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Estimating in-season discards from the Northeast United States groundfish fishery: an investigation of the separate ratio method (Part II)

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A working paper in support of the Discard Estimation Methodology Review

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Introduction

The Magnuson-Stevens Reauthorization Act requires United States fishery managers to set annual catch limits (ACLs) for all overfished stocks by 2010 (2011 for all stocks). Monitoring of ACLs will require that fishery catches (landings and discards) can be monitored effectively in near real-time. Additionally, Amendment 16 to the Northeast Multispecies Fishery Management Plan allows for the addition of up to 17 new groundfish sectors to begin operations on May 1, 2010 in the Northeast United States groundfish fishery (currently there are two sectors; NEFMC 2009). Each sector will receive Annual Catch Entitlements (ACEs) of certain federally managed groundfish stocks (Table 1). The ACEs are smaller subdivisions of the federal commercial groundfish ACLs which are sub-components of the overall groundfish ACLs. Effectively monitoring the large numbers of quotas, many of which will be small, will require new methods to ensure that the fishery yield is maximized and catch limits are not exceeded.

A standard method for providing near real-time estimates of species stock landings under the sector management regime has been developed (Palmer 2010); however, a standard method for estimating discards has not been established. Currently, near real-time estimates of discards are estimated using a 'moving window' approach. A variation of the 'moving window' approach was investigated by Nitschke (2010) and found to be susceptible to estimation bias and operationally problematic to implement at low sample sizes. Several alternative approaches were investigated including a cumulative method, a quarterly stratified cumulative method and the combined ratio method; all methods exhibited improved performance relative to the 'moving window' approach. The combined ratio, as well as the cumulative method (hereafter referred to as the separate ratio), were investigated as part of the Standardized Bycatch Reporting Methodology (SBRM; Wigely et al 2007) and found to perform similarly both with regards to estimation accuracy and precision. Ultimately, the combined ratio method was used as the preferred method for SBRM as well as in the most recent update of the groundfish stock assessments (NEFSC 2008).

The separate ratio method is similar to the combined ratio except that the combined ratio uses a single pooled annual discard rate applied to stratum-specific estimates of total catch (Cochran 1963). When stratum sizes (expressed as number of trips) are the same, the methods are identical. This paper will explore the performance of the separate ratio method under a variety of temporal stratifications, strata sizes, discard patterns, and sampling rates (observer coverage levels).

Overview of Amendment 16 and anticipated discard strata sizes under sector management and the overall importance of discards relative to total catch

Amendment 16 does not place specific requirements on sector membership; a sector can contain vessels fishing different gear types and operating over a wide area. It is anticipated that some sectors will be organized by gear type (e.g., fixed vs. mobile) and general regions of fishing activity (e.g., Gulf of Maine, Georges Bank); however, many sectors will have more heterogeneous memberships. To account for the variability in fishing practices, some level of stratification will be necessary when estimating discards to achieve estimates with moderate precision. Amendment 16 is unclear on how discard strata will be defined for the purposes of in-season discard estimation, but it does provide the following guidance on stratification for the purposes of assumed discard rates (i.e., estimated using discard information from previous years when in-season information is unavailable).

- "Discard rates used if data from an adequate at-sea monitoring program is [*sic*] not available will be determined using a sector-specific discard rate. A sector-specific discard rate will be calculated for each stock and gear…" (Section 4.2.3.5.3, Pg. 110, NEFMC 2009).

- "Assumed discards will be calculated for the gear/species combinations shown in Table 19." (Section 4.2.3.5.3, Pg. 110, NEFMC 2009)

For the purposes of this paper it has been assumed that the stratification specified by Amendment 16 for assumed discard rates will also apply to in-season discard rates. All discards will be estimated using a species, stock, gear, sector stratification scheme with discards only calculated for the species-gear combinations shown in Table 2. For the purposes of these analyses, otter trawl and gillnet mesh size were assumed to be greater than 6.0" consistent with regulated mesh sizes in the groundfish fishery (USOFR 2009).

