportions at age, and proportions by sex in total catches of a target species were estimated for various sampling strategies:

(1) the fraction of hauls sampled (f_1) from each observed vessel was varied from 0.2 to 1.0 in increments of 0.2;

(2) the number of fish sampled (f_2) from each observed haul (m_i) was varied from 5 to 200 fish in varying increments.

3.3 COMPARISON OF WEEKLY CATCH ESTIMATES FROM PRODUCTION REPORTS AND OBSERVER DATA

Simple regression analysis was used to further explore the differences between industry reported and observer based estimates of weekly catch by processor. The ratio of observer based weekly catch estimates (W_{OBS}) and the production reports (W_{WPR}) by processor was calculated as a means of identifying large differences between observer estimates and production reports.

4.0 RESULTS

We present our analysis results separately for each demonstration fishery. Fishery 1, the offshore fishery for pollock, is conducted in three distinct time periods with separate quotas: the A season (January 1 to April 15), the CDQ fishery (April 16 to August 15), the B season (August 16 to December 31). Catch and bycatch estimation results for this fishery are presented by season so that the effects of differences in sampling effort within and between seasons can be assessed. Estimates of biological characteristics of the catches are presented separately for three geographic regions: the South East (SE), the North West (NW), and the EBS. We address the regions separately because the length at age of pollock vary among regions, and the sampling effort for collecting data on biological characteristics differs among regions.

The offshore fishery for yellowfin sole in the BSAI region is open until the quota is caught, or is closed when the limit for prohibited species bycatch is exceeded. Thus, we did not partition this fishery by season in our analyses.

While tables will be found within the text of this section, figures are presented grouped following the text. This was done to facilitate the continuity of the text for the reader.

4.1 DEMONSTRATION FISHERY 1: Pollock

4.1.1 Estimates of Catch

Figure 4-1 presents five estimates of the total groundfish catch in the offshore pollock fishery. One estimate is our synthesized blend estimate based on the algorithm employed through 1994, one is the sum of the WPR estimates, and one is the sum of the adjusted OTC estimates. The two additional estimates were derived using equation (1.1), and two sources of data for haul weights:

(1) estimated groundfish catch weights based on all hauls where the observer made an independent catch weight estimate (OBS, all hauls);

(2) estimated groundfish catch weights based only on hauls that were observed and also sampled for determining species composition; hauls with only observer catch weight estimates were excluded from this data set (OBS, subsampled).

These two data sets were adjusted for PSC and NONA species as described earlier in Section 2.2. For the CDQ fishery, estimates are provided using only observer data. The blend system and WPRs are not used for this fishery because the vessels are required to have certified holding bins and two observers who generally estimate the weights of all hauls.

Our catch estimates and associated standard errors are presented in Table 4-1. The standard errors were estimated by taking the square root of equation (1.3).

Table 4-1. Statistical estimates of total groundfish catch and associated standard errors based on the different data groups for the 1994 BSAI pollock fishery (N/A denotes not applicable)

Data Group	A Season		CDQ fishery		B Season	
	Total Catch (metric tons)	Standard Error	Total Catch (metric tons)	Standard Error	Total Catch metric tons)	Standard Error
Adjusted OTC	365,507	N/A	5,666	N/A	385,609	N/A
Adjusted OBS (all hauls)	384,637	8,135	5,991	204	393,663	2,037
Adjusted OBS (subsampled)	383,906	8,174	5,960	205	404,742	2,597
Blend	370,935	N/A	N/A	N/A	396,407	N/A
WPR	365,604	N/A	N/A	N/A	385,898	N/A

The variance of our synthesized blend, adjusted OTC, and WPR estimates cannot be calculated, precluding a statistical comparison among all five estimates. Note the relatively "tight" confidence limits of the statistical estimates. The adjusted OTC and WPR estimates for A and B seasons fall below the lower 95% confidence limits for the statistical estimates derived using both observer data sets. The confidence limits of the estimates using the two different observer data sets overlap, and there does not appear to be any bias introduced by the inclusion of the unsampled hauls or improvement in precision by use of the larger data set.

Tables 4-2, 4-3, and 4-4 compare estimates of total groundfish, pollock, Pacific cod, rock sole, chinook, other salmon, and herring for the A and B seasons and the CDQ fishery derived using different estimation techniques.[6] Contrasts are presented, first, between the blend estimate of total groundfish catch and each of the four other estimates of total groundfish catch that we developed. We selected the blend estimate as a "baseline" against which to contrast the other estimates, since that is the estimate currently used in management. We, secondly, provide estimates of catch of individual species generated statistically using our two estimation techniques described in Section 3.2.2 (see Footnote 6)

[6]As can be seen in Section 3.2.2, the methods for calculating catch of individual species using the standard two-stage estimator and the ratio estimator yield similar estimates (this is also the case for both estimators when used with the delta estimator). Therefore, to conserve space, we only present the catch estimates in Tables 4-2, 4-3, and 4-4 as developed with and without the delta estimator. However, the variance of the catch estimates does differ among all four estimators (two-stage and ratio, with and without delta), as will be discussed in Section 4.1.2.

Table 4-2. Comparison of various catch estimates derived from statistical estimators and the blend method for *the A Season fishery during the 1994 BSAI* pollock fishery

Species	Non-blend catch estimate	Catch estimate based on blend estimate of total catch	Percent difference between statistical estimator and the estimate based on blend total catch
Total groundfish (metric tons)			
Adjusted OTC	365,507	370,935	-1.5
Adjusted OBS (all hauls)	384,637	370,935	3.7
Adjusted OBS (subsampled hauls)	383,906	370,935	3.5
WPR	365,604	370,935	-1.4
Pollock (metric tons)			
Adjusted OBS (subsampled hauls); Without delta estimator	366,984	323,039	13.6
Adjusted OBS (subsampled hauls); With delta estimator	391,057	323,039	21.1
Pacific cod (metric tons)			
Adjusted OBS (subsampled hauls); Without delta estimator	7,368	4,654	58.3
Adjusted OBS (subsampled hauls); With delta estimator	9,398	4,654	101.9
Rock sole (metric tons)			
Adjusted OBS (subsampled hauls); Without delta estimator	3,720	3,128	18.9
Adjusted OBS (subsampled hauls); With delta estimator	13,170	3,128	321.0
Chinook (number of individuals)			
Adjusted OBS (subsampled hauls); Without delta estimator	13,851	12,474	11.0
Adjusted OBS (subsampled hauls); With delta estimator	14,823	12,474	18.8
Other salmon (number of individuals)			
Adjusted OBS (subsampled hauls); Without delta estimator	497	451	10.3
Adjusted OBS (subsampled hauls); With delta estimator	501	451	11.2
Herring (metric tons)			
Adjusted OBS (subsampled hauls); Without delta estimator	1	1	23.9
Adjusted OBS (subsampled hauls); With delta estimator	1	1	22.3

Table 4-3. Comparison of various catch estimates derived from statistical estimators for the CDQ fishery during the 1994 BSAI pollock fishery; blend estimates are not made for the CDQ fishery (N/A denotes not applicable)

Species	Non-blend catch estimate	Catch estimate based on blend estimate of total catch	Percent difference between statistical estimator and the estimate based on adjusted OTC
Total groundfish (metric tons)			
Adjusted OTC	5,666	N/A	N/A
Adjusted OBS (all hauls)	5,991	N/A	+5.7
Adjusted OBS (subsampled hauls)	5,960	N/A	+5.2
WPR	N/A	N/A	N/A
Pollock (metric tons)			
Adjusted OBS (subsampled hauls); Without delta estimator	5,088	N/A	N/A
Adjusted OBS (subsampled hauls); With delta estimator	5,248	N/A	N/A
Pacific cod (metric tons)			
Adjusted OBS (subsampled hauls); Without delta estimator	126	N/A	N/A
Adjusted OBS (subsampled hauls); With delta estimator	130	N/A	N/A
Rock sole (metric tons)			
Adjusted OBS (subsampled hauls); Without delta estimator	20	N/A	N/A
Adjusted OBS (subsampled hauls); With delta estimator	20	N/A	N/A
Chinook (number of individuals)			
Adjusted OBS (subsampled hauls); Without delta estimator	48	N/A	N/A
Adjusted OBS (subsampled hauls); With delta estimator	48	N/A	N/A
Other salmon (number of individuals)			
Adjusted OBS (subsampled hauls); Without delta estimator	78	N/A	N/A
Adjusted OBS (subsampled hauls); With delta estimator	79	N/A	N/A
Herring (metric tons)			
Adjusted OBS (subsampled hauls); Without delta estimator	41	N/A	N/A
Adjusted OBS (subsampled hauls); With delta estimator	14	N/A	N/A

Table 4-4. Comparison of various catch estimates derived from statistical estimators and the blend method for the B Season fishery during the 1994 BSAI pollock fishery

Species	Non-blend catch estimate	Catch estimate based on blend estimate of total catch	Percent difference between statistical estimator and the estimate based on blend total catch
Total groundfish (metric tons)			
Adjusted OTC	385,609	396,407	-2.7
Adjusted OBS (all hauls)	393,663	396,407	-0.7
Adjusted OBS (subsampled hauls)	404,742	396,407	2.1
WPR	385,898	396,407	-2.7
Pollock (metric tons)			
Adjusted OBS (subsampled hauls); Without delta estimator	388,433	372,458	4.3
Adjusted OBS (subsampled hauls); With delta estimator	413,481	372,458	11.0
Pacific cod (metric tons)			
Adjusted OBS (subsampled hauls); Without delta estimator	6,228	4,506	38.2
Adjusted OBS (subsampled hauls); With delta estimator	8,702	4,506	93.1
Rock sole (metric tons)			
Adjusted OBS (subsampled hauls); Without delta estimator	193	182	6.0
Adjusted OBS (subsampled hauls); With delta estimator	227	182	25.0
Chinook (number of individuals)			
Adjusted OBS (subsampled hauls); Without delta estimator	1,934	1,978	-2.2
Adjusted OBS (subsampled hauls); With delta estimator	1,832	1,978	-7.4
Other salmon (number of individuals)			
Adjusted OBS (subsampled hauls); Without delta estimator	37,993	44,348	-14.3
Adjusted OBS (subsampled hauls); With delta estimator	36,015	44,348	-18.8
Herring (metric tons)			
Adjusted OBS (subsampled hauls); Without delta estimator	563	575	-2.1
Adjusted OBS (subsampled hauls); With delta estimator	786	575	36.6

and compare those estimates to an estimate derived from the blend estimate of total groundfish catch.

As is evident in Table 4-2, the differences among the estimates of total groundfish catch for the A season are small (<5 percent), with the two statistical estimates being greater than the blend, and the OTC and WPR estimates being less. The fact that the OTC and WPR estimates fall below the lower 95 percent confidence limits of the two statistical estimates is a reflection to some extent of the relatively low variance of those estimates (the standard error is less than 5 percent of the estimates).

Differences among the three estimates of individual species catch in the A season are much greater than among the estimates of total groundfish catch. The estimate derived using the standard two stage cluster estimator is consistently closer to the estimate based on the blend than the estimate derived using the delta estimator. In addition the agreement among the estimation techniques is best for the species that dominates the harvest (pollock) and for the species that are quantified numerically (salmon), and worst for the less abundant species (Pacific cod, rock sole, herring).

The blend is not applied in the CDQ fishery, and, in this case, we contrast only the two statistical estimates of total catch to the estimate based on the adjusted OTC data (Table 4-3). These estimates differ from each other to a somewhat higher degree than do the estimates for the A season. Estimates of individual species catches derived for this fishery with and without the delta estimator are generally in closer agreement than in the case of the A season fishery, with the largest difference occurring with herring.

The contrasts among estimators for the B season fishery are very similar to those for the A season fishery, in magnitude of differences. However, while in the A season fishery the statistical estimates of individual species catch were consistently higher than the estimate based on the blend, that consistency is not present in the results for the B season.

Figure 4-2 addresses factors that influence the precision of the catch estimates and shows the expected changes in coefficient of variation (cv) in fleetwide estimates of total groundfish catch in relation to observer coverage and the proportion of hauls sampled from each vessel. The estimated cvs are based on equations 1.1 and 1.3, using sample-based estimates of the population variances in the first and second stage of sampling. The fraction of vessels in a fleet with observer coverage (f_1) was varied from 0.2 to 1.0 in increments of 0.2. The fraction of hauls sampled for each observed vessel (f_2) was varied from 0.1 to 1.0 in increments of 0.1. Note that the cv for the CDQ fishery is much larger than that for the A and B seasons.

Figures 4-3 through 4-9 show cumulative weekly catch estimates for total groundfish catch, pollock catch, Pacific cod, rock sole, chinook bycatch, other salmon and herring during each season based on observer subsampled data. Confidence limits are presented for individual species catch estimates. In Figures 4-3 through 4-9, we present the results for the standard two-stage estimate (without the delta estimator) to calculate cumulative weekly catch estimates for groundfish species and the ratio estimator with the delta estimator for prohibited species. We selected these estimators based on the anticipated performance of the estimators, the results of comparisons of the cv values for each of the individual species catch estimates, and the proportion of the species analyzed in the observed subsampled catches, as is discussed further in Section 4.1.2. Plots of this type could be used for the inseason monitoring of fleetwide catch. Note how the size of the confidence limit varies substantially among the species. Also note that herring catch is presented in kilograms rather than metric tons because of the small magnitude of catch.

Table 4-5 provides estimates of total groundfish catches and the standard error of those estimates for a small number of vessels selected based on the presence of salmon in total catch, as discussed below. These estimates illustrate the substantial variability in harvest among vessels and among hauls from a single vessel. No consistent relationship is evident between magnitude of catch and variability as reflected in the standard error.

Table 4-5. Estimates of total groundfish catch and associated standard error for selected vessels participating in the 1994 BSAI pollock fishery (N/A denotes not applicable). Catch estimates based on the observer subsampled data set. Vessels were assigned simple numeric characters to maintain anonymity.

Vessel	A Season		CDQ fishery		B Season	
	Total Catch (mt)	Standard Error	Total Catch (mt)	Standard Error	Total Catch (mt)	Standard Error
1	9,140	228	N/A	N/A	11,072	398
2	4,808	135	N/A	N/A	6,515	581
3	20,293	425	1,611	26	15,008	348
4	7,486	251	468	79	10,127	589
5	25,120	146	N/A	N/A	23,240	756
6	12,528	159	N/A	N/A	15,100	87

Figure 4-10 presents the expected changes in the cvs of total catch estimates for individual vessels in relation to the fraction of hauls sampled (f_2). A very large difference among vessels is apparent in the gains in precision that could be achieved by increasing both observer coverage and fraction of hauls sampled. In general, vessels with large catches would show the greatest increases in the precision of the catch estimates from increases in subsampling and coverage.

4.1.2 Coefficient of Variation in Estimates of Catch by Species

Estimates of the total catch were investigated for the following non-prohibited species: Pollock, Pacific cod, and rock sole. Figure 4-11 shows estimates of the coefficient of variation for estimates of fleetwide catches of non-prohibited species using the four estimation techniques presented in Section 3.2.2[7]. The application of the delta estimator, when incorporated into the standard two-stage estimator, generally results in the highest cv values. The lowest cv values for all three species generally resulted from the ratio estimator with the delta estimator.

Figures 4-12 and 4-13 show expected changes in the cvs for fleetwide estimates (using methods 1a and 2a) of total pollock catch by season in relation to observer coverage (f_1), and the fraction of hauls sampled from each vessel (f_2). These figures show that while the ratio estimator with the delta estimator yields lower cvs than does the standard two-stage estimator, gains in precision using either method are much greater from increasing the fraction of vessels sampled than from increasing the fraction of hauls sampled. For 100% observer coverage, highly precise estimates of total catch are achieved with low fraction of hauls sampled. The average fraction of hauls that were sampled for the offshore pollock fishery in 1994 was about 63% overall, with 54% in the A season, 58% in the B season, and 92% in the CDQ fishery. No substantial gain in precision would be obtained by increasing the number of hauls sampled.

Figures 4-14 through 4-17 present expected changes in cv calculated as for pollock above, for Pacific cod, and rock sole, each of which comprise relatively small fractions of the total groundfish catch to the pollock fishery. What is most striking in these results is that CDQ fishery exhibits the highest variability for all the species evaluated, and that this variability can be best addressed through a high fraction of vessels sampled, as is currently the management practice for this fishery. For other seasons, the greatest gains in precision are from increases in the fraction of vessels sampled, with relatively little gain in precision with increases in the fraction of hauls sampled. Differences in the magnitude of cv estimates using the two estimation techniques are not as great as in the case of total pollock catch.

Figure 4-18 presents a comparison of the four methods for estimating fleetwide prohibited species catch variability of chinook salmon, other salmon, and herring. No single method is superior across all species and seasons. As a general observation, the standard two-stage and ratio estimators without inclusion of the delta estimator tend to yield the lowest cv.

The effects of changing sampling strategies on fleetwide estimates of prohibited species catches (chinook, other salmon, herring) were investigated. Figures 4-19 to 4-24 show the expected cvs for statistical estimates of total catches for prohibited species using the standard two-stage estimator (method 1a) and the ratio estimator with the delta estimator

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[7]In discussing coefficient of variation results, we present all four estimation methods here since unlike the catch estimates, each method provides a different estimate of the coefficient of variation.

(method 2a). We selected two estimators for each species that yielded the lowest cvs in at least one of the seasons, in order to investigate the sensitivity of the variance estimation techniques to changes in fraction of vessels samples and fraction of hauls sampled. Except in the case of herring, further reductions in cv are minimal as the fraction of hauls sampled is increased beyond 50% (except for the CDQ fishery) whereas substantial cv reductions continue as the fraction of cruises sampled is increased.

Figures 4-25 to 4-30 show the expected changes in cvs of estimates of total catch of chinook, other salmon species, and herring for individual vessels in relation to the fraction of hauls sampled (f_2) (see footnote 5). The estimates of total catch of chinook and other salmon by vessel are presented in Table 4-6. The results demonstrate that vessel-specific estimates of prohibited species catches can be highly imprecise and there is no apparent relationship between magnitude of salmon catch and precision.

Table 4-6. Estimates of total catch of chinook salmon and other salmon, with associated coefficient of variation (CV) for selected vessels participating in the 1994 BSAI pollock fishery (N/A denotes not available). Catch estimates based on the observer subsampled data set and calculated using the ratio estimator with the delta estimator. Vessels were assigned simple numeric characters to maintain anonymity.

Vessel	Salmon Species	A Season		CDQ fishery		B Season	
		Total Catch (#)	cv	Total Catch (#)	cv	Total Catch (#)	cv
1	chinook	854	0.42	N/A	N/A	12	0.46
	other	0	--	N/A	N/A	807	0.47
2	chinook	21	0.67	N/A	N/A	0	--
	other	0	--	N/A	N/A	551	0.37
3	chinook	711	0.11	2	0.25	31	0.25
	other	76	0.28	43	0.09	258	0.16
4	chinook	263	0.37	0	--	133	0.30
	other	3	0.63	0	--	714	0.26
5	chinook	42	0.47	N/A	N/A	121	0.19
	other	3	0.79	N/A	N/A	733	0.34
6	chinook	922	0.12	N/A	N/A	161	0.06
	other	4	0.75	N/A	N/A	9505	0.04

4.1.3 Estimates of Biological Characteristics of Catches

In this section we provide estimates of the cv for pollock population characteristics estimated from fleetwide catches and using different sampling strategies. We estimate proportions by age, mean length, and proportion of females in total catches from the SE region, the NW region , and the EBS region. The fraction of hauls sampled is varied from 0.2 to 1.0 in increments of 0.2, and the number of fish sampled from each haul is varied between 5 and 200.

The age-length relationships for pollock by region are presented in Figure 4-31 (Wespestad, pers. com.). Based on these curves we used length data for pollock as a proxy for their age. The estimated proportions of ages 1 to 10+ in the fleetwide catches of pollock by region is presented in Figure 4-32. Expected cvs of estimated proportions at age by region for various sampling strategies are presented in Figures 4-33 to 4-41. The changes in the cvs of estimated proportions of females and estimated mean length of pollock in the fleetwide catches by season are presented in Figures 4-42 to 4-44.

The results reveal substantial regional differences in the precision of estimated proportions by age, proportions by sex, and mean length of pollock for the fleetwide catches. The fishing effort is significantly different between regions, with highest number of hauls and catch size in the SE region, and the lowest number of hauls and catch size in the EBS region. The SE region, therefore, receives a substantially higher sampling effort than EBS region since the fractions of hauls sampled, and the numbers of fish sampled from each haul are the same for both regions. The results suggest that catches from the SE and NW regions are oversampled for size and sex composition. The number of fish sampled per haul could be reduced as low as 40 to 80 fish without any detectable loss in precision. For the SE region, the results also suggest that sampling of 20% or less of the hauls would yield highly satisfactory cvs ($cv<0.1$) for estimated proportions by age or sex. However, for other regions the cv appears to be substantially reduced over all increments of the fraction of hauls sampled, with the greatest reduction occurring as the fraction increases to greater than 80%. This result strongly suggests that the composition of catches varies significantly from vessel to vessel.

4.1.4 Comparison of Weekly Catch Estimates of Individual Observers and Industry

In this section, data from individual observers was analyzed to examine how estimates of weekly catch based on individual observer samples compare with industry reports of weekly catch.

Figures 4-45 and 4-46 show comparisons of weekly catch estimates based on observer reports and industry reports and the linear best fit lines for the A and B seasons, respectively. Figures 4-47 and 4-48 present the average square error between each estimate based on observer data and the corresponding weekly industry report, for seasons A and B, respectively.

Similarly, Figures 4-49 and 4-50 show the ratio of observer report to industry report in each season. The variability illustrated in these figures results from both observer and industry estimate impression, but provides no basis for validating either source of estimates.

4.2 DEMONSTRATION FISHERY 2: Yellowfin Sole

4.2.1 Estimates of Catch

Figure 4-51 presents five estimates of the total fleetwide groundfish catch in the offshore fishery for yellowfin sole. These estimates and standard errors of the two statistical estimates are presented in Table 4-7. The standard errors are estimated by taking the square root of equation (1.3). The blend, WPR, and adjusted OTC estimates are outside the lower 95% confidence limits of both statistical estimators; however, the confidence intervals for the two statistical estimators are fairly similar and overlap.

Table 4-7. Statistical estimates of total groundfish catch and associated standard errors based on the different data groups available for the 1994 BSAI yellowfin sole fishery (N/A denotes not applicable)

Data Group	Total Catch (metric tons)	Standard Error
Adjusted OTC	192,885	N/A
Observer Estimates (all hauls)	213,387	1,275
Observer Estimates (subsampled hauls)	213,236	1,449
Blend Algorithm	195,135	N/A
WPR	193,590	N/A

Table 4-8 compares estimates catch of total groundfish, yellowfin sole, Pacific cod, pollock, halibut, bairdi Tanner crab, other Tanner crab, red king crab, and other king crab using different estimation techniques (see Footnote 6). Contrasts are presented, first, between the blend estimate of total groundfish catch and the four other estimates and, secondly, between the blend estimates for individual species catch and statistical estimates with and without the delta estimator (see Footnote 6) using the observer subsampled data set. The differences among the estimates of total groundfish catch are fairly small, although the difference between the blend and the statistical estimators is greater than in the pollock fishery (approximately 9 percent). Similar to the pollock fishery, both statistical estimates are greater than the blend estimate and the adjusted OTC and WPR estimates are less than the blend.

For individual species estimates, most of the results from the yellowfin sole fishery are consistent with the results of the pollock analysis. Differences among the three estimates of

Table 4-8. Comparison of various catch estimates derived from statistical estimators and the blend method for the 1994 BSAI yellowfin sole fishery

Species	Non-blend catch estimate	Catch estimate based on blend estimate of total catch	Percent difference between statistical estimator and the estimate based on blend total catch
Total groundfish (metric tons)			
Adjusted OTC	192,885	195,135	-1.2
Adjusted OBS (all hauls)	213,387	195,135	9.4
Adjusted OBS (subsampled hauls)	213,236	195,135	9.3
WPR	193,590	195,135	-0.8
Yellowfin sole (metric tons)			
Adjusted OBS (subsampled hauls); Without delta estimator	122,007	95,491	27.8
Adjusted OBS (subsampled hauls); With delta estimator	170,952	95,491	79.0
Pacific cod (metric tons)			
Adjusted OBS (subsampled hauls); Without delta estimator	18,885	12,695	48.8
Adjusted OBS (subsampled hauls); With delta estimator	21,886	12,695	72.4
Pollock (metric tons)			
Adjusted OBS (subsampled hauls); Without delta estimator	41,129	31,063	35.6
Adjusted OBS (subsampled hauls); With delta estimator	48,442	31,063	55.9
Halibut (metric tons)			
Adjusted OBS (subsampled hauls); Without delta estimator	755	760	-0.7
Adjusted OBS (subsampled hauls); With delta estimator	790	760	3.9
Bairdi Tanner crab (number of individuals)			
Adjusted OBS (subsampled hauls); Without delta estimator	1,188,340	1,105,625	7.5
Adjusted OBS (subsampled hauls); With delta estimator	1,175,839	1,105,625	6.4
Other Tanner crab (number of individuals)			
Adjusted OBS (subsampled hauls); Without delta estimator	8,493,579	8,260,188	2.8
Adjusted OBS (subsampled hauls); With delta estimator	8,958,705	8,260,188	8.5
Red king crab (number of individuals)			
Adjusted OBS (subsampled hauls); Without delta estimator	16,232	15,115	7.4
Adjusted OBS (subsampled hauls); With delta estimator	16,676	15,115	10.3
Other king crab (number of individuals)			
Adjusted OBS (subsampled hauls); Without delta estimator	12,319	12,543	-1.8
Adjusted OBS (subsampled hauls); With delta estimator	12,696	12,543	1.2

individual species catch are generally greater than among the estimates of total groundfish catch. Estimates derived using a statistical estimator without the delta estimator are consistently closer to the blend estimate than estimates derived with the delta estimator. In addition, agreement appears to be greatest for species that dominate the harvest (yellowfin sole) or are quantified numerically (all four species of crabs). In considering the estimates of catch of individual species statistically derived using the delta estimator, we note that the sum of catch estimates of the different species exceeds all estimates of total catch. These results are a consequence of the distributions and statistical properties of the data we employed in the analyses. It is important to recognize in consideration of the application of statistical procedures such as these in management that these catch estimates are statistically derived and have an associated degree of uncertainty and confidence limits, as is discussed further in the next section.

Figure 4-52 shows the expected changes in coefficient of variation (cv) in fleetwide estimates of total groundfish catch as a function of observer coverage and the fraction of hauls sampled from each vessel. The plot shows that the cv is relatively unaffected by increases in the fraction of hauls sampled but it is strongly affected by the fraction of vessels sampled.

Figures 4-53 through 4-61 show cumulative weekly catch estimates for catch for total groundfish, yellowfin sole, pollock, Pacific cod, Pacific halibut, bairdi Tanner crab, other Tanner crab, red king crab, and other king crab bycatch. Confidence intervals are presented for individual species catch estimates. In these figures, we present the results for estimators selected based on the anticipated performance of the estimators, the results of comparisons of the cv values for each of the individual species catch estimates, and the proportion of the species analyzed in the observed subsampled catches. As in the case of the pollock fishery, plots of this type could be used for the inseason monitoring of catch and bycatch. The differences among species in magnitude of the confidence limits illustrate the differing level of uncertainty associated with the species estimates.

Table 4-9 provides estimates of total groundfish catches for a small number of vessels from the 1994 EBS yellowfin sole fishery (selected based on diversity of catch). Figure 4-62 presents the expected changes in the cvs of total catch estimates for individual vessels as a function of the fraction of hauls sampled (f_2). Clearly the degree of uncertainty in catch estimates varies widely among vessels and appears unrelated to the size of the catch.

4.2.2 Coefficient of Variation in Estimates of Catch by Species

Estimates of the total catch were investigated for the following non-prohibited species or species groups: yellowfin sole, pollock and Pacific cod. Figure 4-63 shows estimates of the coefficient of variation for estimates of fleetwide catches of non-prohibited species using the four estimation techniques presented in Section 3.2.2 (see Footnote 7). The application of the delta estimator, when incorporated into the standard two-stage estimator, increases the cv dramatically (i.e., yields a much larger variance estimate). The lowest cv for all three species was produced by the ratio estimator with delta. Figures 4-64 through 4-66 show changes in the cvs for estimates of non-prohibited species catch as a function of the fraction of cruises sampled (f_i) and the fraction of hauls sampled (f_2). As in the case of the pollock fishery, cv is most impacted by fraction of vessels sampled.

Table 4-9. Estimates of total groundfish catch and associated standard error for selected factory trawlers participating in the 1994 BSAI yellowfin sole fishery. Catch estimates based on the observer subsampled data set. Vessels were assigned simple numeric characters to maintain anonymity.

Vessel	Total Catch (mt)	Standard Error
7	299	16
8	7,275	142
9	6,352	158
10	8,068	214
11	598	19
12	1,845	127

Estimates of total fleetwide catches for the following prohibited species or species groups were investigated: Pacific halibut, bairdi Tanner crab, other Tanner crab, red king crab, and other king crab. Figure 4-67 provides cvs for estimated fleetwide catches of prohibited species based on the four different estimation methods. Only marginal differences in cvs result from three of the four methods with the standard two-stage estimator with delta estimator yielding the highest cv. Most vessels have very few hauls with prohibited species catches for any particular species. The delta-estimate of mean catch per haul is identical to the usual sample mean when only one haul has catch size greater than 0. Figures 4-68 through 4-72 present cvs for estimated fleetwide catches of prohibited species in relation to fraction of vessels sampled (f_1) and the fraction of hauls sampled (f_2), for methods 1a and 2a. The ratio estimator tends to produce lower cv values with or without the delta estimator than the two-stage estimator for most species.

4.2.3 Estimates of Biological Characteristics of Catches

In this section we provide estimates of the cv for yellowfin sole population characteristics estimated from fleetwide catches and using different sampling strategies (see footnote 5). We estimate proportions by age, mean length, and proportion of females in total catches from the 1994 EBS fishery. The fraction of hauls sampled are varied from 0.2 to 1.0 in increments of 0.2, and the number of fish sampled from each haul are varied between 5 and 200.

Figure 4-73 presents the length at age relationship for yellowfin sole based on 12 years (1979 to 1990) of data from AFSC surveys (Wilderbuer 1996). Based on this age-length curve we used length frequency data as a proxy for the age composition in yellowfin sole catches. The estimated proportions of ages 3 to 14+ in the fleetwide catches of yellowfin sole is presented in Figure 4-74. Figures 4-75 to 4-78 present cvs for estimated proportions at age using various sampling strategies. Yellowfin sole begin to recruit to the fishery at age 7 and they are fully recruited at age 13 (Wilderbuer 1996). Estimated age of 50% maturity is around 10.5 years (Nichol 1996).

The cvs for the estimated proportions of females and for estimated mean length of yellowfin sole are presented in Figure 4-79. These plots illustrate that the optimal fraction of hauls to be sampled and the optimum number of fish to be sampled per haul varies widely depending on which biological characteristic is considered.

4.2.4 Comparison of Weekly Catch Estimates of Individual Observers and Industry

Figure 4-80 shows a comparison of weekly catch estimates based on observer reports and industry reports, and the linear best-fit lines. Figure 4-81 presents the average square error between each estimate based on observer data and the corresponding weekly industry report. Similarly, Figure 4-82 shows the ratio of observer report to industry report. Variability is higher than in the pollock fishery and the source of the variability would be both data sets, with there being no means of independent validation of either.

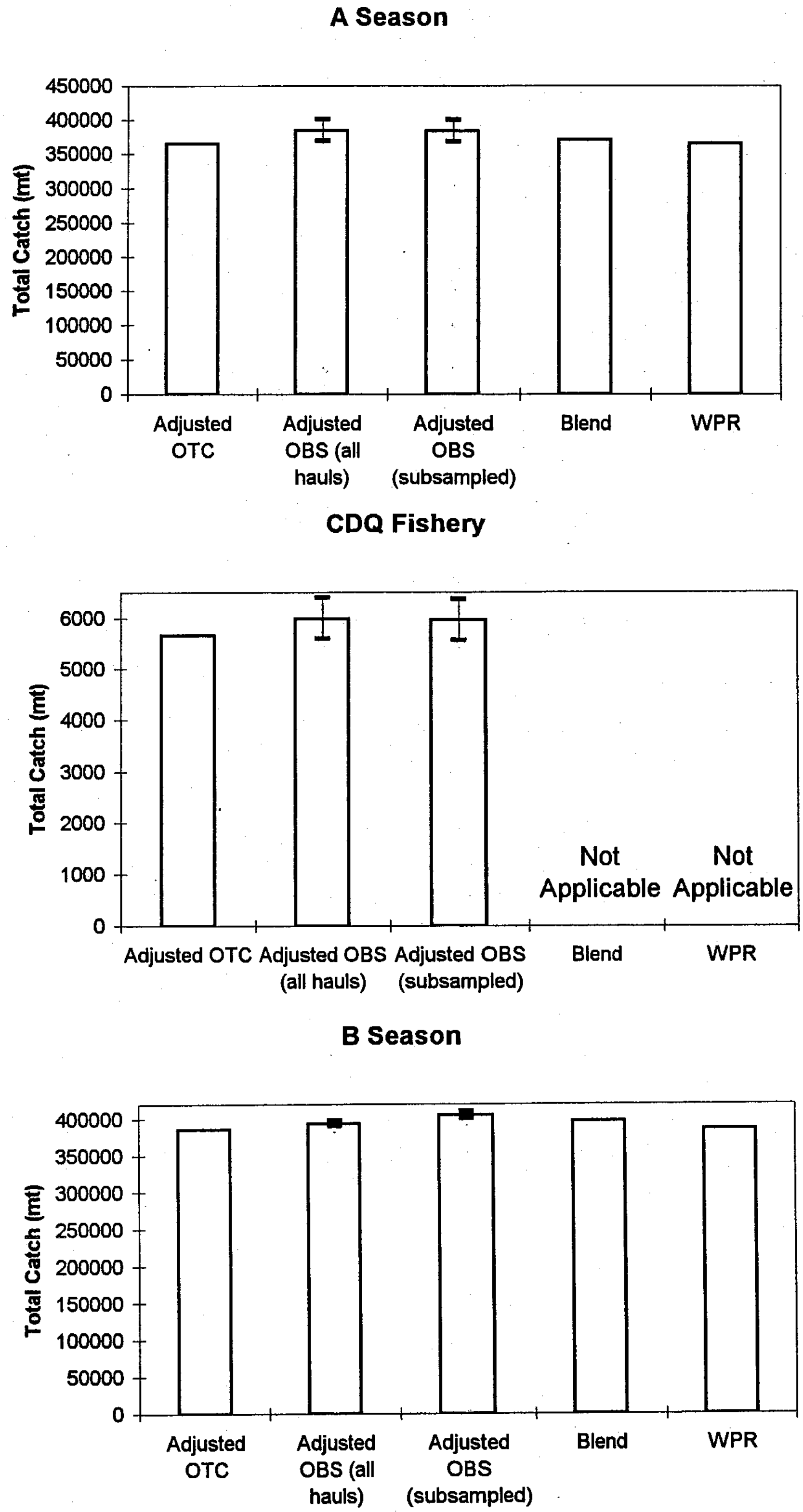


Figure 4-1. Total groundfish catch estimates for the three seasons of the 1994 BSAI pollock fishery using five different estimation methods. The upper and lower 95% confidence interval for adjusted OBS estimates are shown as T-bars.

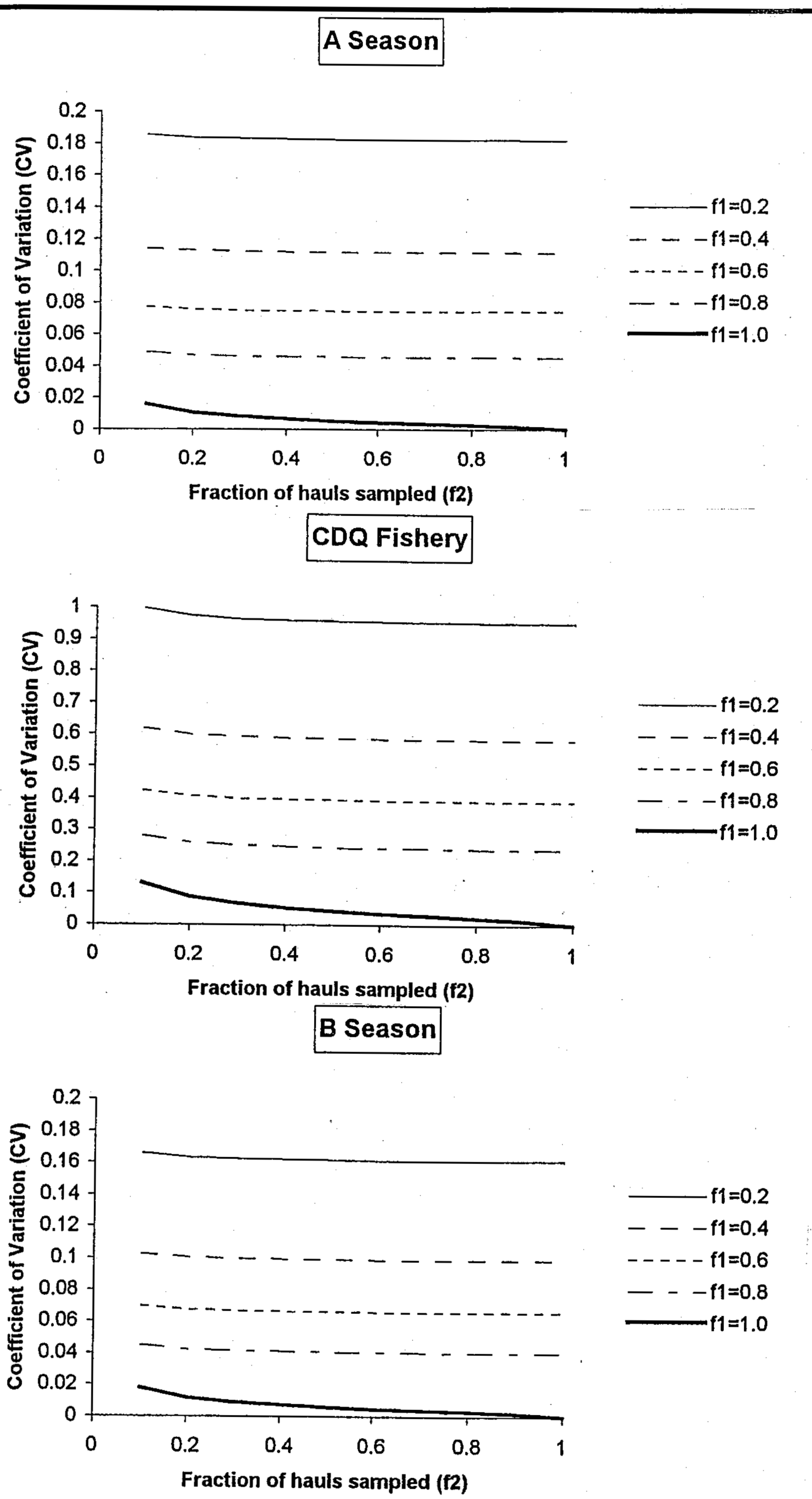
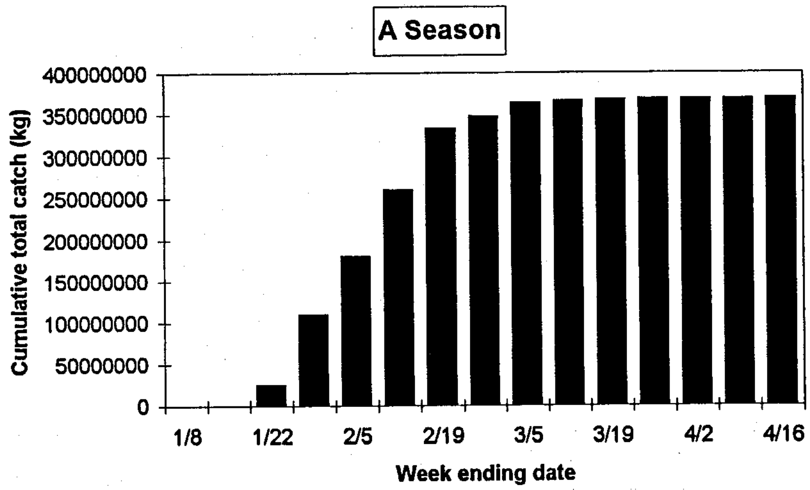
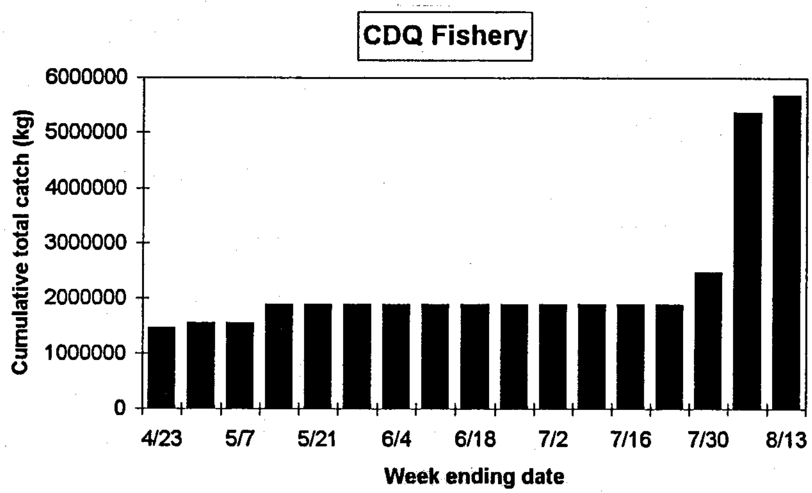


Figure 4-2. Associated coefficients of variation in estimated fleetwide catch of all groundfish species during the three seasons on the 1994 BSAI pollock fishery as a function of the fraction of vessels sampled (f_1) and the fraction of hauls sampled (f_2). Statistics based on the adjusted OTC data set.





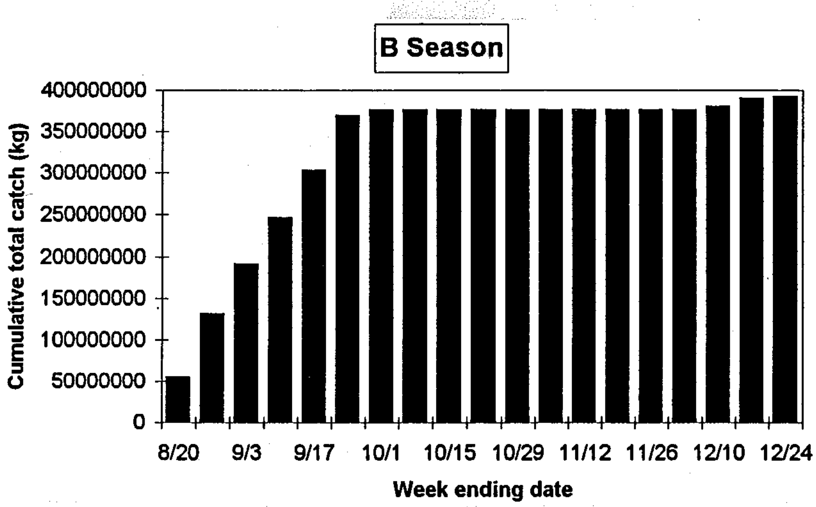


Figure 4-3. Estimates of cumulative weekly total catch of all groundfish species for the three seasons of the 1994 BSAI pollock fishery. Estimates are based on the adjusted OTC data set.

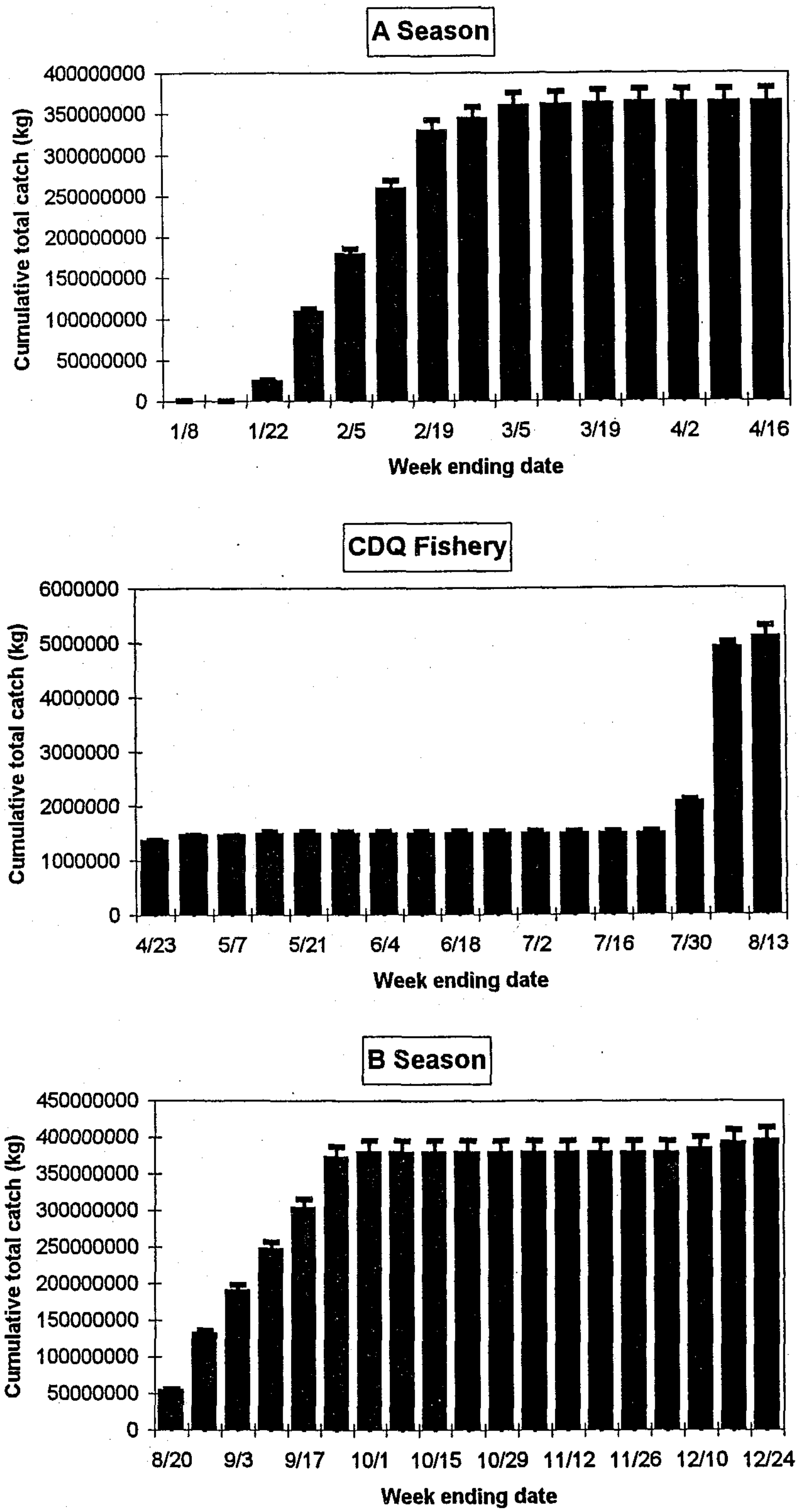


Figure 4-4. Estimates of cumulative weekly catch of pollock for the three seasons of the 1994 BSAI pollock fishery. The upper 95% confidence intervals are shown as T-bars. Estimates are based on the standard two-stage estimator and the observer subsampled data set.

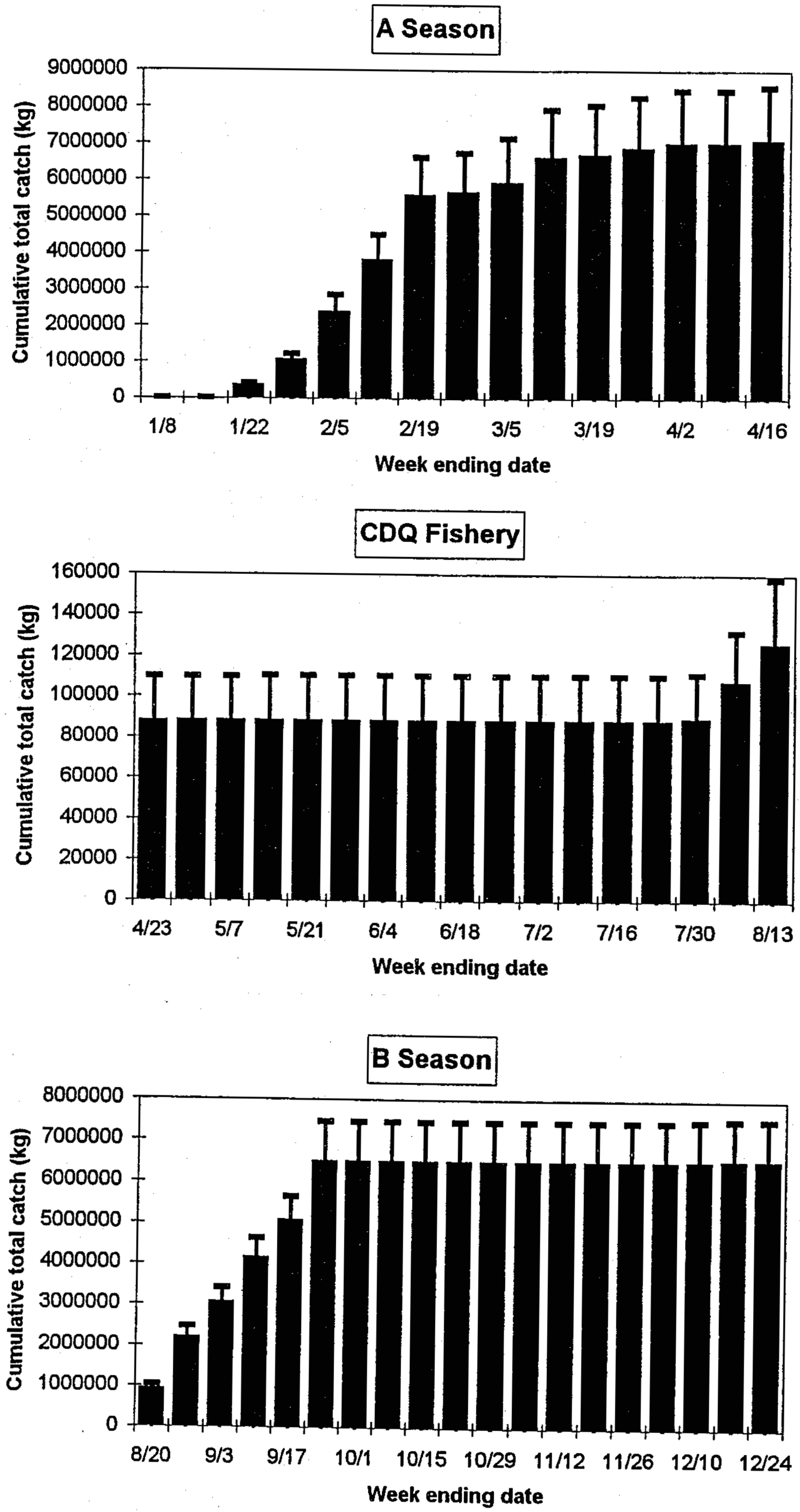


Figure 4-5. Estimates of cumulative weekly catch of Pacific cod for the three seasons of the 1994 BSAI pollock fishery. The upper 95% confidence intervals are shown as T-bars. Estimates are based on the standard two-stage estimator and the observer subsampled data set.