To anticipate the potential sizes of discard strata likely to be encountered under sector management, vessel trip report (VTR) data from calendar year 2008 were grouped by sector, gear type and region fished[1]. Region fished was used as a proxy for stock area with regions defined as shown in Table 3. All trips were included in this analysis, regardless of the catch composition. Failure to omit non-groundfish trips could elevate the forecasted strata sizes; however given the mesh size restrictions placed on otter trawl and gillnet gear (> 6.0") the trip counts are likely an accurate representation of groundfish activity in 2008. Forecasted strata sizes (both in terms of number of trips and total vessels) for the sector, gear and stock/region strata are shown in Tables 4a-c. There are a wide range of stratum sizes ranging from less than 10 trips and five vessels to greater than 500 trips and 25 vessels. While it is not known how fishing activity will change under Amendment 16 (e.g., fleet consolidation, increases/decreases in the number of trips), these estimates provide the best current predictors of likely stratum sizes.

While this paper will focus on methods to estimate discards, it is important to keep in mind that a general assumption of the work presented in this paper is that landings are known with certainty. Variability in the total catch of all species, K_{all}, will directly impact both the temporal stability and precision of discard estimates. It is unlikely that landings will be known with certainty at any given point throughout the year for several reasons including less than 100% industry compliance (e.g., late reporting, non-reporting) and poor quality data (e.g., incorrect reporting of trip identifiers, incorrect reporting of species and/or landed pounds). It is anticipated that stringent quality controls and compliance

[1] 2008 data are the last complete year available at the time of writing

enforcement measures will minimize theses occurrences but it is unreasonable to expect that they will not occur to some extent throughout the fishing year. A standard method has been developed to handle missing and poor quality data with regards to landing estimates (Palmer 2010). However, the precautionary approach of this method attempts to overestimate landings when data are missing to ensure that quotas are not exceeded. As information becomes available later in the fishing year, or data are corrected in response to data quality audits, landings will be re-estimated using updated information. This approach could create substantial variability in estimates of K_{all} and in turn, discard estimates.

Estimated discards are only one of the components of total catch that will be used to monitor ACLs and a sector's ACE allocation. Total catch is composed of estimated landings, estimated discard (based on unobserved trips) and observed discards (Wigley 2010). Table 5 shows the ratio of discards to total catch by stock and gear type obtained from observed trips between 2004 and 2008. In the calculation of these ratios, regulatory discards (discarding due to trip limits) were not excluded and Amendment 16 requires the retention of all legal sized fish. Ratios ranged from near zero to 0.82, though ratios were less than 0.20 in 31 of the 35 stock/gear combinations examined. It is recognized that these are averaged over a five year time period and that interannual variability in species availability and/or execution of the fishery could increase/decrease the discards of a particular stock. Overall, discards are likely to be a minor fraction of total catch.

An investigation of the separate ratio method.

A discard simulator was developed in SAS[2] based in part on the work of Nitschke (2010) and Wigley et al. (2007) to further explore the separate ratio method (Equations 1 and 2). In particular, the simulations were focused on comparing the performance of the separate ratio method at varying levels of temporal stratification (e.g., monthly, quarterly, yearly).

The simulator relied on SAS data tables identical to those used to support SBRM analyses (Wigely et al. 2007) and the most recent groundfish assessments (NEFSC 2008). These data tables contain haul-level information on both the retained and discarded catch recorded by the Northeast Fisheries Observer Program (NEFOP). The haul-level data were aggregated to the subtrip level (one record per trip for each gear type and statistical area fished). The most recent five years of data (2004 to 2008) were aggregated and collapsed to a single year (2010) to construct a single year base set from which the simulator could draw population sets. The simulator can be run for all federally managed species, though only those species for which discards will need to be estimated for the groundfish fishery are considered in this paper (Table 1). A summary of the information available within the base sets on a stock, and gear, basis is provided in Table 7.

For each simulation, a population set was constructed from the base data set using random sampling without replacement. Population pulls were constrained by the following parameters: the gear type (fish otter trawl, sink gillnet, benthic longline per

[2] SAS Institute Inc., Cary, NC.

Table 2), mesh size (for fish otter trawl and sink gillnet only, held constant at >6.0" for all simulations), region (using statistical area groupings shown in Table 6), and either the number of trips (fixed number of trips, number of vessels variable) or the fleet size (fixed number of vessels, number of trips variable). Fixing the fleet size may better represent the discard patterns observed within a sector given that intra-vessel discard patterns are likely more homogenous than inter-vessel patterns. In the current version of the simulator, fixing the fleet size does not allow the number of trips to be fixed. For every simulation, the seed value used to draw the population set is archived so that subsequent simulations can be run on identical populations (e.g., run a monthly stratified simulation on the same population used for a yearly stratified simulation).

Subsequent to the creation of the population set, an observed set was created based on the specified observed coverage level. For most simulation, the observer coverage rate was held constant at 0.3 (30% observer coverage) as this is the lower bound of observer coverage anticipated for the groundfish fishery in 2010. The observed set was taken from the population using random sampling without replacement. For every simulation, the seed value used to create the observed set is archived so that subsequent simulations can be run using the identical set of observed trips.

The simulator supports a variety of temporal stratifications of the separate ratio method (weekly, biweekly, monthly, quarterly, yearly), though this paper only explores the monthly, quarterly and yearly temporal strata as these appeared to be the only feasible strata options given the size of the stratums expected under sector management (Tables 4a-c). With yearly stratification, there is only a single temporal stratum and discards are continually updated throughout the year as more information becomes available (Figure 1). The update frequency is contingent on the computational frequency (e.g., daily, weekly). The impact of computational frequency on estimator performance is investigated later in the paper.

With monthly and quarterly stratification, discards are updated throughout the month/quarter but once the month/quarter has passed, the discards are fixed and cannot be impacted by information from trips occurring in other months/quarters. At the start of each month/quarter, the discard rate from the previous month/quarter is carried forward until there is at least one observer trip within that month/quarter available to calculate a new monthly/quarterly rate. This has 'moving window'-like properties, however, the difference is that the final rates are not established until the end of the period and interim values have no influence on the final estimate.

Using the separate ratio method, the total discarded pounds of species *j* is defined as:

$$(1) \qquad \hat{D}_{1,j} = \sum_{h=1}^{L} K_h r_{s,jh}$$

where

(2) $$r_{s,jh} = \frac{\sum_{i=1}^{n_h} d_{jih}}{\sum_{i=1}^{n_h} k_{ih}}$$

$\hat{D}_{1,j}$ is the total estimated discarded pounds for species *j*;
K_h is the total kept pounds in stratum *h*;
$r_{s,jh}$ is the separate ratio for species *j* in stratum *h*;
d_{jih} is discards of species j from observed trip *i* in stratum *h*;
k_{ih} is kept pounds of all species on observed trip *i* in stratum *h*;
N_h is the number of trips in stratum *h*;
n_h is the number of observed trips in stratum *h*.
L is the number of strata *h*=1,…,*L*

And the variance of $\hat{D}_{1,j}$ is defined as:

(3) $$V(\hat{D}_{1,j}) = \sum_{h=1}^{L} K_h^2 \left(\frac{N_h - n_h}{n_h N_h}\right) \frac{1}{\left(\frac{\sum_{i=1}^{n_h} k_{ih}}{n_h}\right)^2} \left[\frac{\sum_{i=1}^{n_h}\left(d_{jih}^2 + \left(r_{s,jh}\right)^2 k_{ih}^2 - 2 r_{s,jh} d_{jih} k_{ih}\right)}{n_h - 1}\right]$$

The number of iterations for each simulation must be specified. Nitschke (2010) carried out each simulation for 5000 iterations. To examine the sensitivity of the simulation results to the number of iterations, four separate simulations of 1000 iterations and a single 3000 iteration simulation were conducted using the yearly and monthly stratified approaches (Figures 2a and b). Results suggest that 1000 iterations are sufficient to achieve stable performance and this was selected as the standard number of iterations for all subsequent simulations.

For each simulation, the simulator produces a table of summary statistics for all of individual iterations (one record per iteration). From these run-specific summary statistics, simulation summaries can be generated as means of assessing general estimator performance:

1. **Median relative difference**: The median value from 1000 iterations of the relative difference between the estimated discards and the true discard value (relative measure of median-bias).
2. **Mean relative difference**: The mean value from 1000 iterations of the relative difference between the estimated discards and the true discard value (relative measure of mean-bias).
3. **Fraction of runs +/- 5.0% difference**: The fraction of iterations within +/- 5% relative difference (measure of the probability that any single realization is correct).