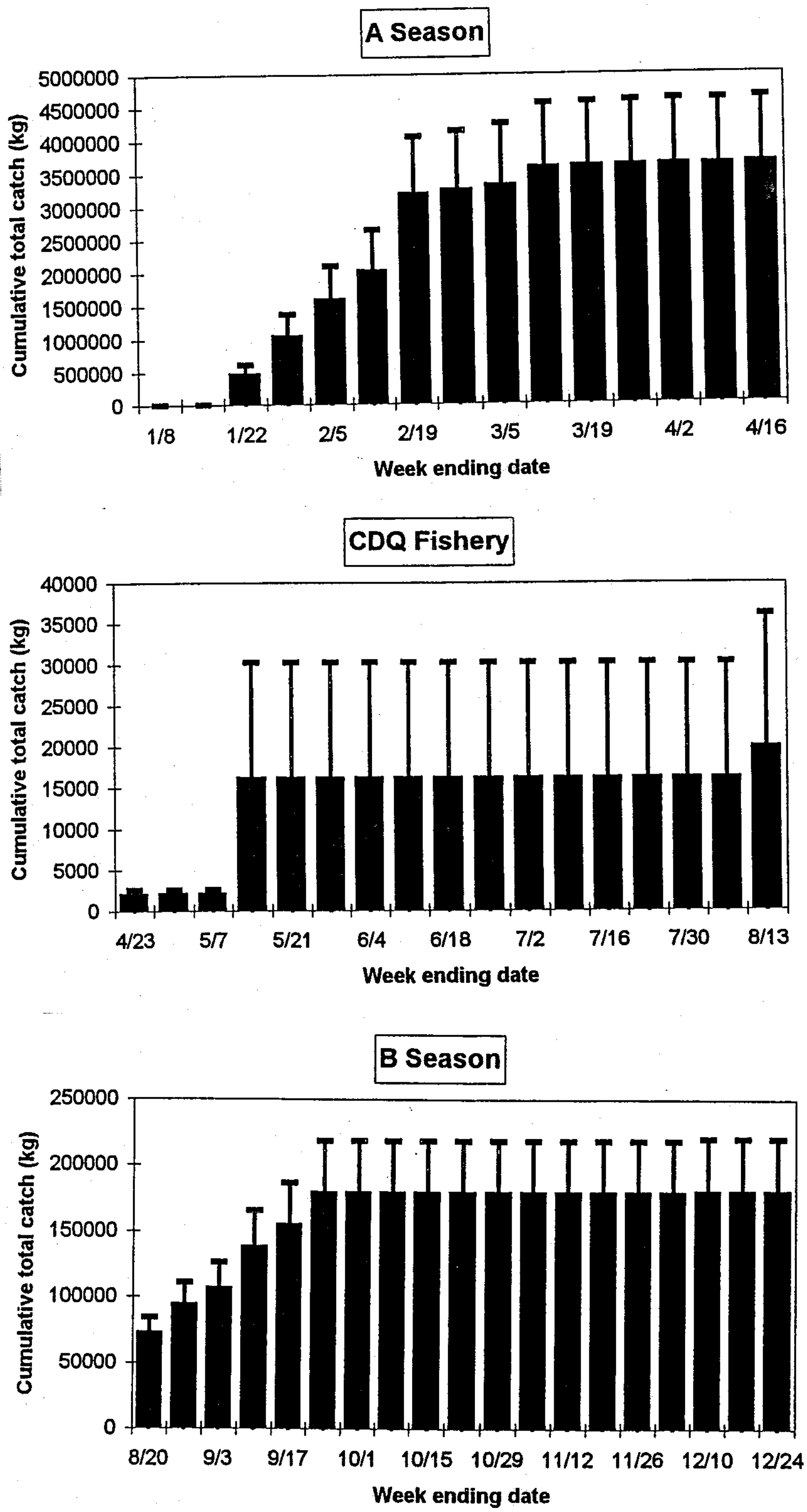


Figure 4-6. Estimates of cumulative weekly catch of rock sole for the three seasons of the 1994 BSAI pollock fishery. The upper 95% confidence intervals are shown as T-bars. Estimates are based on the standard two-stage estimator and the observer subsampled data set.

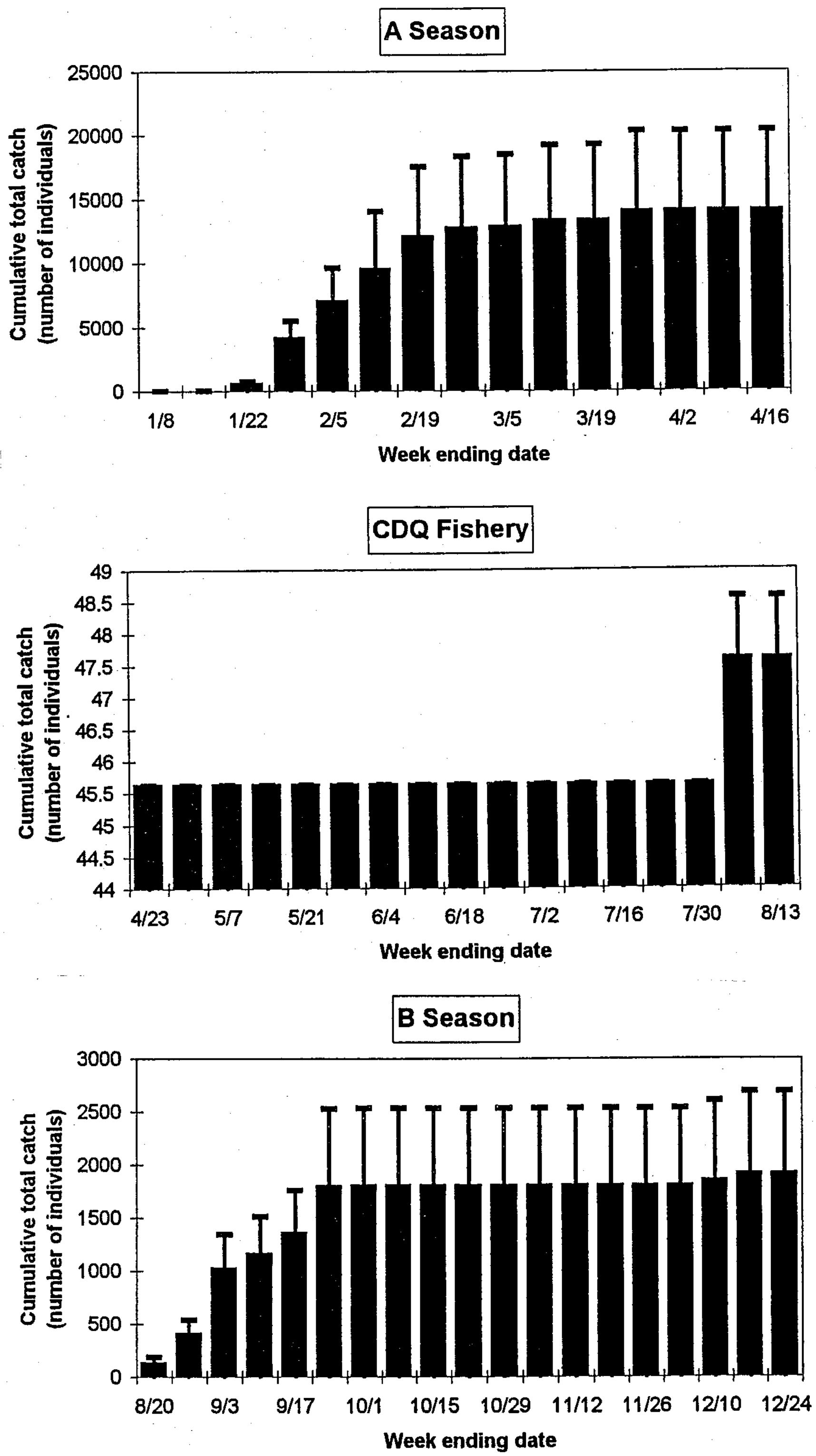


Figure 4-7. Estimates of cumulative weekly catch of chinook salmon for the three seasons of the 1994 BSAI pollock fishery. The upper 95% confidence intervals are shown as T-bars. Estimates are based on the ratio estimator with the delta estimator and the observer subsampled data set.

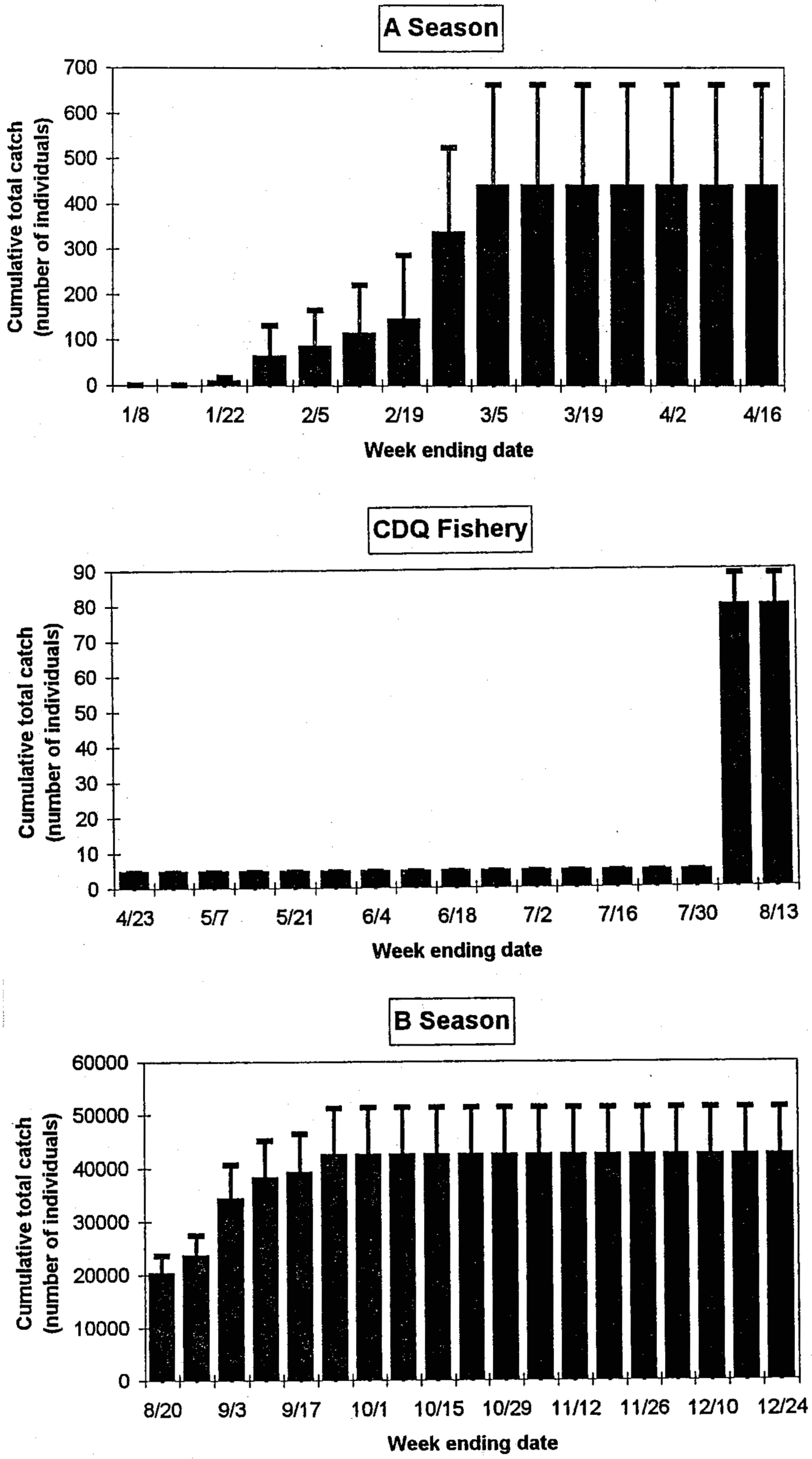
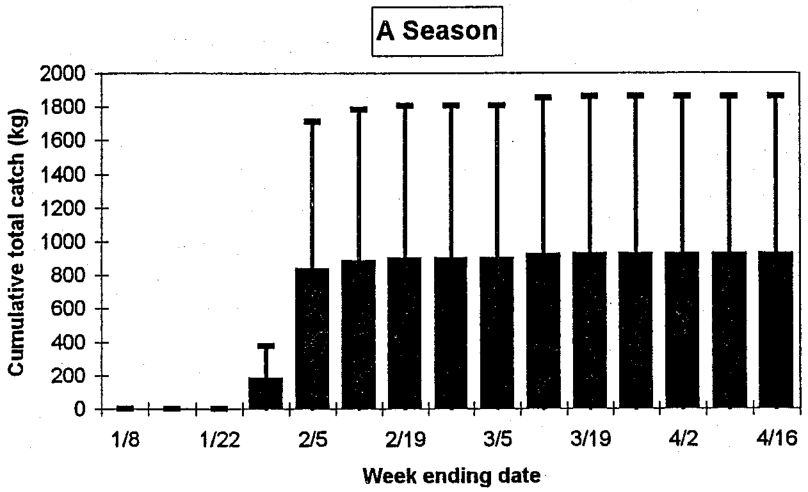
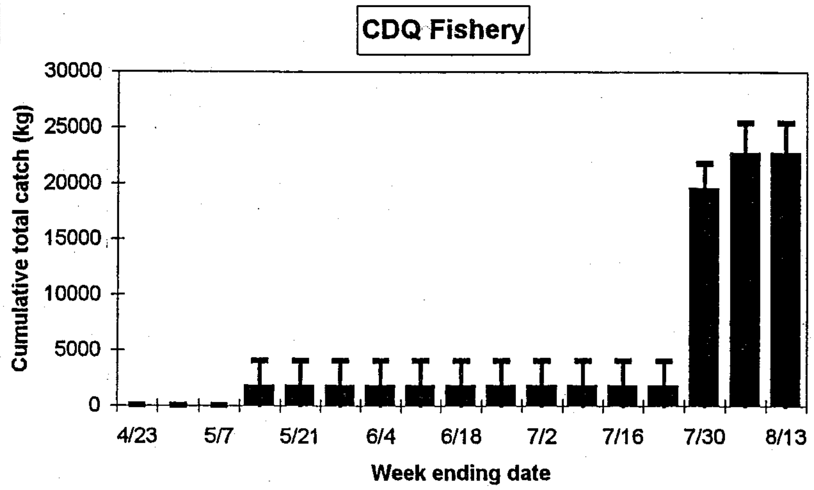


Figure 4-8. Estimates of cumulative weekly catch of other salmon for the three seasons of the 1994 BSAI pollock fishery. The upper 95% confidence intervals are shown as T-bars. Estimates are based on the ratio estimator with the delta estimator and the observer subsampled data set.





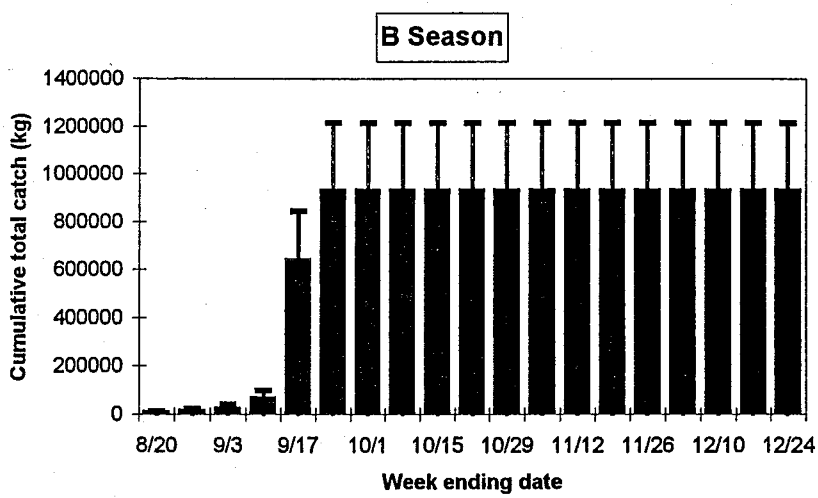


Figure 4-9. Estimates of cumulative weekly catch of herring for the three seasons of the 1994 BSAI pollock fishery. The upper 95% confidence intervals are shown as T-bars. Estimates are based on the ratio estimator with the delta estimator and the observer subsampled data set.

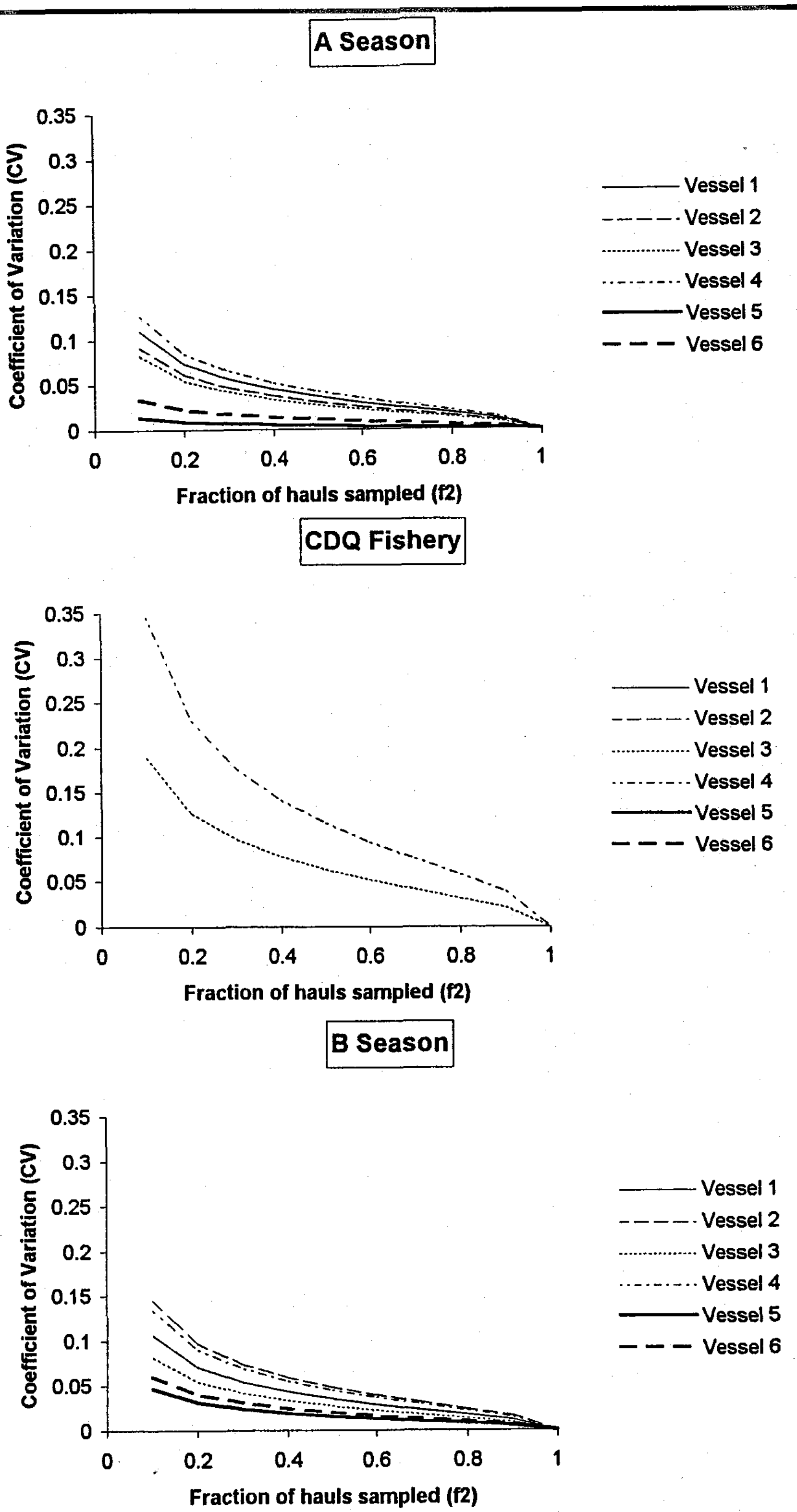


Figure 4-10. Associated coefficients of variation in several vessels' estimated catch of all groundfish species in the three seasons of the 1994 BSAI pollock fishery in relation to fraction of hauls sampled (f_2). Fraction of vessels sampled was held at 1.0. Statistics based on the observer subsampled data set. Vessels were assigned simple numeric characters to maintain anonymity.

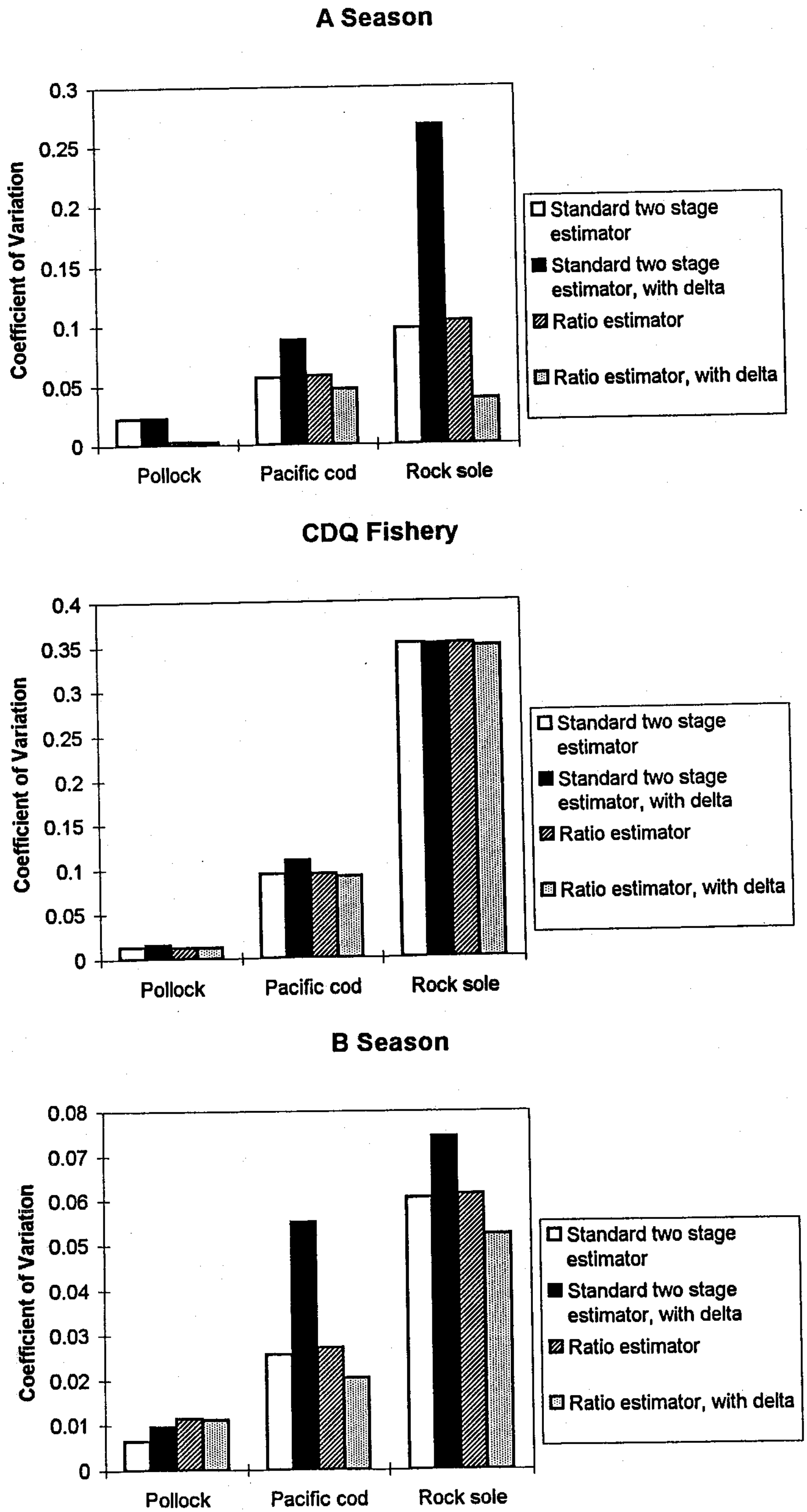


Figure 4-11. Associated coefficients of variation for four different fleetwide catch estimates of three groundfish species caught during the three seasons of the 1994 BSAI pollock fishery

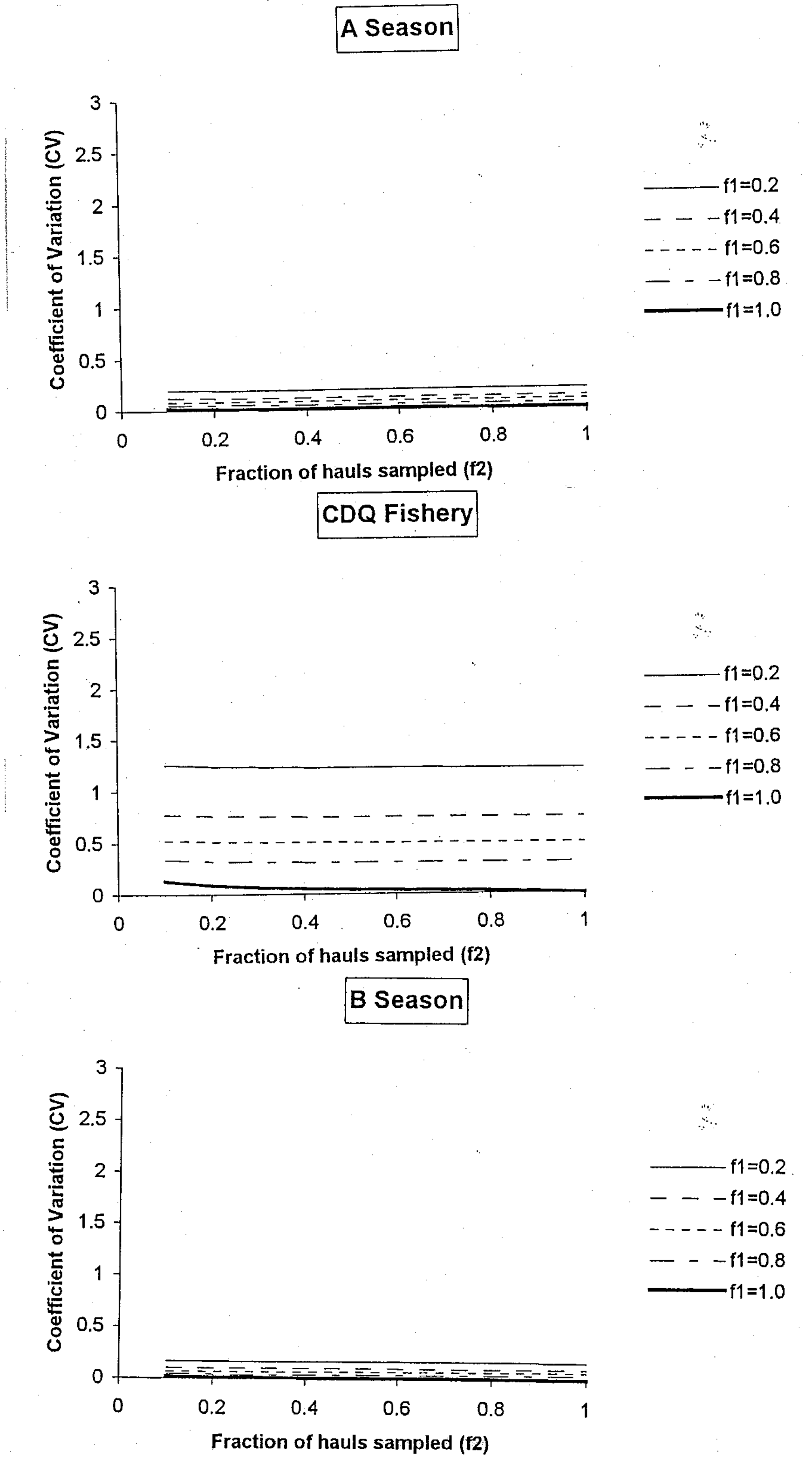
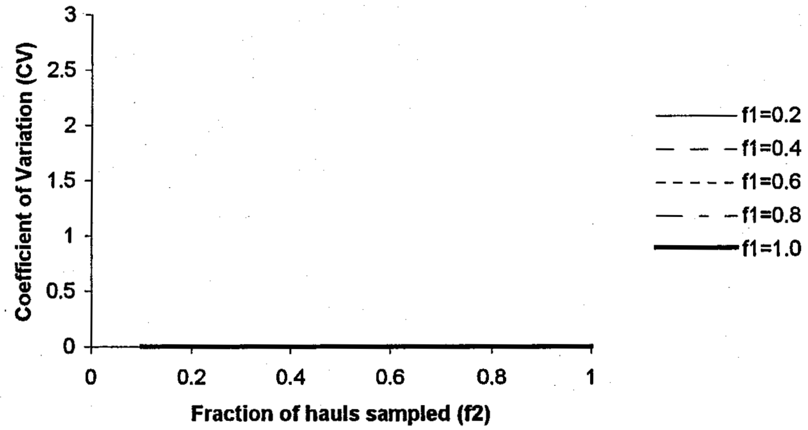
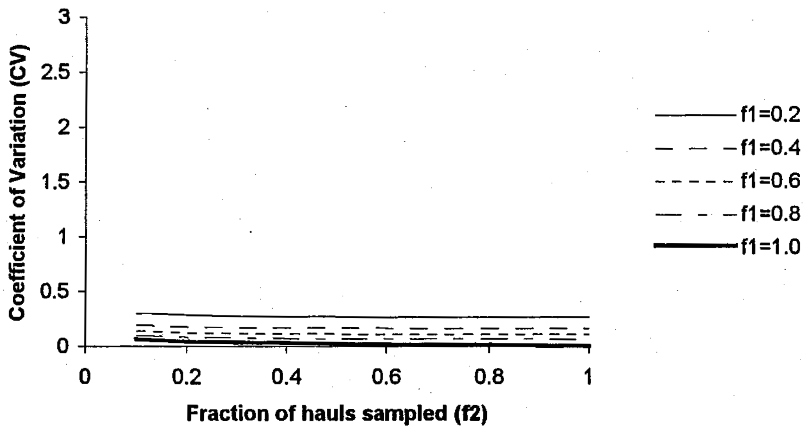


Figure 4-12. Associated coefficients of variation in estimated fleetwide catch of pollock in the three seasons of the 1994 BSAI pollock fishery using the standard two-stage estimator. The coefficients of variation are shown in relation to the fraction of vessels sampled (f_1) and fraction of hauls sampled (f_2).

A Season



CDQ Fishery



B Season

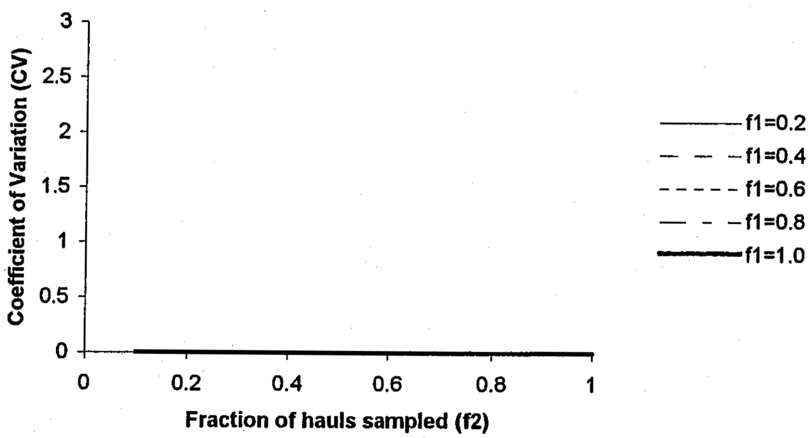


Figure 4-13. Associated coefficients of variation in estimated fleetwide catch of pollock the three seasons of the 1994 BSAI pollock fishery using the ratio estimator with the delta estimator. The coefficients of variation are shown in relation to the fraction of vessels sampled (f_1) and fraction of hauls sampled (f_2)

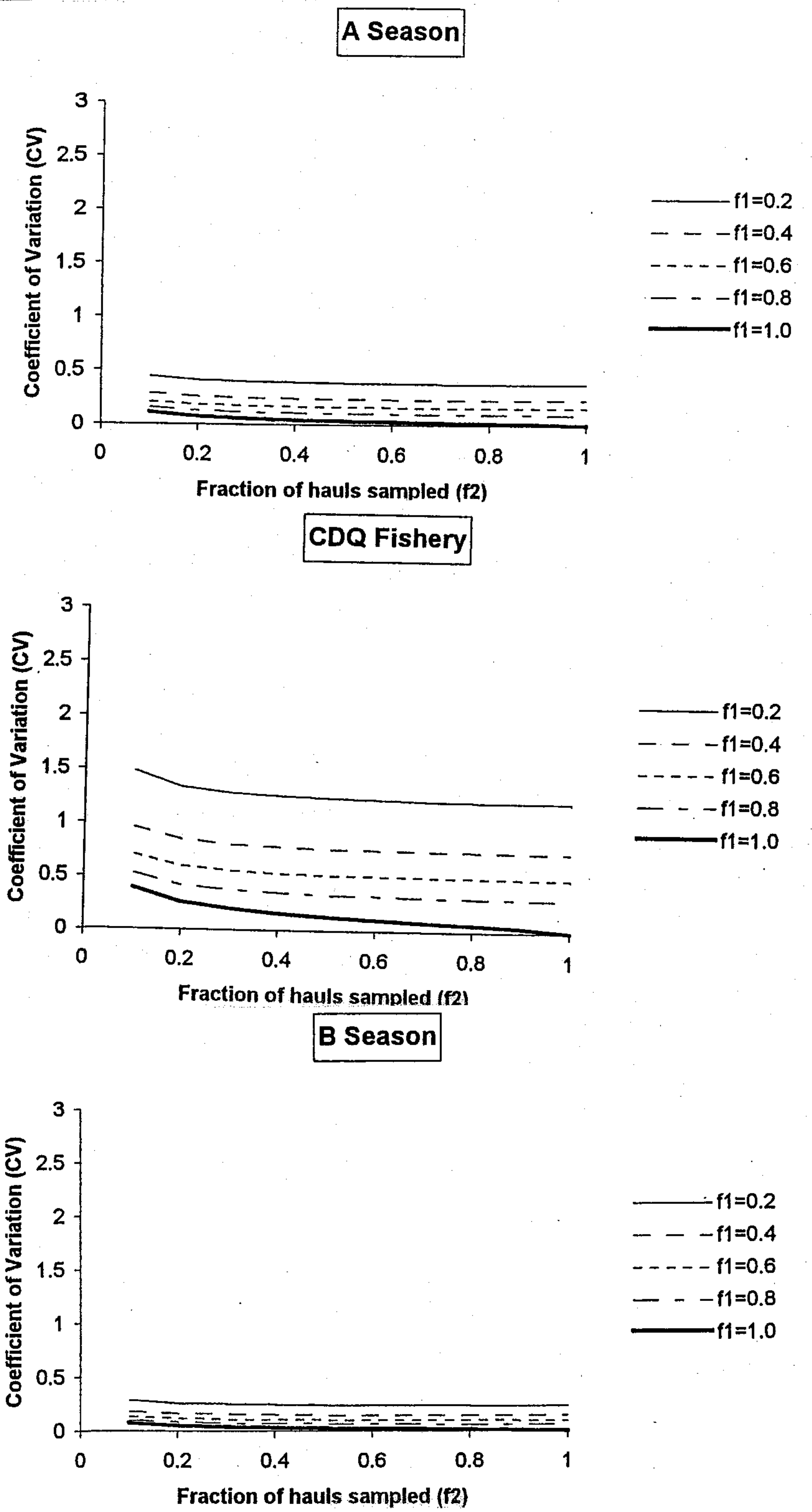


Figure 4-14. Associated coefficients of variation in estimated fleetwide catch of Pacific cod during the three seasons of the 1994 BSAI pollock fishery using the standard two-stage estimator. The coefficients of variation are shown in relation to the fraction of vessels sampled (f_1) and fraction of hauls sampled (f_2)

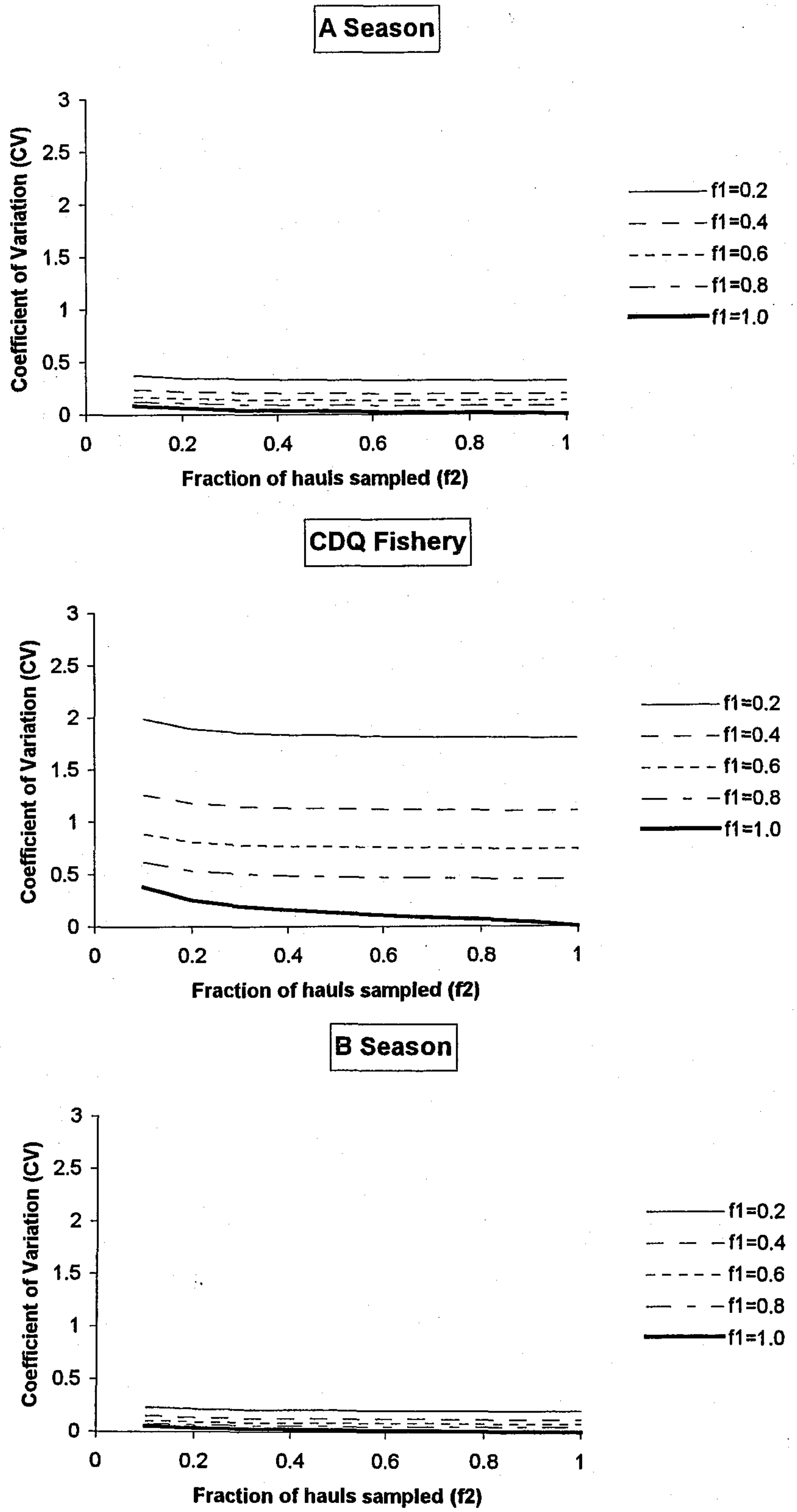
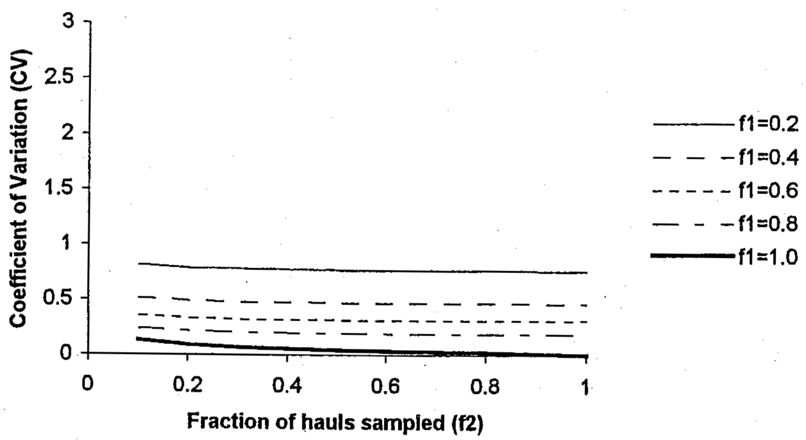
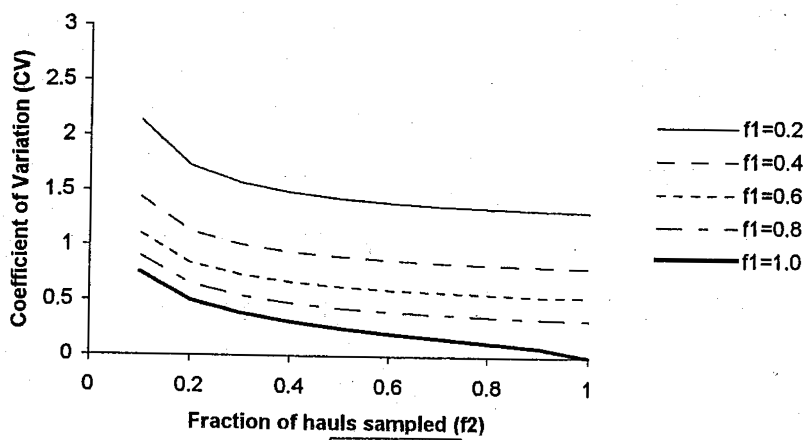


Figure 4-15. Associated coefficients of variation in estimated fleetwide catch of Pacific cod during the three seasons of the 1994 BSAI pollock fishery using the ratio estimator with the delta estimator. The coefficients of variation are shown in relation to the fraction of vessels sampled (f_1) and fraction of hauls sampled (f_2).

A Season



CDQ Fishery



B Season

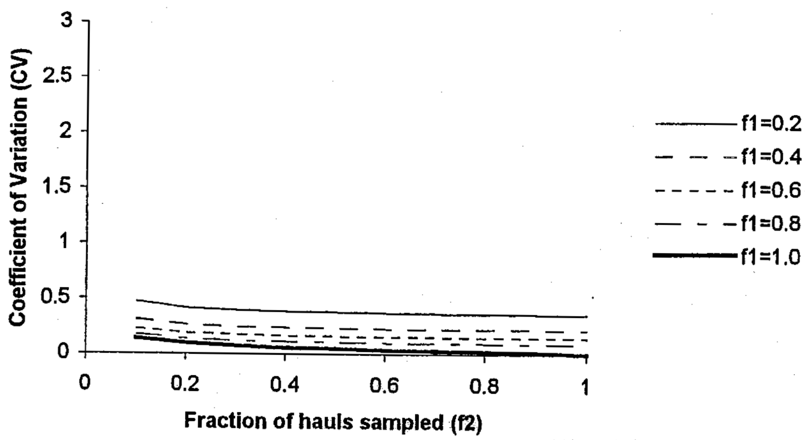
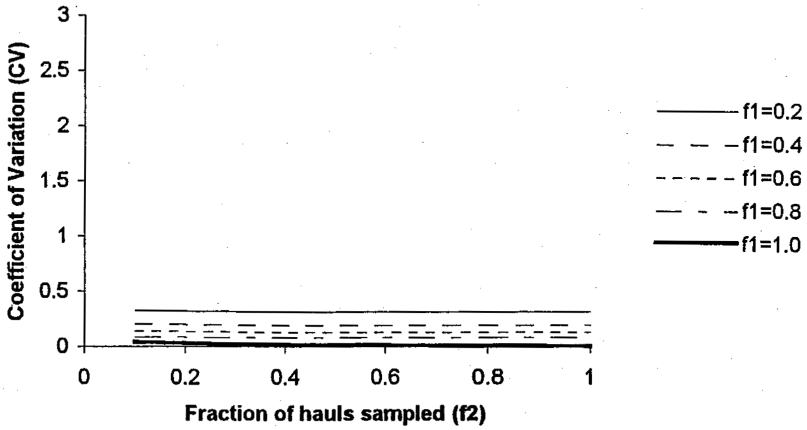
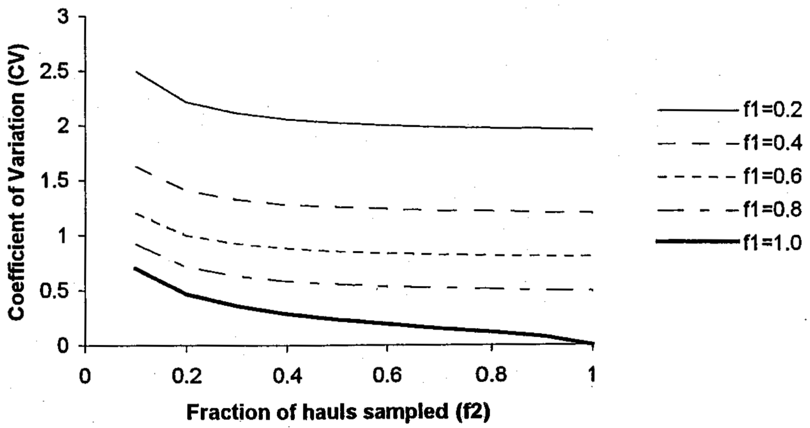


Figure 4-16. Associated coefficients of variation in estimated fleetwide catch of rock sole during the three seasons of the 1994 BSAI pollock fishery using the standard two-stage estimator. The coefficients of variation are shown in relation to the fraction of vessels sampled (f_1) and fraction of hauls sampled (f_2)

A Season



CDQ Fishery



B Season

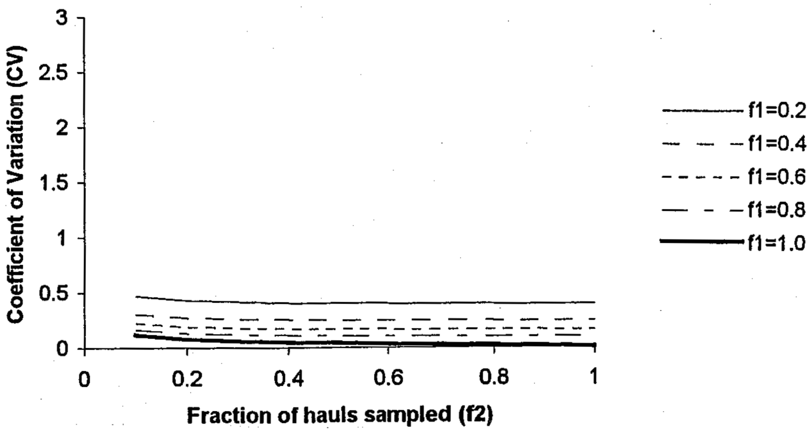


Figure 4-17. Associated coefficients of variation in estimated fleetwide catch of rock sole during the three seasons of the 1994 BSAI pollock fishery using the ratio estimator with the delta estimator. The coefficients of variation are shown in relation to the fraction of vessels sampled (f_1) and fraction of hauls sampled (f_2).

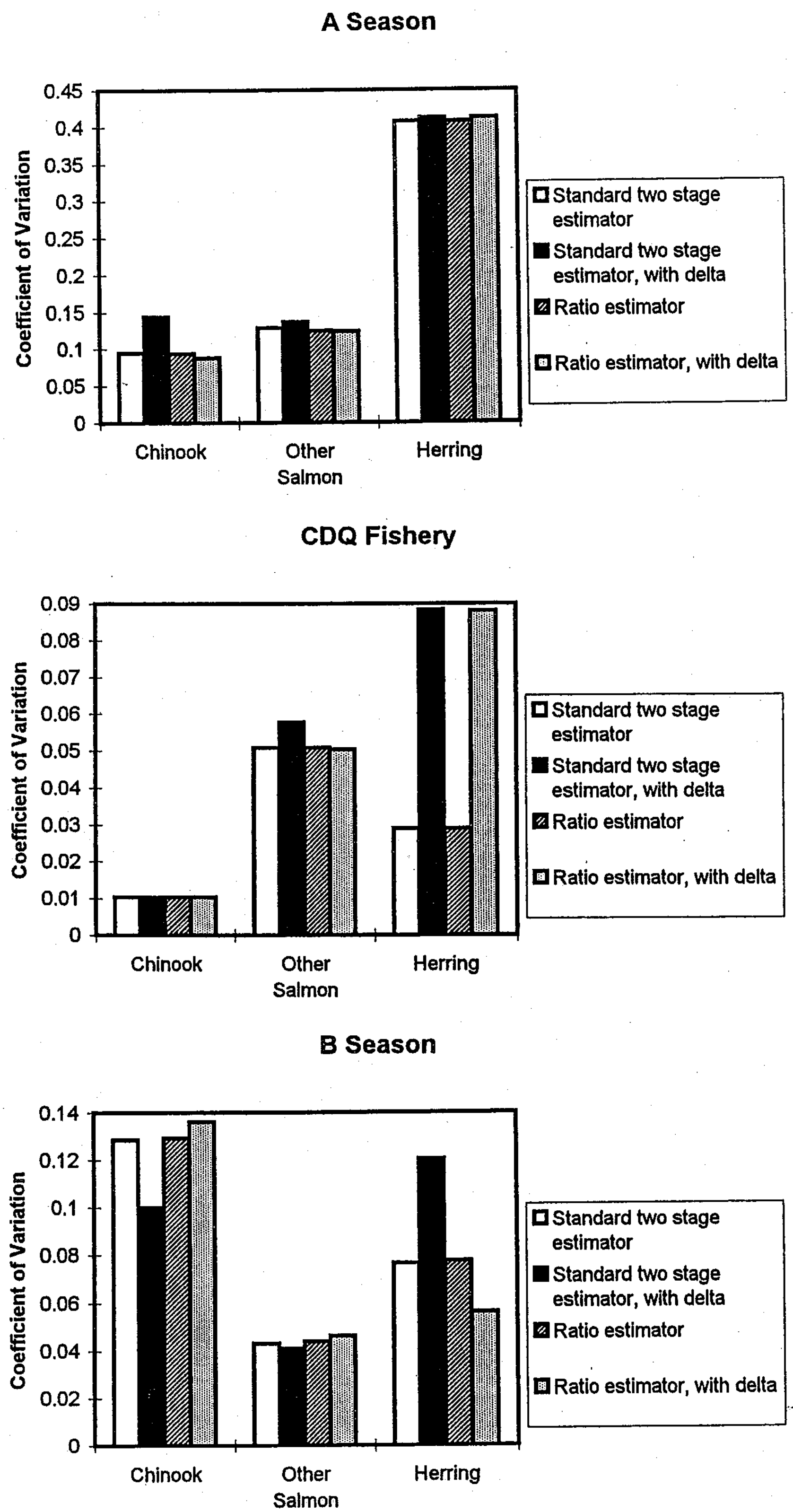
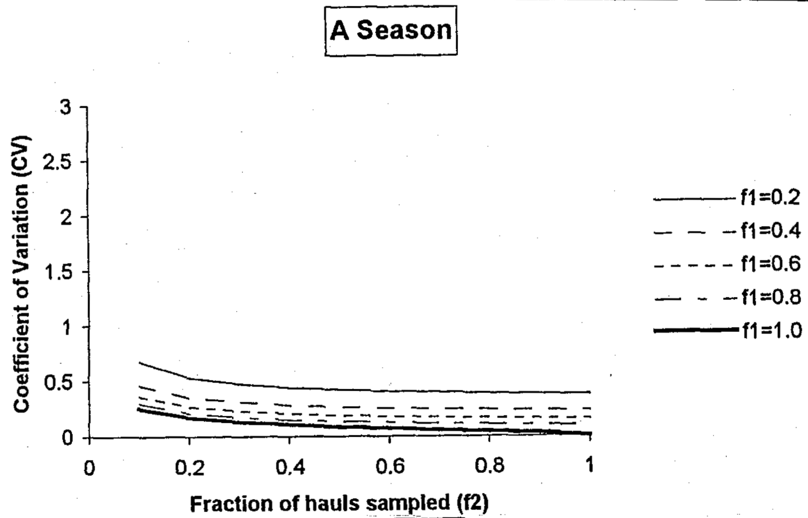
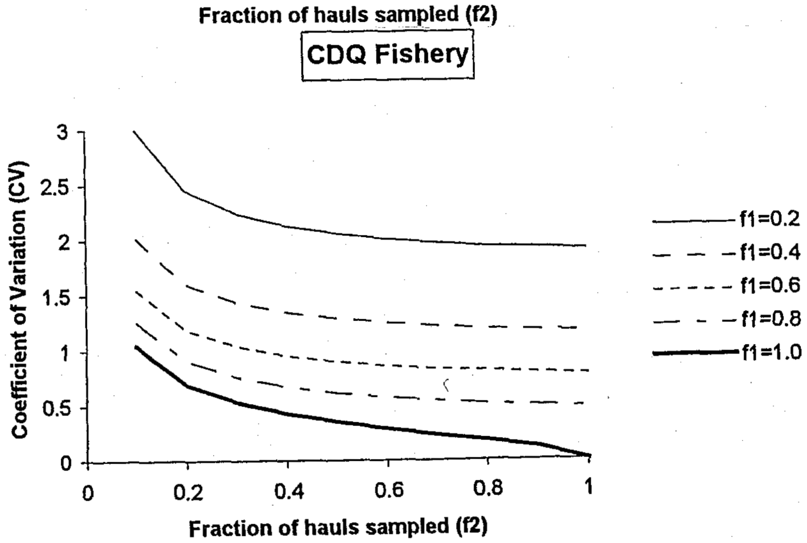


Figure 4-18. Associated coefficients of variation from four different fleetwide catch estimates of three prohibited species in the three seasons of the 1994 BSAI pollock fishery.