4. **Interquartile range of the terminal discard estimate**: The interquartile range of the relative differences from the 1000 iterations (measure of the spread of realizations – how wrong can the estimator be?).
5. **Mean terminal CV**: The mean of the CV at the end of the year from each of the 1000 iterations (measure of the level of precision associated with the end of the year discard estimate).
6. **Mean number of weeks with null dk**: The mean number of weeks when a dk ratio could not be computed (measure of how much imputation will be required).
7. **Mean number of weeks with null variance**: The mean number of weeks when a variance could not be computed (measure of how much of the time series will be without 'real' estimates of precision).
8. **Mean week when quota was first exceeded**: The mean week when the estimated discards exceeded the quota (assumes no uncertainty in the landings; measure of how bias/variability in the discard estimates will lead to premature closure of a fishery). In these analyses the 'quota' was artificially set as the true catchy (actual landings and discard).
9. **Mean number of weeks when discard estimates were adjusted down**: The mean number of weeks when the discard estimates in week t+1 < week t (measure how many 'down' corrections occurred).
10. **Average change when discard estimate was adjusted down**: The average change relative to the terminal discard estimate when 'down' corrections occurred (measure of the average magnitude of the 'down' corrections).

Prior to a performing a structured experiment to evaluate estimator performance, several investigative simulations were performed examining the performance of the yearly stratified method and monthly stratified method across a wide variety of discard patterns. Candidate stocks and gear were selected from Table 7 based primarily on the variability in ratio of discards to retained catch (dk ratio); stock/gears were selected across the range of dk ratio CV values observed. For each stock/gear combination shown in Figures 4 and 5, simulations were conducted using both temporal stratifications on identical populations with identical sets of observed trips (population was restricted by a fleet size of 15 vessels). The investigative results suggest that the yearly stratified method exhibited a smaller amount of bias in the discard estimates as well as less variability among the individual runs relative to the monthly stratified approach (Figure 4). In general, the monthly stratified approach performed better on those stock/gears with less variability in the dk ratios; the example of discards of Gulf of Maine Atlantic cod *Gadus morhua* in the longline fishery is an exception. The coefficients of variation (CV) of the terminal discard estimates (end of the year) from the monthly stratified method were generally lower than the yearly stratified method, though the amount of variability in the terminal CV was greater (Figure 5).

Subsequent to the investigative simulations, a factorial design experiment was conducted to examine the performance of the monthly, quarterly and yearly stratified methods across a range of fleet sizes and discard patterns. Fleet sizes were selected to cover the range of observed stratum sizes in Tables 4a-c; three fleet sizes were selected: small (5 vessels), medium (15 vessels) and large (25 vessels). Three different levels of discard variability were also selected (based on Table 7): low (Georges Bank haddock *Melanogrammus aeglefinus* discards in the longline fishery), medium (Gulf of Maine haddock *Melanogrammus aeglefinus* discards in the gillnet fishery), and high (witch flounder *Glyptocephalus cynoglossus* discards in the trawl fishery). In all 27 simulations (3 temporal strata x 3 fleet sizes x 3 discard patterns) discards were computed weekly and the observer coverage was held constant at 0.3.

Overall, the results suggest that the yearly stratified approach performs better when the populations are small (small fleets) and discard variability is high (Tables 8a-c). As the population size becomes larger and discards patterns less variable, the monthly and quarterly stratified approaches are comparable to the yearly stratified approach. The monthly and quarterly approaches consistently have lower terminal CV values which would be expected since variance reduction is one of the benefits of stratification. However, to some extent these lower CVs are an artificial product of small sample sizes. When strata are sufficiently small, the monthly and quarterly approaches may have insufficient observations in some of temporal strata to calculate a CV. Because of the cumulative nature of the variance calculation (Equation 3), null variances in individual strata have the effect of artificially lowering the terminal CV.

Implementation of the separate ratio method can be problematic from an operational standpoint in that discard ratios are being continually updated and can fluctuate from week to week. For example, the estimates of discard for trips occurring in week 1 may be different when recalculated in week 2 using an updated ratio. The monthly and quarterly approaches attempt to isolate this effect, such that once the month/quarter has passed, those discards will be held constant for the remainder of the year. However, because the discard ratio is continually being reset at each time step, discard estimates at the beginning of each time step will vary widely. Conversely, the yearly approach can experience substantial variability early in the year, but large discarding events late in the year are largely buffered by an accumulated years worth of observations resulting in less variability in the discard estimates. This reduces the variability of the yearly approach at the end of the fishing season, which is the period of the year when catches are most likely to be nearing the quota. Comparing the mean number of weeks when discard estimates are adjusted down and the average change when a down adjustment occurs in Tables 8a-c, these properties can be observed. The yearly approach experiences a larger number of down adjustment throughout the year, but they are of a much smaller magnitude relative to the monthly and quarterly approaches.

Comparison of asymptotic variance estimates to bootstrapped estimates of variance

Asymptotic [analytic] variances of the discard estimate D_{1j} can be calculated by Equation 3 (Wigley et al. 2007 after Cochran 1963). The variance estimate assumes certain properties of the underlying data which may not be met, particularly at low sample sizes. Alternatively discards and their associated variances can be estimated by using nonparametric bootstrap techniques which only assume that the sample is representative from the population from which it was drawn. Regardless of the approach, small samples are problematic.

For a subset of the simulations, discards and variances were estimated using the nonparametric bootstrap by drawing a random sample with replacement from the observed set of the same size as the original observed set (i.e., observed trips could be used multiple times). For each iteration, the observed set was resampled 500 times (500 bootstraps pulls for each of the 1000 iterations). For each iteration, several diagnostics are archived including: the bootstrap seed value (for further investigation), the mean terminal discard estimate (discard estimate at the end of the year) and the CV of the terminal discard estimate. The mean terminal discard estimates and CVs derived from the bootstrap can then be compared to the point estimates obtained from the analytical approach.

The two methods were compared under three levels of mean terminal CVs observed in the analytical runs: low, medium and high (based on Figure 5). The examples chosen were discards of Gulf of Maine Atlantic cod in the longline fishery, discards of Georges Bank yellowtail flounder *Limanda ferrunginea* in the trawl fishery, and pollock *Pollachius virens* in the longline fishery. The yearly stratified analytic runs from the investigative simulations were reproduced using a bootstrap approach (same population and observed set of trips). In all situations the fleet size was held at 15 vessels with resulting populations of 76, 113 and 215 trips, respectively. Discards were computed weekly in all simulations.

The analytic estimates of discards are nearly identical to the bootstrap means (Figures 8a through 8c). However, the example of Gulf of Maine Atlantic cod in the longline fishery shows some evidence that the analytic estimates are slightly lower than the bootstrap estimates. In all the other comparisons, the estimate pairs showed close agreement.

The comparison of CVs showed evidence that the analytic CVs are biased low relative to the bootstrap CVs (Figures 9a through 9c). The amount of bias is positively correlated with the CV. In general the amount of bias is small relative to the CV (approximately 10 to 20%). The strong relationship between the two estimates of variance does suggest that the analytic variance is sufficient for inferring general scale, but may be insufficient for providing an accurate measure of the true variance. Analytic estimates of variance can be problematic when the frequency of zero observations in the population is high (Figure 9c). Pollock discards are rare in the longline fishery resulting in a high proportion of trips with zero discards (Table 3). When the population set is small, the bootstrap method is capable of achieving higher variances than can be estimated using an analytical approach because of the sampling with replacement. Rerunning the pollock example with a population size of 650 trips removes this artifact (Figure 9d).

How does the computational frequency affect discard estimates and measures of precision?

Amendment 16 will require sector managers to file weekly reports that document sector catch to date. To facilitate this report, discard estimates must be available on a weekly basis. It is likely that as sectors near their ACE for a particular stock, the National Marine Fisheries Service (NMFS) will require reporting at a higher frequency, possibly daily. To investigate whether the computational frequency of discard rates will impact discard estimates and measures of precision, the performance of the monthly, quarterly and yearly stratification approaches were explored when discard estimates are generated both daily and weekly.

Because the separate ratio is continually updated the computational frequency should not impact the estimates of discards at any given time. Results support this conclusion (Table 6). The most significant impacts of the computational frequency are the number and magnitude of adjustments. When discard estimates are computed weekly, there are fewer ‘down’ adjustments of the discard estimates, but they are of a larger magnitude. This trend is identical across all temporal stratification.