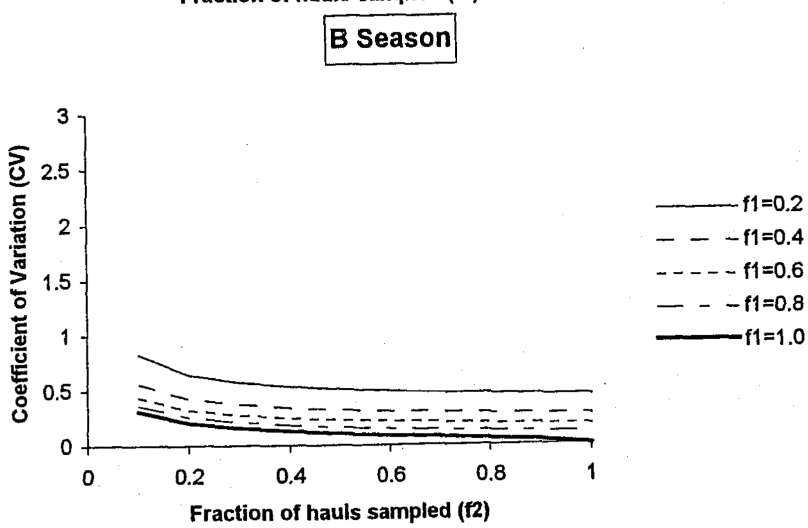
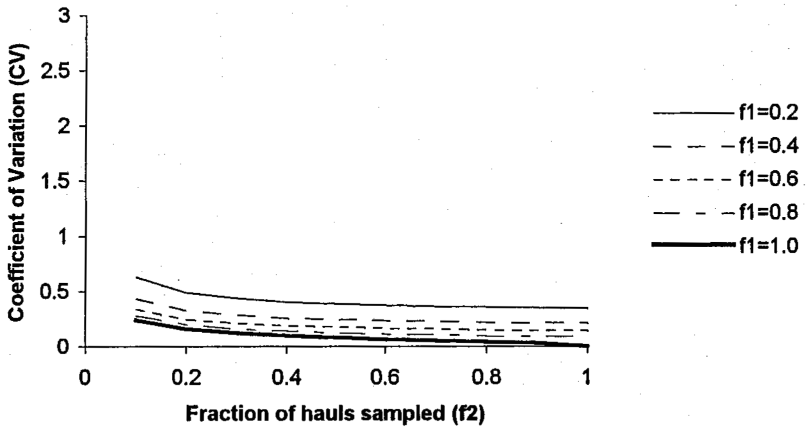
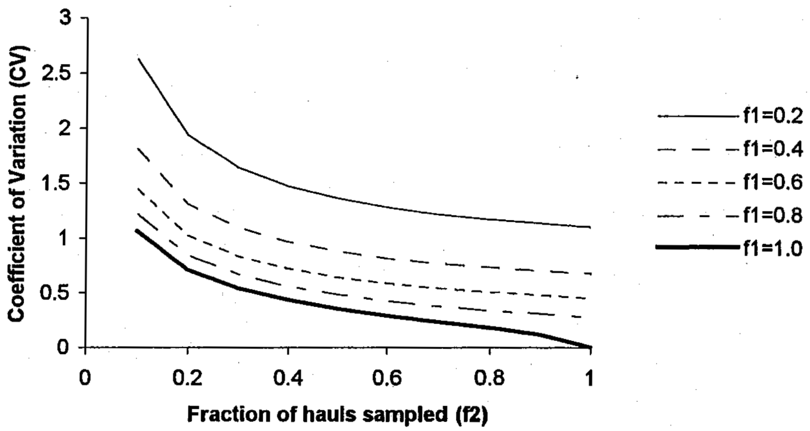


Figure 4-19. Associated coefficients of variation in estimated fleetwide catch of chinook salmon during the three seasons of the 1994 BSAI pollock fishery using the standard two-stage estimator. The coefficients of variation are shown in relation to the fraction of vessels sampled (f_1) and fraction of hauls sampled (f_2).

A Season



CDQ Fishery



B Season

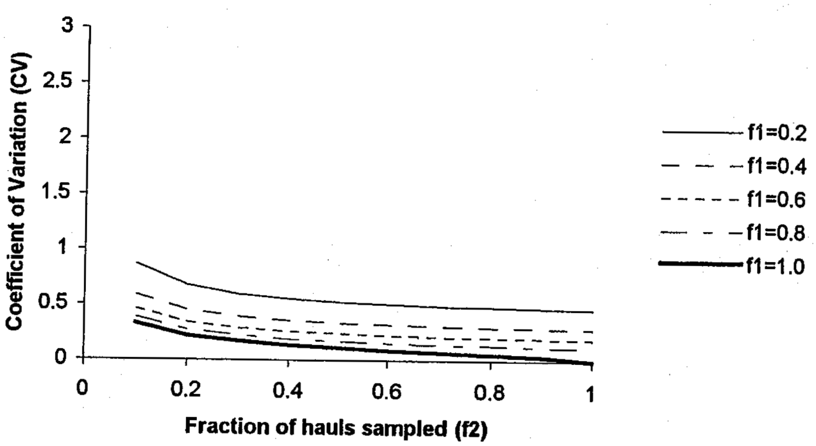


Figure 4-20. Associated coefficients of variation in estimated fleetwide catch of chinook salmon during the three seasons of the 1994 BSAI pollock fishery using the ratio estimator with the delta estimator. The coefficients of variation are shown in relation to the fraction of vessels sampled (f_1) and fraction of hauls sampled (f_2).

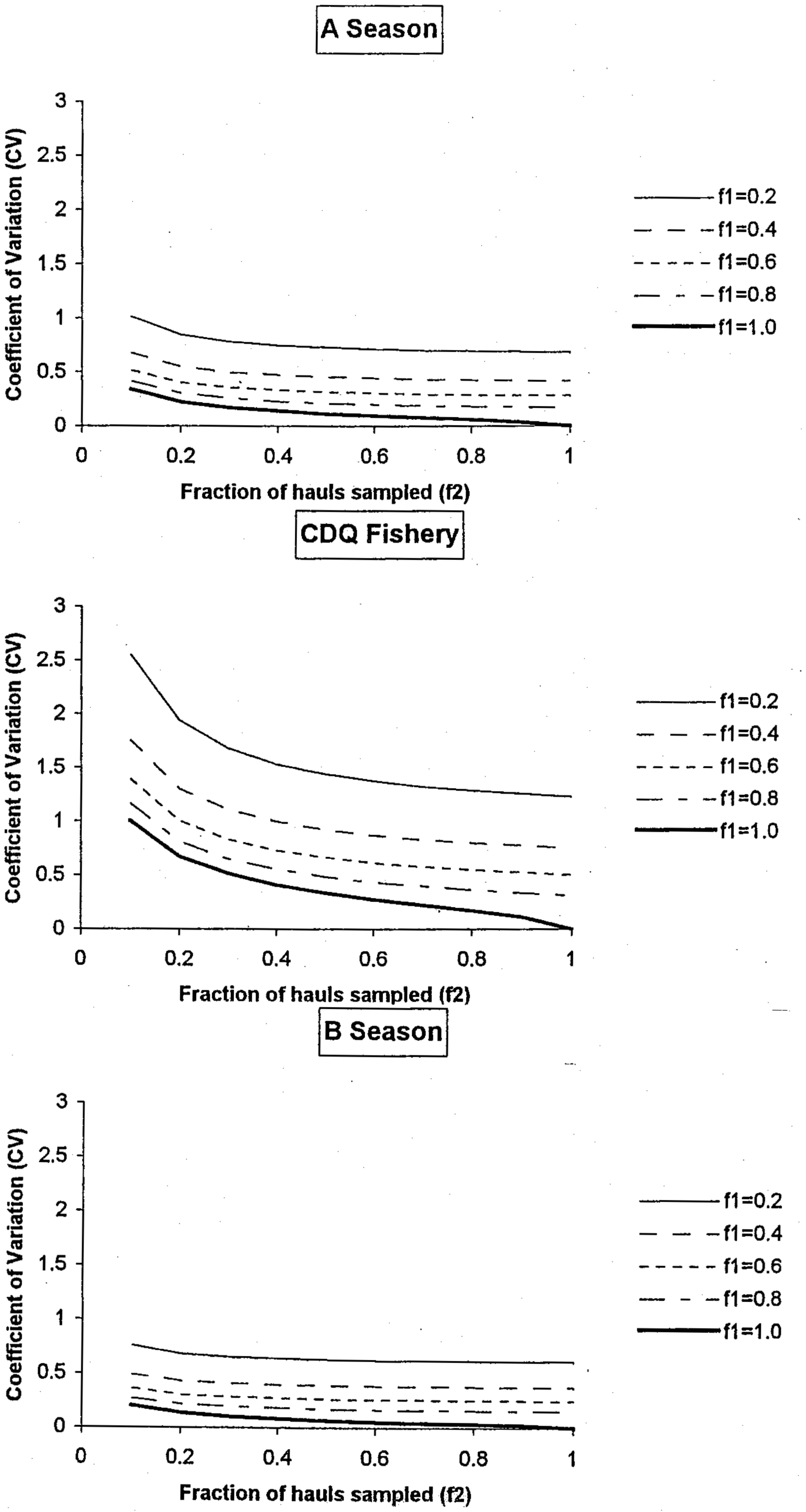


Figure 4-21. Associated coefficients of variation in estimated fleetwide catch of salmon other than chinook during the three seasons of the 1994 BSAI pollock fishery using the standard two-stage estimator. The coefficients of variation are shown in relation to the fraction of vessels sampled (f_1) and fraction of hauls sampled (f_2).

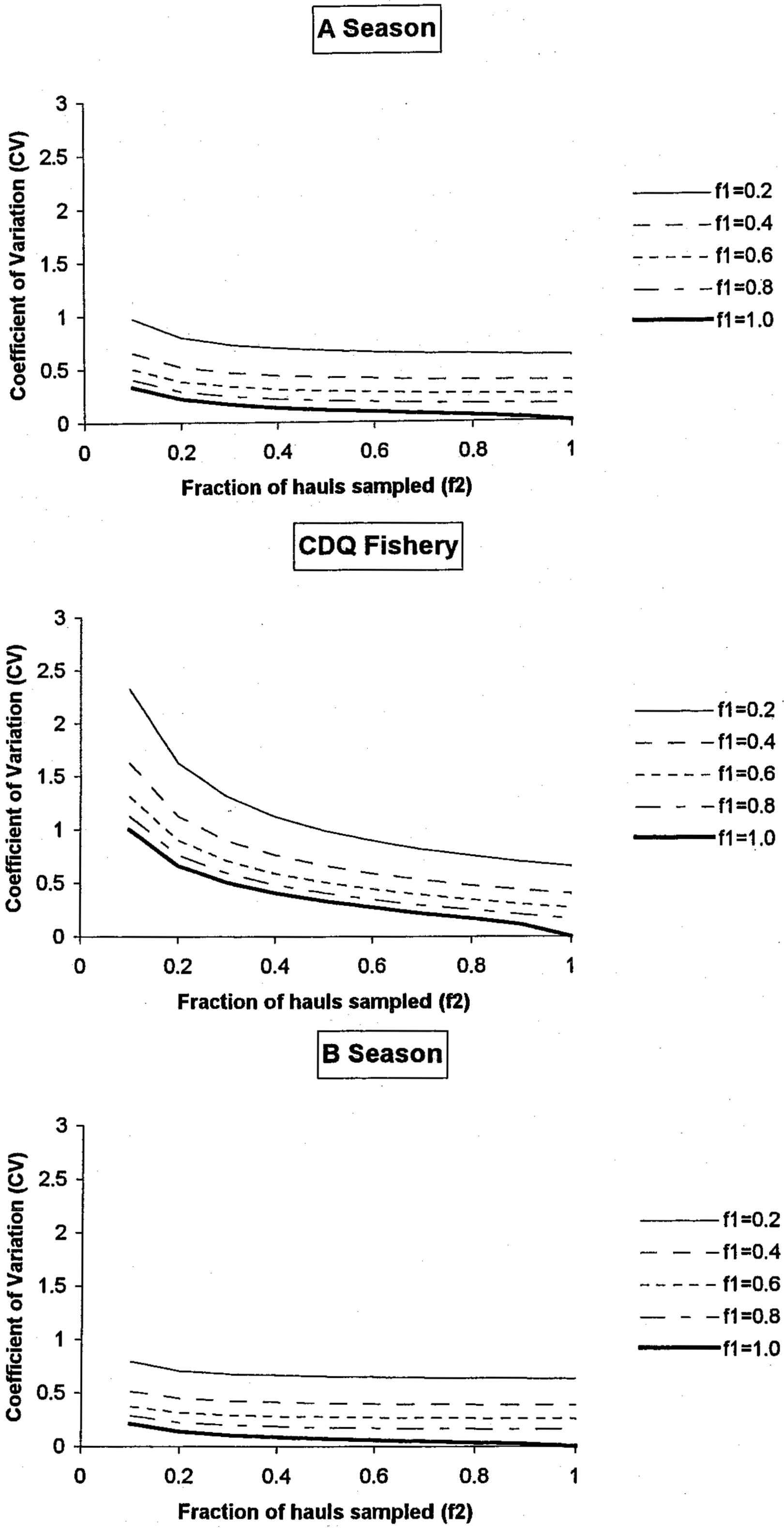
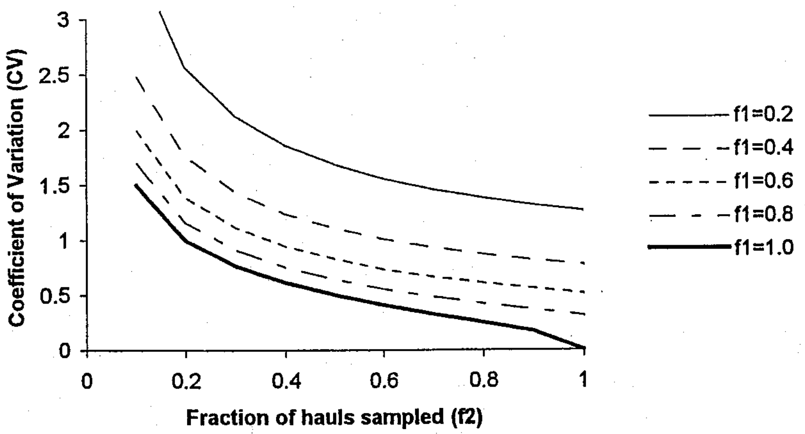
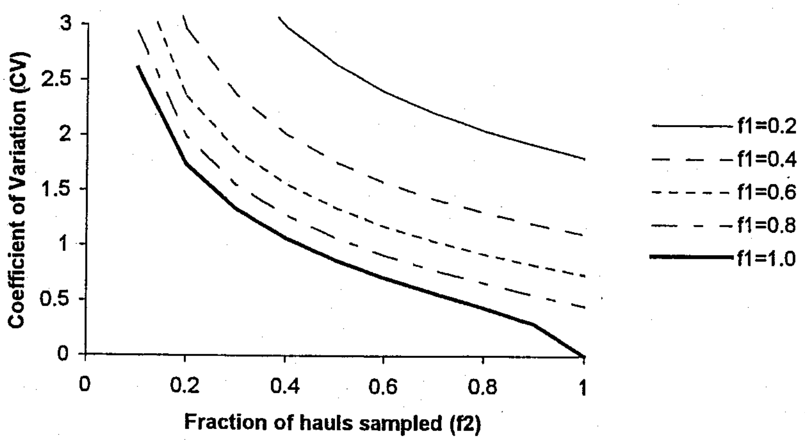


Figure 4-22. Associated coefficients of variation in estimated fleetwide catch of salmon other than chinook during the three seasons of the 1994 BSAI pollock fishery using the ratio estimator with the delta estimator. The coefficients of variation are shown in relation to the fraction of vessels sampled (f_1) and fraction of hauls sampled (f_2).

A Season



CDQ Fishery



B Season

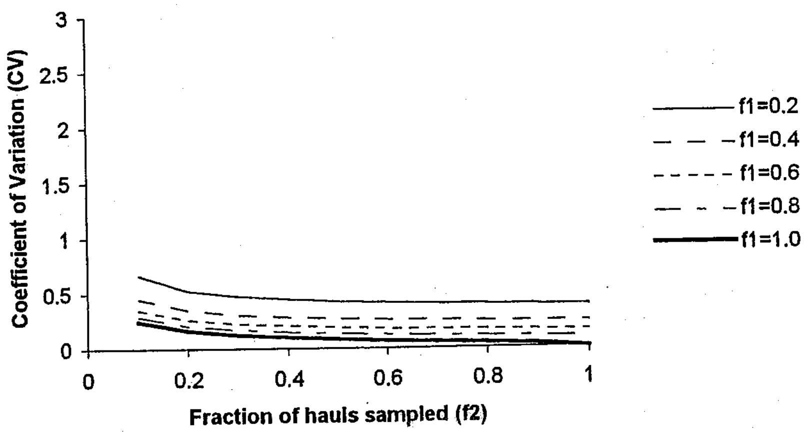


Figure 4-23. Associated coefficients of variation in estimated fleetwide catch of herring during the three seasons of the 1994 BSAI pollock fishery using the standard two-stage estimator. The coefficients of variation are shown in relation to the fraction of vessels sampled (f_1) and fraction of hauls sampled (f_2)

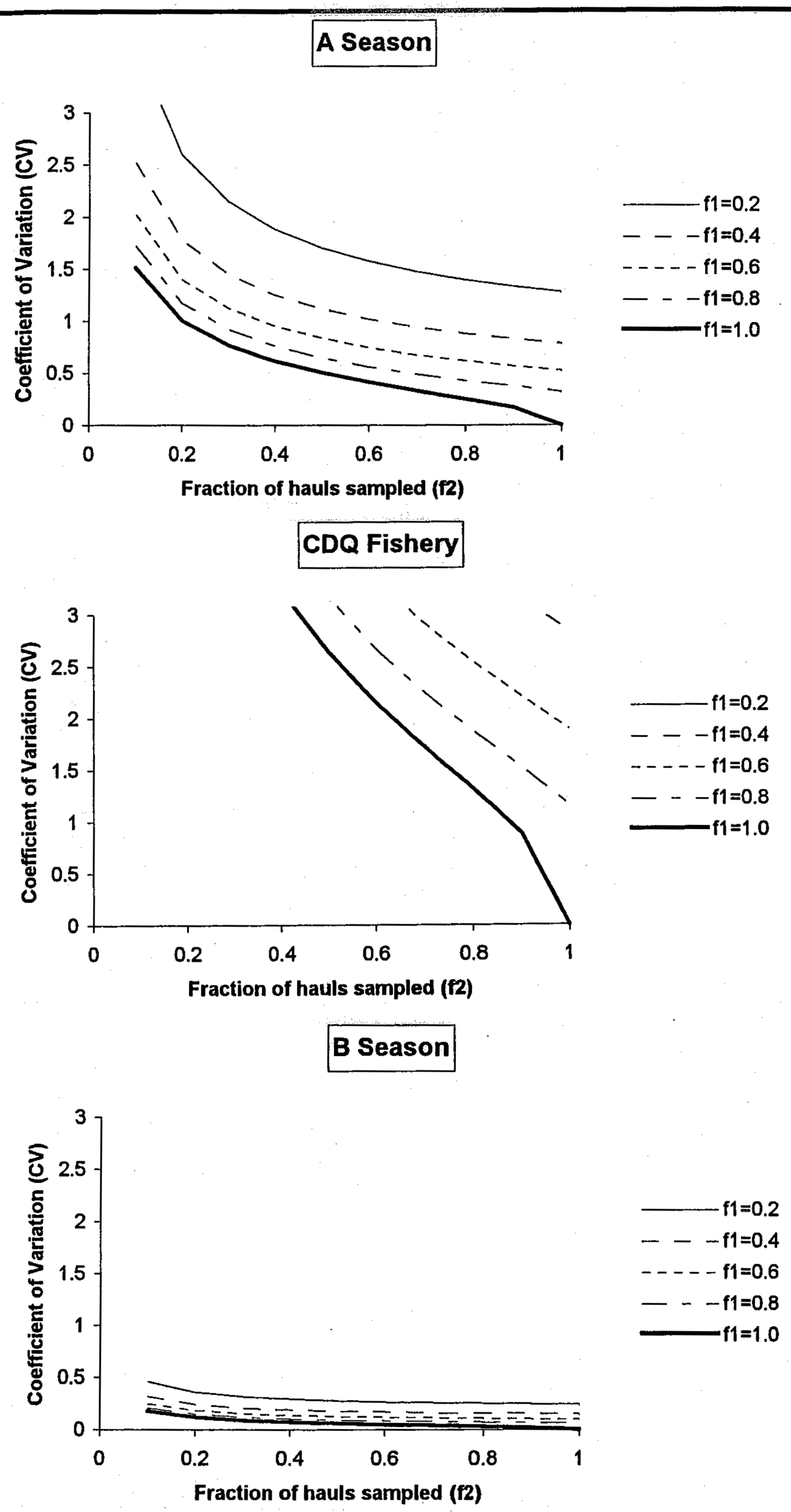
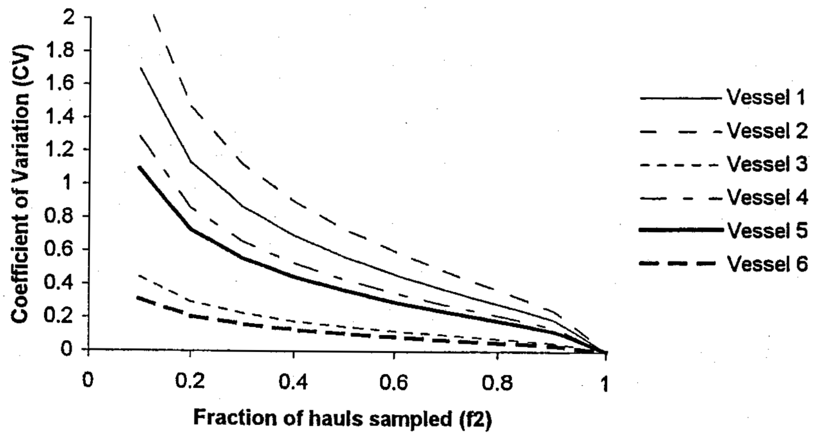
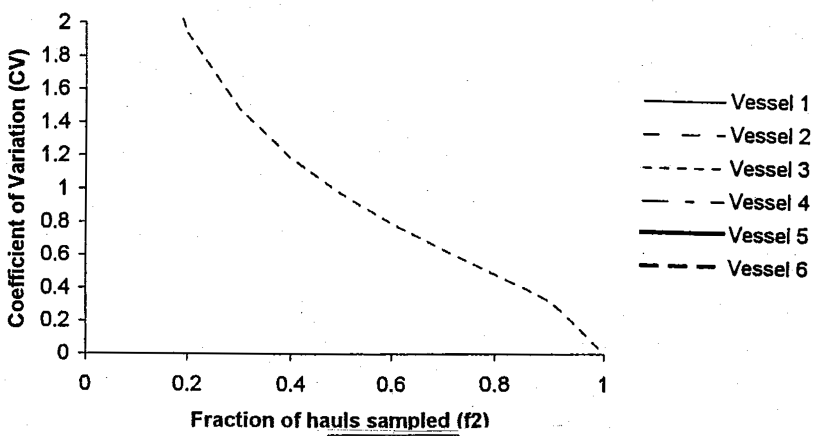


Figure 4-24. Associated coefficients of variation in estimated fleetwide catch of herring during the three seasons of the 1994 BSAI pollock fishery using the ratio estimator with the delta estimator. The coefficients of variation are shown in relation to the fraction of vessels sampled (f_1) and fraction of hauls sampled (f_2).

A Season



CDQ Fishery



B Season

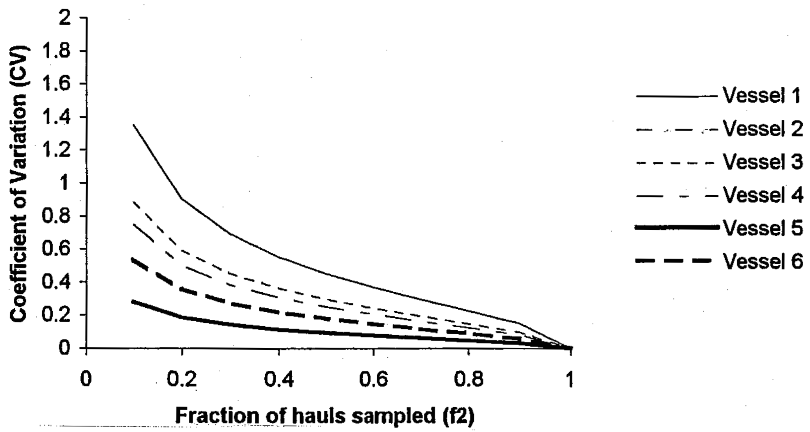


Figure 4-25. Associated coefficients of variation in estimated fleetwide catch of chinook salmon from individual vessels during the three seasons of the 1994 BSAI pollock fishery using the standard two-stage estimator. The coefficients of variation are shown in relation to the fraction of hauls sampled (f_2). The fraction of vessels sampled was held at 1.0. Vessels were assigned simple numeric characters to maintain anonymity.

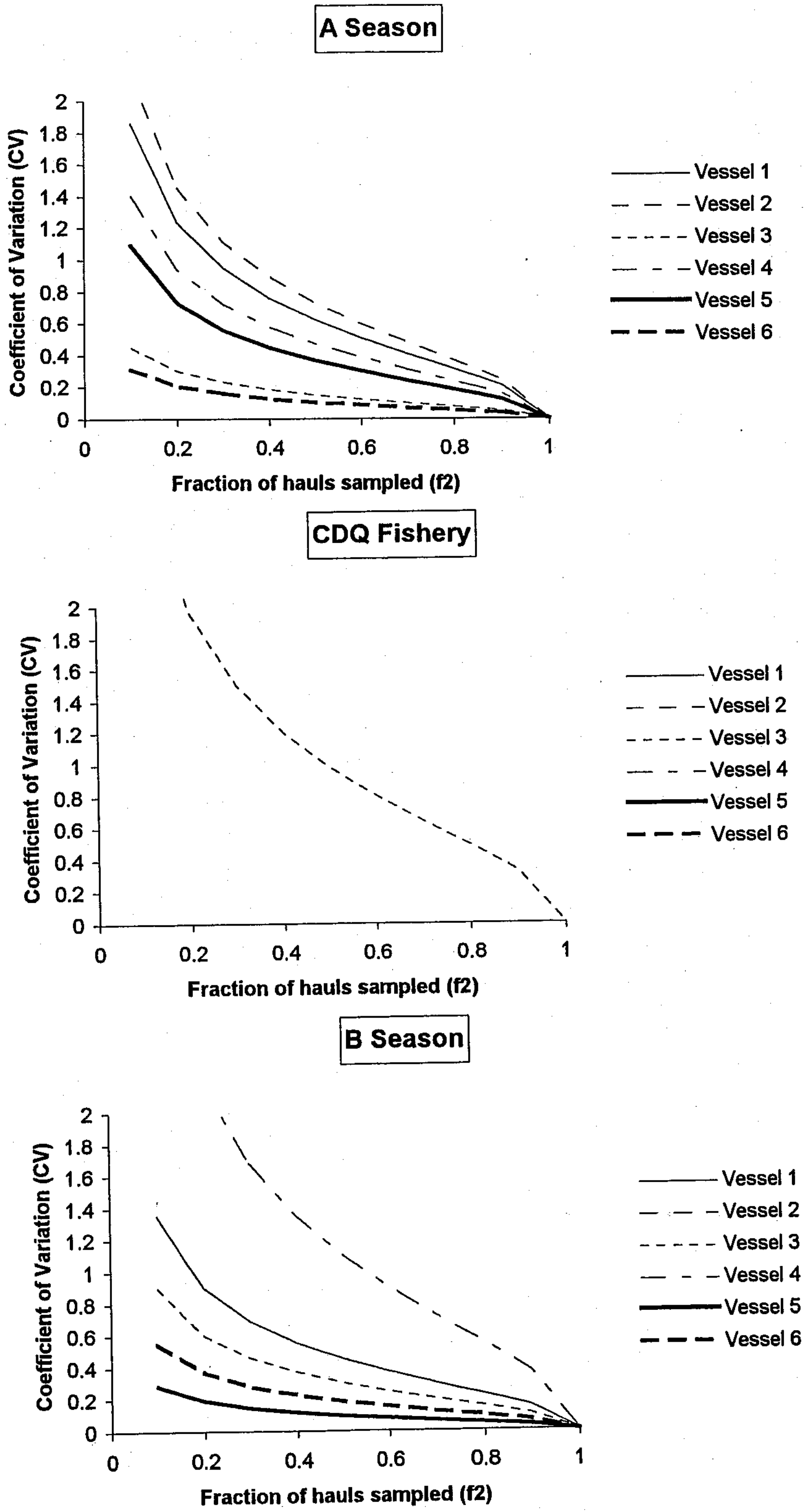
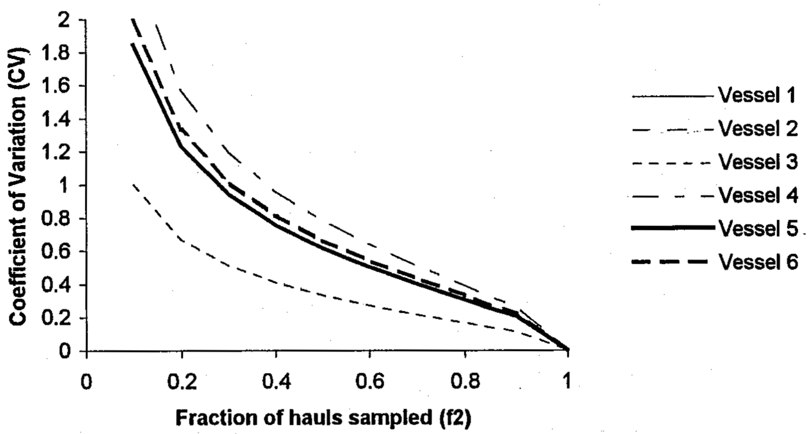
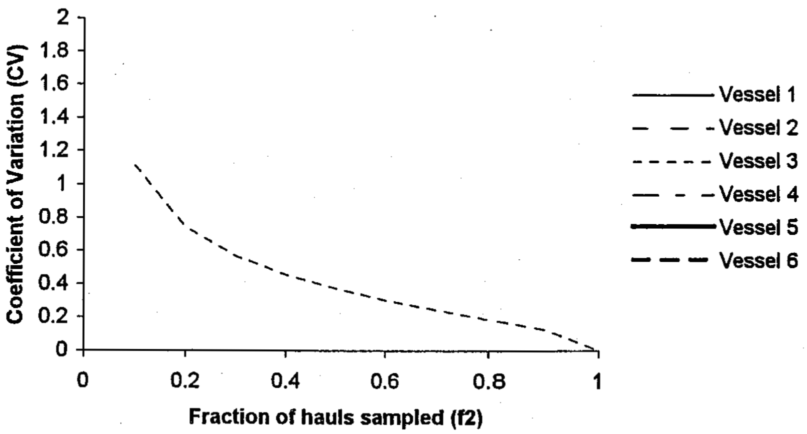


Figure 4-26. Associated coefficients of variation in estimated catch of chinook salmon from individual vessels during the three seasons of the 1994 BSAI pollock fishery using the ratio estimator. The coefficients of variation are shown in relation to hauls sampled (f_2). The fraction of vessels sampled was held at 1.0. Vessels were assigned simple numeric characters to maintain anonymity.

A Season



CDQ Fishery



B Season

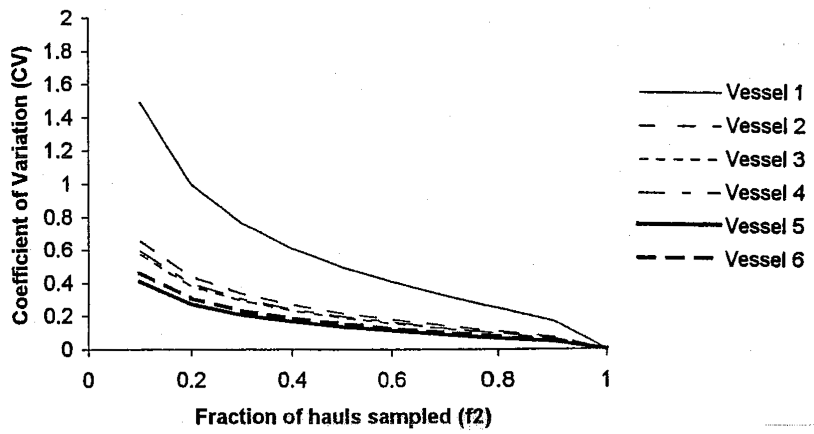
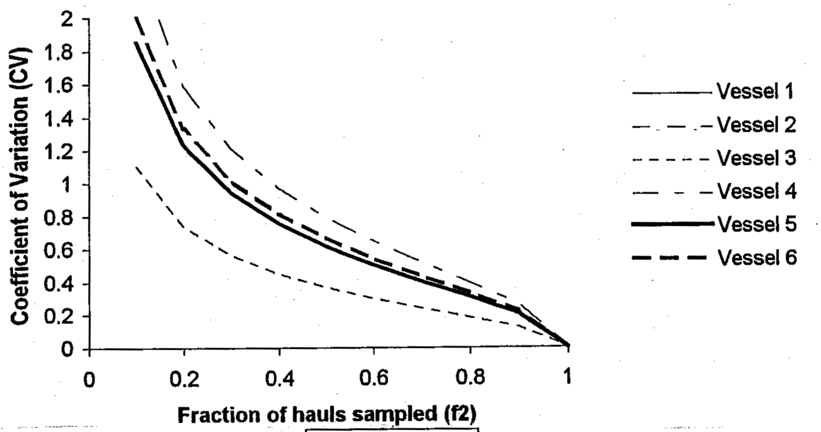
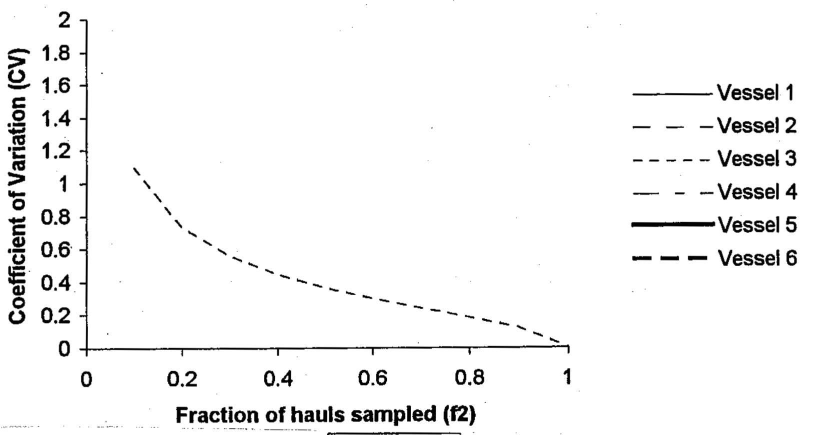


Figure 4-27. Associated coefficients of variation in estimated catch of salmon other than chinook from individual vessels during the three seasons of the 1994 BSAI pollock fishery using the standard two-stage estimator. The coefficients of variation are shown in relation to the fraction of hauls sampled (f_2). The fraction of vessels sampled was held at 1.0. Vessels were assigned simple numeric characters to maintain anonymity.

A Season



CDQ Fishery



B Season

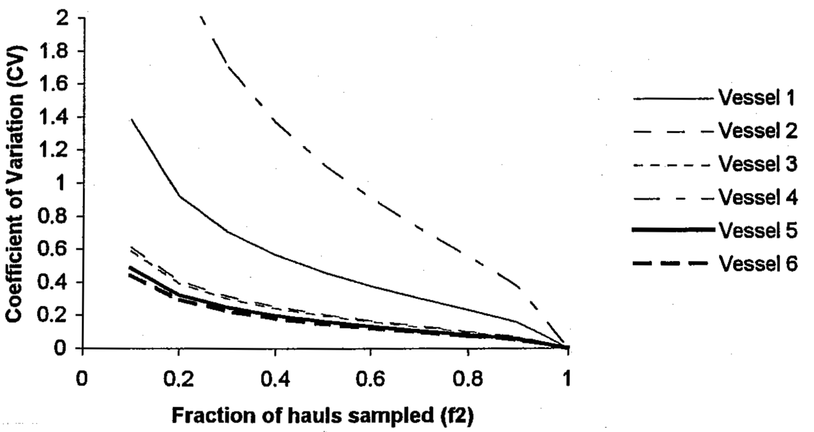


Figure 4-28. Associated coefficients of variation in estimated catch of salmon other than chinook from individual vessels during the three seasons of the 1994 BSAI pollock fishery using the ratio estimator with the delta estimator. The coefficients of variation are shown in relation to the fraction of hauls sampled (f_2). The fraction of vessels sampled was held at 1.0. Vessels were assigned simple numeric characters to maintain anonymity.

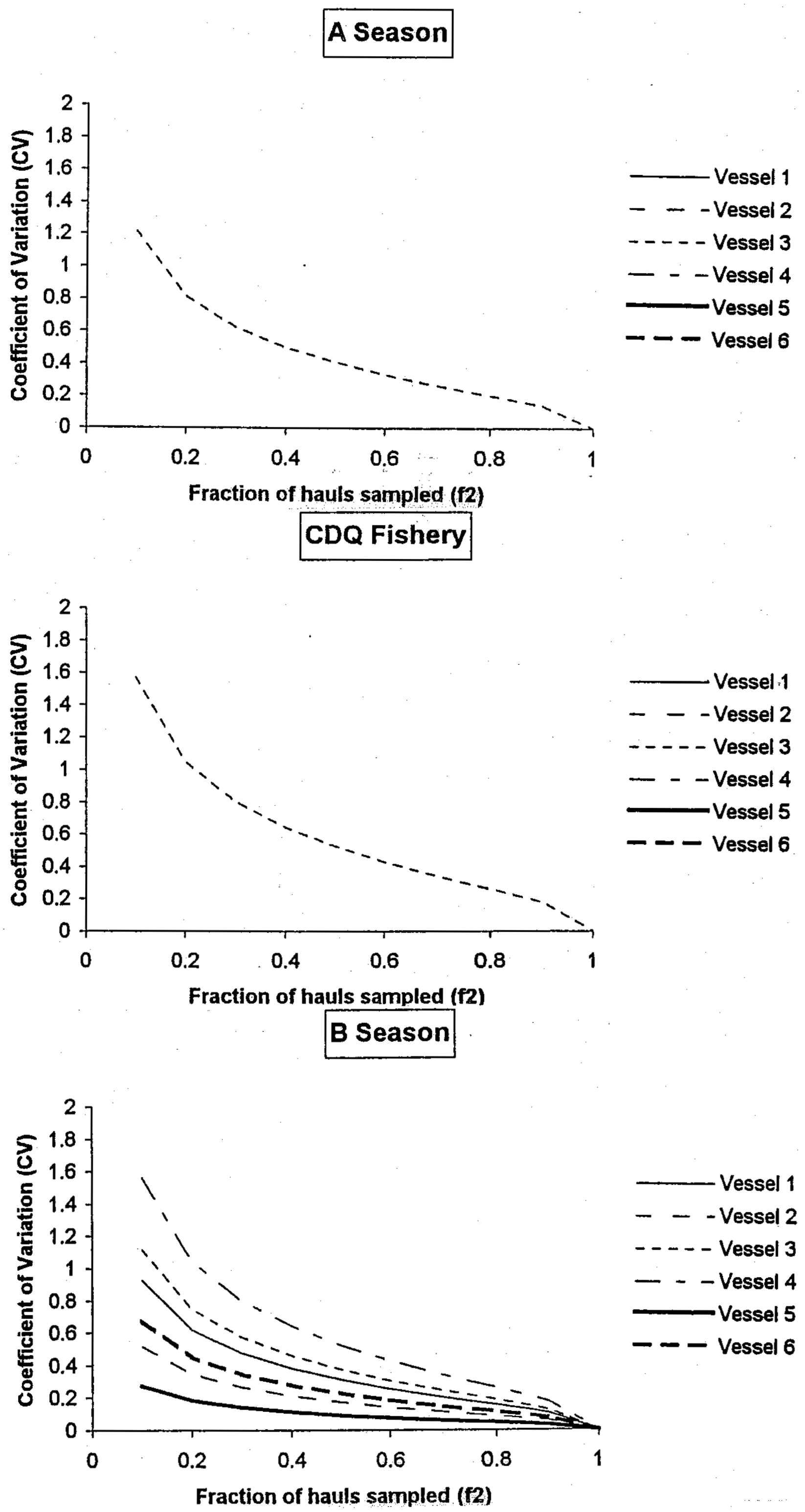
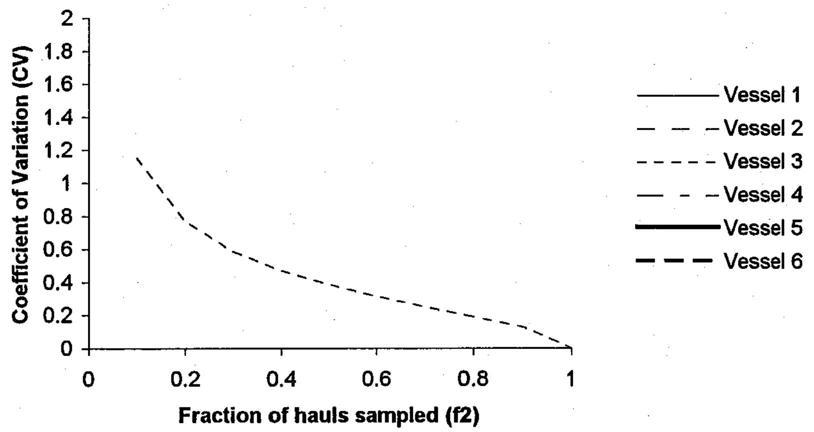
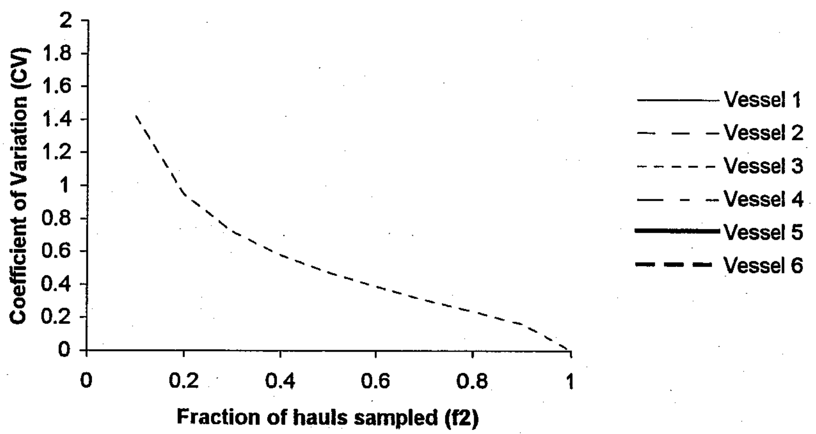


Figure 4-29. Associated coefficients of variation in estimated catch of herring from individual vessels during the three seasons of the 1994 BSAI pollock fishery using the standard two-stage estimator. The coefficients of variation are shown in relation to the fraction of hauls sampled (f_2). The fraction of vessels sampled was held at 1.0. Vessels were assigned simple numeric characters to maintain anonymity.

A Season



CDQ Fishery



B Season

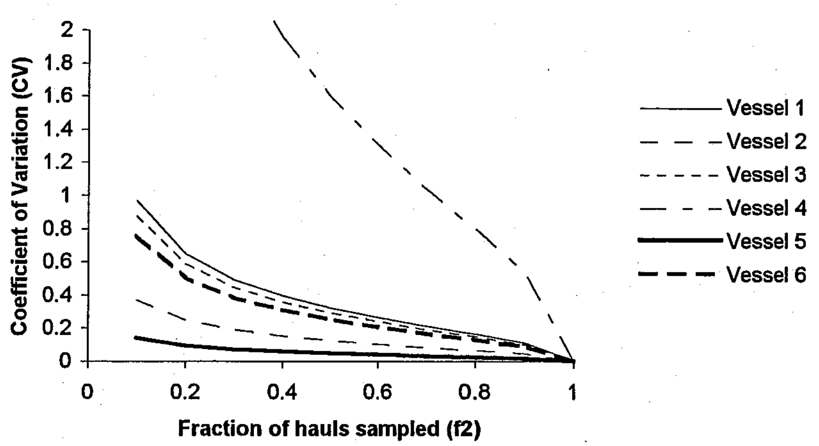


Figure 4-30. Associated coefficients of variation in estimated catch of herring from individual vessels during the three seasons of the 1994 BSAI pollock fishery using the ratio estimator. The coefficients of variation are shown in relation to the fraction of hauls sampled (f_2). The fraction of vessels sampled was held at 1.0. Vessels were assigned simple numeric characters to maintain anonymity.

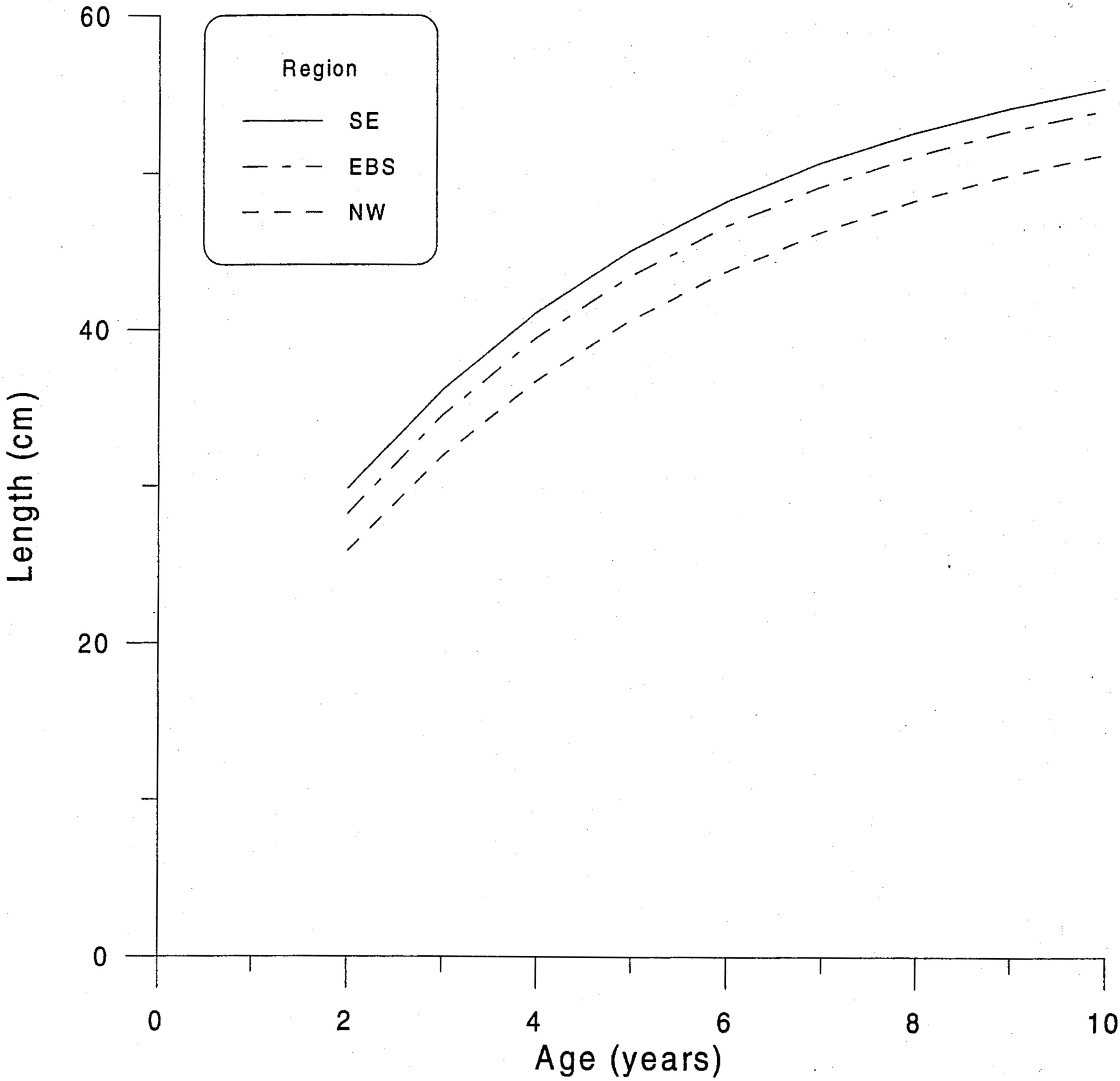


Figure 4-31. Age-length relationships for pollock by region. (SE - Southeast [areas 501, 509, 512, 513, 514, 516, 517, 519]; EBS - Eastern Bering Sea [areas 54, 542, 543]; NW - Northwest [areas 521, 523, 524])

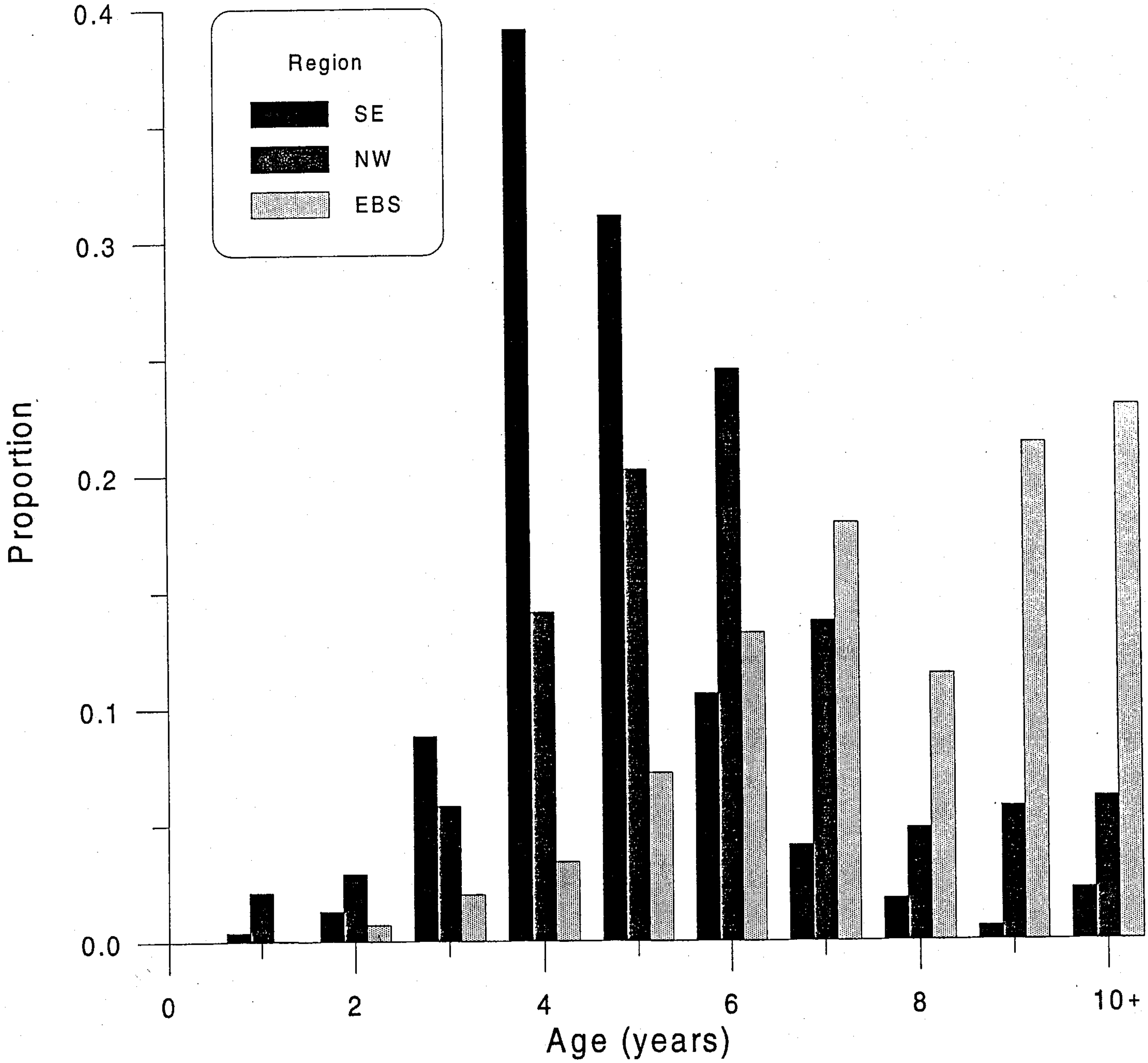


Figure 4-32. Estimated proportions at ages 1 to 10+ in overall catches of pollock catch by region for the 1994. (SE - Southeast [areas 501, 509, 512, 513, 514, 516, 517, 519]; EBS - Eastern Bering Sea [areas 54, 542, 543]; NW - Northwest [areas 521, 523, 524])

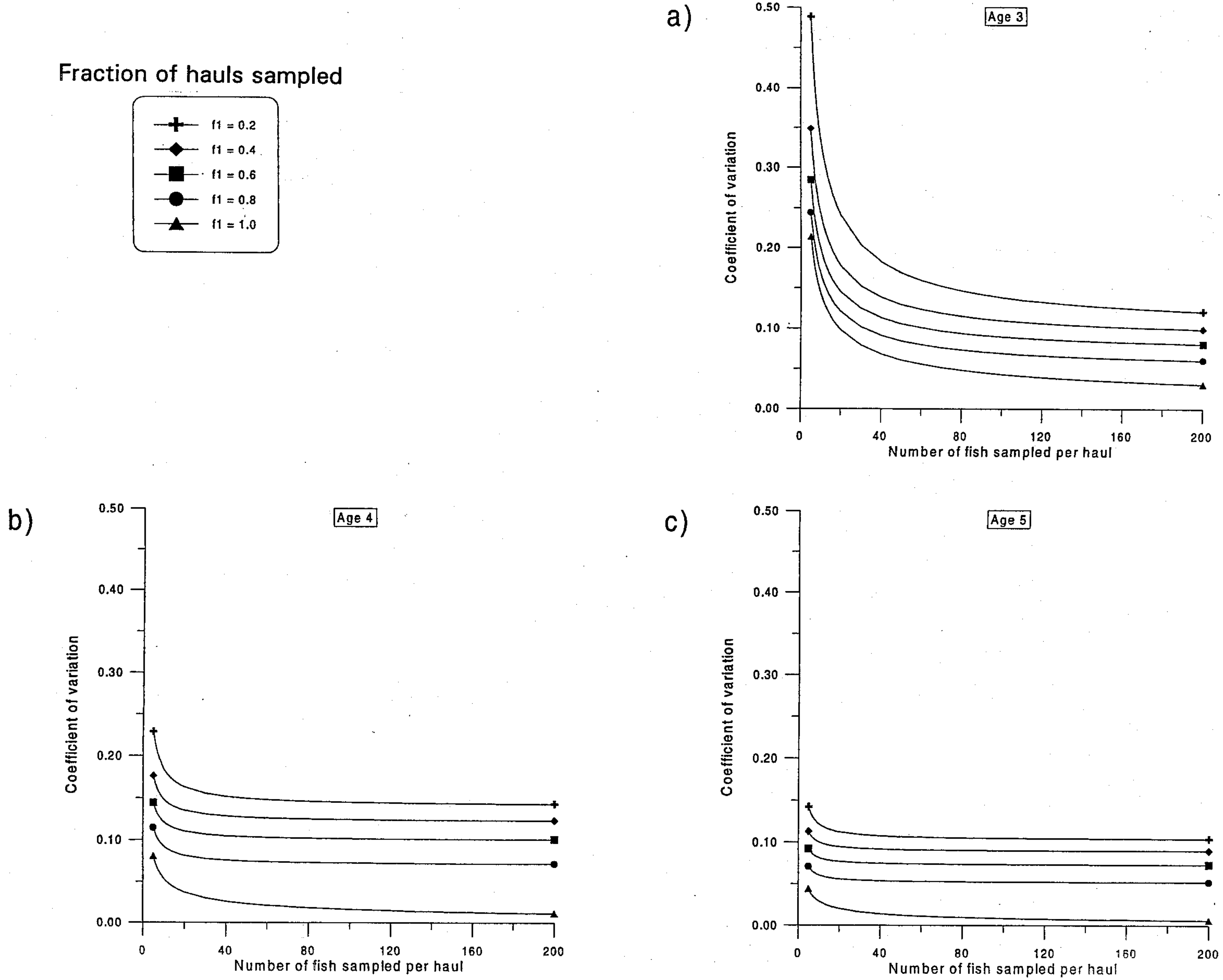


Figure 4-33. Associated coefficients of variation in estimated proportions of pollock in the Eastern Bering Sea region at a) age 3, b) age 4, and c) age 5, as function of the fraction of hauls samples (f_1) and the number of fish sampled per haul, for the 1994 BSAI pollock fishery

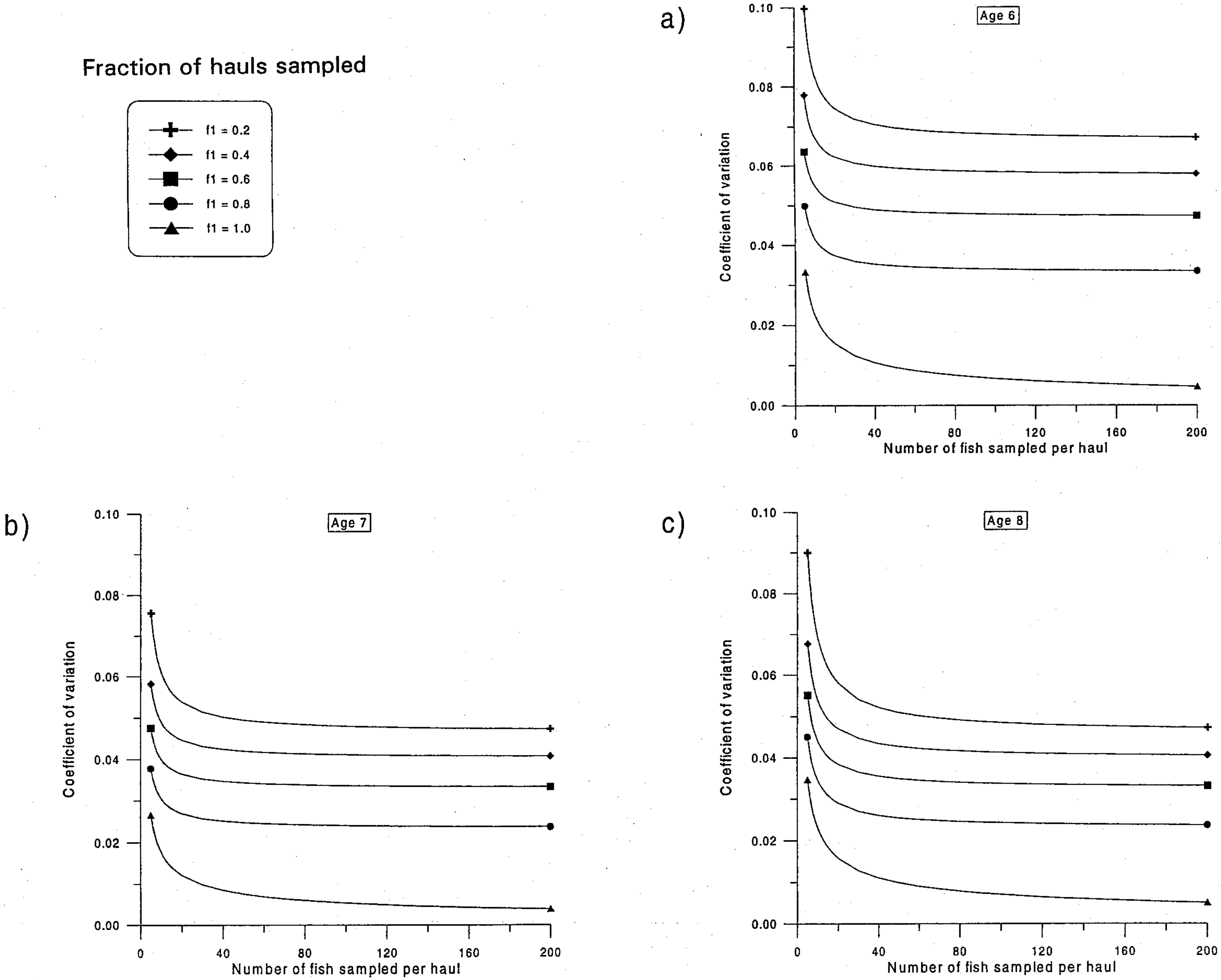
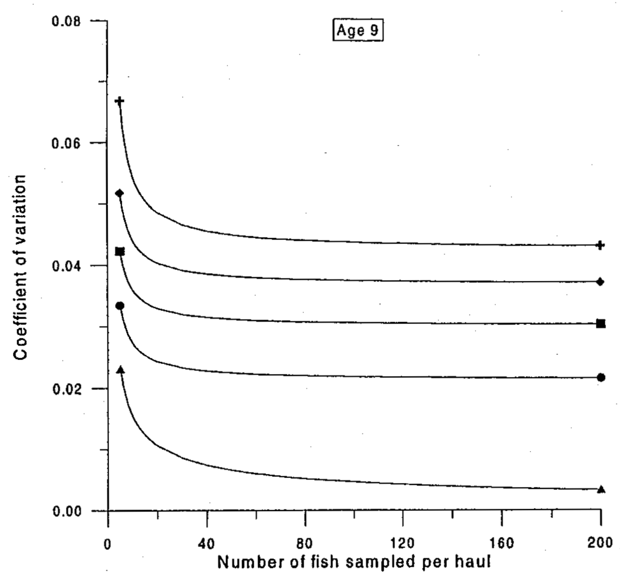


Figure 4-34. Associated coefficients of variation in estimated proportions of pollock in the Eastern Bering Sea region at a) age 6, b) age 7, and c) age 8, as function of the fraction of hauls samples (f_1) and the number of fish sampled per haul, for the 1994 BSAI pollock fishery

a)



b)

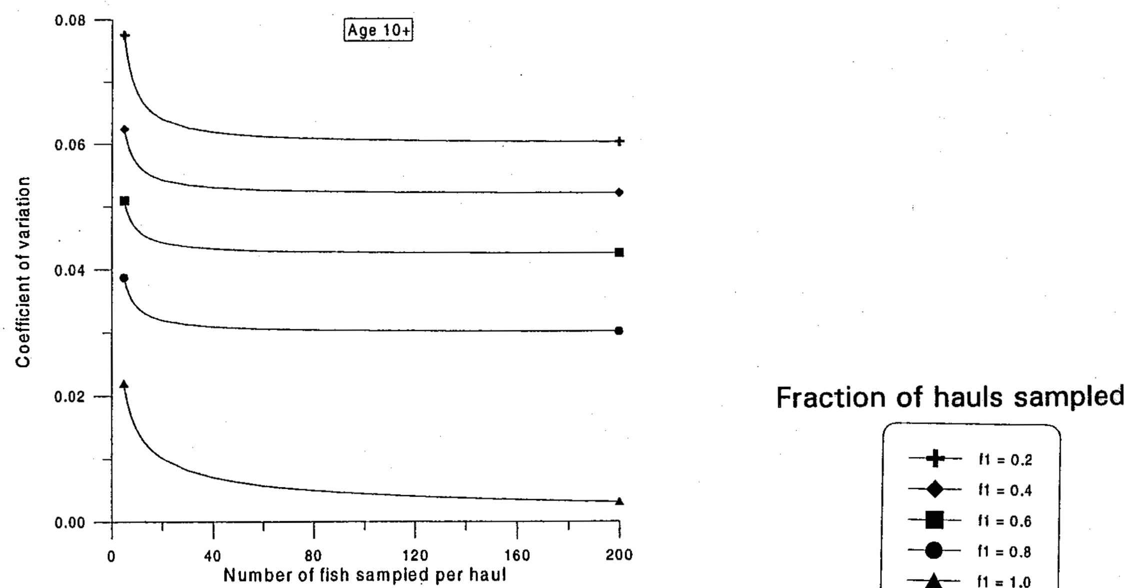


Figure 4-35. Associated coefficients of variation in estimated proportions of pollock in the Eastern Bering Sea region at a) age 9 and b) age 10+, as a function of the fraction of hauls sampled (f_1) and the number of fish sampled per haul, for the 1994 BSAI pollock fishery.

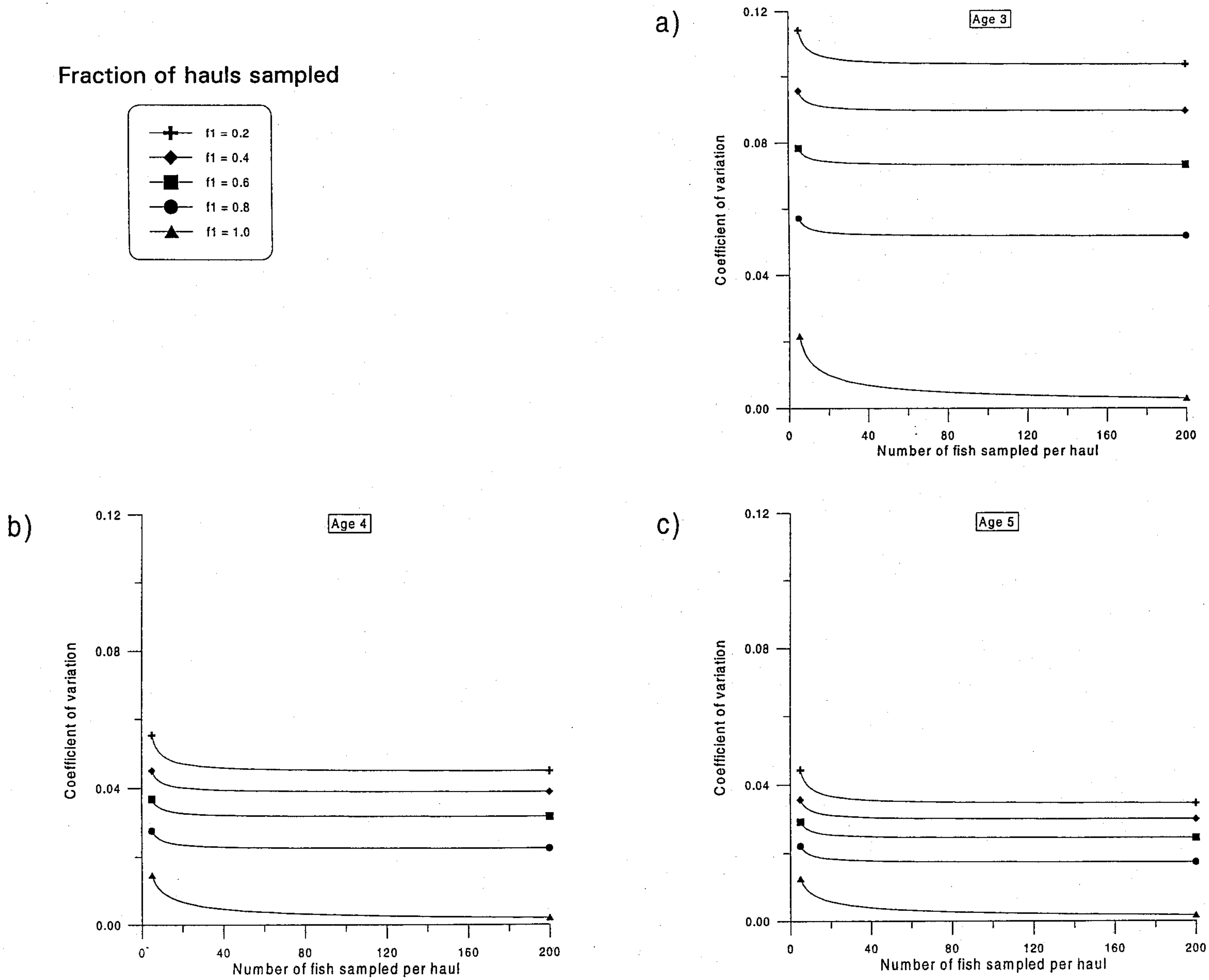


Figure 4-36. Associated coefficients of variation in estimated proportions of pollock in the northwest region at a) age 3, b) age 4, and c) age 5, as a function of the fraction of hauls sampled (f_1) and the number of fish sampled per haul, for the 1994 BSAI pollock fishery

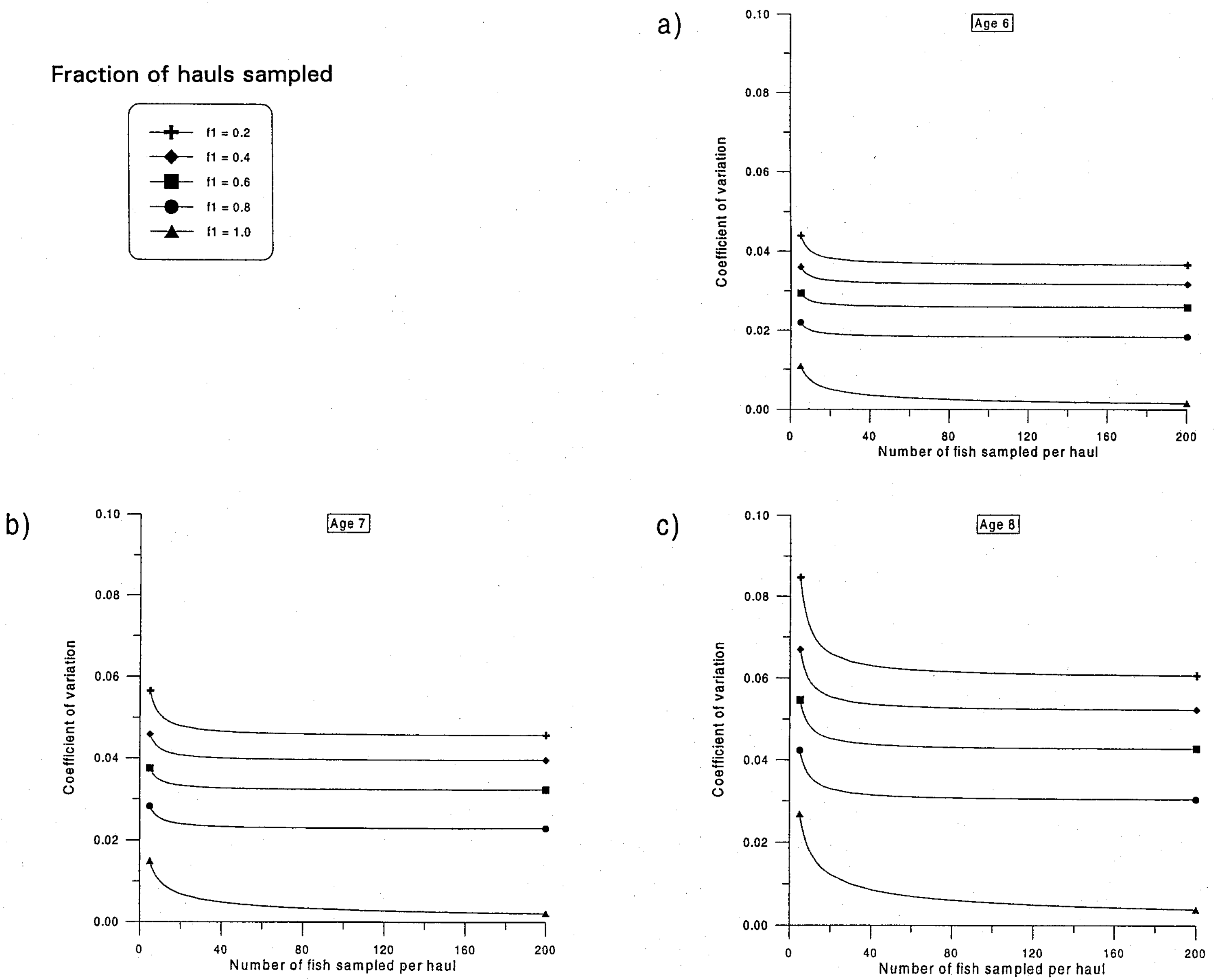


Figure 4-37. Associated coefficients of variation in estimated proportions of pollock in the northwest region at a) age 6, b) age 7, and c) age 8, as a function of the fraction of hauls sampled (f_1) and the number of fish sampled per haul, for the 1994 BSAI pollock fishery.

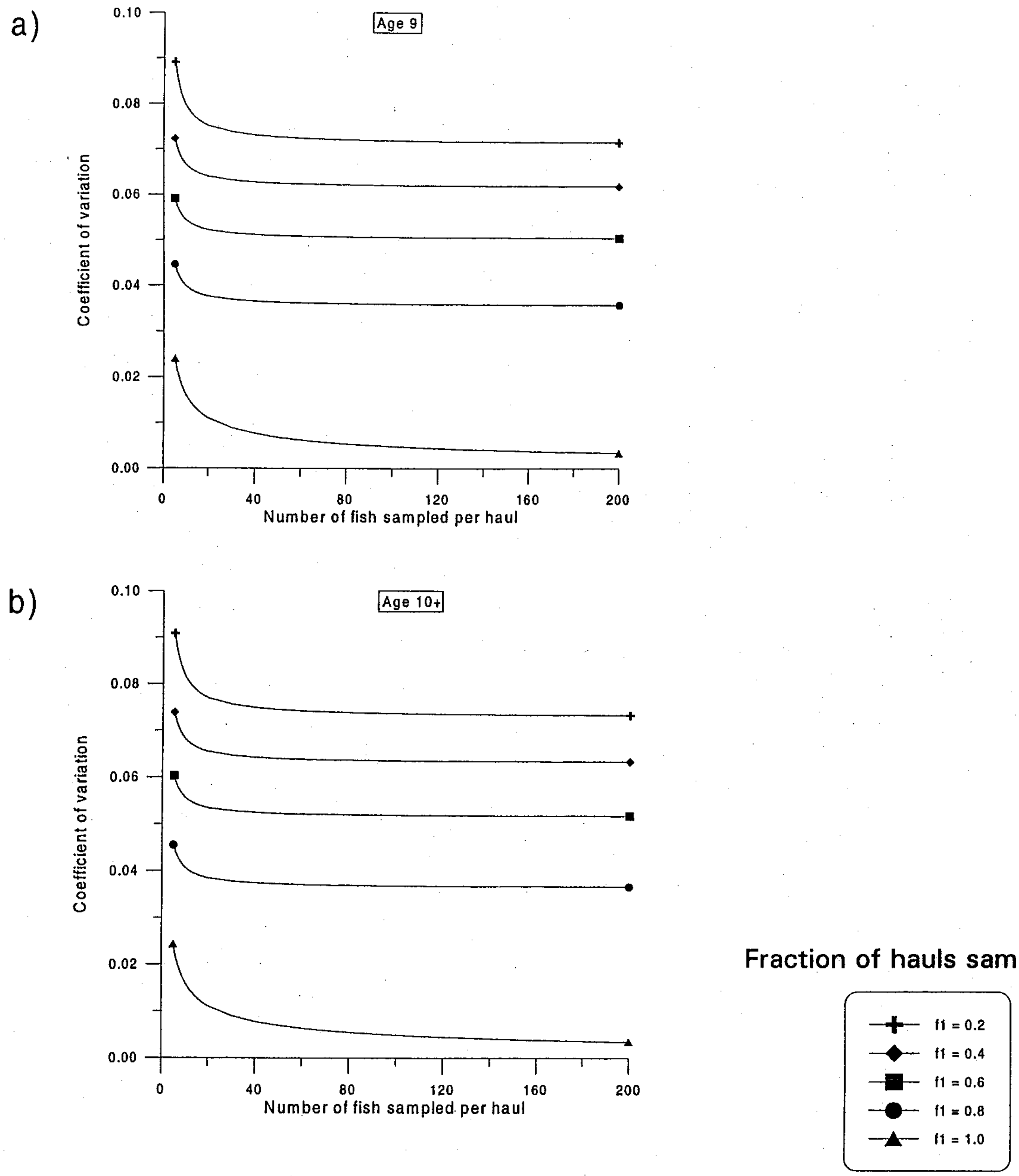


Figure 4-38. Associated coefficients of variation in estimated proportions of pollock in the northwest region at a) age 9 and b) age 10+, as a function of the fraction of hauls sampled (f_1) and the number of fish sampled per haul, for the 1994 BSAI pollock fishery

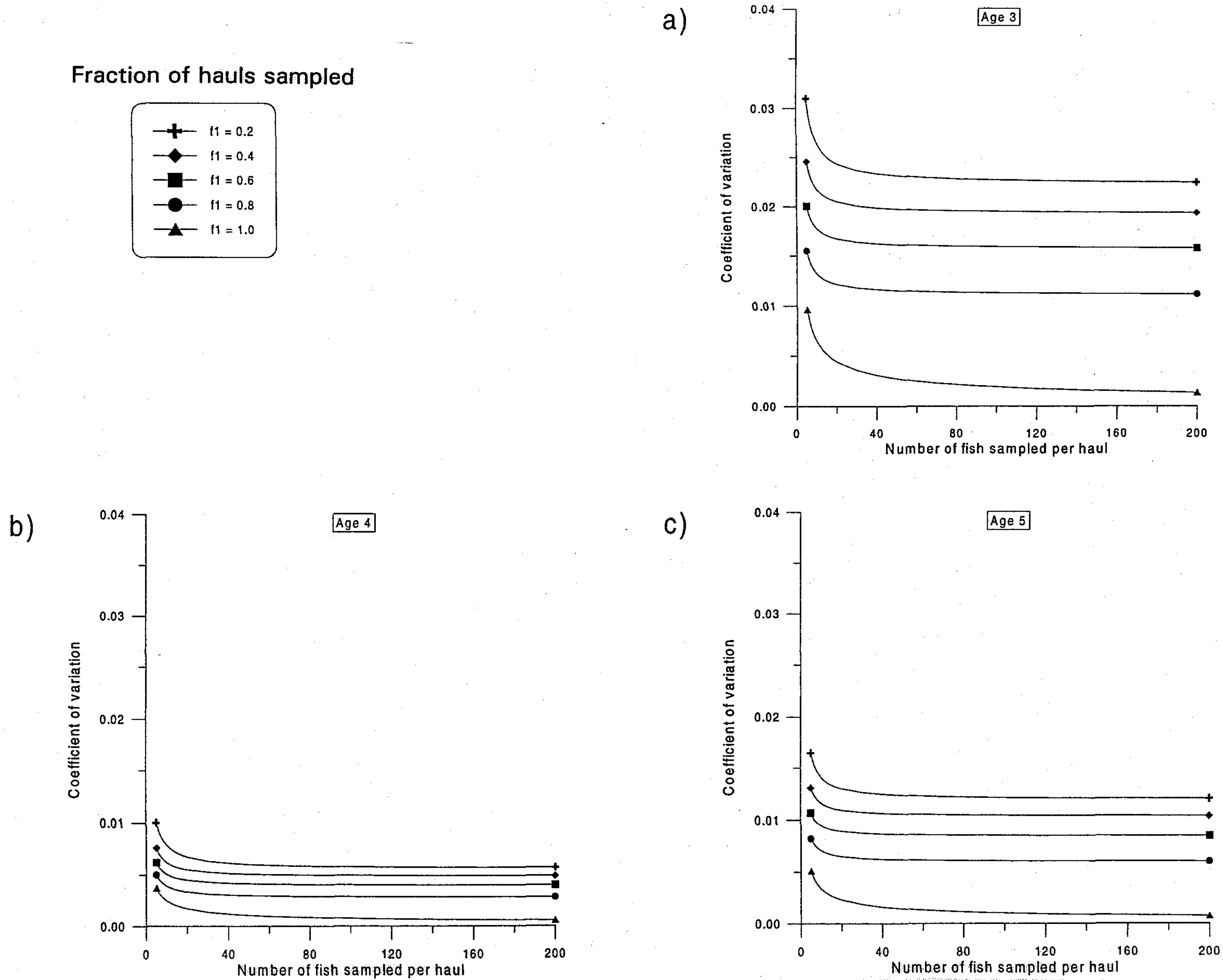


Figure 4-39. Associated coefficients of variation in estimated proportions of pollock in the southeast region at a) age 3, b) age 4, and c) age 5, as a function of the fraction of hauls sampled (f_1) and the number of fish sampled per haul, for the 1994 BSAI pollock fishery

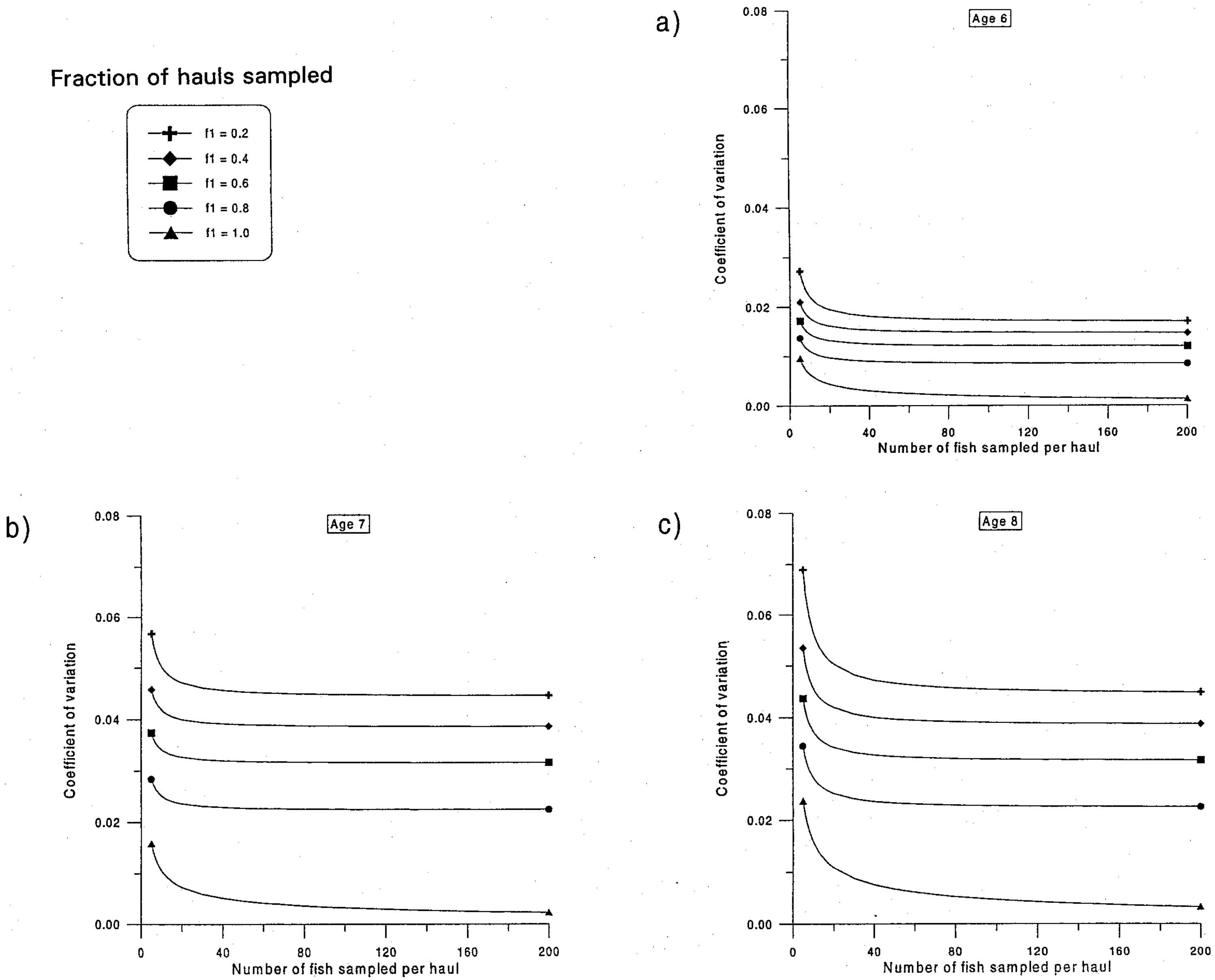


Figure 4-40. Associated coefficients of variation in estimated proportions of pollock in the southeast region at a) age 6, b) age 7, and c) age 8, as a function of the fraction of hauls sampled (f_1) and the number of fish sampled per haul, for the 1994 BSAI pollock fishery.

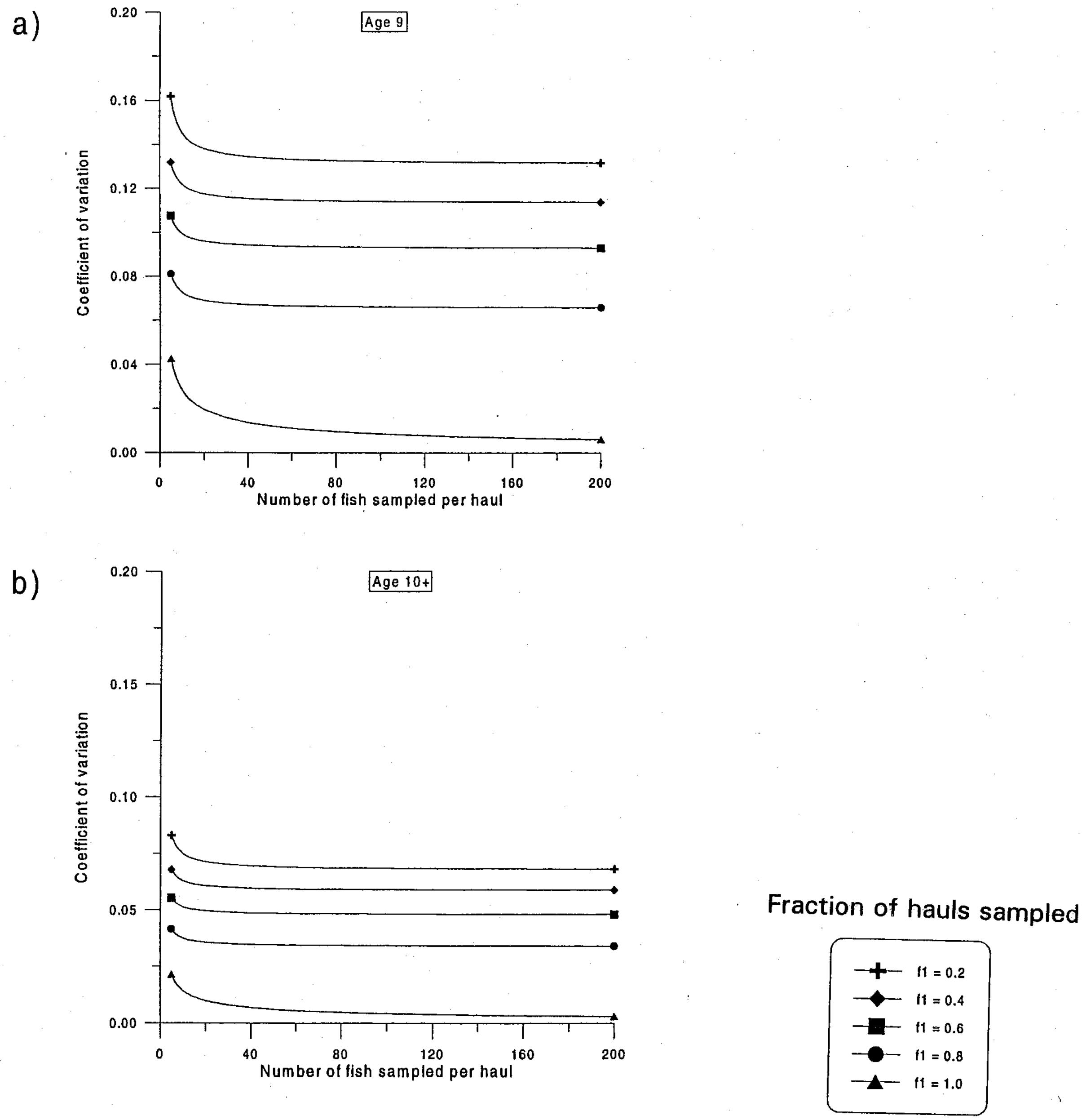


Figure 4-41. Associated coefficients of variation in estimated proportions of pollock in the southeast region at a) age 9 and b) age 10+, as a function of the fraction of hauls sampled (f_1) and the number of fish sampled per haul, for the 1994 BSAI pollock fishery.

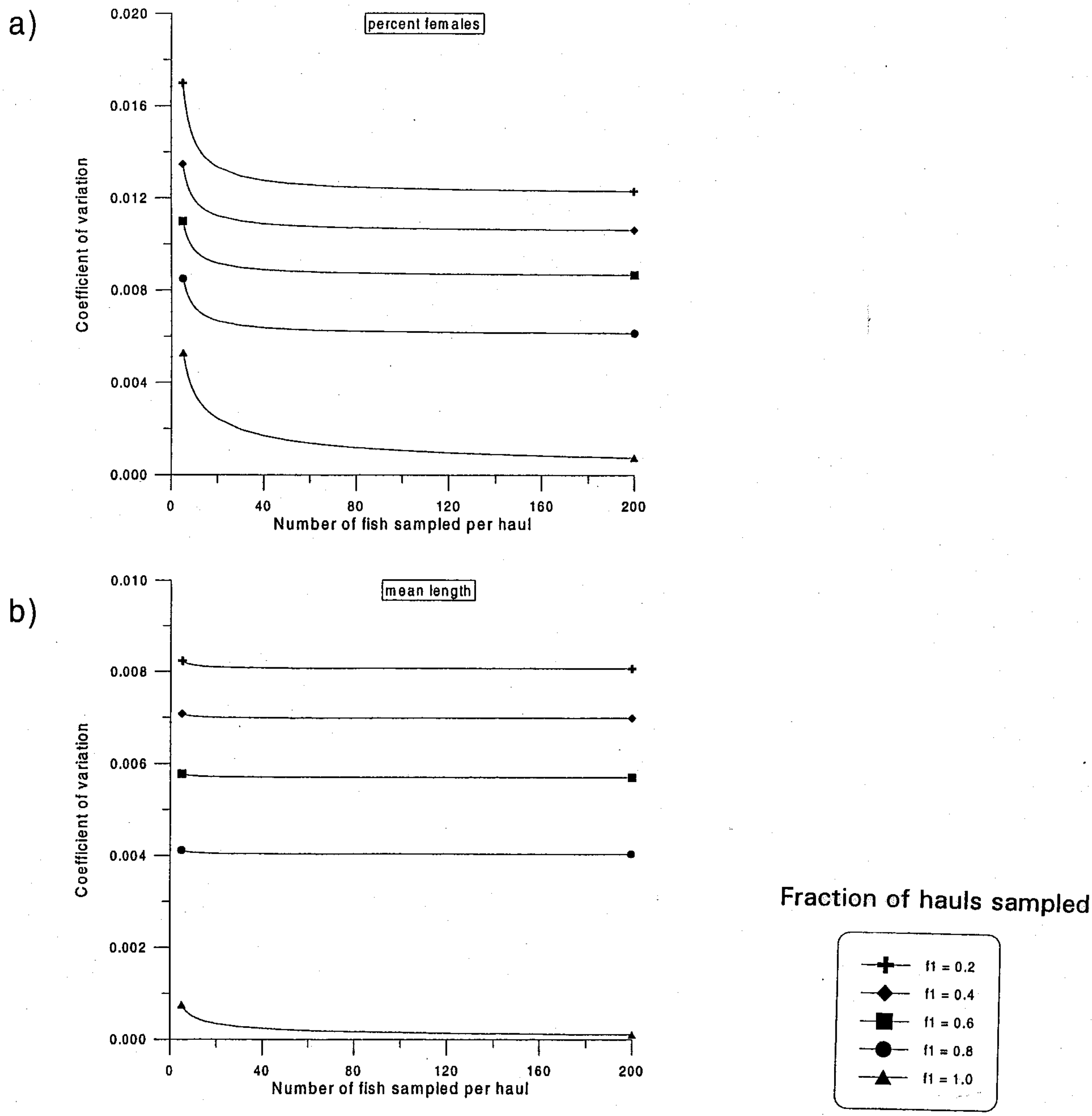


Figure 4-42. Associated coefficients of variation in a) estimated percent females and b) estimated mean length of pollock in the Eastern Bering Sea region, as a function of the fraction of hauls sampled (f_1) and the number of fish sampled per haul, for the 1994 BSAI pollock fishery

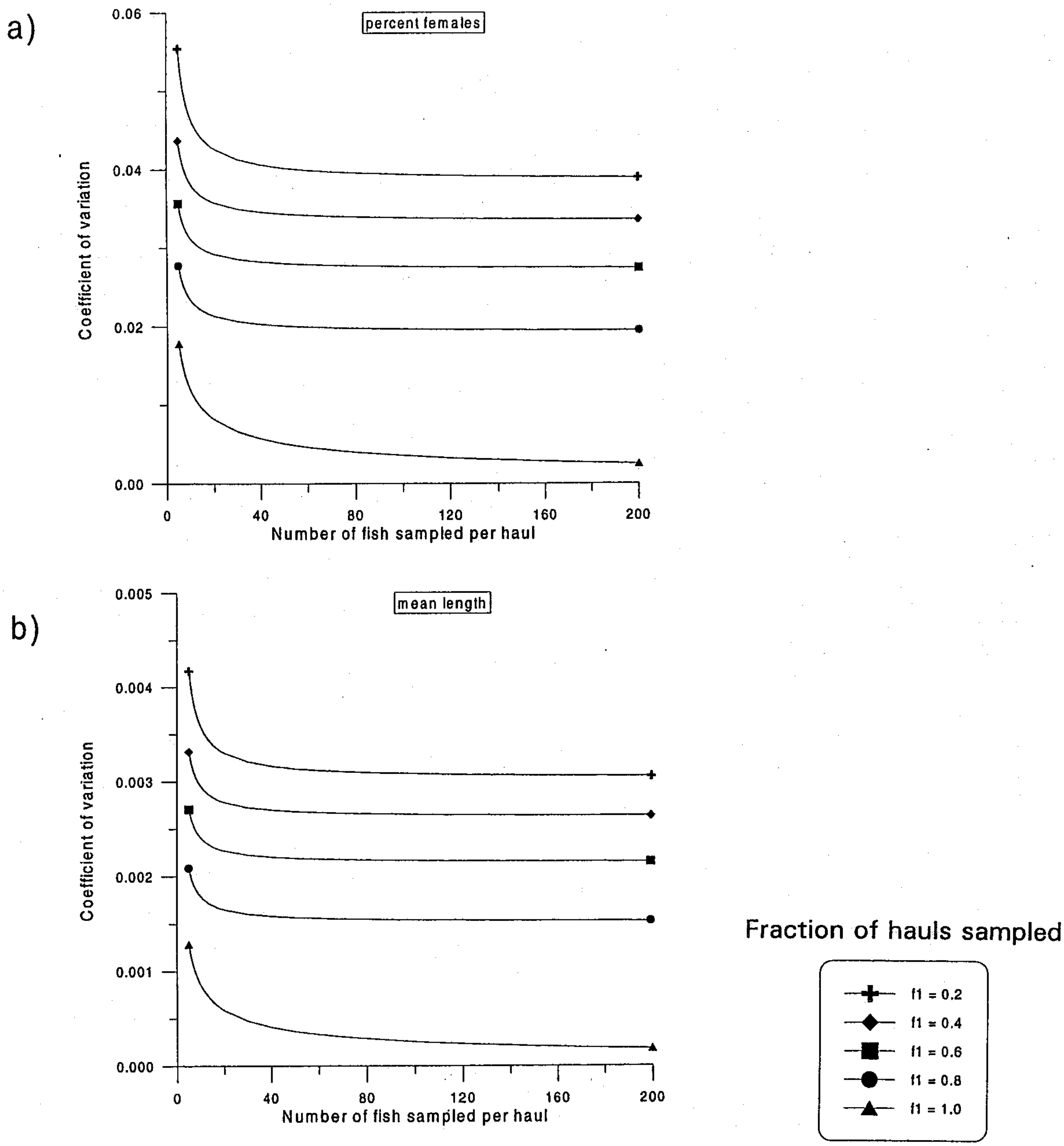


Figure 4-43. Associated coefficients of variation in a) estimated percent females and b) estimated mean length of pollock in the northwest region, as a function of the fraction of hauls sampled (f_1) and the number of fish sampled per haul, for the 1994 BSAI pollock fishery.

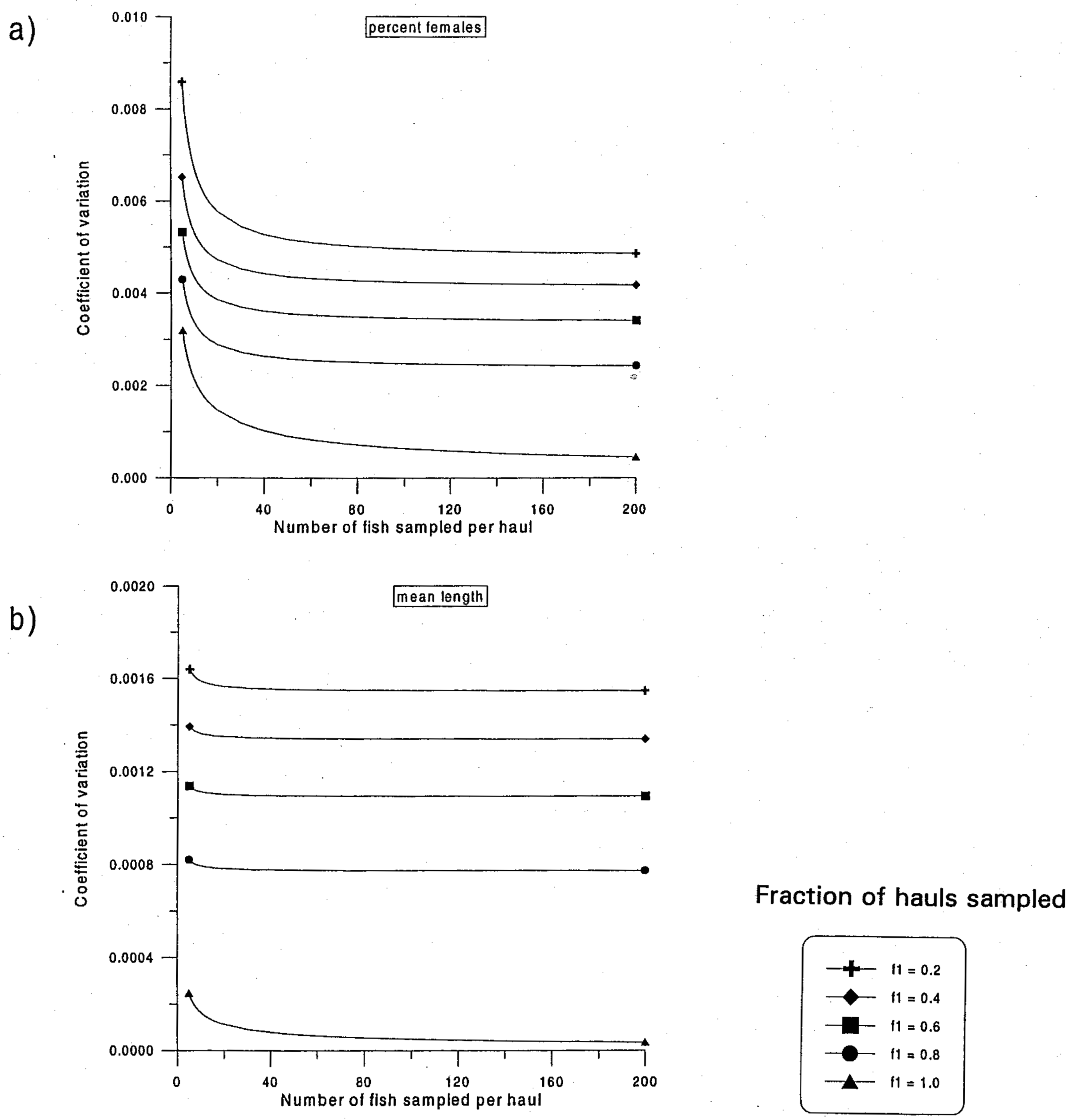


Figure 4-44. Associated coefficients of variation in a) estimated percent females and b) estimated mean length of pollock in the southeast region, as a function of the fraction of hauls sampled (f_1) and the number of fish sampled per haul, for the 1994 BSAI pollock fishery.