How is the precision of discard estimates affected by the level of observer coverage?

It is expected that observer coverage in fishing year 2010 will range from 30 to 40% contingent on a variety of factors, but notably, NMFS funding, average trip length and whether a vessel is in the common pool or an organized sector. Amendment 16 states that observer coverage must "… meet the coefficient of variation in the Standardized Bycatch Reporting Methodology." (NEFMC 2009, Section 4.2.3.5.3 Pg. 109). The threshold coefficient of variation widely used in the Standardized Bycatch Reporting Methodology is 30% (0.30). It is unknown whether the 30 – 40% observer coverage expected in 2010 will be sufficient to meet this standard for all stocks, gears and sectors. Examining the results shown in Figure 5 where fleet size was held constant at 15 vessels, of the six stock/gear/sector strata examined only two had mean terminal CVs below the 30% threshold. To better understand how discard estimates and their associated CVs will vary in response to realized observer coverage, three scenarios of discard variability were examined: low (discards of Gulf of Maine haddock in the longline fishery), medium (discards of Acadian redfish *Sebastes fasciatus* in the trawl fishery) and high (discards of Gulf of Maine haddock in the trawl fishery). Sixteen levels of observer coverage were explored ranging from 0.1 to 1.0, with observer coverage rates sampled every 0.01 from 0.95 to 1.0. All simulations were performed using the yearly stratified approach on a population pull of 200 trips and discards computed weekly.

Overall, the mean bias of the discard estimates were low (< ±0.05) at all levels of observer coverage (Figure 10). Bias generally decreased with increasing observer coverage. A 40% observer coverage was sufficient to achieve a 0.30 CV in only the discard estimates of Georges Bank haddock in the longline fishery (Figure 11). It is important to note the strata sizes in all of these simulations were relatively large compared to the strata sizes shown in Tables 4a-c; results from Tables 8a-c indicate that the CVs increase with decreasing strata sizes. If the discard patterns used in these simulations are similar to what will be observed in 2010, observer coverage rates ≤40% will likely be insufficient to achieve 0.30 CV across all strata.

What can the precision of a discard estimate tell us about management uncertainty?

The results from these simulations suggest that discard estimates are highly variable with the accuracy contingent on the variability of the discards occurring in the population, the size of the strata being sampled and the level of observer coverage (sampling rate). Given the large variability in possible discard estimates caused by differences in the sampling frame, what is the certainty that any single discard point estimate accurately reflects the true discards?

By comparing the mean terminal CV of each simulation to the proportion of iterations within ± bounds of the true discards, the terminal CV can be translated into a probability that any point discard estimate reflects the true value. Results show a strong functional relationship between the average terminal CV and the probability of any single discard estimate accurately reflecting the truth (Figure 12). For example, at an average CV of 0.3, there's an approximate 15% probability than any single discard estimate is ± 5% of the true value and a 25% probability that an estimate is ± 10% of the true value. It's important to note that this relationship addresses the likelihoods at an aggregate level, but not necessarily at the level of an individual point estimate. The spread in terminal CVs within each simulation iteration is variable (Figure 5). Individual iterations can be relatively precise, but inaccurate and vice versa. Despite these limitations, there is the potential that the CV of a discard estimate could be used to inform management actions resulting from in-season discard estimates (e.g., a decision to close the fishery).

Conclusions

From an operational standpoint, it is advantageous to apply a single preferred method that performs well under the suite of conditions expected. The yearly stratified separate ratio method appears to be the most robust of the discard estimators examined. The monthly and quarterly temporally stratified approaches are susceptible to estimation bias when applied to small strata and/or strata with high variability in the discard patterns. These methods can provide more precise estimates of discards relative to the yearly method, however when applied to small strata, the estimates of precision may be artificially low.

The analytic (asymptotic) methods of estimating variance are slightly biased (low), but the bias problems are small relative to the scale of the precision. The analytical method is probably sufficient for providing uncertainty information needed to inform management decisions, but if more accurate measures of precision are needed, a bootstrap approach may need to be implemented.

Given the small strata sizes likely under Amendment 16 an expectation of discard estimate CVs below "…the coefficient of variation in the Standardized Bycatch Reporting Methodology" may be unrealistic. If the discard patterns used in these simulations are similar to what will be observed in 2010, observer coverage rates ±40% will likely be insufficient to achieve 0.30 CV across all strata.