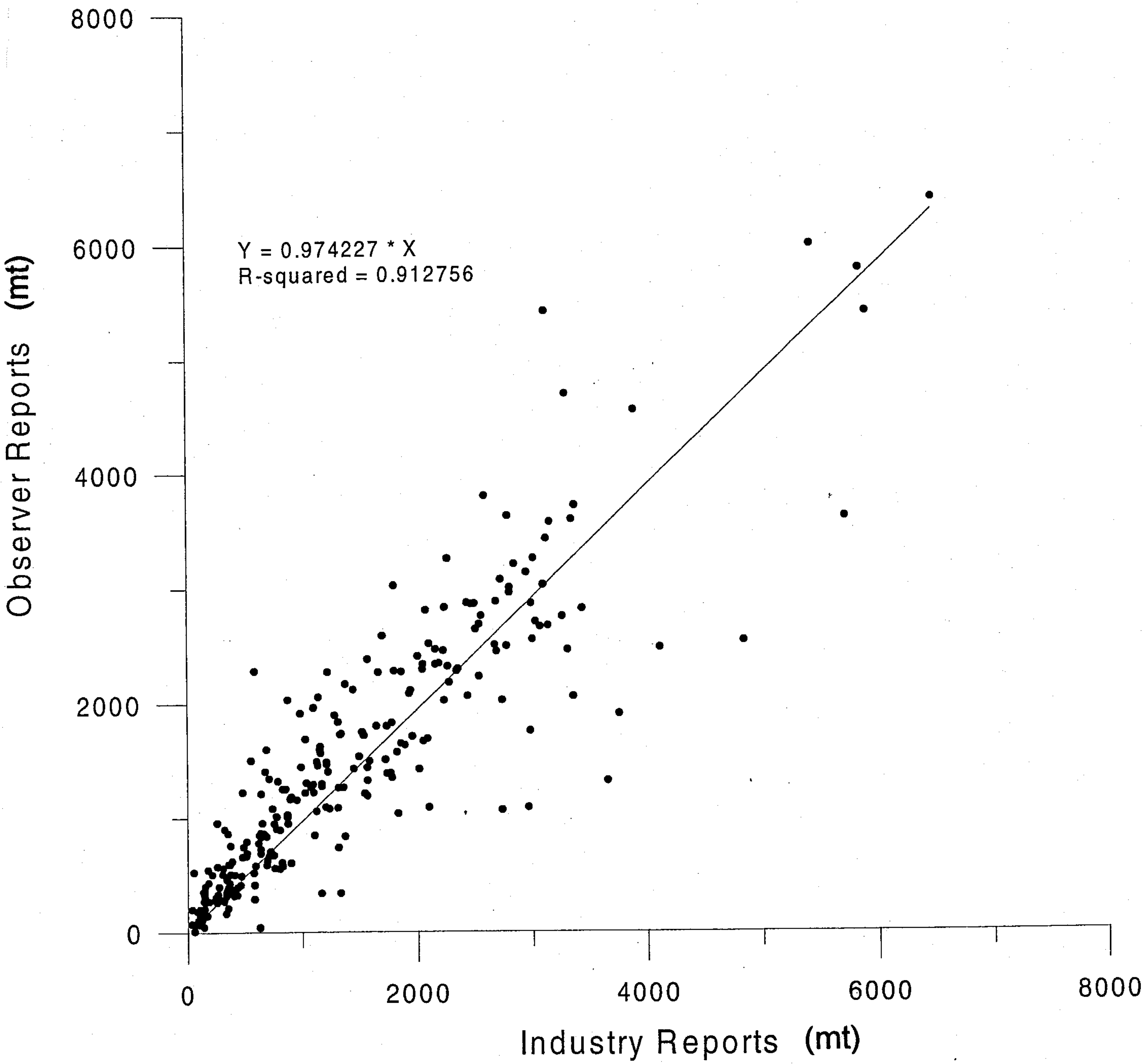


Figure 4-45. 1994 BSAI offshore pollock fishery, A Season - comparison of weekly catch estimates based on observer reports and industry reports

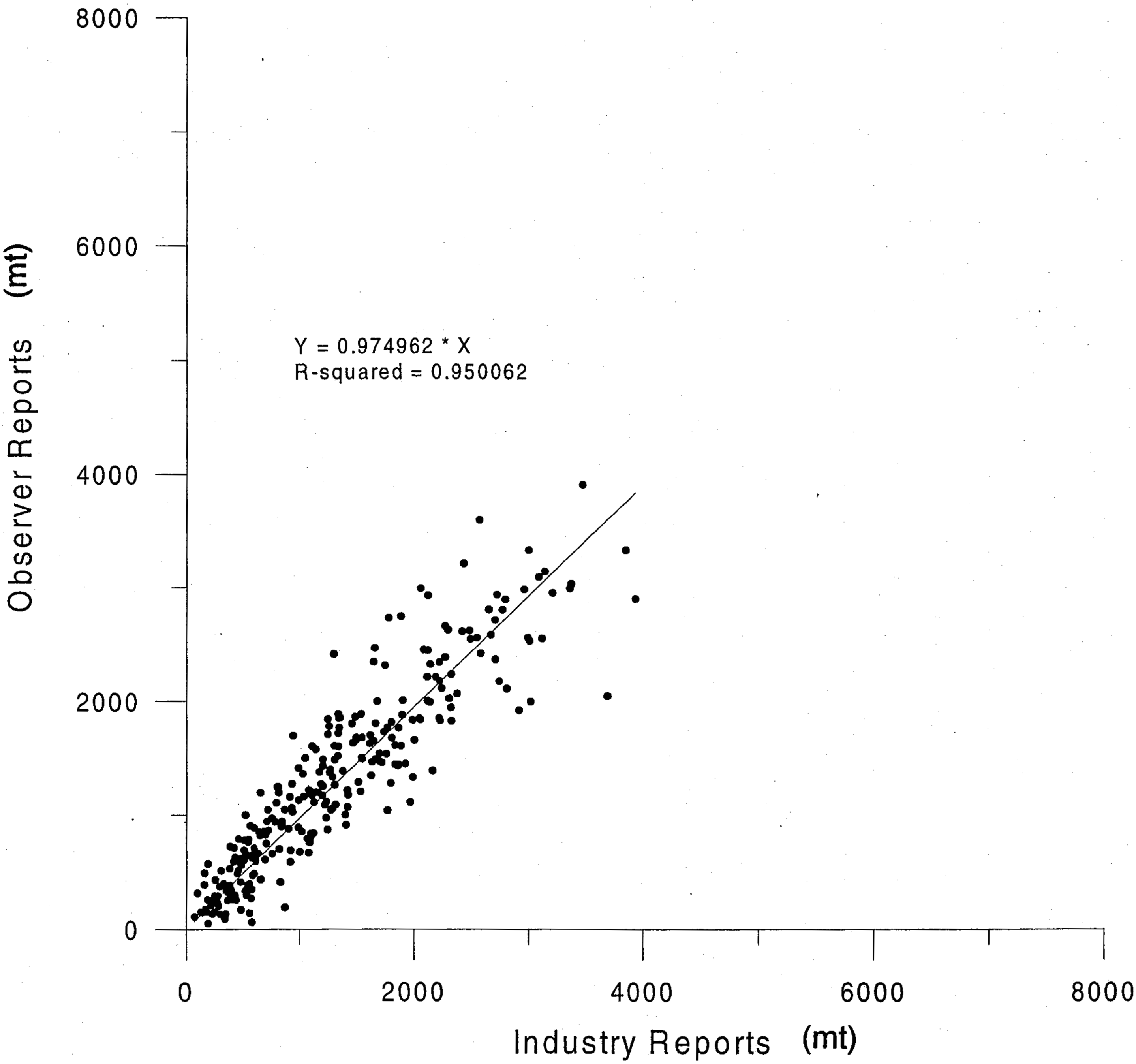


Figure 4-46. 1994 BSAI offshore pollock fishery, B Season - comparison of weekly catch estimates based on observer reports and industry reports.

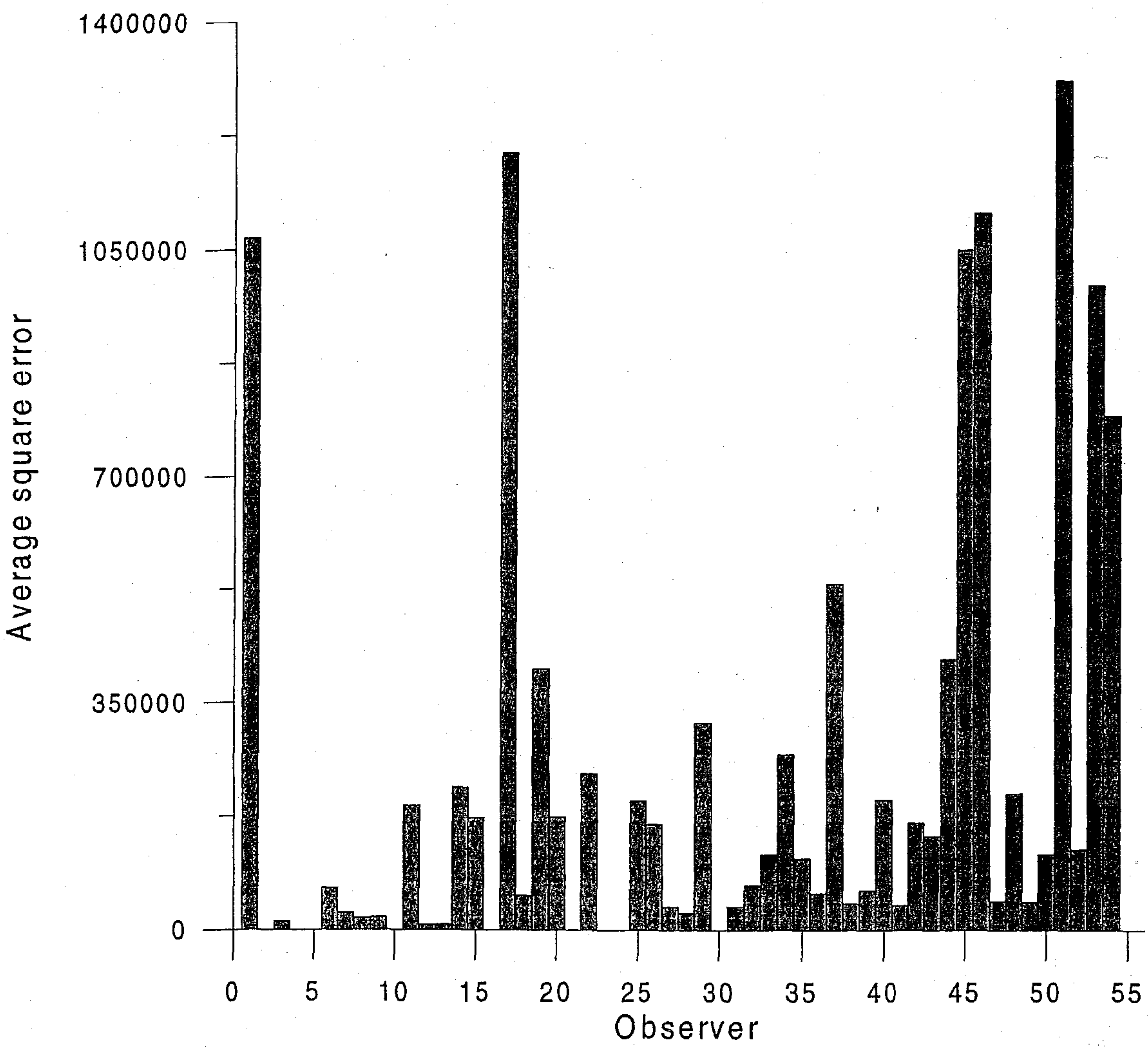


Figure 4-47. Average square errors between observer estimates and corresponding weekly production report estimates for the A Season of the 1994 BSAI pollock fishery (provide a measure of closeness to best-fit line through points of observer estimates vs. weekly production report). Simple numeric characters were assigned to each observer to maintain anonymity.

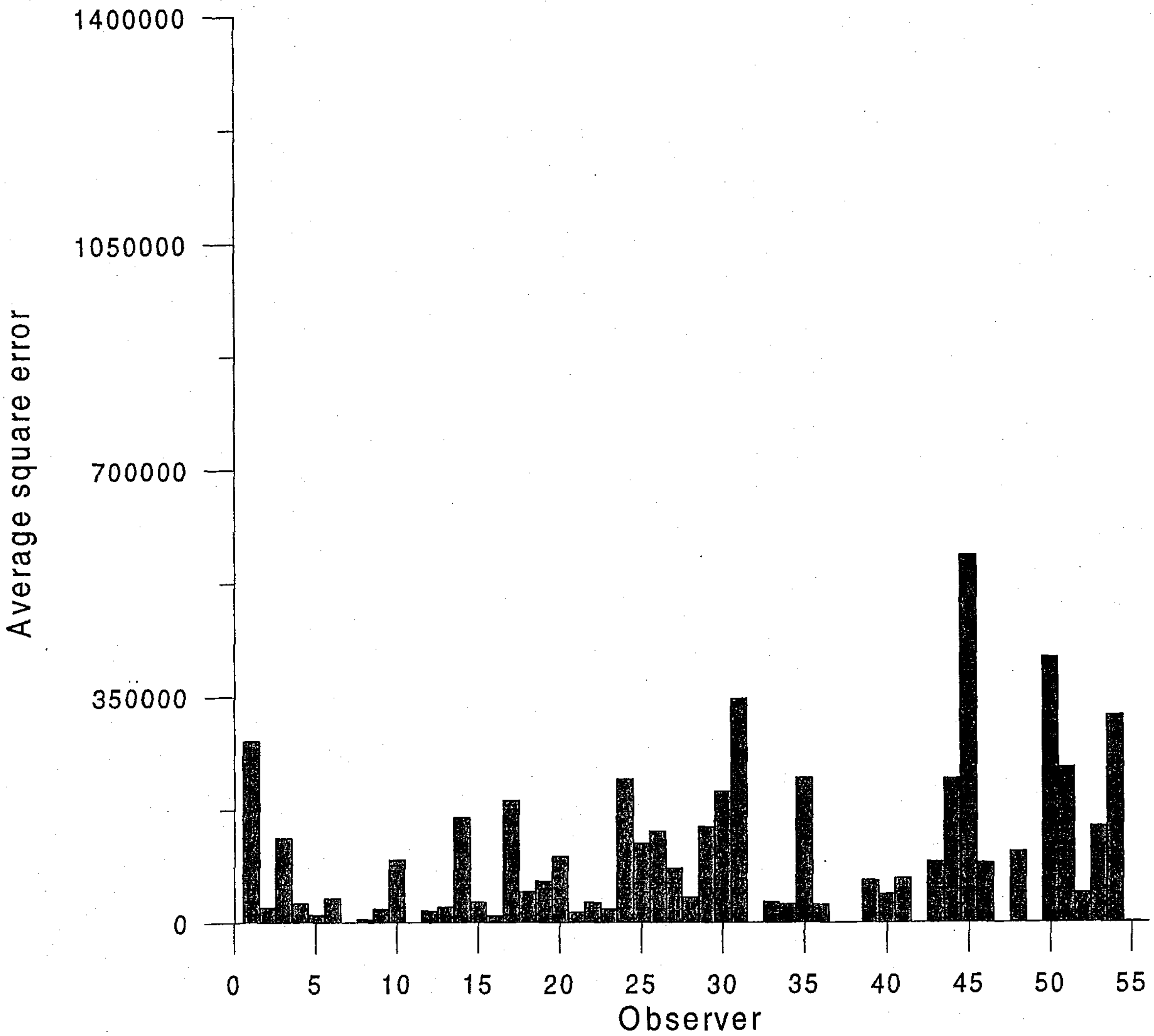


Figure 4-48. Average square errors between observer estimates and corresponding weekly production report estimates for the B Season of the 1994 BSAI pollock fishery (provide a measure of closeness to best-fit line through points of observer estimates vs. weekly production report). Simple numeric characters were assigned to each observer to maintain anonymity.

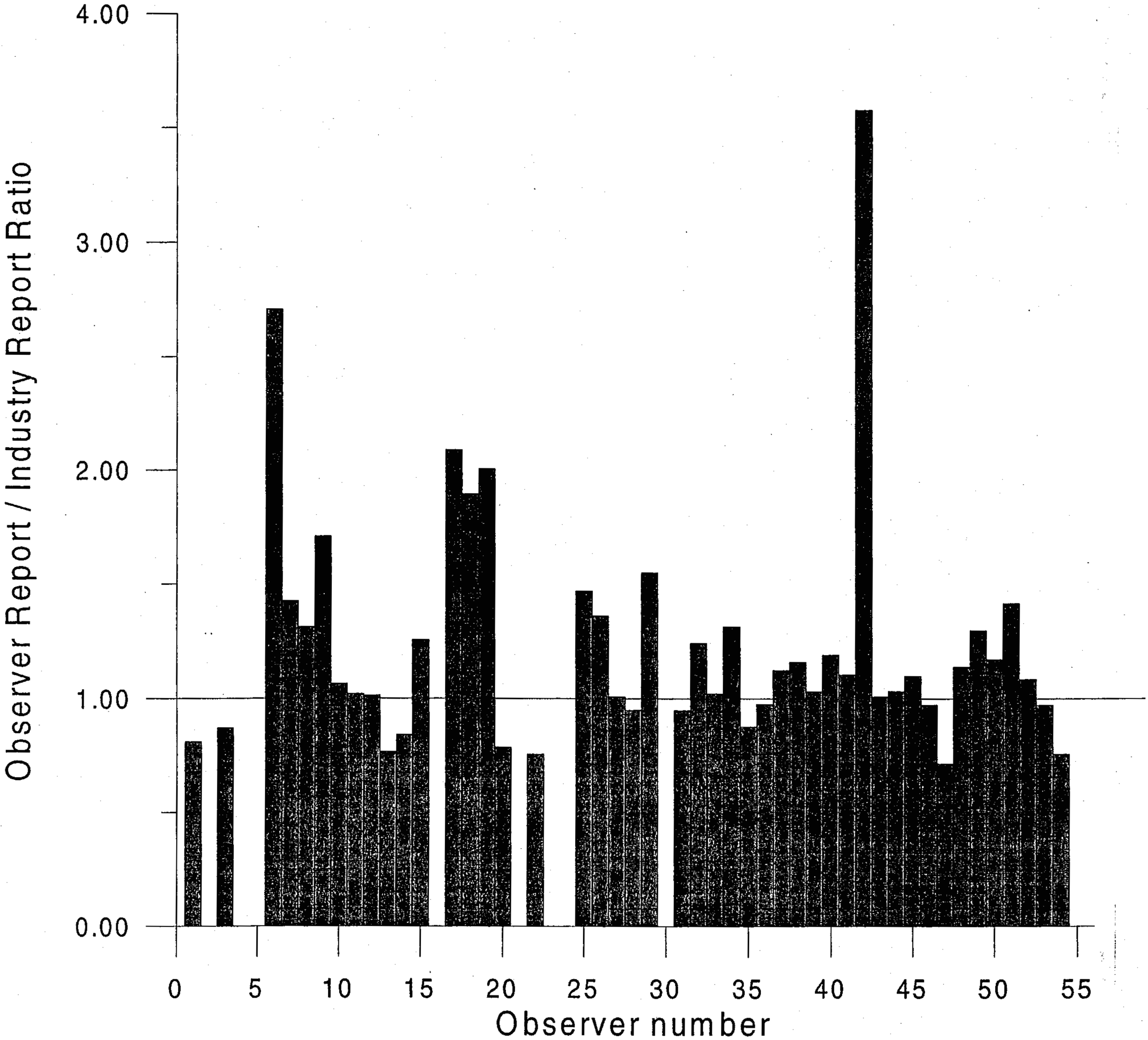


Figure 4-49. Ratios of observer reports to industry reports for the 1994 BSAI pollock fishery, A Season. Simple numeric characters were assigned to each observer to maintain anonymity.

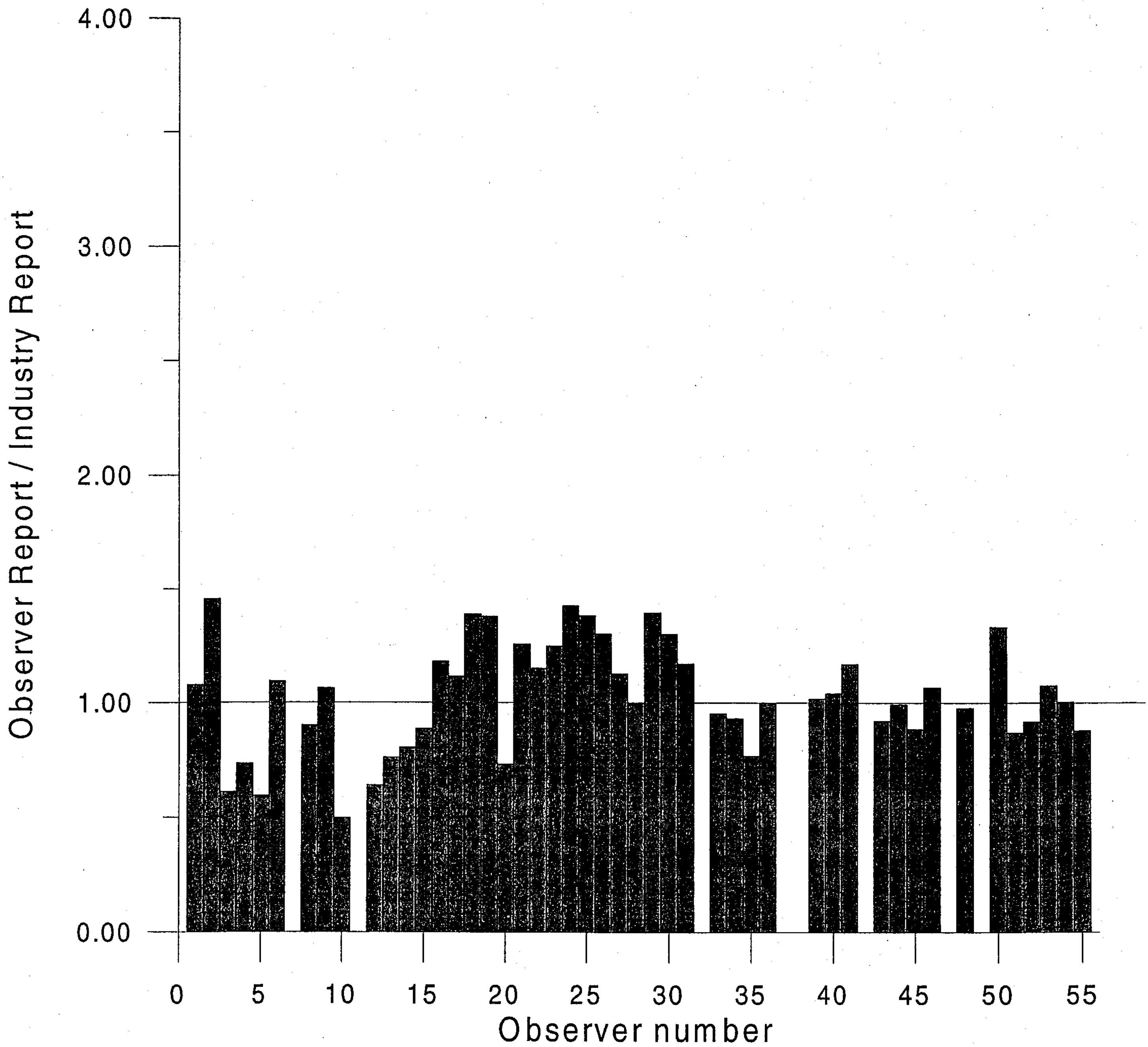


Figure 4-50. Ratios of observer reports to industry reports for the 1994 BSAI pollock fishery, B Season. Simple numeric characters were assigned to each observer to maintain anonymity.

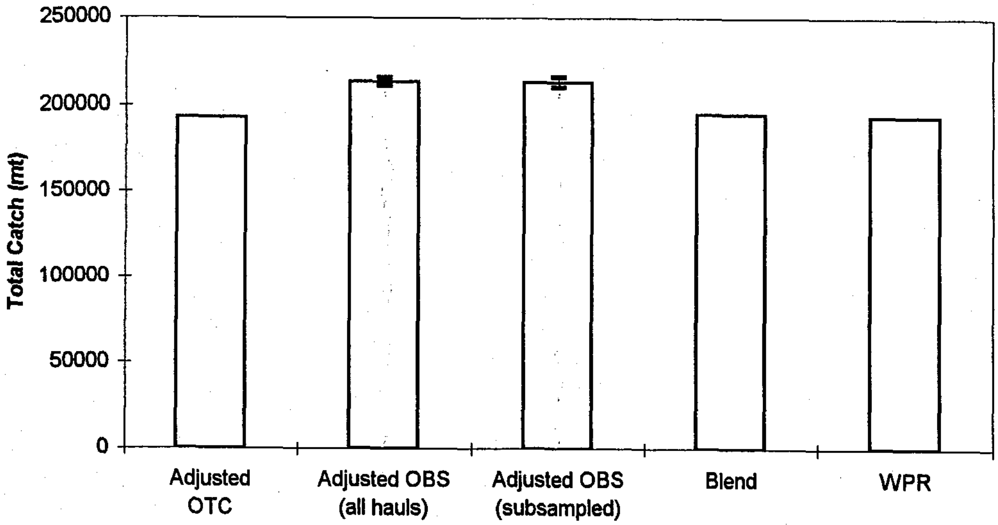


Figure 4-51. Total groundfish catch estimates for the 1994 BSAI yellowfin sole fishery using five different estimation methods. The upper and lower 95% confidence intervals for the adjusted OBS estimates are shown as T-bars.

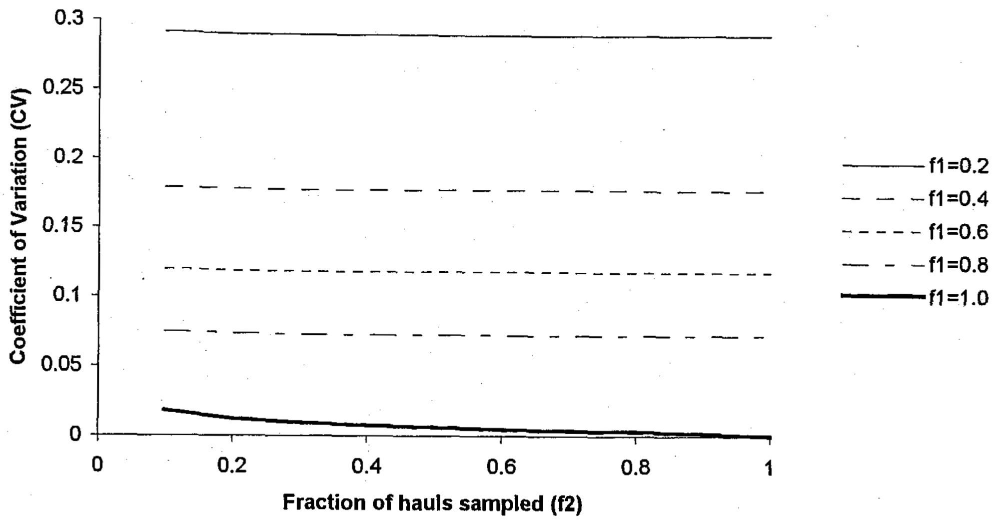


Figure 4-52. Associated coefficients of variation in estimated fleetwide catch of all groundfish species during the 1994 BSAI yellowfin sole fishery, as a function of the fraction of vessels sampled (f_1) and the fraction of hauls sampled (f_2). Statistics based on the adjusted OTC data set.

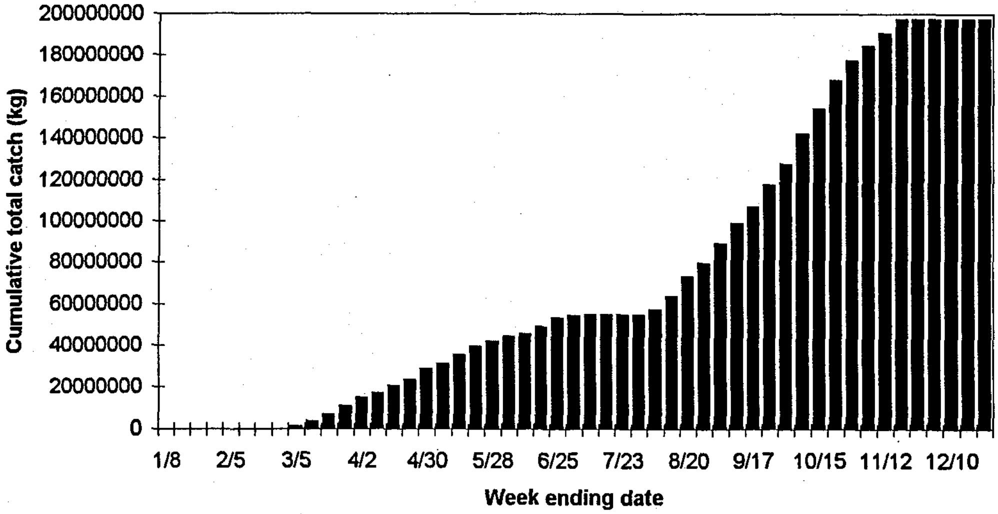


Figure 4-53. Estimates of cumulative weekly total catch of all groundfish species during the 1994 BSAI yellowfin sole fishery. The upper 95% confidence intervals are shown as T-bars. Estimates are based on the adjusted OTC data set.

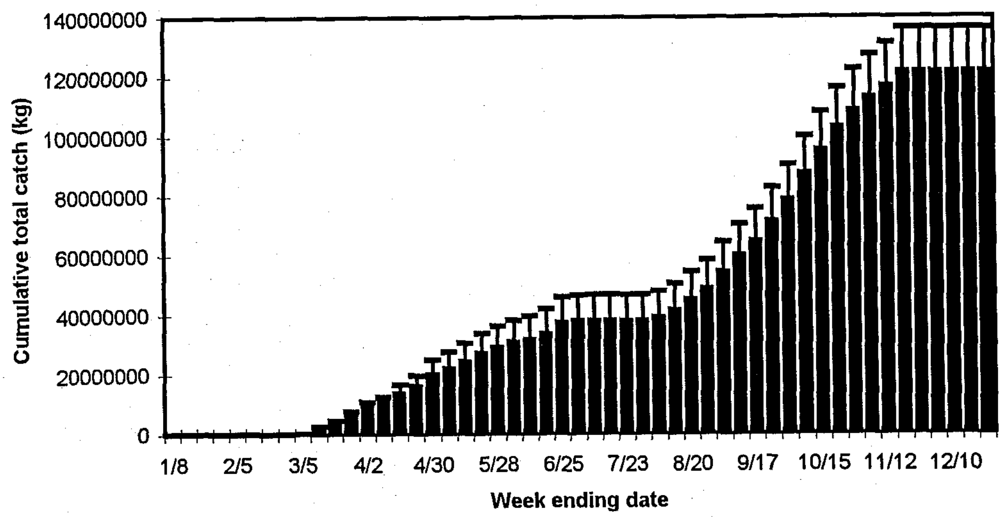


Figure 4-54. Estimates of cumulative weekly catch of yellowfin sole during the 1994 BSAI yellowfin sole fishery. The upper 95% confidence intervals are shown as T-bars. Estimates are based on the standard two-stage estimator and the observer subsampled data set.

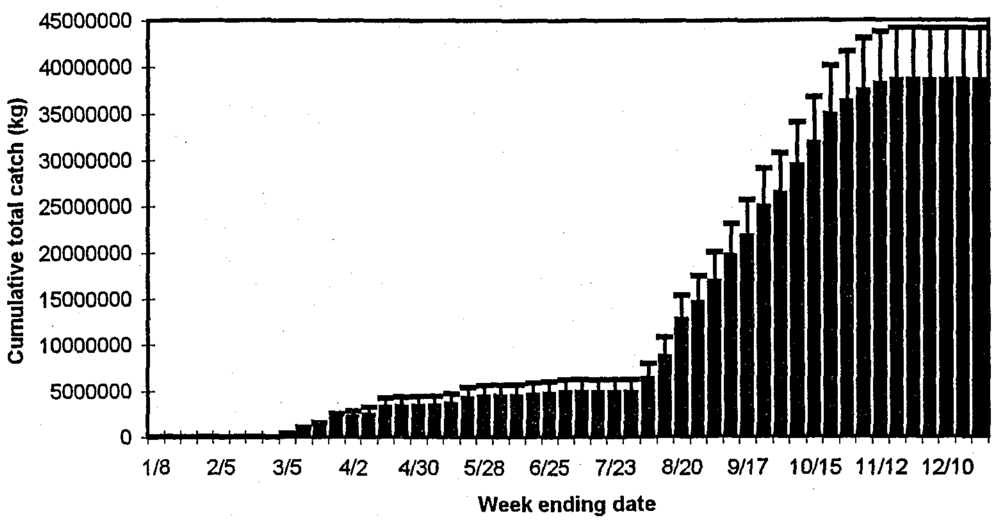


Figure 4-55. Estimates of cumulative weekly catch of pollock during the 1994 BSAI yellowfin sole fishery. The upper 95% confidence intervals are shown as T-bars. Estimates are based on the standard two-stage estimator and the observer subsampled data set.

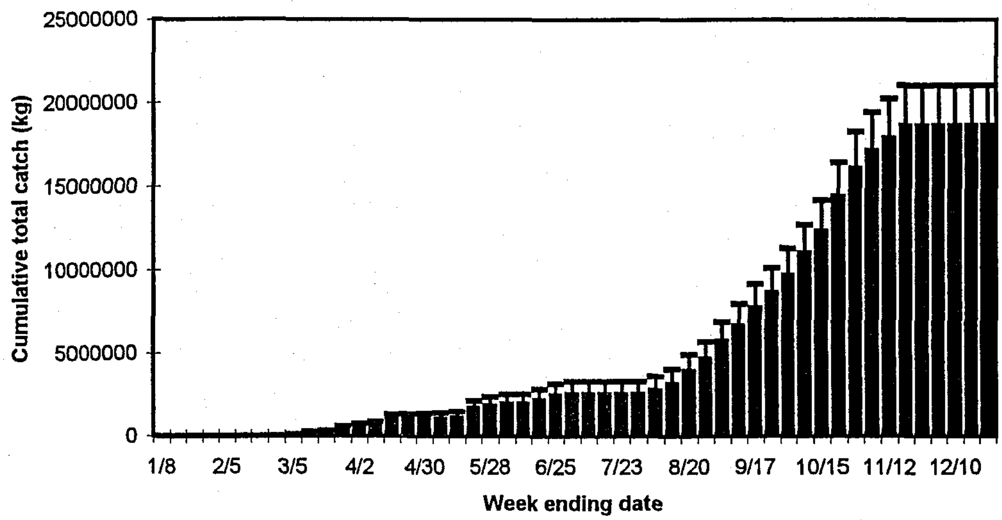


Figure 4-56. Estimates of cumulative weekly catch of Pacific cod during the 1994 BSAI yellowfin sole fishery. The upper 95% confidence intervals are shown as T-bars. Estimates are based on the standard two-stage estimator and the observer subsampled data set.

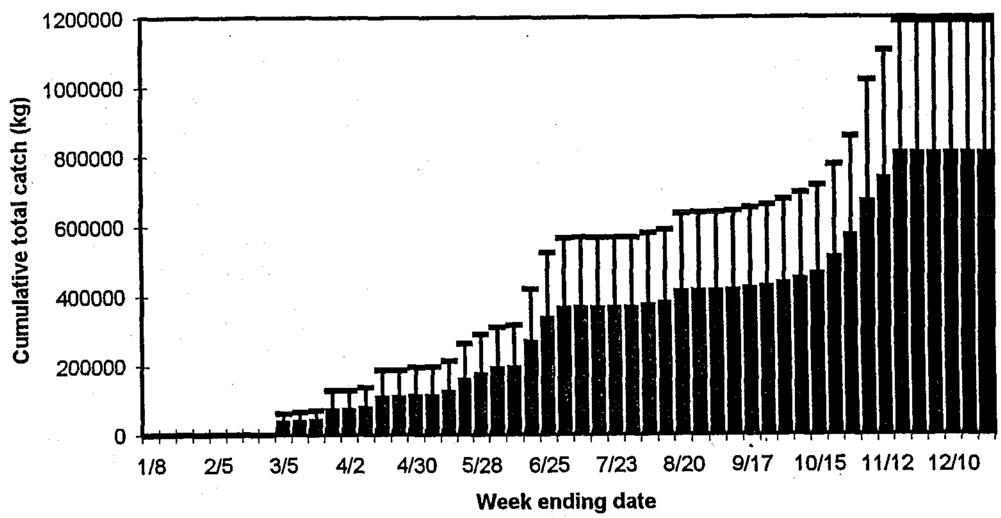


Figure 4-57. Estimates of cumulative weekly catch of halibut during the 1994 BSAI yellowfin sole fishery. The upper 95% confidence intervals are shown as T-bars. Estimates are based on the ratio estimator with the delta estimator and the observer subsampled data set.

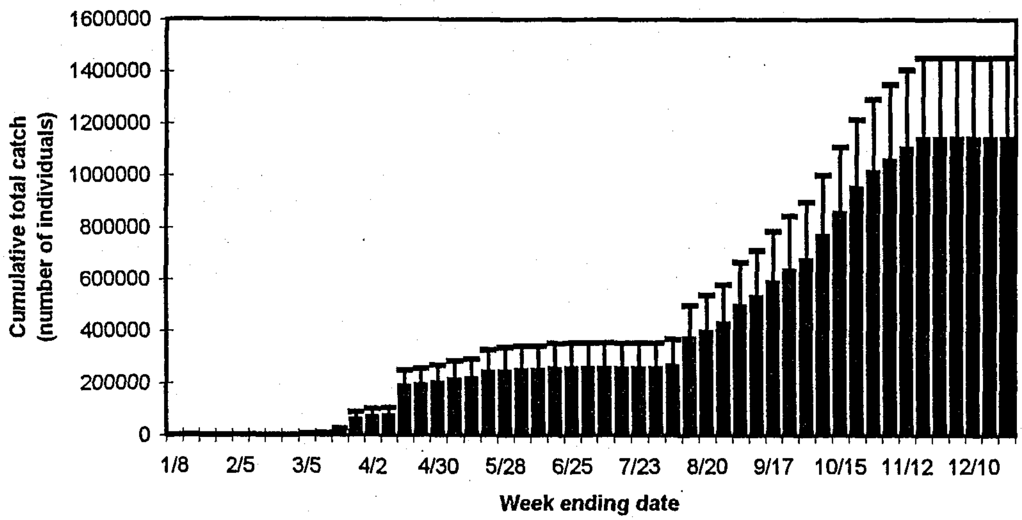


Figure 4-58. Estimates of cumulative weekly catch of bairdi Tanner crab during the 1994 BSAI yellowfin sole fishery. The upper 95% confidence intervals are shown as T-bars. Estimates are based on the ratio estimator with the delta estimator and the observer subsampled data set.

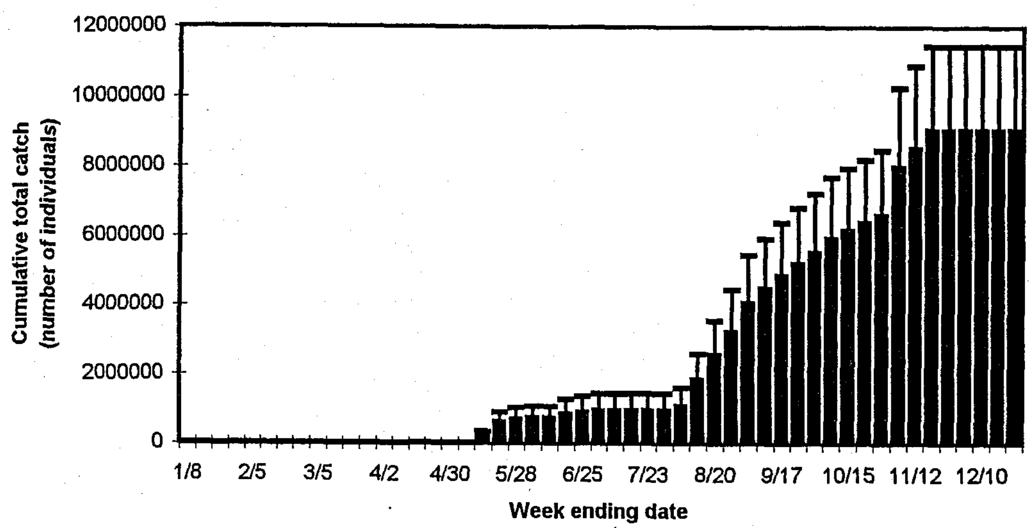


Figure 4-59. Estimates of cumulative weekly catch of other Tanner crab during the 1994 BSAI yellowfin sole fishery. The upper 95% confidence intervals are shown as T-bars. Estimates are based on the ratio estimator with the delta estimator and the observer subsampled data set.

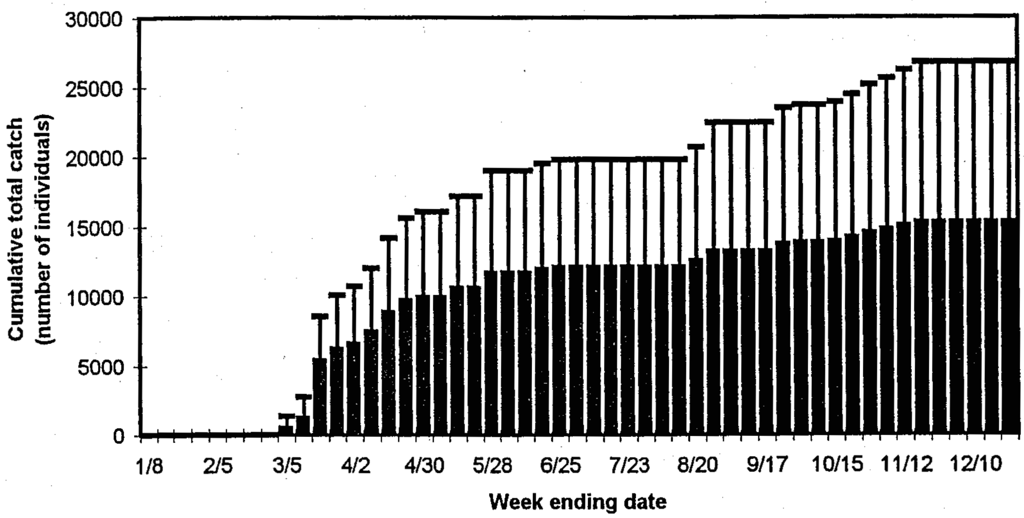


Figure 4-60. Estimates of cumulative weekly catch of red king crab during the 1994 BSAI yellowfin sole fishery. The upper 95% confidence intervals are shown as T-bars. Estimates are based on the ratio estimator with the delta estimator and the observer subsampled data set.

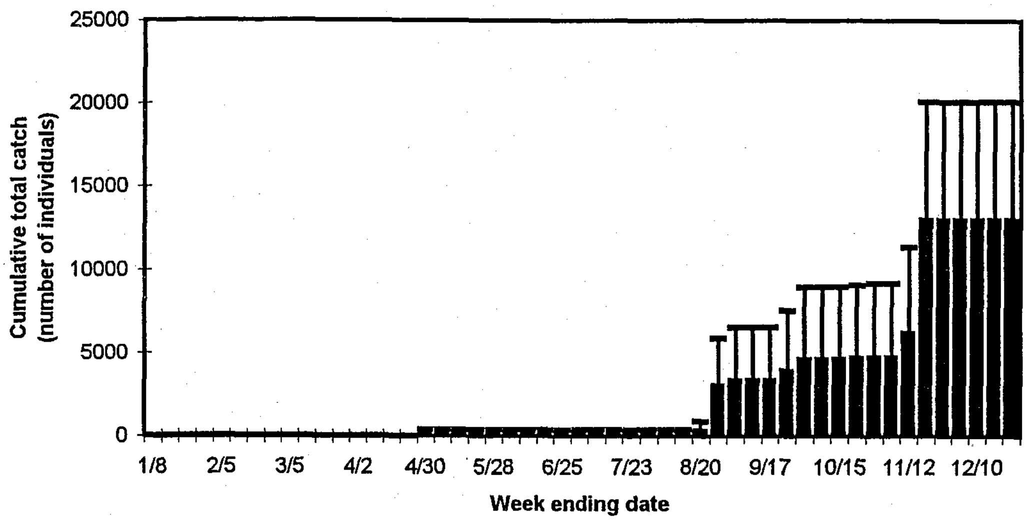


Figure 4-61. Estimates of cumulative weekly catch of other king crab during the 1994 BSAI yellowfin sole fishery. The upper 95% confidence intervals are shown as T-bars. Estimates are based on the ratio estimator with the delta estimator and the observer subsampled data set.

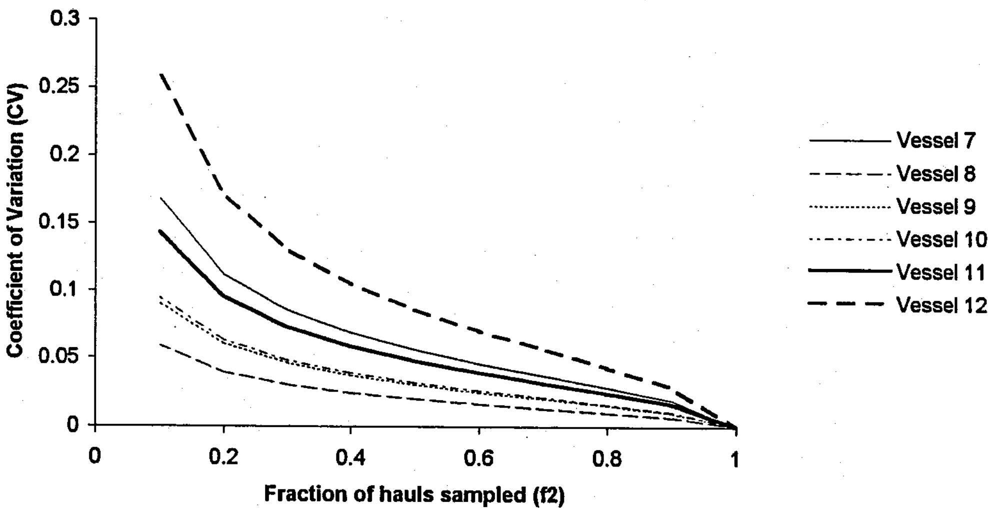


Figure 4-62. Associated coefficients of variation for total catch of selected factory trawlers participating in the 1994 BSAI yellowfin sole fishery in relation to fraction of hauls sampled (f_2). Fraction of vessels sampled was held at 1.0. Statistics based on observer subsampled data sets. Vessels were assigned simple numeric characters to maintain anonymity.

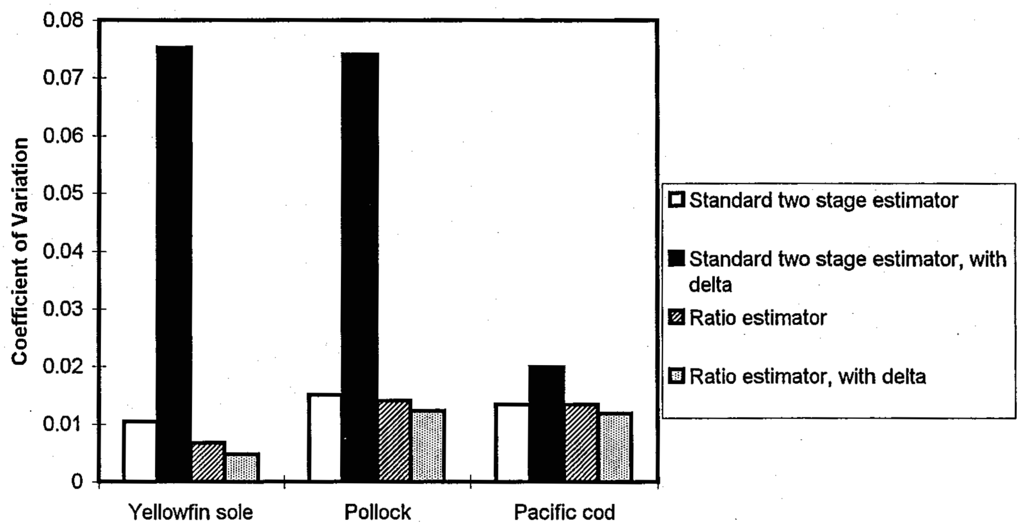
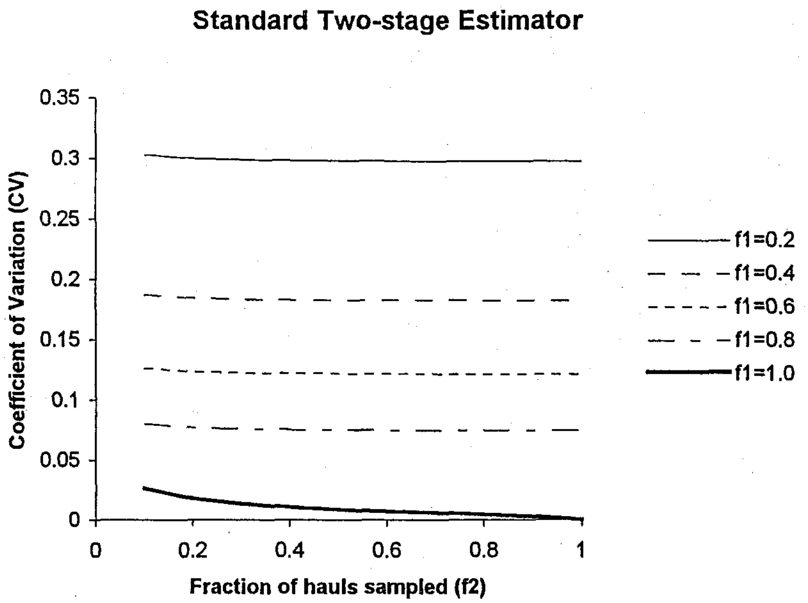


Figure 4-63. Associated coefficients of variation for four different fleetwide catch estimates of three groundfish species caught during the 1994 BSAI yellowfin sole fishery



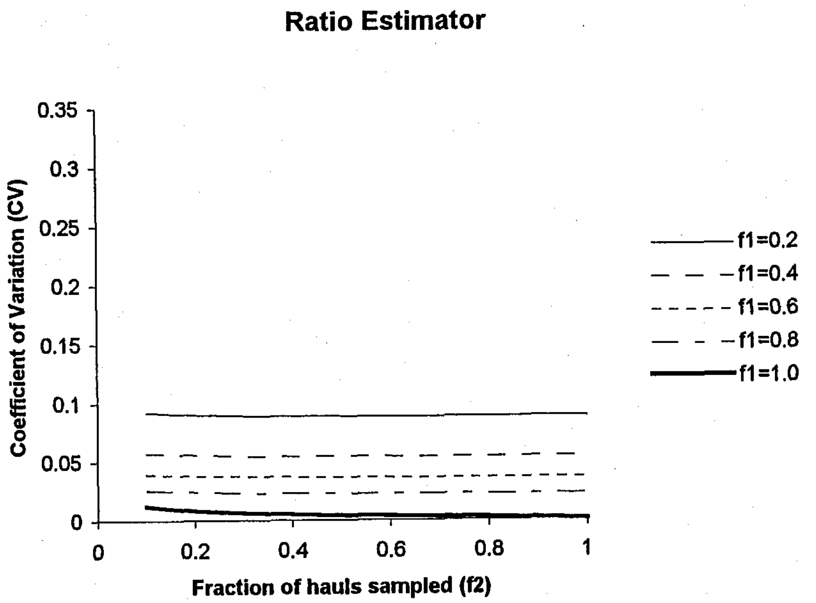
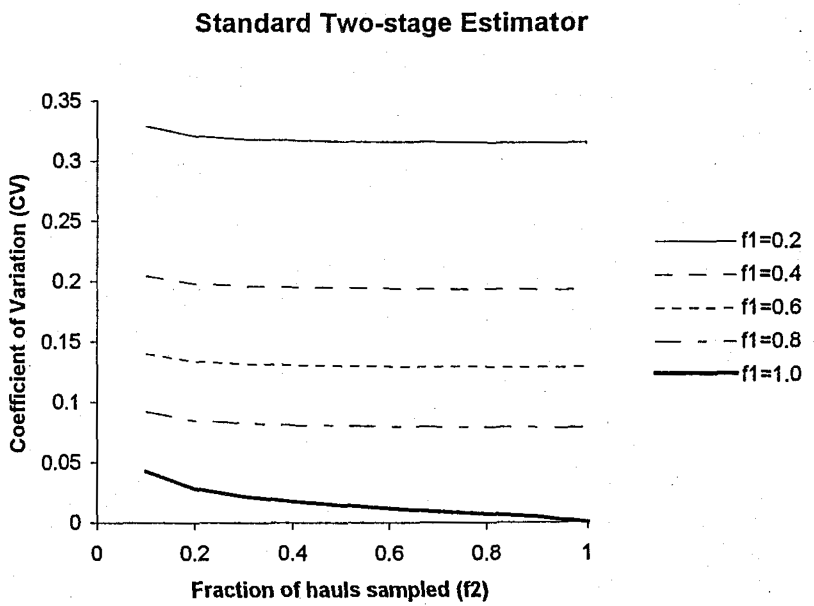


Figure 4-64. Associated coefficients of variation in estimated fleetwide catch of yellowfin sole during the 1994 BSAI yellowfin sole fishery as a function of the fraction of vessels sampled (f_1) and the fraction of hauls sampled (f_2). Results are presented for the standard two-stage estimator and the ratio estimator with the delta estimator.



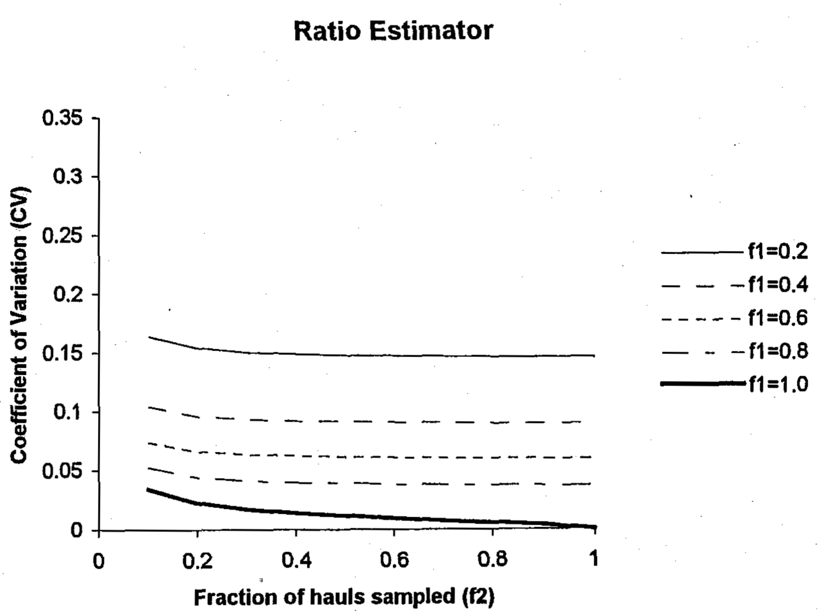
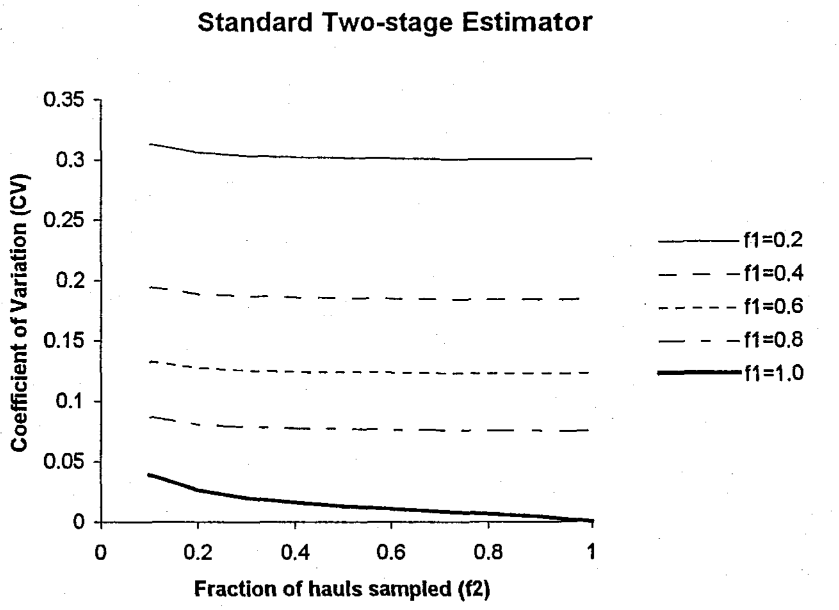


Figure 4-65. Associated coefficients of variation in estimated fleetwide catch of pollock during the 1994 BSAI yellowfin sole fishery as a function of the fraction of vessels sampled (f_1) and the fraction of hauls sampled (f_2). Results are presented for the standard two-stage estimator and the ratio estimator with the delta estimator.



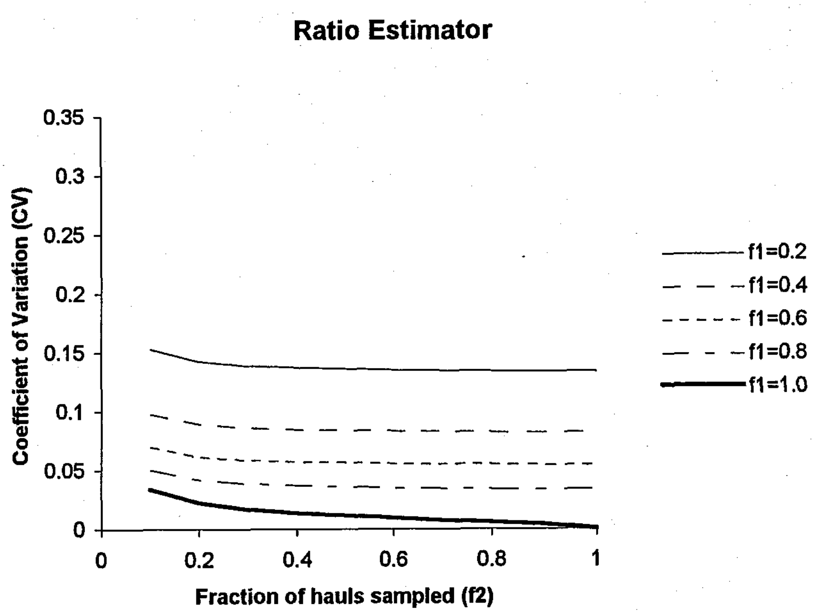


Figure 4-66. Associated coefficients of variation in estimated fleetwide catch of Pacific cod during the 1994 BSAI yellowfin sole fishery as a function of the fraction of vessels sampled (f_1) and the fraction of hauls sampled (f_2). Results are presented for the standard two-stage estimator and the ratio estimator with the delta estimator.

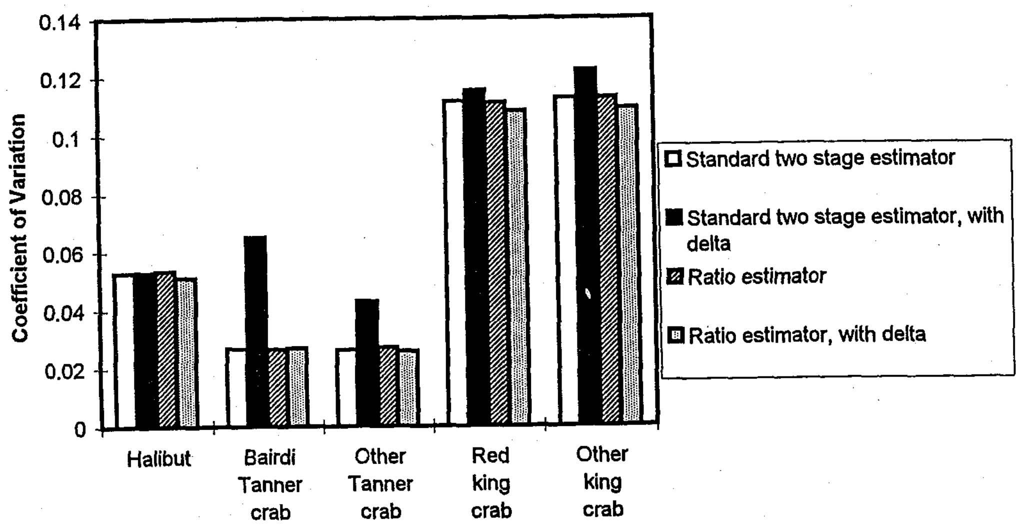
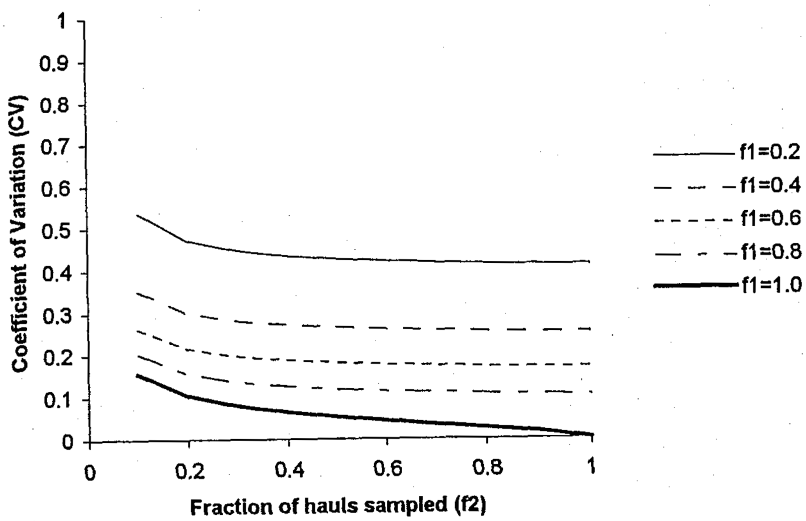


Figure 4-67. Associated coefficients of variation from four different fleetwide catch estimates of five prohibited species caught during the 1994 BSAI yellowfin sole fishery

Standard Two-stage Estimator



Ratio Estimator

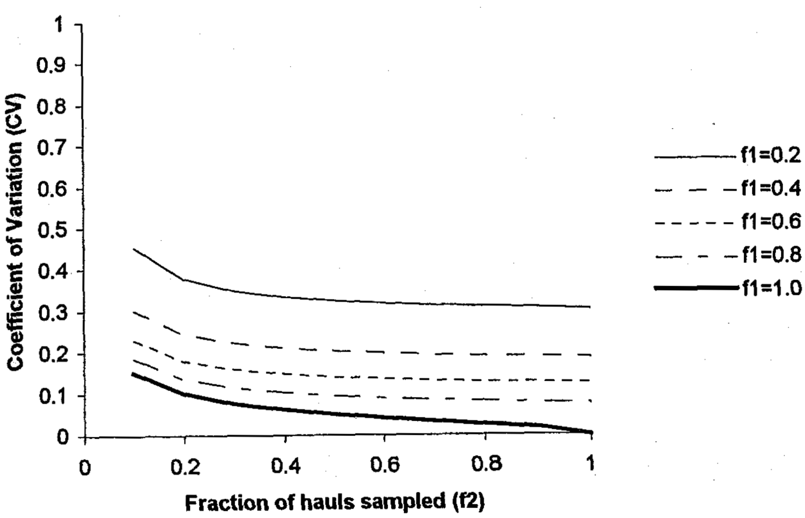
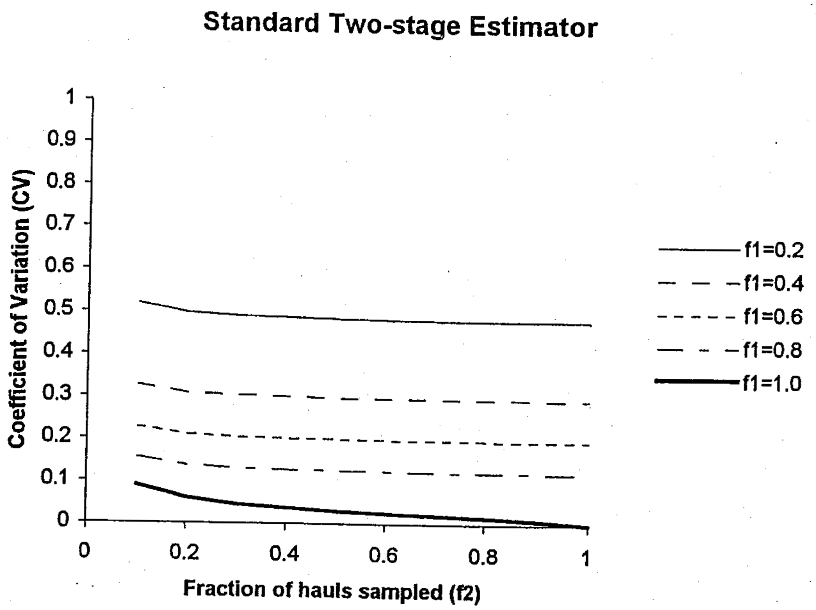


Figure 4-68. Associated coefficients of variation in estimated fleetwide catch of halibut during the 1994 BSAI yellowfin sole fishery as a function of the fraction of vessels sampled (f_1) and the fraction of hauls sampled (f_2). Results are presented for the standard two-stage estimator and the ratio estimator with the delta estimator.



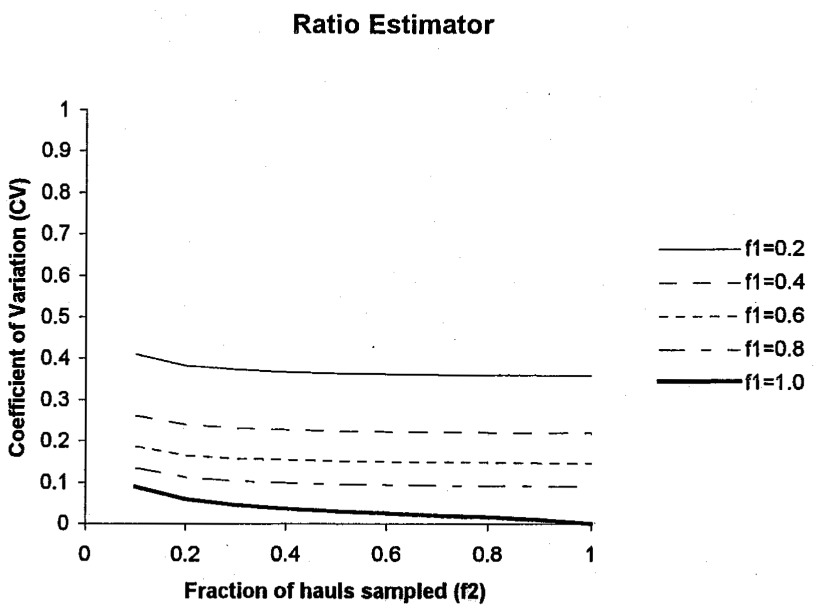
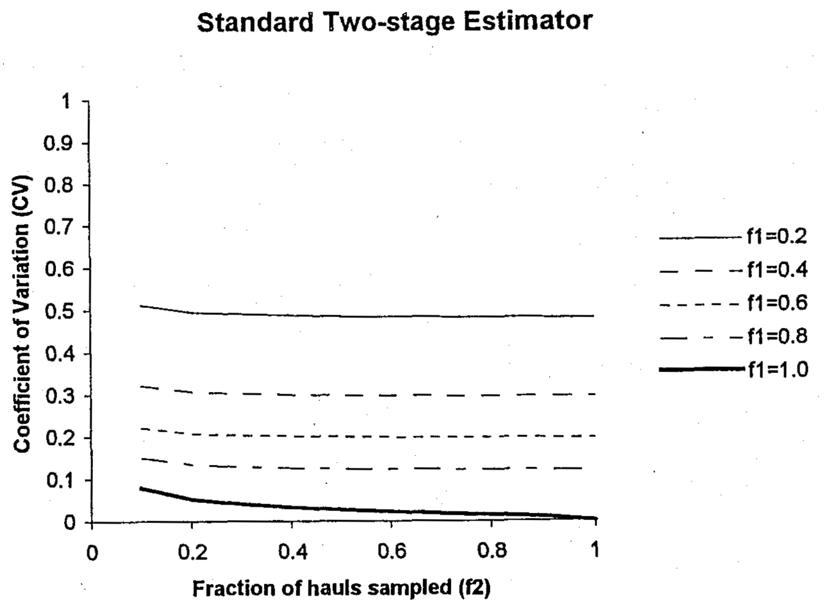


Figure 4-69. Associated coefficients of variation in estimated fleetwide catch of bairdi Tanner crab during the 1994 BSAI yellowfin sole fishery as a function of the fraction of vessels sampled (f_1) and the fraction of hauls sampled (f_2). Results are presented for the standard two-stage estimator and the ratio estimator with the delta estimator.



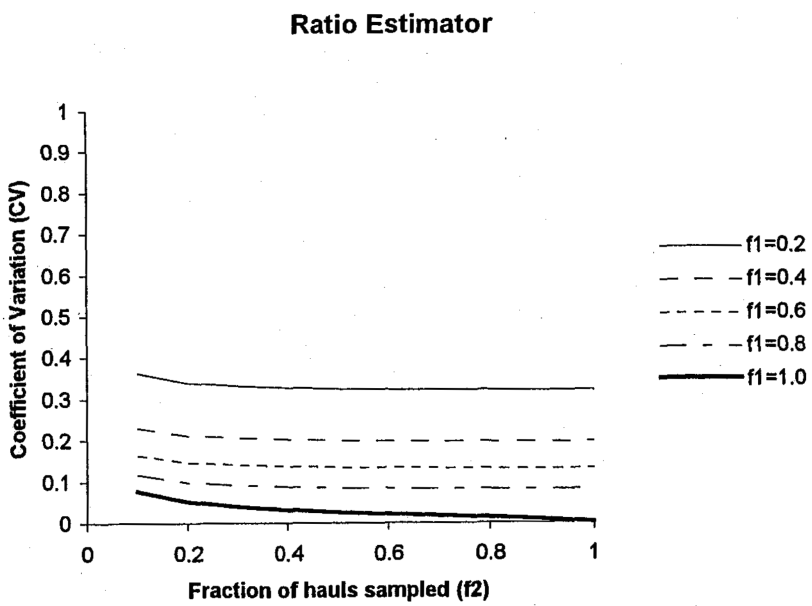


Figure 4-70. Associated coefficients of variation in estimated fleetwide catch of other Tanner crab during the 1994 BSAI yellowfin sole fishery as a function of the fraction of vessels sampled (f_1) and the fraction of hauls sampled (f_2). Results are presented for the standard two-stage estimator and the ratio estimator with the delta estimator.

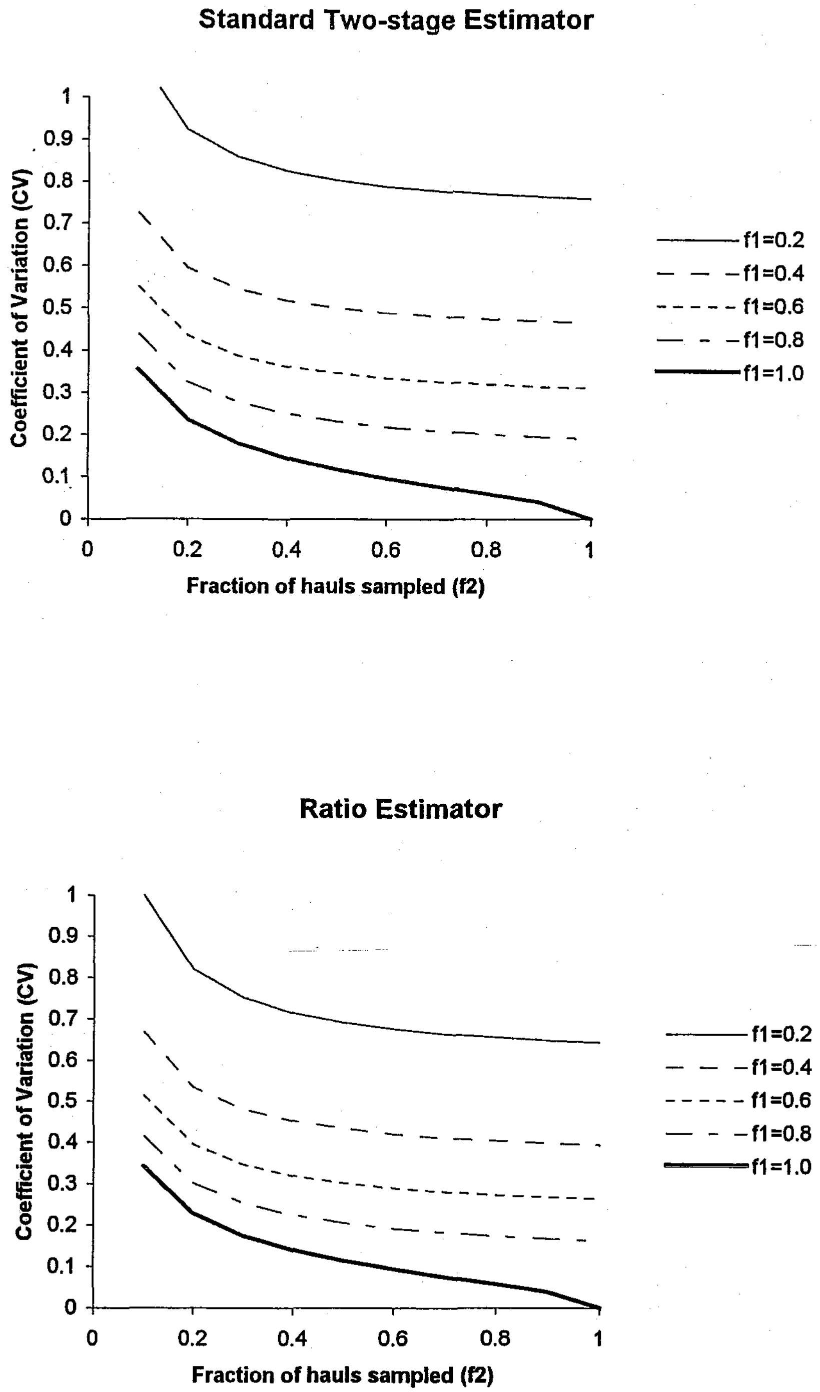
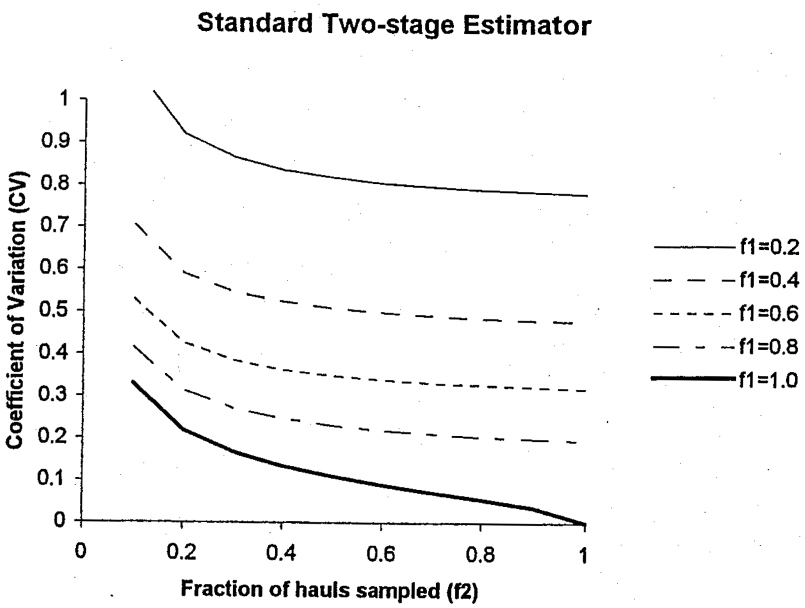


Figure 4-71. Associated coefficients of variation in estimated fleetwide catch of red king crab during the 1994 BSAI yellowfin sole fishery as a function of the fraction of vessels sampled (f_1) and the fraction of hauls sampled (f_2). Results are presented for the standard two-stage estimator and the ratio estimator with the delta estimator.



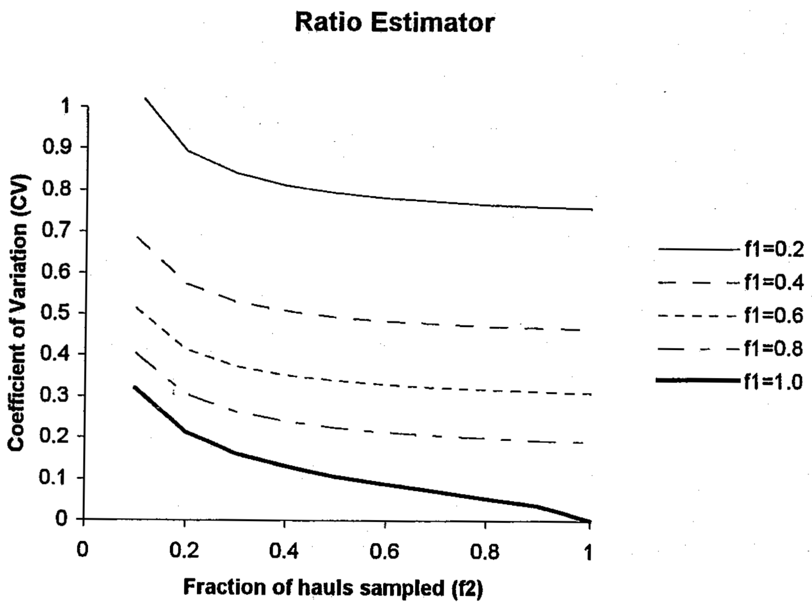


Figure 4-72. Associated coefficients of variation in estimated fleetwide catch of other king crab during the 1994 BSAI yellowfin sole fishery as a function of the fraction of vessels sampled (f_1) and the fraction of hauls sampled (f_2). Results are presented for the standard two-stage estimator and the ratio estimator with the delta estimator.

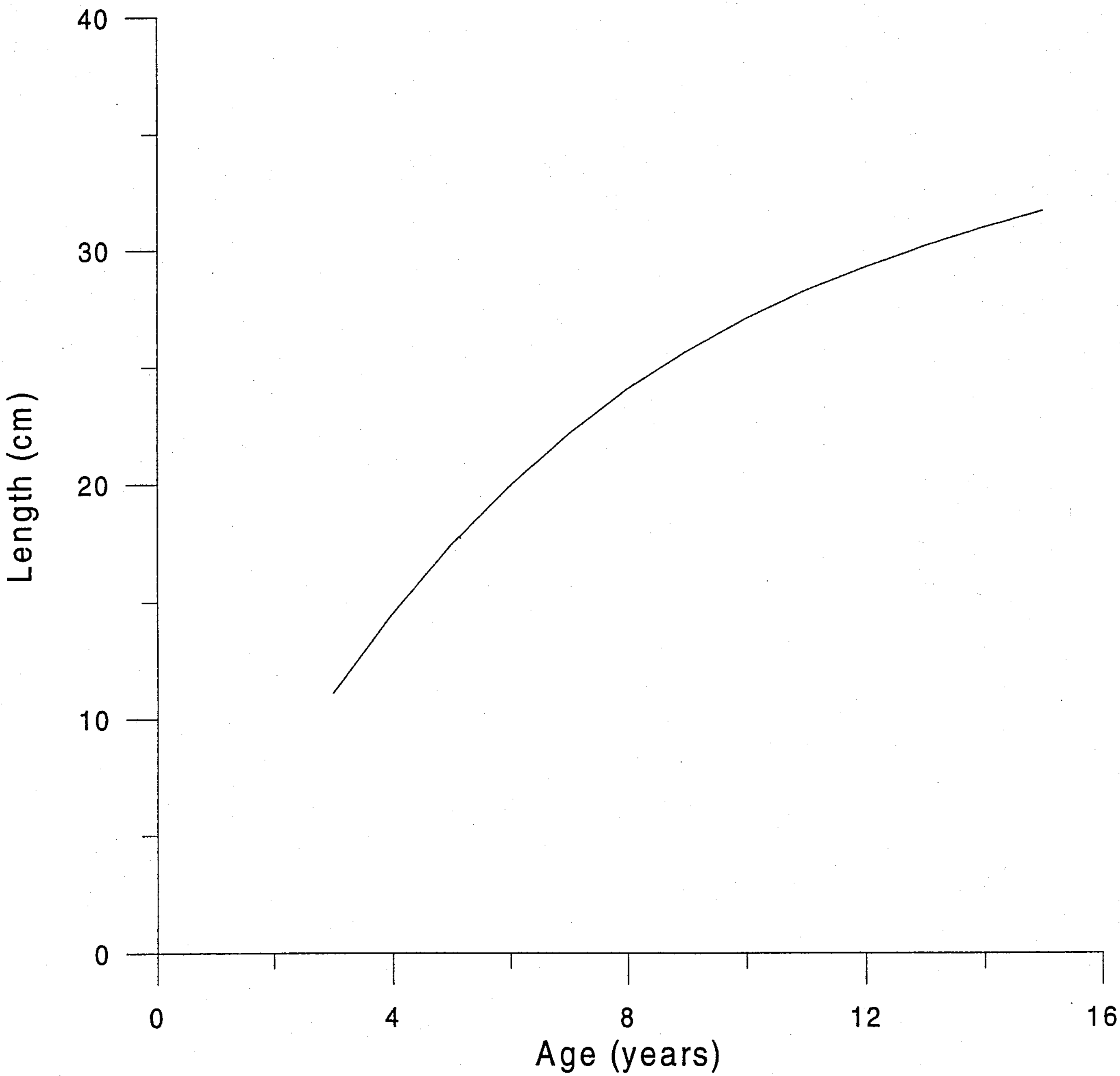


Figure 4-73. Age-length relationships for the 1994 BSAI yellowfin sole fishery

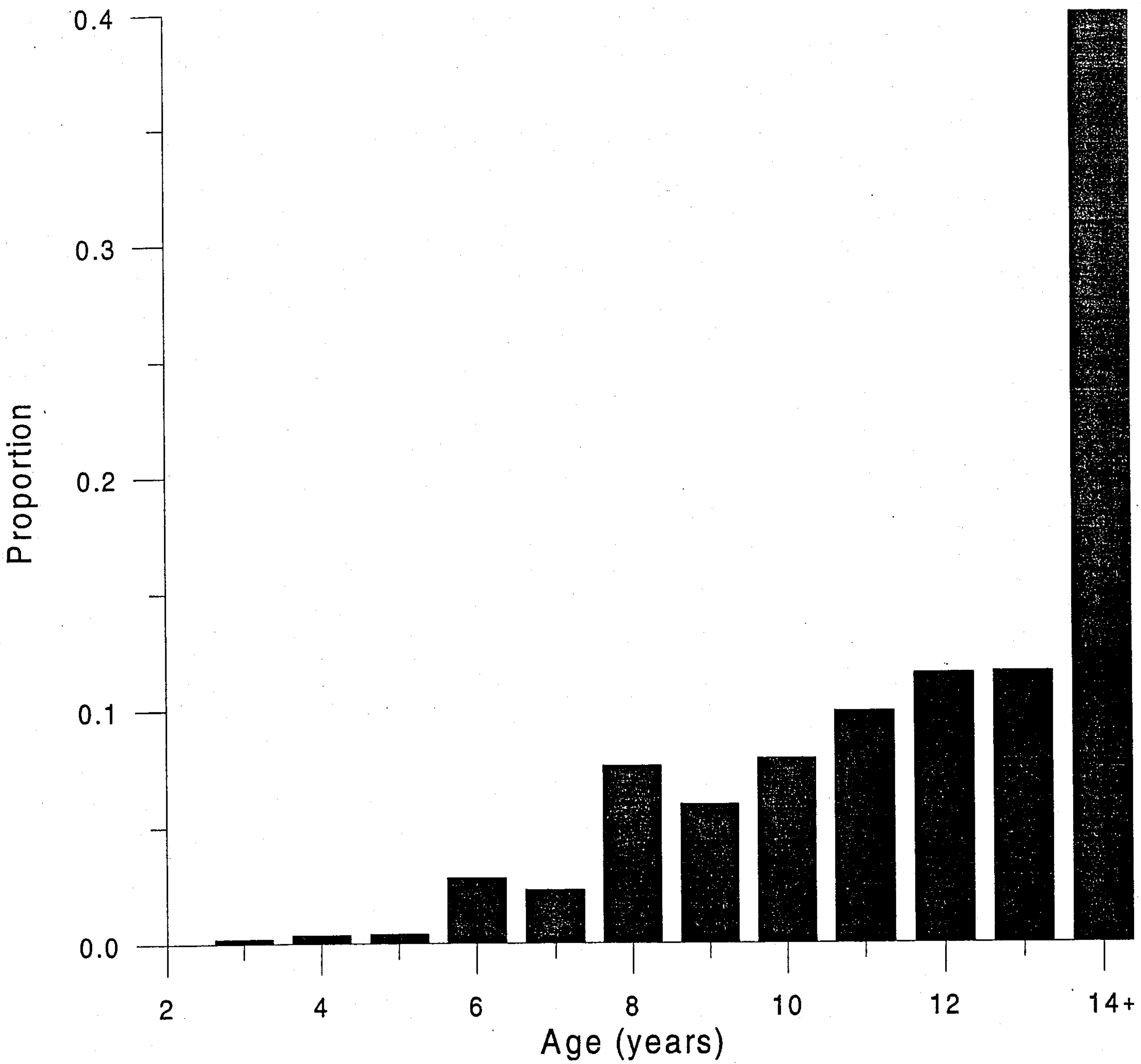


Figure 4-74. Estimated proportions at age for yellowfin sole caught during the 1994 BSAI yellowfin sole fishery

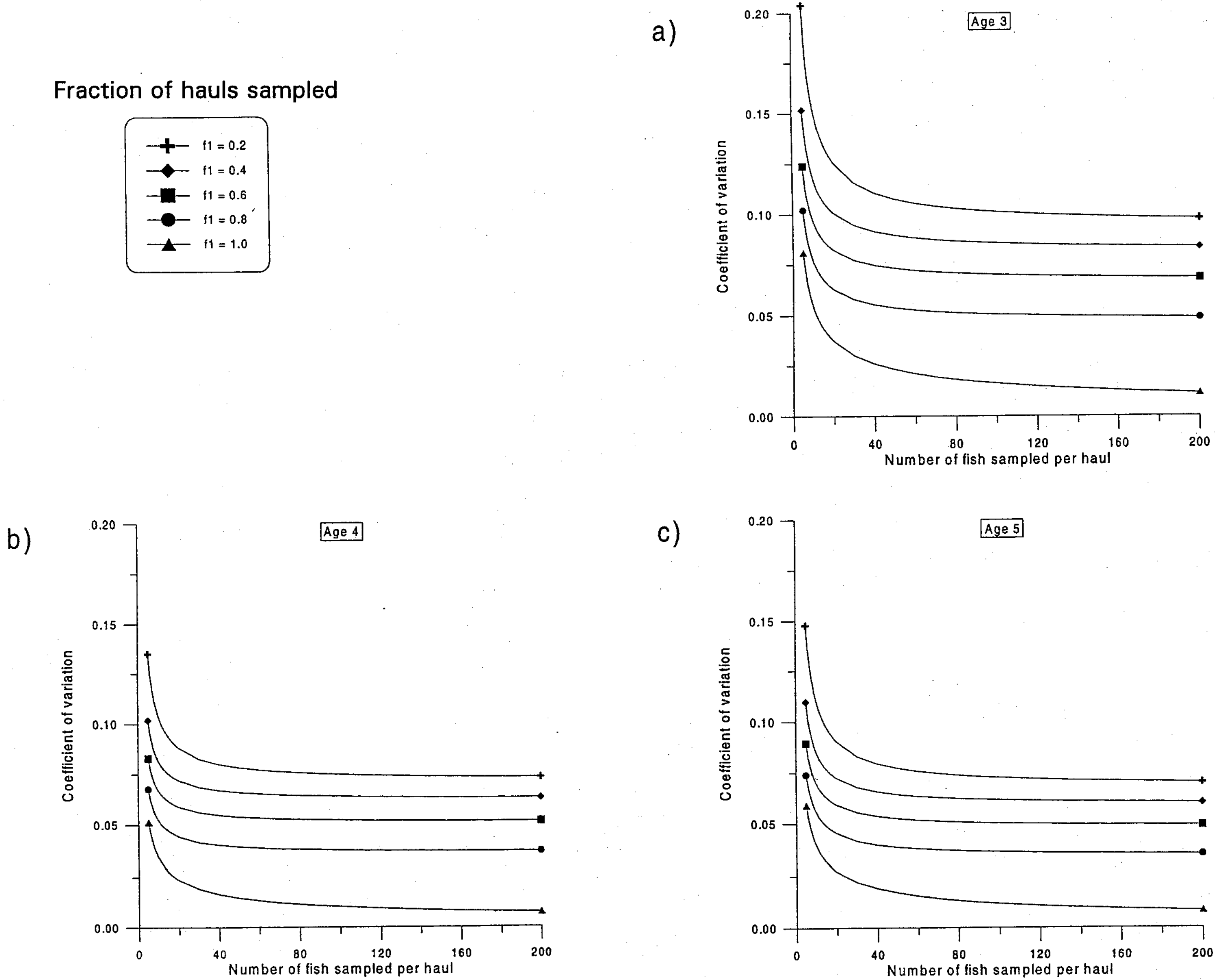


Figure 4-75. Associated coefficients of variation in estimated proportions of yellowfin sole at a) age 3, b) age 4, and c) age 5, as a function of the fraction of hauls sampled and the number of fish sampled per haul, for the 1994 BSAI yellowfin sole fishery

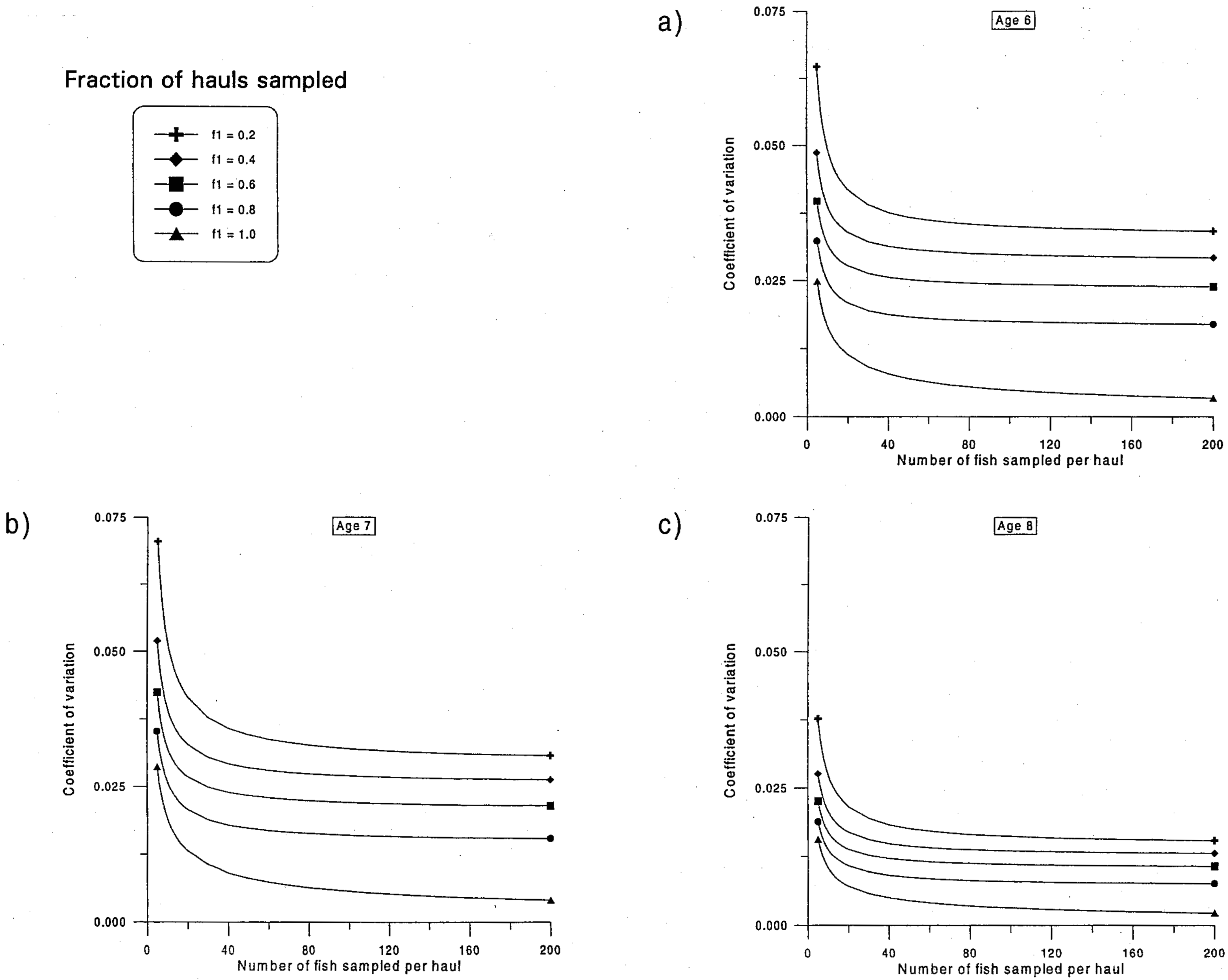


Figure 4-76. Associated coefficients of variation in estimated proportions of yellowfin sole at a) age 6, b) age 7, and c) age 8, as a function of the fraction of hauls sampled and the number of fish sampled per haul, for the 1994 BSAI yellowfin sole fishery

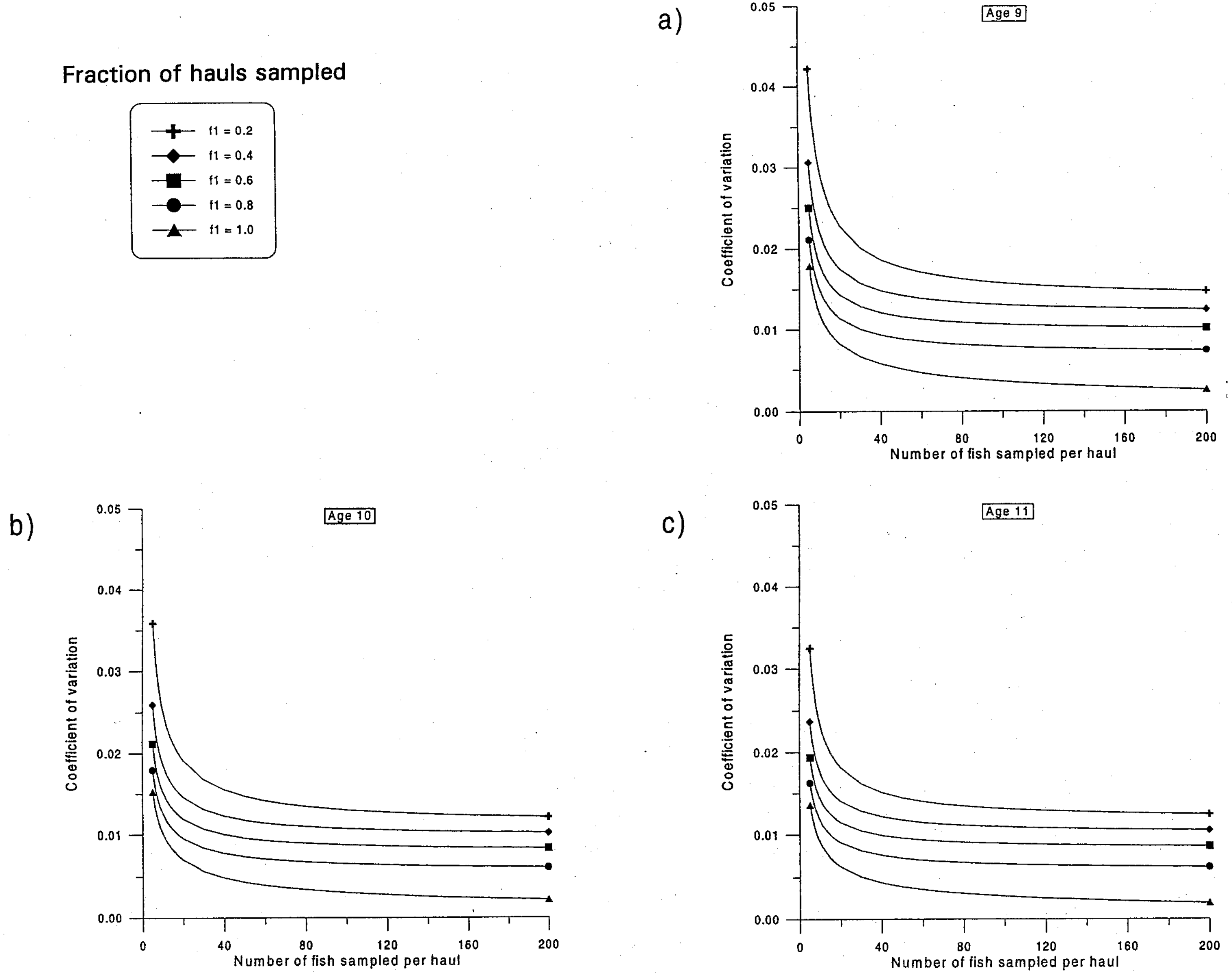


Figure 4-77. Associated coefficients of variation in estimated proportions of yellowfin sole at a) age 9, b) age 10, and c) age 11, as a function of the fraction of hauls sampled and the number of fish sampled per haul, for the 1994 BSAI yellowfin sole fishery

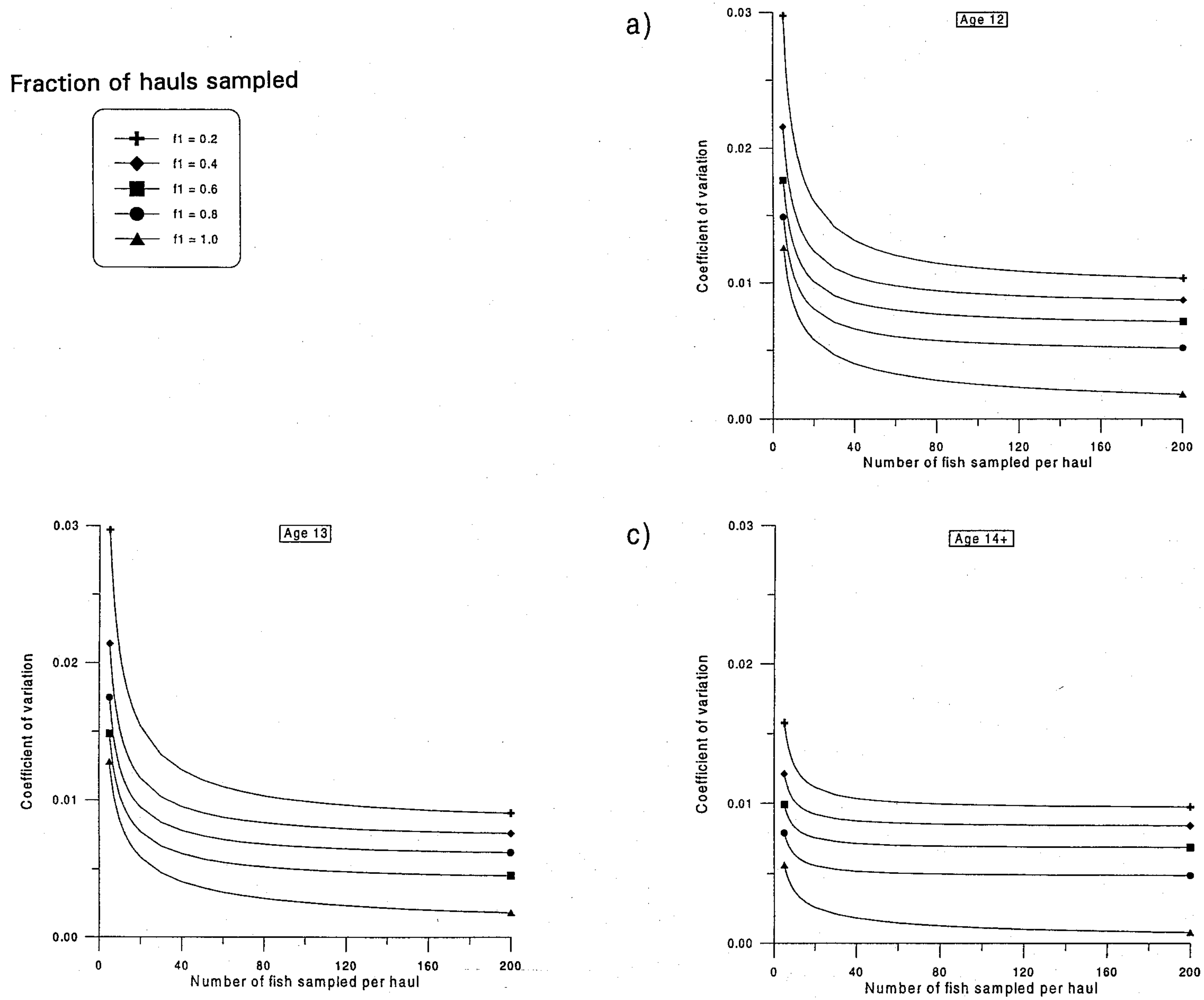


Figure 4-78. Associated coefficient of variation in estimated proportions of yellowfin sole at a) age 12, b) age 13, and c) age 14+, as a function of the fraction of hauls sampled and the number of fish sampled per haul, for the 1994 BSAI yellowfin sole fishery