There is the potential that the CV of a discard estimate could be used to inform management actions resulting from in-season discard estimates (e.g., a decision to close the fishery). It is recognized that uncertainty in estimating discards may complicate ACE monitoring; however, the extent will depend not only on the uncertainty in the discard estimate, but also the contribution of discards to the overall ACE accounting (variable by sector and stock) and the variability/stability of landings estimates.

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Tables

Table 1. List of stocks included in the Northeast Multispecies Fishery Management Plan for which groundfish sectors will be allocated annual catch entitlements (ACE) in fishing year 2010. Georges Bank Atlantic cod (*Gadus morhua*) and haddock (*Melanogramus aeglefinus*) will be subdivided into the Eastern and Western United States (US) and Canada (CN) Resources Sharing Agreement areas.

Species	**Stock**	**Sub-stock**
Atlantic cod (*Gadus morhua*)	Gulf of Maine	
	Georges Bank	Eastern US/CN Western US/CN
Haddock (*Melanogrammus aeglefinus*)	Gulf of Maine	
	Georges Bank	Eastern US/CN Western US/CN
Pollock (*Pollachius virens*)	Unit	
White hake (*Urophycis tenuis*)	Unit	
Acadian redfish (*Sebastes fasciatus*)	Unit	
Yellowtail flounder (*Limanda ferruginea*)	Gulf of Maine/Cape Cod	
	Georges Bank	
	Southern New England/Mid-Atlantic	
Winter flounder (*Pseudopleuronectes americanus*)	Gulf of Maine	
	Georges Bank	
Witch flounder (*Glyptocephalus cynoglossus*)	Unit	
American plaice (*Hippoglossoides platessoides*)	Unit	

Table 2. Species and gear types for which calculated discard rates will be applied as specified by Amendment 16 (modified from Table 19, NEFMC 2009).

Gear	**Species**
Trawl	All
Gillnet	Atlanitc cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), pollock (*Pollachius virens*), white hake (*Urophycis tenuis*), yellowtail flounder (*Limanda ferruginea*), winter flounder (*Pseudopleuronectes americanus*), witch flounder (*Glyptocephalus cynoglossus*), American plaice (*Hippoglossoides platessoides*), Acadian redfish (*Sebastes fasciatus*)
Longline	Atlanitc cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), pollock (*Pollachius virens*), white hake (*Urophycis tenuis*), Acadian redfish (*Sebastes fasciatus*)

Table 3. List of the general regions and the statistical areas that define them used to approximate stock areas in Table 4a through 4c.

Region	Statistical areas
Gulf of Maine (GOM)	464, 465, 467, 511, 512, 513, 514, 515
Georges Bank (GBK)	521, 522, 525, 526, 561, 562
Southern New England/Mid-Atlantic (SNE)	537, 538, 539, 611, 612, 613, 614, 615, 616

Table 4a. Examples of potential discard stratum sizes for fish otter trawl (OTF) gear under sector management. Stratum sizes were estimated using 2008 vessel trip report data and sector roster lists current as of January 1, 2010. Data were divided into stock/region using the definitions included in Table 3. **Note: NEFS = Northeast Fisheries Sector, NCCS = Northeast Coastal Communities Sector, GOM = Gulf of Maine, GBK = Georges Bank, SNE = Southern New England/Mid-Atlantic. Georges Banks is not subdivided into eastern/western United States Canada as shown in Table 2.*