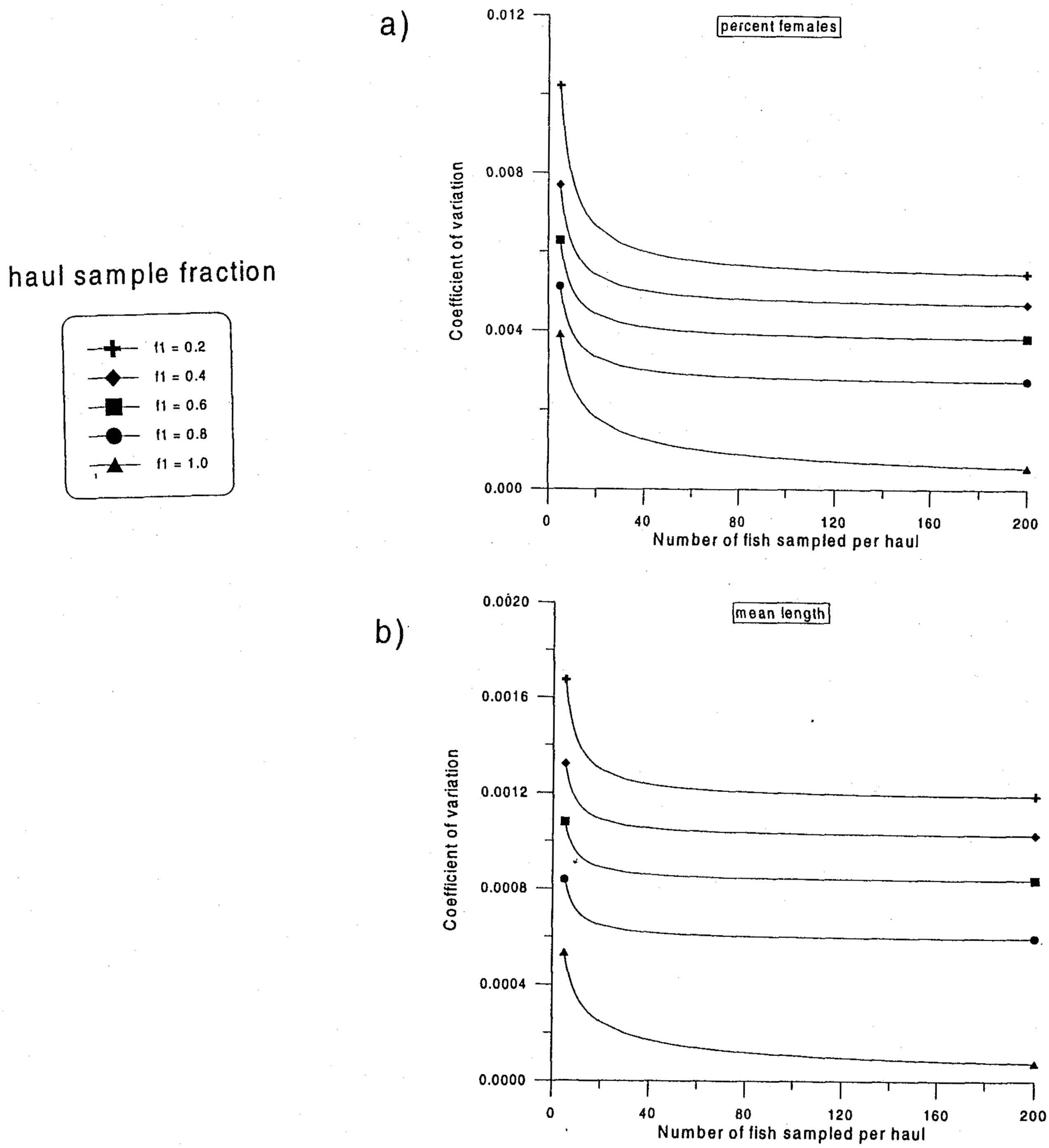


Figure 4-79. Associated coefficients of variation in a) estimated percent females and b) estimated mean length of yellowfin sole, as a function of the fraction of hauls sampled and the number of fish sampled per haul, for the 1994 BSAI yellowfin sole fishery

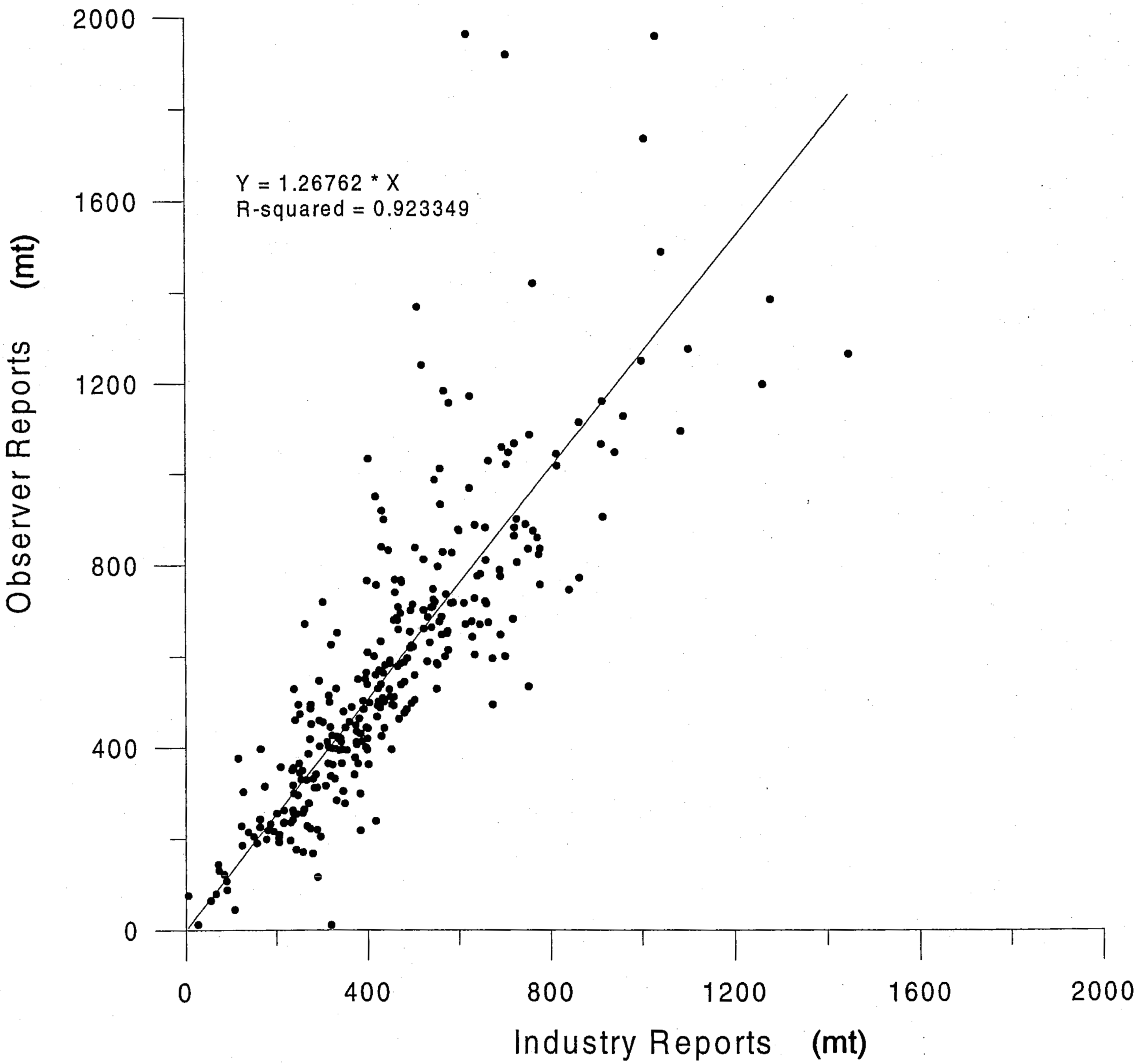


Figure 4-80. 1994 BSAI yellowfin sole fishery - comparison of weekly catch estimates based on observer reports and industry reports

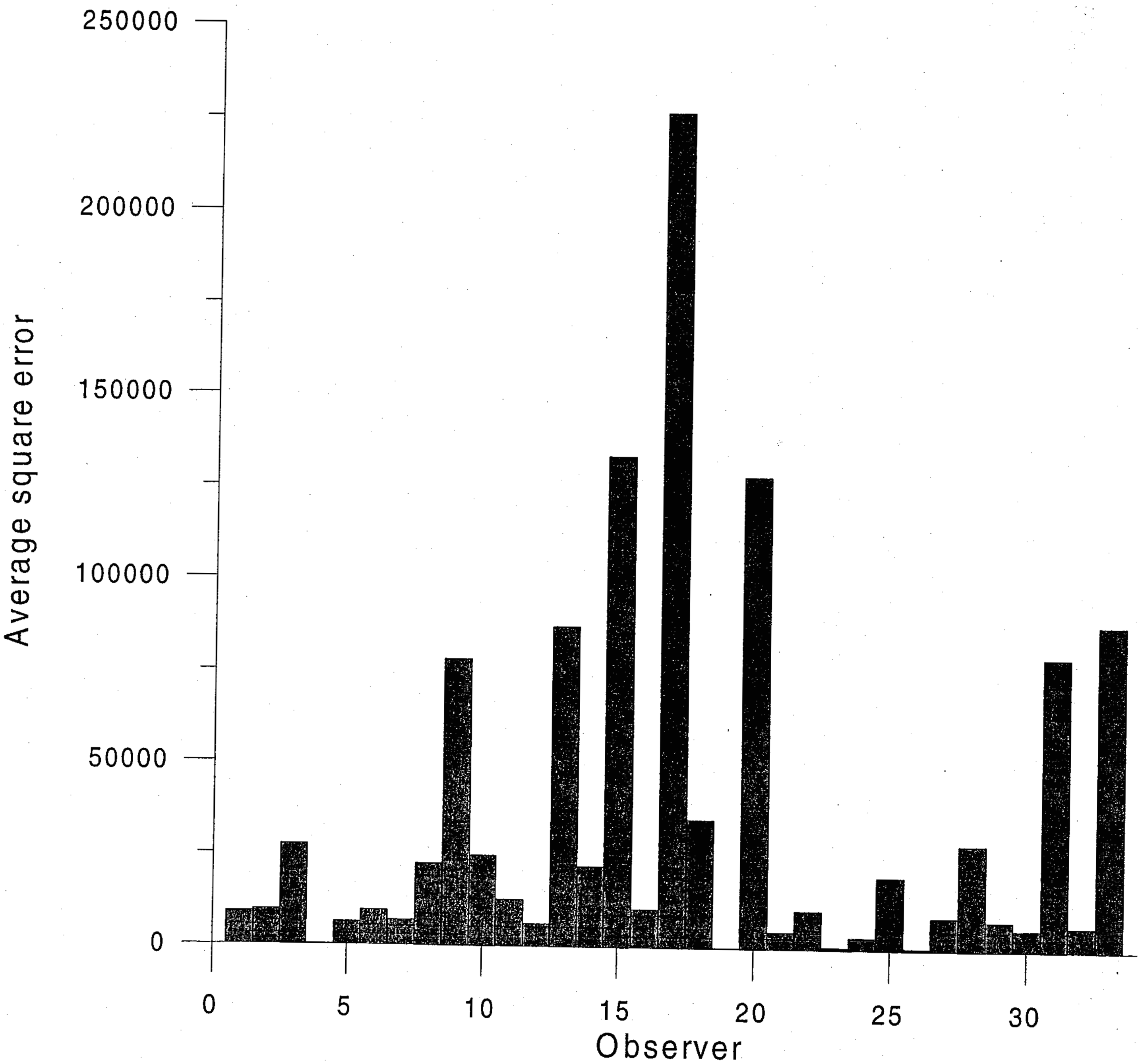


Figure 4-81. Average square errors between observer estimates and corresponding weekly production report estimates for the 1994 BSAI yellowfin sole fishery (provides a measure of closeness to best-fit line through points of observer estimates vs. weekly production report). Simple numeric characters were assigned to each observer to maintain anonymity.

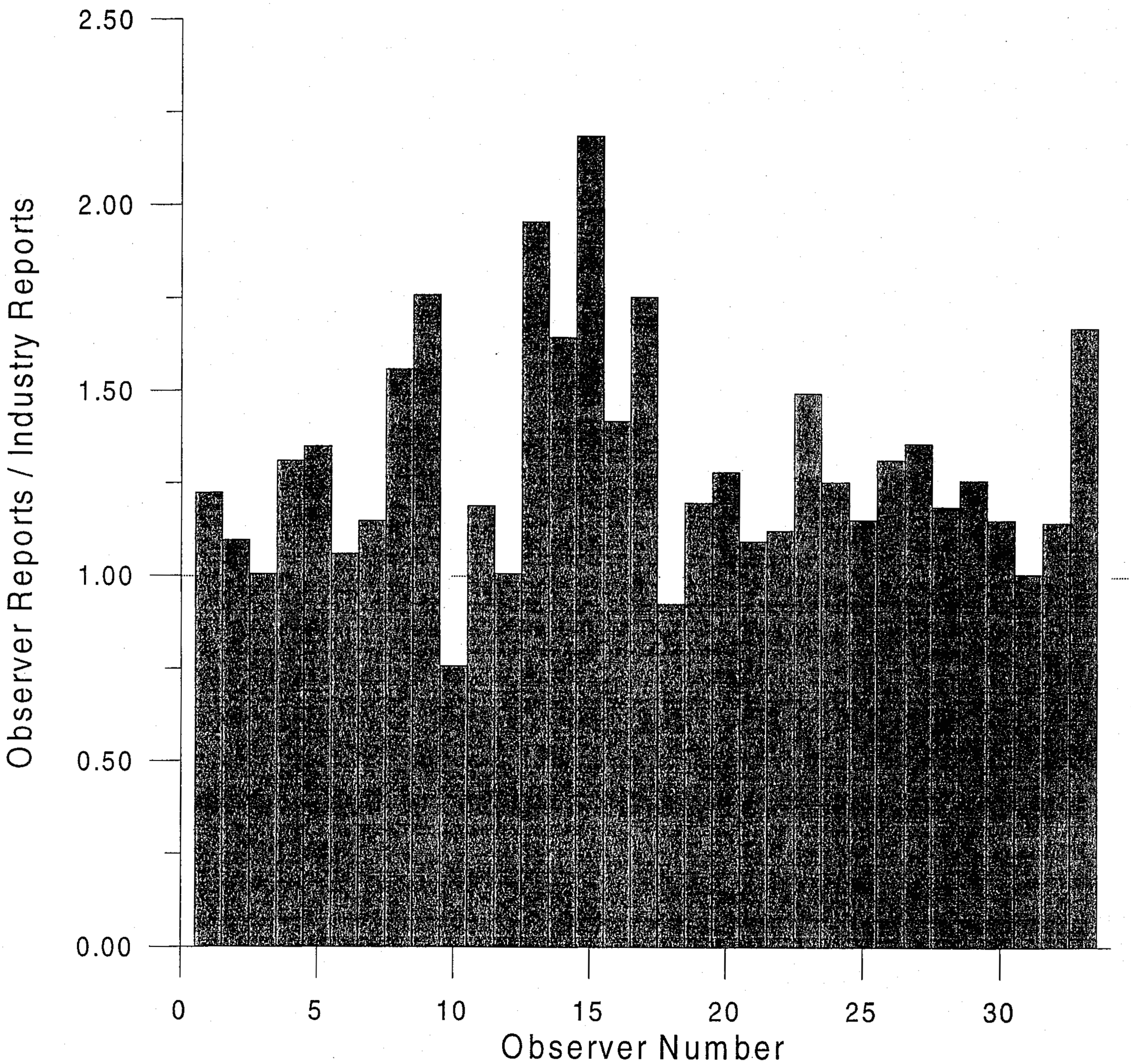


Figure 4-82. Ratios of observer reports to industry reports for the 1994 BSAI yellowfin sole fishery. Simple numeric characters were assigned to each observer to maintain anonymity.

5.0 CONCLUSIONS AND RECOMMENDATIONS

It is important to note that this project consisted of exploratory data integration and statistical analysis as a basis for investigating the relative merits of various alternative means of estimating catch and catch characteristics of harvests taken in the groundfish fishery in the EEZ off Alaska. While we have attempted to duplicate the procedures employed by AFSC to estimate total and individual species catch, using actual raw data sets, for the purposes of comparison to alternative estimation procedures, we have not employed in this project any catch estimates provided by AFSC.

It is also important to note that there is no independent means of validating any of the estimates derived in our analyses. The only basis for addressing the merits of each estimation procedure is through comparison with estimates derived following other procedures. Thus, in evaluating alternative means of estimating total groundfish catch as well as total species catch, we have focussed on comparisons of alternative estimators to our own application of the blend analysis. We selected the blend analysis for this focus because it is the procedure currently used in management of these fisheries, and these comparisons illustrate what the potential consequences to management decisions might have been if one of the other catch estimation procedures had been employed. However, such comparisons do not provide a basis for determining which estimates may be biased or the magnitude and direction of any biases. For statistical estimates, procedures that produce the most efficient estimators (i.e., those with the tightest confidence limits and the lowest cv) would generally be preferable to procedures yielding higher cvs. For example, in the case of prohibited species, use of an estimator with a large confidence limit is more likely to result in premature closure of a fishery or excessive harvest of the species than would be the case if an estimator with lower cv were used. However, as in the case of catch estimates, the validity of each of the variance estimates cannot be established through comparisons among them.

Our analyses provide insights to characteristics of observer program data and procedures not previously available. Our major findings are as follows:

- the blend estimate of total groundfish catch in the pollock fishery is lower than, but within the 95% confidence limits of the two statistical estimates of that catch in both A and B seasons; the WPR and adjusted OTC estimates fall below the 95% confidence limits of the statistical estimates; the WPR and adjusted OTC estimates do not have confidence limits, since they are simply the sums of the complete respective data sets and thus have no associated variance; because all of the data sets are not independent of each other (e.g., observer data on PSC and NONA catch was used to adjust the OTC data; the OTC data set includes some of the same data included in the OBS data set), rigorous statistical contrasts among the estimates are not valid; the differences among these estimates could be a result of inherent bias in the OTC or WPR data sets, or from biases in some procedural element of the observer program, or a combination of both; the narrow confidence limits of the statistical estimates encompass the blend, and the difference between the blend estimate and statistical estimates of catch is less than 5%; thus, the consequences to management decisions of use of the statistical estimates instead of the blend estimates in the pollock fishery would have been minimal in 1994, the year during which these data were collected.

- for the yellowfin sole fishery, the adjusted OTC, blend and WPR estimates of total groundfish catch all fall below the lower 95% confidence limits of the two statistical estimators; while this result is, in part, due to the relatively narrow confidence limits of the estimates (i.e., its relatively high precision), the non-statistical estimates are all on the order of 10% lower than the statistical estimates of the total groundfish catch and in relative close agreement with each other; we have no rigorous explanation for these differences, or for why the differences are larger than in the case of the pollock fishery; one observation based on the limited information developed on individual vessel catch in the two fisheries (Tables 4-5 and 4-9) is that the variation in catch among vessels in the yellowfin sole fishery may be greater than in the pollock fishery, which might introduce some type of bias into the estimates; management of this fishery using the statistical estimator instead of the blend estimate would have potentially resulted in attaining TACs earlier in the season.

- focusing on the fleetwide estimates of individual species catches, the statistical estimates derived using the delta estimator are, in nearly all cases, higher than the statistical estimates derived without the delta estimator, and the statistical estimates are generally higher than the estimates derived using the blend; the differences are very large for some species, particularly in the A Season pollock fishery (e.g., 101%, 321%); the largest differences occur for the species that make up a small portion of the total catch, and the differences among the estimates are most likely due to the underlying distribution of the species catch per haul within the data sets used in our analyses; as was discussed above, the data sets used in these investigative analyses do not provide a means of validating any of the estimators investigated; given the substantial differences among some of the estimates for some species, these results do not provide a basis for identifying which is the most valid; the adoption of one of the statistical estimators could clearly have impacted the management of these fisheries in the year during which the data were collected.

- the precision of statistical estimates of fleetwide catch in both the pollock and yellowfin sole fisheries is more dependent on observer coverage of vessels than on fraction of hauls sampled; our analyses suggest that substantial improvements in the precision of statistical catch estimates that can be derived from the current observer program could only be attained by sampling nearly all hauls, and that the existing level of observer coverage and haul fraction sampled provide for adequate statistical precision, at least for the most abundant species in the catch. However, the statistical precision decreases substantially for those species that comprise a relatively low proportion of the total catch; because of the high variability in catch, the need for complete observer coverage of the CDQ season within the pollock fishery is strongly substantiated by the results of these analyses.

- substantial differences in haul variability exist among vessels participating in both the pollock and the yellowfin sole fisheries, such that the same magnitude increase in fraction of hauls sampled may result in a substantially different magnitude of decrease in cv for different vessels; the implication of this finding is that taking into account the among-vessel variability in catch, if it could be projected in some way, might permit more optimal allocation of observer effort; the limited data examined suggest that, in the pollock fishery, improved precision in individual vessel catch estimates could result if the fraction of hauls sampled were to be varied according to magnitude of catch of the vessel; however, given the somewhat serendipitous nature of fisheries, the relative magnitude of catch among vessels of a single size class is likely to be, for the most part, unpredictable.

- as a generalization, it appears that most biological characteristics of catch in the experimental pollock fishery could be estimated to an acceptable level of precision by sampling fewer fish than at present (i.e., less than 150), and, in the southeast region, with sampling of as few as 20 percent of the hauls; however, substantial differences exist between regions and among biological characteristics in what would constitute an optimal sampling regime applicable simultaneously to all biological characteristics being recorded

The results of our analyses establish the feasibility of using statistical estimation procedures to manage the observed fisheries and illustrate the benefits that might be gained by doing so. Of greatest benefit is the fact that statistical precision of estimates of target and prohibited species catch could be calculated and tracked. Knowledge of the statistical precision of these estimates would permit fisheries managers to make decisions based on an objective quantitative measure of the uncertainty associated with any management decision they might consider. Such information would be particularly valuable in cases where decisions regarding possible fishery closures might have substantial economic and/or biological consequences, such as when closure due to reaching the maximum allowed catch of a prohibited species is imminent while the target fishery cumulative catch is not near its allowable limit.

Our results also provide managers with a means of evaluating the efficiency and effectiveness of various elements of the observer program for meeting management objectives. We found substantial regional differences in the precision achievable with similar sampling intensity of estimated proportions by age, proportions by sex, and mean length of pollock for the fleetwide catches.[8] The fishing effort is significantly different between regions, with highest number of hauls and catch size in the SE region, and the lowest number of hauls and catch size in the EBS region. Our findings (Figures 4-33 through 4-44) illustrate that less sampling effort in the SE and NW regions is needed to achieve a level of precision for most population attributes that would require a higher level of effort in the EBS region. However, the level of sampling effort necessary to achieve the same level of precision also varied among the attributes themselves. In the SE region for example, the results suggest that sampling of 20% or less of the hauls would yield highly satisfactory cvs ($cv<0.1$) for estimated proportions by sex and for most age groups. However, for other regions, achieving a desirable cv requires that a much higher fraction of hauls be sampled, and the cv appears to be substantially reduced over all increments of the fraction of hauls sampled, with the greatest reduction occurring as the fraction increases to greater than 80%. This result strongly suggests that the composition of catches varies significantly among regions. Many biological characteristics can be quantified with an adequate degree of statistical precision by examining fewer fish than are handled at present. However, because the optimal combination of fraction of hauls sampled and number of fish sampled per haul varies substantially among biological characteristics (e.g., age fraction, sex ratio), managers will have to establish priorities among the measured parameters in order to define the optimal sampling regime. Because the primary cost of the observer program is in stationing observers on vessels, and statistical precision is primarily improved by increasing observer coverage of vessels, it does not appear that the implementation of statistical estimation procedures would contribute to a reduction in overall cost of the observer program, if a high degree of precision is desired for the estimates. However, these findings could contribute to establishing how the observer's efforts devoted to determining catch composition can be best allocated to achieve the highest precision estimates.

Development of a valid statistically-driven management regime would require some modifications of the present observer program. Following current data collection procedures, estimates of overall variance in vessel specific or fleetwide estimates of catch and by-catch cannot be obtained because species composition and weight information is not recorded for each sub-sampling unit (e.g., by baskets or partial-haul samples). For individual vessel estimates the sub-sampling of catches could potentially have a large effect on the variance of weekly catch and by-catch estimates. Inseason management based on individual vessels quotas could potentially be quite sensitive to variability caused by sub-sampling. For fleetwide estimates the effects of sub-sampling will generally be smaller, because of the larger sample sizes at the third sampling stage.

Experiments were conducted onboard one vessel during 1995 to evaluate the effect of basket subsampling on the precision of catch and bycatch estimates. The results indicated

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[8]We selected age and sex proportions and mean length to examine in our analyses because they are important inputs to management of these stocks; this same analytical approach could be applied to investigate in more detail the impact of alternative sampling strategies on other population attributes.

that the variability in species composition between baskets is small relative to the variability in composition between tows (Han Lin-Lai, personal communication, National Marine Fisheries Service, Woods Hole, MA). However, for the single cruise subject to experimental basket sampling, the catch rates of prohibited species were relatively low. The results, hence, may not represent typical variability resulting from basket sampling. Areas or vessels with higher rates of prohibited species, for example, could potentially have much more variability between basket samples.

A large-scale experiment was conducted during the spring of 1996 in order to obtain approximate estimates of the overall variance in fleetwide catch and by-catch estimates, including the component resulting from sub-sampling of catches. For the two demonstration fisheries selected in cooperation with AFSC and NOAA's Office of Management in Juneau, a systematic sample of about every 5th tow sampled by the observers was subject to experimental subsampling. The systematic selection is practical to implement in the field, and reduces the effects of local homogeneity by spreading the sampling out in time.

Of the three kinds of sampling used to estimate catch composition whole haul sampling provides for the greatest precision since it is a total census of harvest. However, whole haul sampling is only feasible in limited circumstances, such as for observing the bycatch of prohibited species in some fisheries (e.g., counting the number of salmon in a haul targeting pollock). Whole haul sampling would not be possible for highly mixed catches, or for prohibited species that occur in large quantities. Many logistical constraints also exist to modifications of existing procedures. Observers typically have less than ten baskets for collecting and weighing the sampled catch from a sampled haul. Thus, if whole-haul sampling is employed for all prohibited species, the baskets may fill up long before the entire haul has been sampled. The sampled fish would then have to be processed before sampling could continue, thus slowing down the handling of the catch by the vessel crew. Partial-haul sampling is an alternative because it is less time consuming, and interferes less with the work of the fishermen. In partial-haul sampling, a fairly large fraction of the haul is usually sampled. For vessels with a surveyed holding-bin an approximate estimate of the total weight of the partial haul may be obtained by observing the change in volume from taking out a partial sample of the catch. However, for partial haul sampling, the sampling unit may not always be clearly defined. As a result, it may not be feasible to obtain estimates of sampling variability resulting from this type of sub-sampling. However, the observer manual instructs (p. 3-15) that samples be selected from different parts of the bin or hold. We think it may be possible to obtain approximate estimates of the variance component due to sub-sampling by recording the information for each sample from the catch. One possibility, for instance, could be to conceptually divide the whole catch into four parts, and then record the partial haul-samples from each quarter of the catch. This would allow an approximate estimate of the variance.

In conducting the analyses reported here, we have identified a number of additional analyses or program modifications that might enhance the observer program and the management of the fisheries to which the program is applied. For a fishery with less than 100% observer coverage of fishing days, the methods for three-stage sampling could be used to estimate the cv of means and proportions for fish in fleetwide catches. For a fishery conducted by a mixed fleet of small (< 125 ft) and large vessels (≥ 125 ft), the fleet could be split into two strata: vessels with 100% coverage, and vessels with 30% coverage. For vessels with certified holding bins, determining the weight of partial haul samples from changes in bin volume using appropriate correction factors for fish density may be possible, but this methodology is not consistent with VIP requirements.

While the results of these analyses suggest many potential ways in which the observer program could be modified to enhance the information obtained, we were not able to fully address logistical constraints nor cost. Managers and participants in these fisheries would be the parties possessing the familiarity with the program necessary to identify the factors that might constrain modifications to the existing observer program and to prioritize the catch parameters of greatest importance and value for managing the affected fish populations. An appropriate follow-on analysis program could, taking into account the catch parameter priorities established by the managers, utilize the statistical findings from the analyses we report here in combination with information on costs of each element of the observer program to develop the optimal means of meeting overall management objectives for all affected fish stocks. In addition, it would be appropriate to have analyses such as these repeated on data collected in different years, when stock abundance, composition and distribution might differ from that occurring in 1994. Such additional analyses would permit assessment of how robust these analytical approaches may be, given annual variability typical for the fisheries considered. In estimating catch of individual species and the variance of those estimates (Section 3.2.2), we considered four different methods, and considered their merit based on the magnitude of the coefficients of variation produced (Figures 4-11 and 4-63). The most efficient estimator is that which yields the lowest coefficient of variation, assuming that none of the estimators are biased. However, the only means of confirming the absence of bias of the estimators would be through simulation, with repeated application of each of the estimators to a data set with a known underlying distribution.

We offer the following recommendations:

- If it could be demonstrated that the 1994 data are typical for groundfish fisheries, our results suggest that statistical procedures should be used for catch estimation, in lieu of the current blend procedure. The advantage of statistical estimation of both total groundfish harvest as well as individual species catch is that the degree of uncertainty associated with the estimates could be taken into account in tracking cumulative harvest and addressing the need for season closures, a consideration not available to managers under the current estimation protocols. Fisheries managers should evaluate, based on these findings, whether the observer coverage of vessels is sufficiently high to yield levels of precision that satisfy management objectives, and modify coverage as necessary.

- Complete observer coverage of the CDQ pollock fishery should be maintained, since any reduction in observer coverage would result in substantial reduction in precision of estimates of total groundfish as well as individual species catches.

- Statistical estimation procedures described above should be considered by managers for their logistical feasibility. The suggested procedures would provide additional types of data for statistical estimation, and could enhance the optimization of the observer effort available to the program overall.

- Fisheries managers should consider the ratio estimator with delta as the preferred individual species catch estimation method because of its high efficiency; however, since our comparisons among estimation methods do not provide a basis for establishing biases inherent in any of the methods, their validity should be established through simulations, applying the individual estimation methods to a data set with a known underlying distribution.

- Guidelines should be developed for sampling for biological characteristics of catch that take into account the differences that exist among regions and among biological characteristics. Our results illustrate that observer effort devoted to sampling for species population characteristics could be optimized in terms of fraction of hauls sampled and number of fish sampled per haul to achieve higher levels of precision in estimates of those characteristics than may presently be the case.

- It would be appropriate to repeat analyses such as these on data collected in different years, when stock abundance, composition and distribution might differ from that occurring in 1994. Such additional analyses would permit assessment of how robust these analytical approaches may be, given annual variability typical for the fisheries considered; the Fortran programs developed as part of this project would allow AFSC to conduct these analyses.

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APPENDIX A

TABLES OF RESULTS FOR DEMONSTRATION FISHERY 1: POLLOCK TARGET FISHERY

Appendix A includes coefficient of variation output for catch estimates of total catch, pollock, Pacific cod, rock sole, chinook salmon, other salmon, and herring. Coefficients of variation for total catch estimates are based on the adjusted OTC data set. Coefficients of variation for individual species are presented for the standard two-stage estimator and the bycatch ratio estimator.

The species and statistical estimator codes used in the output descriptions are defined below:

plck = pollock
pcod = Pacific cod
rsol = rock sole
chin = chinook salmon
osal = other salmon
herr = herring

T = true and indicates that the estimator was used to create the corresponding output

F = false and indicates that the estimator was not used to create the corresponding output (F for bycatch ratio indicates that the standard two-stage estimator was used)

species = total catch
delta = F
first stage = vessel

A_Season

Estimated catch: 3.811404E+08

Vessel sample fraction (f1)

		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	.2773	.1852	.1418	.1141	.0936	.0770	.0624	.0487	.0345	.0157
	.20	.2748	.1834	.1402	.1126	.0921	.0755	.0608	.0469	.0323	.0105
	.30	.2740	.1828	.1397	.1121	.0916	.0750	.0603	.0463	.0315	.0080
Haul	.40	.2736	.1824	.1394	.1118	.0914	.0747	.0600	.0460	.0311	.0064
sample	.50	.2733	.1823	.1392	.1117	.0912	.0746	.0599	.0458	.0308	.0052
fraction	.60	.2732	.1821	.1391	.1116	.0911	.0745	.0598	.0457	.0306	.0043
(f2)	.70	.2730	.1820	.1391	.1115	.0911	.0744	.0597	.0456	.0305	.0034
	.80	.2729	.1820	.1390	.1115	.0910	.0743	.0596	.0456	.0304	.0026
	.90	.2729	.1819	.1390	.1114	.0910	.0743	.0596	.0455	.0304	.0017
	1.00	.2728	.1819	.1389	.1114	.0909	.0743	.0595	.0455	.0303	.0000

CDQ_fishery

Estimated catch: 5959756.000000

Vessel sample fraction (f1)

		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	1.4864	.9957	.7650	.6183	.5103	.4234	.3482	.2788	.2095	.1297
	.20	1.4547	.9719	.7444	.5991	.4917	.4046	.3285	.2570	.1831	.0865
	.30	1.4439	.9639	.7374	.5926	.4853	.3981	.3216	.2493	.1733	.0660
Haul	.40	1.4385	.9598	.7339	.5893	.4821	.3948	.3181	.2454	.1683	.0530
sample	.50	1.4353	.9574	.7317	.5873	.4802	.3928	.3160	.2430	.1652	.0432
fraction	.60	1.4331	.9558	.7303	.5859	.4789	.3915	.3146	.2414	.1631	.0353
(f2)	.70	1.4315	.9546	.7293	.5850	.4779	.3906	.3136	.2402	.1615	.0283
	.80	1.4304	.9537	.7285	.5843	.4772	.3899	.3128	.2393	.1604	.0216
	.90	1.4295	.9530	.7279	.5837	.4767	.3893	.3123	.2387	.1595	.0144
	1.00	1.4287	.9525	.7275	.5833	.4762	.3889	.3118	.2381	.1587	.0000

B_Season

Estimated catch: 4.004679E+08

Vessel sample fraction (f1)

		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	.2480	.1659	.1272	.1025	.0843	.0696	.0568	.0449	.0327	.0177
	.20	.2444	.1632	.1249	.1004	.0822	.0675	.0546	.0424	.0296	.0118
	.30	.2432	.1623	.1241	.0996	.0815	.0668	.0538	.0415	.0285	.0090
Haul	.40	.2426	.1619	.1237	.0993	.0812	.0664	.0534	.0411	.0279	.0072
sample	.50	.2423	.1616	.1235	.0991	.0810	.0662	.0532	.0408	.0276	.0059
fraction	.60	.2420	.1614	.1233	.0989	.0808	.0660	.0530	.0406	.0273	.0048
(f2)	.70	.2419	.1613	.1232	.0988	.0807	.0659	.0529	.0405	.0271	.0039
	.80	.2417	.1612	.1231	.0987	.0806	.0659	.0528	.0404	.0270	.0030
	.90	.2416	.1611	.1231	.0987	.0806	.0658	.0528	.0403	.0269	.0020
	1.00	.2416	.1610	.1230	.0986	.0805	.0657	.0527	.0403	.0268	.0000

species = plck
bycatch ratio = F
delta = F
first stage = vessel

A_Season

Estimated catch: 3.669844E+08

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	.2931	.1958	.1499	.1206	.0989	.0813	.0660	.0515	.0365	.0165
	.20	.2905	.1939	.1482	.1190	.0974	.0798	.0643	.0496	.0341	.0110
	.30	.2897	.1932	.1477	.1185	.0969	.0793	.0637	.0490	.0333	.0084
Haul	.40	.2892	.1929	.1474	.1182	.0966	.0790	.0635	.0487	.0328	.0067
sample	.50	.2890	.1927	.1472	.1181	.0965	.0788	.0633	.0485	.0326	.0055
fraction	.60	.2888	.1926	.1471	.1180	.0964	.0787	.0632	.0483	.0324	.0045
(f2)	.70	.2887	.1925	.1470	.1179	.0963	.0786	.0631	.0482	.0323	.0036
	.80	.2886	.1924	.1470	.1178	.0962	.0786	.0630	.0482	.0322	.0028
	.90	.2885	.1923	.1469	.1178	.0962	.0785	.0630	.0481	.0321	.0018
	1.00	.2885	.1923	.1469	.1178	.0962	.0785	.0629	.0481	.0321	.0000

CDQ_fishery

Estimated catch: 5088148.000000

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	1.8802	1.2571	.9636	.7764	.6382	.5263	.4289	.3378	.2446	.1280
	.20	1.8558	1.2388	.9478	.7616	.6238	.5117	.4134	.3205	.2230	.0853
	.30	1.8476	1.2327	.9424	.7566	.6189	.5067	.4082	.3146	.2153	.0652
Haul	.40	1.8435	1.2296	.9397	.7541	.6165	.5042	.4055	.3115	.2113	.0523
sample	.50	1.8410	1.2278	.9381	.7526	.6150	.5027	.4039	.3097	.2089	.0427
fraction	.60	1.8394	1.2265	.9370	.7516	.6140	.5017	.4028	.3085	.2073	.0348
(f2)	.70	1.8382	1.2256	.9363	.7509	.6133	.5010	.4021	.3076	.2061	.0279
	.80	1.8373	1.2250	.9357	.7503	.6128	.5005	.4015	.3069	.2052	.0213
	.90	1.8366	1.2245	.9352	.7499	.6124	.5001	.4010	.3064	.2046	.0142
	1.00	1.8361	1.2240	.9349	.7496	.6120	.4997	.4007	.3060	.2040	.0000

B_Season

Estimated catch: 3.884329E+08

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	.2554	.1708	.1310	.1056	.0868	.0717	.0585	.0462	.0336	.0181
	.20	.2518	.1681	.1286	.1034	.0847	.0695	.0562	.0436	.0305	.0121
	.30	.2506	.1672	.1279	.1027	.0840	.0688	.0554	.0428	.0293	.0092
Haul	.40	.2500	.1668	.1275	.1023	.0836	.0684	.0550	.0423	.0287	.0074
sample	.50	.2496	.1665	.1272	.1021	.0834	.0682	.0548	.0420	.0284	.0060
fraction	.60	.2494	.1663	.1271	.1019	.0833	.0680	.0546	.0418	.0281	.0049
(f2)	.70	.2492	.1662	.1269	.1018	.0832	.0679	.0545	.0417	.0280	.0040
	.80	.2491	.1661	.1269	.1017	.0831	.0679	.0544	.0416	.0278	.0030
	.90	.2490	.1660	.1268	.1017	.0830	.0678	.0544	.0415	.0277	.0020
	1.00	.2489	.1659	.1267	.1016	.0830	.0677	.0543	.0415	.0277	.0000

species = plck
bycatch ratio = T
delta = T
first stage = vessel

A_Season

Total catch: 3.811404E+08
Species catch: 3.910571E+08
Ratio: 1.026018

Haul sample fraction (f2)	Vessel sample fraction (f1) .10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
.10	.0240	.0162	.0125	.0102	.0085	.0071	.0060	.0049	.0040	.0029
.20	.0230	.0154	.0118	.0096	.0079	.0065	.0054	.0043	.0032	.0020
.30	.0226	.0151	.0116	.0093	.0077	.0063	.0052	.0041	.0029	.0015
.40	.0225	.0150	.0115	.0092	.0076	.0062	.0050	.0039	.0028	.0012
.50	.0224	.0149	.0114	.0092	.0075	.0062	.0050	.0038	.0027	.0010
.60	.0223	.0149	.0114	.0091	.0075	.0061	.0049	.0038	.0026	.0008
.70	.0222	.0148	.0113	.0091	.0074	.0061	.0049	.0038	.0026	.0006
.80	.0222	.0148	.0113	.0091	.0074	.0061	.0049	.0037	.0025	.0005
.90	.0222	.0148	.0113	.0091	.0074	.0060	.0048	.0037	.0025	.0003
1.00	.0221	.0148	.0113	.0090	.0074	.0060	.0048	.0037	.0025	.0000

CDQ_fishery

Total catch: 5959756.000000
Species catch: 5248021.000000
Ratio: 8.805764E-01

Haul sample fraction (f2)	Vessel sample fraction (f1) .10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
.10	.4475	.3022	.2346	.1920	.1612	.1368	.1163	.0982	.0814	.0648
.20	.4206	.2823	.2174	.1762	.1460	.1218	.1010	.0820	.0635	.0432
.30	.4113	.2753	.2113	.1706	.1406	.1164	.0954	.0759	.0562	.0330
.40	.4065	.2717	.2082	.1677	.1378	.1135	.0924	.0726	.0523	.0265
.50	.4037	.2696	.2064	.1660	.1361	.1118	.0906	.0706	.0497	.0216
.60	.4017	.2681	.2051	.1648	.1349	.1106	.0893	.0692	.0480	.0176
.70	.4003	.2671	.2042	.1639	.1341	.1098	.0884	.0682	.0466	.0141
.80	.3993	.2663	.2035	.1633	.1335	.1092	.0878	.0674	.0456	.0108
.90	.3985	.2657	.2030	.1628	.1330	.1087	.0872	.0668	.0449	.0072
1.00	.3978	.2652	.2026	.1624	.1326	.1083	.0868	.0663	.0442	.0000

B_Season

Total catch: 4.004679E+08
Species catch: 4.134811E+08
Ratio: 1.032495

Haul sample fraction (f2)	Vessel sample fraction (f1) .10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
.10	.0149	.0101	.0078	.0063	.0053	.0045	.0037	.0031	.0025	.0019
.20	.0143	.0096	.0073	.0059	.0049	.0041	.0033	.0027	.0020	.0013
.30	.0140	.0094	.0072	.0058	.0048	.0039	.0032	.0025	.0018	.0010
.40	.0139	.0093	.0071	.0057	.0047	.0039	.0031	.0024	.0017	.0008
.50	.0138	.0092	.0071	.0057	.0047	.0038	.0031	.0024	.0017	.0006
.60	.0138	.0092	.0070	.0056	.0046	.0038	.0031	.0024	.0016	.0005
.70	.0138	.0092	.0070	.0056	.0046	.0038	.0030	.0023	.0016	.0004
.80	.0137	.0092	.0070	.0056	.0046	.0037	.0030	.0023	.0016	.0003
.90	.0137	.0091	.0070	.0056	.0046	.0037	.0030	.0023	.0015	.0002
1.00	.0137	.0091	.0070	.0056	.0046	.0037	.0030	.0023	.0015	.0000

species = pcod
bycatch ratio = F
delta = F
first stage = vessel

A_Season

Estimated catch: 7367710.000000

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	.6561	.4444	.3462	.2847	.2404	.2056	.1765	.1512	.1280	.1059
	.20	.6068	.4079	.3149	.2559	.2129	.1786	.1492	.1228	.0973	.0706
	.30	.5894	.3950	.3037	.2456	.2029	.1686	.1390	.1117	.0846	.0539
Haul	.40	.5805	.3884	.2979	.2403	.1978	.1634	.1335	.1057	.0775	.0432
sample	.50	.5751	.3843	.2944	.2370	.1946	.1602	.1301	.1020	.0729	.0353
fraction	.60	.5715	.3816	.2921	.2348	.1924	.1580	.1278	.0994	.0697	.0288
(f2)	.70	.5689	.3797	.2904	.2332	.1909	.1564	.1262	.0975	.0673	.0231
	.80	.5670	.3782	.2891	.2320	.1897	.1552	.1249	.0961	.0654	.0176
	.90	.5654	.3771	.2881	.2311	.1888	.1543	.1239	.0950	.0639	.0118
	1.00	.5642	.3761	.2873	.2303	.1881	.1536	.1231	.0940	.0627	.0000

CDQ_fishery

Estimated catch: 125630.000000

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	2.1751	1.4780	1.1557	.9546	.8103	.6978	.6047	.5241	.4516	.3838
	.20	1.9780	1.3324	1.0309	.8406	.7021	.5920	.4987	.4151	.3361	.2559
	.30	1.9078	1.2802	.9858	.7990	.6621	.5522	.4579	.3718	.2875	.1954
Haul	.40	1.8717	1.2532	.9625	.7774	.6411	.5313	.4361	.3481	.2598	.1567
sample	.50	1.8497	1.2368	.9482	.7641	.6283	.5183	.4225	.3331	.2417	.1279
fraction	.60	1.8349	1.2257	.9386	.7551	.6195	.5094	.4132	.3227	.2288	.1045
(f2)	.70	1.8242	1.2178	.9316	.7487	.6132	.5030	.4064	.3151	.2191	.0838
	.80	1.8162	1.2117	.9264	.7438	.6084	.4981	.4012	.3092	.2116	.0640
	.90	1.8099	1.2070	.9223	.7399	.6046	.4943	.3971	.3046	.2055	.0426
	1.00	1.8049	1.2033	.9190	.7368	.6016	.4912	.3939	.3008	.2005	.0000

B_Season

Estimated catch: 6228397.000000

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	.4178	.2837	.2216	.1828	.1550	.1332	.1152	.0995	.0854	.0721
	.20	.3817	.2569	.1987	.1619	.1351	.1137	.0956	.0793	.0639	.0481
	.30	.3688	.2474	.1904	.1543	.1277	.1064	.0881	.0713	.0549	.0367
Haul	.40	.3622	.2425	.1862	.1503	.1239	.1026	.0841	.0670	.0498	.0294
sample	.50	.3582	.2395	.1836	.1479	.1215	.1002	.0816	.0642	.0464	.0240
fraction	.60	.3555	.2375	.1818	.1462	.1199	.0986	.0799	.0623	.0441	.0196
(f2)	.70	.3536	.2360	.1806	.1451	.1188	.0974	.0787	.0609	.0423	.0157
	.80	.3521	.2349	.1796	.1442	.1179	.0965	.0777	.0599	.0409	.0120
	.90	.3510	.2341	.1789	.1435	.1172	.0958	.0770	.0590	.0398	.0080
	1.00	.3501	.2334	.1783	.1429	.1167	.0953	.0764	.0583	.0389	.0000

species = pcod
bycatch ratio = T
delta = T
first stage = vessel

A_Season

Total catch: 3.811404E+08
Species catch: 9397556.000000
Ratio: 2.465642E-02

Vessel sample fraction (f1)

Haul sample fraction (f2)	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
.10	.5499	.3720	.2892	.2373	.1998	.1702	.1454	.1236	.1036	.0842
.20	.5129	.3445	.2656	.2156	.1790	.1497	.1246	.1018	.0797	.0561
.30	.4999	.3348	.2572	.2078	.1715	.1422	.1168	.0934	.0700	.0429
.40	.4933	.3299	.2529	.2038	.1676	.1383	.1128	.0889	.0646	.0344
.50	.4893	.3269	.2503	.2014	.1652	.1359	.1102	.0861	.0611	.0281
.60	.4866	.3249	.2486	.1998	.1636	.1343	.1085	.0842	.0587	.0229
.70	.4847	.3234	.2473	.1986	.1625	.1331	.1073	.0828	.0569	.0184
.80	.4833	.3223	.2464	.1977	.1616	.1322	.1063	.0817	.0555	.0140
.90	.4821	.3215	.2456	.1970	.1610	.1315	.1056	.0809	.0544	.0094
1.00	.4812	.3208	.2450	.1965	.1604	.1310	.1050	.0802	.0535	.0000

CDQ_fishery

Total catch: 5959756.000000
Species catch: 130474.300000
Ratio: 2.189256E-02

Vessel sample fraction (f1)

Haul sample fraction (f2)	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
.10	2.9538	1.9892	1.5387	1.2542	1.0470	.8823	.7425	.6173	.4986	.3777
.20	2.8164	1.8870	1.4503	1.1725	.9684	.8039	.6619	.5310	.4007	.2518
.30	2.7691	1.8516	1.4196	1.1440	.9407	.7760	.6327	.4990	.3622	.1923
.40	2.7451	1.8337	1.4040	1.1295	.9265	.7617	.6176	.4821	.3414	.1542
.50	2.7306	1.8228	1.3946	1.1207	.9179	.7530	.6084	.4717	.3282	.1259
.60	2.7209	1.8156	1.3883	1.1148	.9121	.7471	.6022	.4647	.3191	.1028
.70	2.7140	1.8104	1.3837	1.1105	.9080	.7429	.5977	.4596	.3125	.0824
.80	2.7088	1.8065	1.3803	1.1073	.9049	.7397	.5943	.4557	.3074	.0630
.90	2.7047	1.8034	1.3776	1.1049	.9024	.7372	.5916	.4527	.3034	.0420
1.00	2.7015	1.8010	1.3755	1.1029	.9005	.7352	.5895	.4502	.3002	.0000

B_Season

Total catch: 4.004679E+08
Species catch: 8701563.000000
Ratio: 2.172849E-02

Vessel sample fraction (f1)

Haul sample fraction (f2)	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
.10	.3448	.2331	.1812	.1486	.1250	.1065	.0909	.0772	.0645	.0522
.20	.3221	.2163	.1667	.1353	.1123	.0938	.0781	.0637	.0498	.0348
.30	.3141	.2103	.1616	.1305	.1077	.0892	.0733	.0586	.0438	.0266
.40	.3101	.2073	.1589	.1281	.1053	.0868	.0708	.0558	.0404	.0213
.50	.3076	.2055	.1573	.1266	.1038	.0854	.0692	.0541	.0383	.0174
.60	.3060	.2042	.1563	.1256	.1029	.0844	.0682	.0529	.0368	.0142
.70	.3048	.2034	.1555	.1249	.1022	.0837	.0674	.0520	.0357	.0114
.80	.3039	.2027	.1549	.1243	.1016	.0831	.0669	.0514	.0349	.0087
.90	.3032	.2022	.1545	.1239	.1012	.0827	.0664	.0509	.0342	.0058
1.00	.3026	.2018	.1541	.1236	.1009	.0824	.0660	.0504	.0336	.0000

species = rsol
bycatch ratio = F
delta = F
first stage = vessel

A_Season

Estimated catch: 3720106.000000

Vessel sample fraction (f1)

Haul sample fraction (f2)	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
.10	1.2136	.8146	.6276	.5089	.4220	.3523	.2926	.2381	.1850	.1274
.20	1.1758	.7864	.6032	.4863	.4000	.3303	.2696	.2131	.1555	.0849
.30	1.1630	.7768	.5948	.4785	.3925	.3226	.2616	.2041	.1444	.0649
.40	1.1565	.7720	.5906	.4745	.3886	.3187	.2574	.1995	.1385	.0520
.50	1.1526	.7691	.5880	.4721	.3863	.3163	.2549	.1966	.1348	.0425
.60	1.1500	.7671	.5863	.4705	.3847	.3148	.2532	.1947	.1323	.0347
.70	1.1481	.7657	.5851	.4694	.3836	.3136	.2520	.1933	.1305	.0278
.80	1.1467	.7646	.5842	.4685	.3828	.3128	.2511	.1923	.1291	.0212
.90	1.1456	.7638	.5835	.4679	.3821	.3121	.2504	.1914	.1281	.0142
1.00	1.1448	.7632	.5829	.4673	.3816	.3116	.2498	.1908	.1272	.0000

CDQ_fishery

Estimated catch: 19834.000000

Vessel sample fraction (f1)

Haul sample fraction (f2)	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
.10	3.0860	2.1317	1.6984	1.4334	1.2476	1.1066	.9937	.8998	.8194	.7488
.20	2.5315	1.7282	1.3587	1.1295	.9662	.8399	.7366	.6483	.5703	.4992
.30	2.3174	1.5708	1.2247	1.0081	.8520	.7297	.6278	.5390	.4581	.3813
.40	2.2025	1.4859	1.1519	.9415	.7887	.6677	.5657	.4750	.3901	.3057
.50	2.1306	1.4325	1.1059	.8992	.7482	.6277	.5249	.4321	.3429	.2496
.60	2.0813	1.3958	1.0742	.8698	.7199	.5994	.4958	.4009	.3074	.2038
.70	2.0454	1.3690	1.0509	.8482	.6990	.5785	.4740	.3771	.2793	.1634
.80	2.0180	1.3485	1.0331	.8317	.6829	.5622	.4569	.3581	.2562	.1248
.90	1.9964	1.3324	1.0191	.8186	.6701	.5492	.4432	.3427	.2367	.0832
1.00	1.9790	1.3193	1.0077	.8079	.6597	.5386	.4319	.3298	.2199	.0000

B_Season

Estimated catch: 192809.700000

Vessel sample fraction (f1)

Haul sample fraction (f2)	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
.10	.6907	.4714	.3705	.3078	.2632	.2286	.2003	.1762	.1548	.1353
.20	.6127	.4140	.3215	.2633	.2212	.1880	.1601	.1354	.1125	.0902
.30	.5845	.3930	.3034	.2467	.2054	.1723	.1442	.1187	.0943	.0689
.40	.5698	.3821	.2940	.2380	.1969	.1639	.1355	.1095	.0838	.0552
.50	.5608	.3754	.2882	.2326	.1917	.1587	.1300	.1035	.0767	.0451
.60	.5547	.3708	.2842	.2289	.1881	.1551	.1263	.0993	.0717	.0368
.70	.5503	.3675	.2814	.2263	.1855	.1525	.1235	.0962	.0678	.0295
.80	.5470	.3651	.2792	.2243	.1836	.1505	.1214	.0938	.0648	.0225
.90	.5444	.3631	.2775	.2227	.1820	.1489	.1197	.0919	.0623	.0150
1.00	.5424	.3616	.2762	.2214	.1808	.1476	.1184	.0904	.0603	.0000

species = rsol
bycatch ratio = T
delta = T
first stage = vessel

A_Season

Total catch: 3.811404E+08
Species catch: 1.316967E+07
Ratio: 3.455334E-02

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	.4867	.3258	.2502	.2020	.1665	.1378	.1130	.0900	.0668	.0395
	.20	.4777	.3191	.2443	.1965	.1612	.1325	.1074	.0838	.0592	.0264
	.30	.4747	.3168	.2423	.1947	.1594	.1306	.1054	.0816	.0564	.0201
Haul	.40	.4731	.3157	.2413	.1937	.1584	.1297	.1044	.0804	.0550	.0161
sample	.50	.4722	.3150	.2407	.1932	.1579	.1291	.1038	.0798	.0541	.0132
fraction	.60	.4716	.3145	.2403	.1928	.1575	.1288	.1034	.0793	.0535	.0108
(f2)	.70	.4712	.3142	.2400	.1925	.1573	.1285	.1032	.0790	.0531	.0086
	.80	.4708	.3139	.2398	.1923	.1571	.1283	.1029	.0787	.0527	.0066
	.90	.4706	.3137	.2396	.1922	.1569	.1281	.1028	.0786	.0525	.0044
	1.00	.4704	.3136	.2395	.1920	.1568	.1280	.1026	.0784	.0523	.0000

CDQ_fishery

Total catch: 5959756.000000
Species catch: 20020.820000
Ratio: 3.359336E-03

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	3.6578	2.4929	1.9561	1.6224	1.3841	1.1992	1.0474	.9171	.8013	.6949
	.20	3.2706	2.2076	1.7124	1.4006	1.1744	.9955	.8448	.7112	.5865	.4632
	.30	3.1310	2.1039	1.6230	1.3184	1.0957	.9176	.7655	.6277	.4946	.3538
Haul	.40	3.0587	2.0501	1.5764	1.2753	1.0541	.8761	.7226	.5815	.4416	.2837
sample	.50	3.0146	2.0171	1.5478	1.2487	1.0283	.8502	.6956	.5519	.4064	.2316
fraction	.60	2.9848	1.9948	1.5285	1.2307	1.0108	.8325	.6770	.5313	.3812	.1891
(f2)	.70	2.9633	1.9787	1.5145	1.2176	.9981	.8196	.6634	.5160	.3621	.1516
	.80	2.9471	1.9666	1.5039	1.2078	.9884	.8098	.6530	.5043	.3471	.1158
	.90	2.9344	1.9571	1.4956	1.2000	.9808	.8021	.6448	.4950	.3350	.0772
	1.00	2.9242	1.9495	1.4889	1.1938	.9747	.7959	.6381	.4874	.3249	.0000

B_Season

Total catch: 4.004679E+08
Species catch: 227350.000000
Ratio: 5.677109E-04

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	.6891	.4675	.3648	.3006	.2544	.2183	.1882	.1621	.1384	.1160
	.20	.6325	.4256	.3289	.2677	.2231	.1876	.1573	.1301	.1042	.0774
	.30	.6125	.4107	.3160	.2558	.2116	.1761	.1456	.1175	.0899	.0591
Haul	.40	.6023	.4031	.3094	.2496	.2057	.1701	.1393	.1107	.0818	.0474
sample	.50	.5960	.3984	.3053	.2459	.2020	.1664	.1354	.1064	.0766	.0387
fraction	.60	.5918	.3952	.3026	.2433	.1995	.1639	.1328	.1034	.0729	.0316
(f2)	.70	.5888	.3930	.3006	.2415	.1977	.1621	.1308	.1013	.0701	.0253
	.80	.5865	.3913	.2991	.2401	.1964	.1607	.1294	.0996	.0679	.0193
	.90	.5848	.3900	.2980	.2390	.1953	.1596	.1282	.0983	.0662	.0129
	1.00	.5833	.3889	.2970	.2381	.1944	.1588	.1273	.0972	.0648	.0000

```
species       = chin
bycatch ratio = F
delta         = F
first stage   = vessel
```

A_Season

Estimated catch: 13851.350000

Haul sample fraction (f2)	Vessel sample fraction (f1) .10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
.10	.9749	.6766	.5419	.4599	.4028	.3598	.3255	.2973	.2733	.2525
.20	.7722	.5298	.4190	.3507	.3024	.2653	.2353	.2100	.1880	.1683
.30	.6915	.4709	.3691	.3057	.2604	.2252	.1962	.1713	.1491	.1286
.40	.6474	.4384	.3414	.2806	.2367	.2022	.1734	.1482	.1252	.1031
.50	.6195	.4177	.3236	.2643	.2212	.1870	.1582	.1325	.1083	.0842
.60	.6001	.4033	.3112	.2529	.2103	.1762	.1471	.1208	.0954	.0687
.70	.5859	.3927	.3021	.2444	.2021	.1680	.1387	.1117	.0851	.0551
.80	.5750	.3846	.2950	.2379	.1957	.1616	.1320	.1044	.0764	.0421
.90	.5664	.3782	.2894	.2326	.1906	.1565	.1266	.0984	.0688	.0281
1.00	.5594	.3729	.2848	.2284	.1865	.1522	.1221	.0932	.0622	.0000

CDQ_fishery

Estimated catch: 47.783330

Haul sample fraction (f2)	Vessel sample fraction (f1) .10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
.10	4.3475	3.0000	2.3874	2.0123	1.7491	1.5489	1.3884	1.2547	1.1398	1.0388
.20	3.5924	2.4499	1.9238	1.5970	1.3639	1.1832	1.0350	.9082	.7956	.6925
.30	3.3026	2.2367	1.7421	1.4321	1.2085	1.0329	.8865	.7583	.6411	.5289
.40	3.1477	2.1221	1.6437	1.3421	1.1228	.9489	.8019	.6709	.5477	.4241
.50	3.0509	2.0503	1.5818	1.2850	1.0681	.8947	.7466	.6125	.4831	.3463
.60	2.9847	2.0009	1.5391	1.2455	1.0300	.8567	.7074	.5702	.4347	.2827
.70	2.9365	1.9649	1.5079	1.2166	1.0019	.8284	.6779	.5380	.3965	.2267
.80	2.8998	1.9375	1.4840	1.1943	.9803	.8066	.6550	.5126	.3653	.1731
.90	2.8710	1.9159	1.4652	1.1768	.9632	.7892	.6365	.4918	.3390	.1154
1.00	2.8477	1.8984	1.4500	1.1626	.9492	.7750	.6214	.4746	.3164	.0000

B_Season

Estimated catch: 1934.420000

Haul sample fraction (f2)	Vessel sample fraction (f1) .10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
.10	1.1853	.8230	.6594	.5600	.4907	.4385	.3970	.3628	.3338	.3087
.20	.9358	.6424	.5083	.4257	.3673	.3226	.2864	.2559	.2294	.2058
.30	.8362	.5696	.4467	.3703	.3157	.2732	.2384	.2084	.1817	.1572
.40	.7817	.5295	.4125	.3392	.2864	.2449	.2103	.1800	.1524	.1260
.50	.7471	.5039	.3906	.3191	.2672	.2261	.1915	.1606	.1317	.1029
.60	.7231	.4861	.3752	.3050	.2537	.2127	.1778	.1462	.1159	.0840
.70	.7054	.4729	.3638	.2945	.2436	.2026	.1674	.1350	.1031	.0674
.80	.6919	.4628	.3551	.2863	.2357	.1947	.1591	.1260	.0923	.0514
.90	.6812	.4548	.3481	.2798	.2294	.1883	.1524	.1185	.0830	.0343
1.00	.6725	.4483	.3424	.2745	.2242	.1830	.1467	.1121	.0747	.0000

species = chin
bycatch ratio = T
delta = T
first stage = vessel

A_Season

Total catch: 3.811404E+08
Species catch: 14822.810000
Ratio: 3.889067E-05

Vessel sample fraction (f1)

Haul sample fraction (f2)	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
.10	.9049	.6284	.5036	.4277	.3748	.3350	.3034	.2773	.2552	.2360
.20	.7137	.4900	.3878	.3248	.2804	.2463	.2187	.1955	.1753	.1574
.30	.6373	.4342	.3406	.2824	.2408	.2085	.1819	.1591	.1389	.1202
.40	.5955	.4034	.3143	.2585	.2183	.1867	.1604	.1374	.1164	.0964
.50	.5689	.3838	.2975	.2431	.2036	.1724	.1460	.1225	.1005	.0787
.60	.5505	.3701	.2857	.2323	.1932	.1621	.1355	.1115	.0884	.0642
.70	.5369	.3600	.2770	.2242	.1854	.1543	.1275	.1029	.0786	.0515
.80	.5265	.3522	.2702	.2179	.1794	.1482	.1211	.0959	.0704	.0393
.90	.5183	.3461	.2649	.2129	.1745	.1433	.1160	.0902	.0632	.0262
1.00	.5116	.3411	.2605	.2089	.1705	.1392	.1116	.0853	.0568	.0000

CDQ_fishery

Total catch: 5959756.000000
Species catch: 47.594440
Ratio: 7.985972E-06

Vessel sample fraction (f1)

Haul sample fraction (f2)	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
.10	3.7543	2.6260	2.1204	1.8156	1.6051	1.4479	1.3243	1.2233	1.1387	1.0661
.20	2.7894	1.9336	1.5464	1.3106	1.1461	1.0218	.9228	.8410	.7713	.7107
.30	2.3824	1.6390	1.2999	1.0916	.9448	.8326	.7422	.6664	.6009	.5428
.40	2.1503	1.4698	1.1572	.9636	.8259	.7196	.6329	.5591	.4941	.4352
.50	1.9980	1.3581	1.0623	.8778	.7455	.6424	.5571	.4834	.4171	.3554
.60	1.8898	1.2783	.9941	.8157	.6868	.5852	.5002	.4255	.3567	.2902
.70	1.8085	1.2180	.9423	.7682	.6415	.5407	.4553	.3788	.3063	.2326
.80	1.7450	1.1708	.9016	.7306	.6053	.5048	.4184	.3395	.2622	.1777
.90	1.6940	1.1328	.8685	.7000	.5756	.4749	.3873	.3055	.2220	.1185
1.00	1.6521	1.1014	.8412	.6745	.5507	.4496	.3605	.2753	.1836	.0000

B_Season

Total catch: 4.004679E+08
Species catch: 1832.364000
Ratio: 4.575557E-06

Vessel sample fraction (f1)

Haul sample fraction (f2)	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
.10	1.2443	.8644	.6929	.5887	.5162	.4616	.4182	.3825	.3522	.3259
.20	.9788	.6723	.5323	.4461	.3853	.3387	.3010	.2693	.2418	.2173
.30	.8725	.5947	.4667	.3871	.3303	.2862	.2500	.2189	.1913	.1660
.40	.8142	.5518	.4301	.3539	.2990	.2559	.2201	.1888	.1602	.1331
.50	.7771	.5244	.4066	.3324	.2786	.2359	.2000	.1681	.1383	.1086
.60	.7514	.5052	.3901	.3173	.2640	.2216	.1854	.1528	.1214	.0887
.70	.7324	.4911	.3779	.3060	.2532	.2108	.1742	.1408	.1078	.0711
.80	.7179	.4803	.3685	.2972	.2447	.2023	.1654	.1311	.0963	.0543
.90	.7064	.4717	.3610	.2903	.2379	.1954	.1581	.1230	.0863	.0362
1.00	.6970	.4647	.3549	.2846	.2323	.1897	.1521	.1162	.0774	.0000

species = osal
bycatch ratio = F
delta = F
first stage = vessel

A_Season

Estimated catch: 497.138300

Vessel sample fraction (f1)

		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	1.4714	1.0122	.8028	.6740	.5833	.5141	.4582	.4114	.3708	.3349
	.20	1.2417	.8444	.6608	.5464	.4644	.4005	.3477	.3022	.2613	.2233
	.30	1.1551	.7805	.6062	.4966	.4172	.3546	.3020	.2556	.2126	.1705
Haul	.40	1.1092	.7464	.5769	.4697	.3916	.3293	.2764	.2288	.1835	.1367
sample	.50	1.0807	.7253	.5586	.4528	.3753	.3131	.2598	.2111	.1635	.1116
fraction	.60	1.0613	.7108	.5461	.4412	.3641	.3019	.2481	.1984	.1487	.0912
(f2)	.70	1.0472	.7003	.5369	.4327	.3558	.2936	.2394	.1888	.1372	.0731
	.80	1.0366	.6923	.5300	.4262	.3495	.2872	.2327	.1813	.1278	.0558
	.90	1.0282	.6860	.5245	.4211	.3445	.2821	.2273	.1752	.1201	.0372
	1.00	1.0214	.6809	.5201	.4170	.3405	.2780	.2229	.1702	.1135	.0000

CDQ_fishery

Estimated catch: 78.333330

Vessel sample fraction (f1)

		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	3.6640	2.5541	2.0551	1.7530	1.5437	1.3867	1.2626	1.1609	1.0752	1.0014
	.20	2.8025	1.9335	1.5383	1.2963	1.1264	.9972	.8936	.8071	.7329	.6676
	.30	2.4489	1.6763	1.3219	1.1028	.9473	.8276	.7302	.6476	.5751	.5099
Haul	.40	2.2514	1.5316	1.1991	.9920	.8437	.7282	.6329	.5507	.4771	.4088
sample	.50	2.1241	1.4378	1.1190	.9191	.7748	.6613	.5665	.4834	.4071	.3338
fraction	.60	2.0348	1.3717	1.0623	.8672	.7253	.6128	.5176	.4327	.3528	.2725
(f2)	.70	1.9685	1.3224	1.0198	.8280	.6878	.5756	.4796	.3925	.3082	.2185
	.80	1.9173	1.2843	.9868	.7974	.6582	.5460	.4490	.3594	.2700	.1669
	.90	1.8766	1.2538	.9603	.7728	.6343	.5218	.4236	.3314	.2360	.1113
	1.00	1.8433	1.2289	.9386	.7525	.6144	.5017	.4022	.3072	.2048	.0000

B_Season

Estimated catch: 37992.850000

Vessel sample fraction (f1)

		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	1.1130	.7566	.5920	.4893	.4157	.3583	.3109	.2699	.2331	.1989
	.20	1.0094	.6802	.5265	.4295	.3589	.3029	.2555	.2131	.1730	.1326
	.30	.9725	.6527	.5028	.4076	.3379	.2820	.2341	.1904	.1477	.1013
Haul	.40	.9534	.6385	.4905	.3962	.3269	.2710	.2226	.1779	.1332	.0812
sample	.50	.9418	.6298	.4829	.3892	.3201	.2642	.2155	.1700	.1237	.0663
fraction	.60	.9340	.6240	.4779	.3845	.3155	.2595	.2106	.1646	.1169	.0541
(f2)	.70	.9284	.6198	.4742	.3811	.3122	.2561	.2070	.1605	.1118	.0434
	.80	.9242	.6166	.4714	.3785	.3096	.2535	.2043	.1575	.1078	.0331
	.90	.9209	.6141	.4693	.3765	.3077	.2515	.2021	.1550	.1046	.0221
	1.00	.9182	.6121	.4675	.3749	.3061	.2499	.2004	.1530	.1020	.0000

species = osal
bycatch ratio = T
delta = T
first stage = vessel

A_Season

Total catch: 3.811404E+08
Species catch: 501.289600
Ratio: 1.315236E-06

Vessel sample fraction (f1)

Haul sample fraction (f2)	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
.10	1.4048	.9689	.7707	.6492	.5639	.4991	.4470	.4035	.3662	.3333
.20	1.1645	.7938	.6230	.5169	.4411	.3823	.3341	.2927	.2560	.2222
.30	1.0725	.7261	.5653	.4645	.3917	.3345	.2867	.2449	.2065	.1697
.40	1.0234	.6898	.5341	.4359	.3645	.3078	.2598	.2170	.1767	.1361
.50	.9928	.6670	.5145	.4178	.3471	.2906	.2423	.1984	.1561	.1111
.60	.9718	.6514	.5010	.4053	.3351	.2785	.2298	.1850	.1407	.0907
.70	.9566	.6400	.4911	.3961	.3262	.2696	.2205	.1748	.1285	.0727
.80	.9450	.6314	.4835	.3891	.3193	.2627	.2132	.1668	.1186	.0556
.90	.9359	.6245	.4776	.3836	.3139	.2572	.2074	.1602	.1103	.0370
1.00	.9285	.6190	.4728	.3791	.3095	.2527	.2026	.1548	.1032	.0000

CDQ_fishery

Total catch: 5959756.000000
Species catch: 79.151120
Ratio: 1.328093E-05

Vessel sample fraction (f1)

Haul sample fraction (f2)	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
.10	3.3051	2.3256	1.8894	1.6281	1.4488	1.3158	1.2119	1.1277	1.0576	.9979
.20	2.3219	1.6254	1.3136	1.1258	.9962	.8995	.8236	.7616	.7097	.6653
.30	1.8833	1.3114	1.0539	.8979	.7897	.7084	.6440	.5912	.5466	.5081
.40	1.6201	1.1219	.8963	.7588	.6627	.5900	.5320	.4840	.4431	.4074
.50	1.4392	.9910	.7868	.6614	.5732	.5059	.4517	.4064	.3672	.3326
.60	1.3048	.8931	.7043	.5876	.5047	.4409	.3890	.3450	.3064	.2716
.70	1.1996	.8161	.6389	.5286	.4495	.3880	.3372	.2934	.2542	.2178
.80	1.1142	.7531	.5851	.4796	.4032	.3429	.2923	.2478	.2065	.1663
.90	1.0430	.7002	.5396	.4377	.3630	.3033	.2520	.2054	.1599	.1109
1.00	.9823	.6549	.5002	.4010	.3274	.2673	.2144	.1637	.1091	.0000

B_Season

Total catch: 4.004679E+08
Species catch: 36015.270000
Ratio: 8.993298E-05

Vessel sample fraction (f1)

Haul sample fraction (f2)	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
.10	1.1584	.7880	.6170	.5104	.4341	.3746	.3256	.2833	.2455	.2103
.20	1.0469	.7057	.5466	.4462	.3732	.3153	.2663	.2226	.1815	.1402
.30	1.0071	.6761	.5210	.4226	.3505	.2928	.2433	.1983	.1544	.1071
.40	.9865	.6608	.5077	.4103	.3387	.2809	.2310	.1849	.1389	.0859
.50	.9740	.6514	.4996	.4027	.3313	.2735	.2233	.1764	.1287	.0701
.60	.9655	.6451	.4941	.3976	.3263	.2685	.2180	.1705	.1214	.0572
.70	.9595	.6406	.4901	.3939	.3227	.2648	.2141	.1662	.1160	.0459
.80	.9549	.6371	.4871	.3911	.3200	.2621	.2112	.1629	.1117	.0351
.90	.9513	.6344	.4848	.3890	.3179	.2599	.2088	.1602	.1082	.0234
1.00	.9484	.6323	.4829	.3872	.3161	.2581	.2070	.1581	.1054	.0000

species = herr
bycatch ratio = F
delta = F
first stage = vessel

A_Season

Estimated catch: 961.889200

Vessel sample fraction (f1)

Haul sample fraction (f2)	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
.10	5.0878	3.5700	2.8921	2.4848	2.2045	1.9960	1.8325	1.6996	1.5886	1.4939
.20	3.6725	2.5584	2.0570	1.7534	1.5428	1.3847	1.2597	1.1571	1.0706	.9959
.30	3.0585	2.1164	1.6893	1.4287	1.2465	1.1085	.9982	.9068	.8288	.7607
.40	2.6996	1.8563	1.4714	1.2348	1.0679	.9403	.8374	.7510	.6763	.6099
.50	2.4593	1.6810	1.3235	1.1021	.9447	.8232	.7240	.6396	.5653	.4980
.60	2.2851	1.5532	1.2150	1.0040	.8527	.7347	.6373	.5530	.4772	.4066
.70	2.1520	1.4551	1.1311	.9276	.7804	.6644	.5672	.4816	.4027	.3260
.80	2.0466	1.3769	1.0639	.8659	.7214	.6063	.5084	.4203	.3361	.2490
.90	1.9606	1.3129	1.0085	.8146	.6720	.5570	.4575	.3655	.2733	.1660
1.00	1.8890	1.2594	.9618	.7712	.6297	.5141	.4122	.3148	.2099	.0000

CDQ_fishery

Estimated catch: 41279.610000

Vessel sample fraction (f1)

Haul sample fraction (f2)	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
.10	8.6621	6.0917	4.9465	4.2600	3.7888	3.4390	3.1656	2.9439	2.7592	2.6020
.20	6.1170	4.2781	3.4540	2.9570	2.6139	2.3575	2.1558	1.9912	1.8531	1.7347
.30	4.9880	3.4689	2.7840	2.3684	2.0796	1.8623	1.6901	1.5484	1.4286	1.3249
.40	4.3141	2.9830	2.3793	2.0105	1.7524	1.5567	1.4003	1.2705	1.1594	1.0623
.50	3.8535	2.6491	2.0993	1.7612	1.5227	1.3403	1.1931	1.0695	.9625	.8673
.60	3.5131	2.4008	1.8898	1.5732	1.3480	1.1741	1.0322	.9113	.8048	.7082
.70	3.2482	2.2065	1.7246	1.4238	1.2079	1.0393	.8997	.7788	.6698	.5678
.80	3.0344	2.0486	1.5895	1.3005	1.0910	.9253	.7859	.6623	.5472	.4337
.90	2.8571	1.9169	1.4759	1.1959	.9906	.8259	.6843	.5550	.4282	.2891
1.00	2.7068	1.8046	1.3782	1.1051	.9023	.7367	.5907	.4511	.3008	.0000

B_Season

Estimated catch: 562725.900000

Vessel sample fraction (f1)

Haul sample fraction (f2)	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
.10	.9575	.6636	.5307	.4497	.3931	.3504	.3164	.2882	.2643	.2434
.20	.7665	.5251	.4145	.3462	.2978	.2606	.2304	.2048	.1824	.1623
.30	.6912	.4700	.3678	.3040	.2584	.2228	.1934	.1680	.1452	.1240
.40	.6503	.4398	.3420	.2806	.2362	.2012	.1719	.1461	.1224	.0994
.50	.6245	.4207	.3256	.2655	.2218	.1870	.1576	.1313	.1064	.0811
.60	.6067	.4075	.3141	.2550	.2117	.1770	.1473	.1204	.0942	.0663
.70	.5936	.3977	.3057	.2472	.2041	.1695	.1395	.1119	.0845	.0531
.80	.5836	.3903	.2992	.2411	.1983	.1636	.1334	.1052	.0764	.0406
.90	.5757	.3844	.2941	.2363	.1936	.1588	.1284	.0996	.0694	.0270
1.00	.5694	.3796	.2899	.2324	.1898	.1550	.1242	.0949	.0633	.0000

species = herr
bycatch ratio = T
delta = T
first stage = vessel

A_Season

Total catch: 3.811404E+08
Species catch: 949.577300
Ratio: 2.491411E-06

Vessel sample fraction (f1)

		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	5.1544	3.6166	2.9297	2.5170	2.2330	2.0217	1.8560	1.7213	1.6088	1.5128
	.20	3.7221	2.5928	2.0845	1.7767	1.5632	1.4029	1.2761	1.1721	1.0843	1.0085
	.30	3.1010	2.1455	1.7125	1.4481	1.2633	1.1232	1.0114	.9187	.8395	.7703
Haul	.40	2.7380	1.8825	1.4920	1.2519	1.0826	.9532	.8487	.7610	.6850	.6176
sample	.50	2.4951	1.7053	1.3425	1.1178	.9580	.8346	.7339	.6482	.5727	.5043
fraction	.60	2.3190	1.5762	1.2328	1.0186	.8650	.7452	.6462	.5605	.4836	.4117
(f2)	.70	2.1846	1.4770	1.1480	.9414	.7919	.6741	.5754	.4884	.4081	.3301
	.80	2.0780	1.3981	1.0801	.8790	.7323	.6154	.5159	.4263	.3407	.2521
	.90	1.9913	1.3334	1.0242	.8273	.6824	.5656	.4645	.3710	.2772	.1681
	1.00	1.9190	1.2793	.9771	.7834	.6397	.5223	.4188	.3198	.2132	.0000

CDQ_fishery

Total catch: 5959756.000000
Species catch: 13582.500000
Ratio: 2.279037E-03

Vessel sample fraction (f1)

		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	26.0219	18.3272	14.9042	12.8554	11.4515	10.4108	9.5987	8.9414	8.3946	7.9300
	.20	18.1046	12.6967	10.2802	8.8273	7.8271	7.0823	6.4982	6.0231	5.6259	5.2867
	.30	14.5370	10.1479	8.1771	6.9862	6.1622	5.5452	5.0587	4.6606	4.3256	4.0378
Haul	.40	12.3732	8.5945	6.8888	5.8524	5.1310	4.5875	4.1560	3.8003	3.4988	3.2374
sample	.50	10.8701	7.5098	5.9841	5.0513	4.3977	3.9016	3.5045	3.1742	2.8913	2.6433
fraction	.60	9.7401	6.6897	5.2959	4.4377	3.8317	3.3676	2.9923	2.6766	2.4025	2.1583
(f2)	.70	8.8449	6.0360	4.7435	3.9413	3.3696	2.9271	2.5646	2.2549	1.9808	1.7305
	.80	8.1090	5.4950	4.2827	3.5235	2.9764	2.5472	2.1897	1.8775	1.5928	1.3217
	.90	7.4867	5.0342	3.8867	3.1605	2.6302	2.2070	1.8462	1.5204	1.2078	.8811
	1.00	6.9489	4.6326	3.5382	2.8369	2.3163	1.8913	1.5164	1.1581	.7721	.0000

B_Season

Total catch: 4.004679E+08
Species catch: 785532.600000
Ratio: 1.961537E-03

Vessel sample fraction (f1)

		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	.6606	.4593	.3685	.3133	.2750	.2462	.2233	.2045	.1886	.1748
	.20	.5164	.3551	.2814	.2361	.2042	.1798	.1601	.1436	.1292	.1165
	.30	.4584	.3127	.2456	.2040	.1743	.1513	.1325	.1163	.1021	.0890
Haul	.40	.4264	.2892	.2256	.1859	.1572	.1348	.1162	.1000	.0853	.0714
sample	.50	.4060	.2741	.2127	.1741	.1461	.1239	.1053	.0888	.0734	.0583
fraction	.60	.3918	.2636	.2037	.1658	.1381	.1161	.0973	.0804	.0643	.0476
(f2)	.70	.3814	.2558	.1969	.1595	.1321	.1101	.0912	.0739	.0569	.0381
	.80	.3733	.2498	.1917	.1547	.1274	.1054	.0863	.0685	.0506	.0291
	.90	.3670	.2451	.1876	.1509	.1237	.1016	.0823	.0641	.0451	.0194
	1.00	.3618	.2412	.1842	.1477	.1206	.0985	.0790	.0603	.0402	.0000

APPENDIX B

TABLES OF RESULTS FOR DEMONSTRATION FISHERY 2: YELLOWFIN TARGET FISHERY

Appendix B includes coefficient of variation output for catch estimates of total catch, yellowfin sole, pollock, Pacific cod, halibut, bairdi crab, other Tanner crab, red king crab, and other king crab. Coefficients of variation for total catch estimates are based on the adjusted OTC data set. Coefficients of variation for individual species are presented for the standard two-stage estimator and the bycatch ratio estimator.

The species and statistical estimator codes used in the output descriptions are defined below:

ysol = yellowfin sole
plck = pollock
pcod = Pacific cod
halb = halibut
bdcb = bairbi crab
otan = other Tanner crab
rkcb = red king crab
okcb = other king crab

T = true and indicates that the estimator was used to create the corresponding output

F = false and indicates that the estimator was not used to create the corresponding output (F for bycatch ratio indicates that the standard two-stage estimator was used)

species = total catch
delta = F
first stage = vessel

Estimated catch: 2.090877E+08

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	.4362	.2911	.2226	.1788	.1463	.1199	.0967	.0748	.0516	.0178
	.20	.4341	.2896	.2213	.1776	.1451	.1187	.0954	.0733	.0497	.0119
	.30	.4335	.2890	.2208	.1771	.1447	.1183	.0950	.0728	.0490	.0091
Haul	.40	.4331	.2888	.2206	.1769	.1445	.1181	.0948	.0725	.0487	.0073
sample	.50	.4329	.2886	.2205	.1768	.1444	.1180	.0946	.0724	.0485	.0059
fraction	.60	.4328	.2885	.2204	.1767	.1443	.1179	.0946	.0723	.0483	.0048
(f2)	.70	.4327	.2885	.2203	.1767	.1443	.1178	.0945	.0722	.0482	.0039
	.80	.4326	.2884	.2203	.1766	.1442	.1178	.0944	.0722	.0482	.0030
	.90	.4325	.2884	.2202	.1766	.1442	.1177	.0944	.0721	.0481	.0020
	1.00	.4325	.2883	.2202	.1766	.1442	.1177	.0944	.0721	.0481	.0000

```
species        = ysol
bycatch ratio  = F
delta          = F
first stage    = vessel
```

Estimated catch: 1.220067E+08

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	.4532	.3028	.2319	.1866	.1531	.1259	.1021	.0798	.0566	.0260
	.20	.4491	.2997	.2291	.1840	.1506	.1234	.0994	.0768	.0528	.0173
	.30	.4477	.2986	.2282	.1832	.1497	.1225	.0985	.0757	.0515	.0132
Haul	.40	.4470	.2981	.2278	.1827	.1493	.1221	.0981	.0752	.0508	.0106
sample	.50	.4466	.2978	.2275	.1825	.1491	.1218	.0978	.0749	.0504	.0087
fraction	.60	.4463	.2976	.2273	.1823	.1489	.1217	.0976	.0747	.0501	.0071
(f2)	.70	.4461	.2974	.2272	.1822	.1488	.1215	.0975	.0746	.0499	.0057
	.80	.4459	.2973	.2271	.1821	.1487	.1214	.0974	.0744	.0497	.0043
	.90	.4458	.2972	.2270	.1820	.1486	.1214	.0973	.0744	.0496	.0029
	1.00	.4457	.2971	.2269	.1820	.1486	.1213	.0973	.0743	.0495	.0000

```
species       = ysol
bycatch ratio = T
delta         = T
first stage   = vessel
```

```
Total catch:      2.090877E+08
Species catch:    1.709524E+08
Ratio:            8.176109E-01
```

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	.1369	.0917	.0705	.0570	.0470	.0390	.0321	.0257	.0193	.0120
	.20	.1340	.0895	.0686	.0552	.0453	.0373	.0303	.0237	.0169	.0080
	.30	.1330	.0888	.0679	.0546	.0447	.0367	.0296	.0230	.0160	.0061
Haul	.40	.1325	.0884	.0676	.0543	.0444	.0364	.0293	.0226	.0155	.0049
sample	.50	.1322	.0882	.0674	.0541	.0442	.0362	.0291	.0224	.0152	.0040
fraction	.60	.1320	.0880	.0673	.0540	.0441	.0361	.0290	.0222	.0150	.0033
(f2)	.70	.1318	.0879	.0672	.0539	.0440	.0360	.0289	.0221	.0149	.0026
	.80	.1317	.0878	.0671	.0538	.0439	.0359	.0288	.0220	.0148	.0020
	.90	.1316	.0878	.0670	.0538	.0439	.0359	.0288	.0220	.0147	.0013
	1.00	.1316	.0877	.0670	.0537	.0439	.0358	.0287	.0219	.0146	.0000

species = plck
bycatch ratio = F
delta = F
first stage = vessel

Estimated catch: 4.212943E+07

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	.4907	.3287	.2525	.2041	.1684	.1397	.1149	.0919	.0690	.0425
	.20	.4804	.3210	.2458	.1978	.1623	.1336	.1084	.0848	.0604	.0284
	.30	.4769	.3183	.2435	.1957	.1603	.1315	.1062	.0823	.0572	.0217
Haul	.40	.4751	.3170	.2424	.1946	.1592	.1304	.1051	.0810	.0555	.0174
sample	.50	.4741	.3162	.2417	.1940	.1586	.1297	.1044	.0802	.0545	.0142
fraction	.60	.4734	.3157	.2412	.1935	.1582	.1293	.1039	.0797	.0538	.0116
(f2)	.70	.4729	.3153	.2409	.1932	.1579	.1290	.1036	.0793	.0533	.0093
	.80	.4725	.3150	.2406	.1930	.1576	.1288	.1033	.0791	.0530	.0071
	.90	.4722	.3148	.2405	.1928	.1575	.1286	.1031	.0788	.0527	.0047
	1.00	.4719	.3146	.2403	.1927	.1573	.1284	.1030	.0787	.0524	.0000

species = plck
bycatch ratio = T
delta = T
first stage = vessel

Total catch: 2.090877E+08
Species catch: 4.844163E+07
Ratio: 2.316809E-01

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
Haul sample fraction (f2)	.10	.2423	.1634	.1267	.1036	.0867	.0734	.0622	.0522	.0429	.0336
	.20	.2290	.1536	.1182	.0957	.0792	.0659	.0545	.0441	.0338	.0224
	.30	.2244	.1501	.1152	.0929	.0765	.0632	.0517	.0410	.0302	.0171
	.40	.2221	.1484	.1137	.0915	.0751	.0619	.0503	.0394	.0282	.0137
	.50	.2206	.1473	.1128	.0907	.0743	.0610	.0494	.0384	.0269	.0112
	.60	.2197	.1466	.1121	.0901	.0737	.0604	.0488	.0377	.0260	.0091
	.70	.2190	.1461	.1117	.0897	.0733	.0600	.0483	.0372	.0254	.0073
	.80	.2185	.1457	.1114	.0894	.0730	.0597	.0480	.0368	.0249	.0056
	.90	.2181	.1454	.1111	.0891	.0728	.0595	.0477	.0365	.0245	.0037
	1.00	.2178	.1452	.1109	.0889	.0726	.0593	.0475	.0363	.0242	.0000

species = pcod
bycatch ratio = F
delta = F
first stage = vessel

Estimated catch: 1.888493E+07

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	.4668	.3126	.2401	.1939	.1599	.1325	.1088	.0868	.0648	.0390
	.20	.4577	.3057	.2341	.1883	.1545	.1271	.1030	.0805	.0571	.0260
	.30	.4546	.3034	.2321	.1865	.1527	.1252	.1011	.0783	.0542	.0199
Haul	.40	.4530	.3022	.2311	.1855	.1517	.1242	.1001	.0771	.0528	.0159
sample	.50	.4521	.3015	.2305	.1849	.1512	.1237	.0995	.0764	.0519	.0130
fraction	.60	.4514	.3011	.2300	.1846	.1508	.1233	.0991	.0760	.0513	.0106
(f2)	.70	.4510	.3007	.2298	.1843	.1505	.1230	.0988	.0756	.0508	.0085
	.80	.4507	.3005	.2295	.1841	.1503	.1228	.0985	.0754	.0505	.0065
	.90	.4504	.3003	.2294	.1839	.1502	.1227	.0984	.0752	.0502	.0043
	1.00	.4502	.3001	.2292	.1838	.1501	.1225	.0982	.0750	.0500	.0000

species = pcod
bycatch ratio = T
delta = T
first stage = vessel

Total catch: 2.090877E+08
Species catch: 2.188612E+07
Ratio: 1.046743E-01

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
Haul sample fraction (f2)	.10	.2263	.1529	.1188	.0973	.0818	.0695	.0592	.0502	.0417	.0335
	.20	.2121	.1424	.1097	.0890	.0738	.0616	.0512	.0417	.0324	.0223
	.30	.2071	.1387	.1065	.0860	.0709	.0587	.0482	.0384	.0286	.0171
	.40	.2046	.1368	.1048	.0845	.0694	.0572	.0466	.0367	.0265	.0137
	.50	.2031	.1356	.1038	.0835	.0685	.0563	.0456	.0356	.0251	.0112
	.60	.2020	.1349	.1032	.0829	.0679	.0557	.0450	.0349	.0242	.0091
	.70	.2013	.1343	.1027	.0825	.0675	.0552	.0445	.0343	.0235	.0073
	.80	.2007	.1339	.1023	.0821	.0671	.0549	.0441	.0339	.0230	.0056
	.90	.2003	.1336	.1020	.0818	.0669	.0546	.0439	.0336	.0226	.0037
	1.00	.2000	.1333	.1018	.0816	.0667	.0544	.0436	.0333	.0222	.0000

species = halb
bycatch ratio = F
delta = F
first stage = vessel

Estimated catch: 754767.800000

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	.7865	.5370	.4222	.3510	.3003	.2611	.2290	.2016	.1773	.1553
	.20	.6962	.4705	.3655	.2995	.2517	.2141	.1824	.1545	.1287	.1035
	.30	.6633	.4461	.3445	.2803	.2333	.1959	.1640	.1353	.1077	.0791
Haul	.40	.6463	.4334	.3336	.2701	.2236	.1862	.1540	.1245	.0955	.0634
sample	.50	.6358	.4256	.3268	.2638	.2175	.1801	.1477	.1176	.0874	.0518
fraction	.60	.6288	.4204	.3222	.2596	.2133	.1759	.1433	.1128	.0815	.0423
(f2)	.70	.6237	.4165	.3189	.2565	.2103	.1728	.1401	.1092	.0770	.0339
	.80	.6198	.4137	.3164	.2541	.2080	.1705	.1376	.1064	.0735	.0259
	.90	.6168	.4114	.3144	.2523	.2062	.1687	.1356	.1042	.0706	.0173
	1.00	.6144	.4096	.3128	.2508	.2048	.1672	.1341	.1024	.0683	.0000

species   = halb
bycatch ratio = T
delta   = T
first stage   = vessel

Total catch: 2.090877E+08
Species catch: 790307.800000
Ratio: 3.779790E-03

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	.6585	.4531	.3595	.3020	.2614	.2305	.2056	.1847	.1666	.1506
	.20	.5546	.3772	.2953	.2443	.2077	.1792	.1557	.1355	.1173	.1004
	.30	.5153	.3483	.2706	.2217	.1864	.1585	.1351	.1144	.0953	.0767
Haul	.40	.4945	.3328	.2573	.2095	.1747	.1470	.1235	.1023	.0822	.0615
sample	.50	.4816	.3232	.2490	.2019	.1674	.1397	.1160	.0943	.0732	.0502
fraction	.60	.4728	.3167	.2433	.1966	.1623	.1346	.1107	.0886	.0665	.0410
(f2)	.70	.4664	.3119	.2392	.1928	.1585	.1308	.1067	.0842	.0613	.0329
	.80	.4616	.3083	.2360	.1898	.1557	.1279	.1037	.0808	.0570	.0251
	.90	.4577	.3054	.2335	.1875	.1534	.1256	.1012	.0781	.0535	.0167
	1.00	.4547	.3031	.2315	.1856	.1516	.1237	.0992	.0758	.0505	.0000

species = bdcb
bycatch ratio = F
delta = F
first stage = vessel

Estimated catch: 1188340.000000

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	.7707	.5180	.3997	.3247	.2700	.2262	.1889	.1550	.1224	.0881
	.20	.7422	.4967	.3813	.3077	.2535	.2098	.1718	.1366	.1010	.0587
	.30	.7325	.4894	.3749	.3018	.2478	.2040	.1657	.1298	.0928	.0448
Haul	.40	.7275	.4858	.3717	.2988	.2449	.2010	.1626	.1263	.0884	.0360
sample	.50	.7246	.4835	.3698	.2970	.2431	.1992	.1607	.1242	.0856	.0294
fraction	.60	.7226	.4821	.3685	.2958	.2419	.1980	.1594	.1227	.0837	.0240
(f2)	.70	.7212	.4810	.3676	.2949	.2411	.1971	.1585	.1217	.0824	.0192
	.80	.7201	.4802	.3669	.2943	.2404	.1965	.1578	.1209	.0813	.0147
	.90	.7193	.4796	.3663	.2938	.2399	.1960	.1572	.1203	.0805	.0098
	1.00	.7186	.4791	.3659	.2934	.2395	.1956	.1568	.1198	.0798	.0000

species = bdcb
bycatch ratio = T
delta = T
first stage = vessel

Total catch: 2.090877E+08
Species catch: 1175839.000000
Ratio: 5.623662E-03

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	.6060	.4094	.3179	.2604	.2187	.1858	.1581	.1337	.1111	.0889
	.20	.5687	.3817	.2940	.2384	.1976	.1649	.1369	.1113	.0864	.0592
	.30	.5557	.3720	.2856	.2306	.1901	.1574	.1291	.1028	.0764	.0452
Haul	.40	.5491	.3670	.2813	.2266	.1862	.1535	.1249	.0983	.0709	.0363
sample	.50	.5451	.3640	.2787	.2242	.1838	.1511	.1224	.0954	.0673	.0296
fraction	.60	.5424	.3620	.2769	.2225	.1822	.1494	.1207	.0935	.0649	.0242
(f2)	.70	.5404	.3606	.2757	.2213	.1811	.1483	.1194	.0921	.0631	.0194
	.80	.5390	.3595	.2747	.2205	.1802	.1474	.1185	.0910	.0617	.0148
	.90	.5379	.3586	.2740	.2198	.1795	.1467	.1178	.0902	.0606	.0099
	1.00	.5370	.3580	.2734	.2192	.1790	.1461	.1172	.0895	.0597	.0000

species = otan
bycatch ratio = F
delta = F
first stage = vessel

Estimated catch: 8493579.000000

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	.7619	.5113	.3937	.3191	.2644	.2206	.1829	.1485	.1149	.0781
	.20	.7394	.4944	.3791	.3056	.2513	.2074	.1692	.1335	.0971	.0521
	.30	.7317	.4887	.3741	.3009	.2468	.2028	.1643	.1281	.0904	.0398
Haul	.40	.7278	.4858	.3716	.2986	.2445	.2004	.1618	.1253	.0869	.0319
sample	.50	.7255	.4840	.3701	.2971	.2431	.1990	.1603	.1236	.0847	.0260
fraction	.60	.7239	.4829	.3691	.2962	.2421	.1981	.1593	.1225	.0832	.0213
(f2)	.70	.7228	.4820	.3683	.2955	.2415	.1974	.1586	.1216	.0821	.0170
	.80	.7220	.4814	.3678	.2950	.2410	.1969	.1581	.1210	.0813	.0130
	.90	.7213	.4809	.3674	.2946	.2406	.1965	.1576	.1205	.0806	.0087
	1.00	.7208	.4805	.3670	.2943	.2403	.1962	.1573	.1201	.0801	.0000

species = otan
bycatch ratio = T
delta = T
first stage = vessel

Total catch: 2.090877E+08
Species catch: 8958705.000000
Ratio: 4.284663E-02

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	.5352	.3613	.2803	.2293	.1924	.1631	.1385	.1167	.0964	.0763
	.20	.5041	.3382	.2604	.2110	.1747	.1457	.1207	.0978	.0754	.0509
	.30	.4933	.3302	.2534	.2045	.1685	.1394	.1141	.0907	.0670	.0388
Haul	.40	.4878	.3260	.2498	.2012	.1652	.1361	.1107	.0869	.0624	.0311
sample	.50	.4845	.3236	.2477	.1992	.1633	.1341	.1086	.0846	.0595	.0254
fraction	.60	.4823	.3219	.2462	.1978	.1619	.1328	.1072	.0829	.0574	.0208
(f2)	.70	.4807	.3207	.2452	.1968	.1610	.1318	.1061	.0818	.0559	.0166
	.80	.4795	.3198	.2444	.1961	.1603	.1311	.1054	.0809	.0548	.0127
	.90	.4785	.3191	.2438	.1955	.1597	.1305	.1048	.0802	.0538	.0085
	1.00	.4778	.3185	.2433	.1951	.1593	.1300	.1043	.0796	.0531	.0000

species = rkcb
bycatch ratio = F
delta = F
first stage = vessel

Estimated catch: 16232.220000

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	1.5920	1.0934	.8655	.7252	.6261	.5502	.4888	.4372	.3923	.3523
	.20	1.3583	.9223	.7205	.5945	.5040	.4333	.3747	.3239	.2780	.2349
	.30	1.2708	.8577	.6652	.5440	.4561	.3866	.3280	.2760	.2274	.1794
Haul	.40	1.2248	.8235	.6358	.5170	.4302	.3609	.3019	.2486	.1974	.1438
sample	.50	1.1963	.8023	.6174	.5000	.4138	.3446	.2851	.2306	.1769	.1174
fraction	.60	1.1769	.7878	.6049	.4884	.4026	.3333	.2733	.2177	.1618	.0959
(f2)	.70	1.1629	.7774	.5958	.4799	.3943	.3250	.2646	.2081	.1501	.0769
	.80	1.1522	.7694	.5889	.4734	.3880	.3186	.2579	.2006	.1407	.0587
	.90	1.1439	.7631	.5834	.4683	.3831	.3136	.2525	.1945	.1329	.0391
	1.00	1.1372	.7581	.5790	.4642	.3791	.3095	.2481	.1895	.1264	.0000

species   = rkcb
bycatch ratio = T
delta   = T
first stage   = vessel

Total catch: 2.090877E+08
Species catch: 16675.850000
Ratio: 7.975528E-05

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	1.4492	.9993	.7946	.6691	.5810	.5139	.4600	.4151	.3764	.3423
	.20	1.2038	.8204	.6437	.5338	.4553	.3944	.3444	.3015	.2633	.2282
	.30	1.1100	.7513	.5848	.4803	.4049	.3455	.2960	.2525	.2127	.1743
Haul	.40	1.0600	.7143	.5530	.4512	.3771	.3183	.2685	.2241	.1821	.1398
sample	.50	1.0288	.6911	.5330	.4327	.3594	.3008	.2506	.2051	.1610	.1141
fraction	.60	1.0075	.6753	.5192	.4200	.3471	.2885	.2379	.1914	.1453	.0932
(f2)	.70	.9920	.6637	.5092	.4107	.3381	.2794	.2284	.1810	.1329	.0747
	.80	.9802	.6549	.5015	.4036	.3311	.2724	.2210	.1728	.1228	.0571
	.90	.9710	.6479	.4955	.3979	.3256	.2668	.2151	.1661	.1143	.0380
	1.00	.9635	.6423	.4906	.3933	.3212	.2622	.2102	.1606	.1071	.0000

species = okcb
bycatch ratio = F
delta = F
first stage = vessel

Estimated catch: 12318.940000

		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	1.5624	1.0699	.8440	.7045	.6055	.5294	.4674	.4149	.3690	.3276
	.20	1.3582	.9200	.7167	.5893	.4974	.4252	.3651	.3125	.2644	.2184
	.30	1.2830	.8643	.6688	.5455	.4557	.3843	.3239	.2698	.2187	.1668
Haul	.40	1.2436	.8351	.6436	.5222	.4333	.3621	.3011	.2457	.1917	.1338
sample	.50	1.2194	.8170	.6280	.5077	.4193	.3481	.2866	.2300	.1736	.1092
fraction	.60	1.2030	.8047	.6173	.4978	.4097	.3385	.2766	.2189	.1604	.0892
(f2)	.70	1.1911	.7959	.6096	.4906	.4027	.3314	.2691	.2107	.1502	.0715
	.80	1.1822	.7892	.6038	.4852	.3974	.3260	.2634	.2043	.1421	.0546
	.90	1.1751	.7839	.5992	.4809	.3932	.3217	.2589	.1991	.1355	.0364
	1.00	1.1695	.7797	.5955	.4774	.3898	.3183	.2552	.1949	.1299	.0000

```
species        = okcb
bycatch ratio  = T
delta          = T
first stage    = vessel
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Total catch:        2.090877E+08
Species catch:      12696.240000
Ratio:              6.072205E-05
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		Vessel sample fraction (f1)									
		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
	.10	1.5178	1.0394	.8200	.6845	.5884	.5144	.4542	.4033	.3587	.3185
	.20	1.3192	.8936	.6961	.5724	.4832	.4131	.3547	.3036	.2569	.2123
	.30	1.2459	.8394	.6496	.5298	.4426	.3733	.3146	.2621	.2125	.1622
Haul	.40	1.2076	.8109	.6250	.5071	.4208	.3517	.2925	.2386	.1863	.1300
sample	.50	1.1841	.7933	.6098	.4930	.4072	.3381	.2784	.2234	.1686	.1062
fraction	.60	1.1681	.7814	.5994	.4834	.3979	.3287	.2686	.2126	.1558	.0867
(f2)	.70	1.1565	.7728	.5919	.4764	.3910	.3218	.2613	.2046	.1459	.0695
	.80	1.1478	.7662	.5862	.4711	.3859	.3165	.2558	.1983	.1380	.0531
	.90	1.1410	.7611	.5818	.4669	.3818	.3124	.2514	.1933	.1316	.0354
	1.00	1.1355	.7570	.5782	.4636	.3785	.3090	.2478	.1892	.1262	.0000

Versar INC.
ENVIRONMENTAL RISK MANAGEMENT

ESM Operations

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