Sector Name	VTR gear code	Stock/region	Number of trips	Number of vessels
Fixed Gear Sector	OTF	SNE	1	1
NEFS 11	OTF	GBK	1	1
Port Clyde Community Groundfish Sector	OTF	GBK	1	1
Port Clyde Community Groundfish Sector	OTF	SNE	1	1
NCCS	OTF	GBK	3	1
NEFS 4	OTF	SNE	4	2
Tri-State Sector	OTF	SNE	5	2
NEFS 13	OTF	GOM	6	2
NEFS 2	OTF	SNE	6	5
NEFS 8	OTF	SNE	9	6
NEFS 4	OTF	GBK	18	4
NEFS 9	OTF	GOM	21	1
NEFS 8	OTF	GOM	22	1
Sustainable Harvest Sector	OTF	SNE	23	5
NEFS 5	OTF	GBK	24	10
NEFS 9	OTF	SNE	28	7
NEFS 10	OTF	GBK	29	8
NCCS	OTF	SNE	35	1
Common	OTF	GBK	48	8
NEFS 6	OTF	GOM	65	8
NEFS 6	OTF	GBK	71	8
NEFS 4	OTF	GOM	105	2
NEFS 10	OTF	SNE	105	5
Tri-State Sector	OTF	GBK	105	8
NEFS 2	OTF	GBK	111	17
Tri-State Sector	OTF	GOM	149	7
Port Clyde Community Groundfish Sector	OTF	GOM	149	12
NEFS 13	OTF	GBK	153	18
NEFS 7	OTF	GBK	178	13
NEFS 8	OTF	GBK	178	13
NEFS 12	OTF	GOM	230	4
NEFS 7	OTF	SNE	237	11
Common	OTF	GOM	278	13
Sustainable Harvest Sector	OTF	GBK	284	23
NEFS 9	OTF	GBK	286	19
NEFS 13	OTF	SNE	313	19
NEFS 11	OTF	GOM	487	11
NEFS 10	OTF	GOM	547	10
Sustainable Harvest Sector	OTF	GOM	630	26
NEFS 5	OTF	SNE	1436	30
Common	OTF	SNE	2149	68
NEFS 2	OTF	GOM	2917	41

Table 4b. Examples of potential discard stratum sizes for sink gillnet (GNS) gear under sector management. Stratum sizes were estimated using 2008 vessel trip report data and sector roster lists current as of January 1, 2010. Data were divided into stock/region using the definitions included in Table 3. **Note: NEFS = Northeast Fisheries Sector, NCCS = Northeast Coastal Communities Sector, GOM = Gulf of Maine, GBK = Georges Bank, SNE = Southern New England/Mid-Atlantic. Georges Banks is not subdivided into eastern/western United States Canada as shown in Table 2.*

Sector Name	VTR gear code	Stock/region	Number of trips	Number of vessels
Sustainable Harvest Sector	GNS	GBK	1	1
NEFS 3	GNS	SNE	2	2
Port Clyde Community Groundfish Sector	GNS	GBK	3	1
Fixed Gear Sector	GNS	GOM	4	2
Sustainable Harvest Sector	GNS	SNE	4	2
NEFS 3	GNS	GBK	6	3
NEFS 7	GNS	SNE	7	1
Common	GNS	GBK	11	3
NEFS 11	GNS	GBK	12	4
NEFS 10	GNS	GBK	13	4
NEFS 2	GNS	GOM	26	2
Common	GNS	GOM	227	7
Common	GNS	SNE	264	21
Sustainable Harvest Sector	GNS	GOM	288	6
NEFS 10	GNS	GOM	393	8
Fixed Gear Sector	GNS	GBK	480	12
Port Clyde Community Groundfish Sector	GNS	GOM	603	12
NEFS 11	GNS	GOM	813	20
NEFS 3	GNS	GOM	1714	30

Table 4c. Examples of potential discard stratum sizes for benthic longline (LLB) gear under sector management. Stratum sizes were estimated using 2008 vessel trip report data and sector roster lists current as of January 1, 2010. Data were divided into stock/region using the definitions included in Table 3. **Note: NEFS = Northeast Fisheries Sector, NCCS = Northeast Coastal Communities Sector, GOM = Gulf of Maine, GBK = Georges Bank, SNE = Southern New England/Mid-Atlantic. Georges Banks is not subdivided into eastern/western United States Canada as shown in Table 2.*

Sector Name	VTR gear code	Stock/region	Number of trips	Number of vessels
Fixed Gear Sector	LLB	SNE	1	1
NEFS 10	LLB	SNE	1	1
Sustainable Harvest Sector	LLB	GBK	2	1
Fixed Gear Sector	LLB	GOM	3	2
NEFS 11	LLB	GBK	5	1
Common	LLB	GBK	6	1
Port Clyde Community Groundfish Sector	LLB	GOM	17	2
NCCS	LLB	GOM	21	1
Sustainable Harvest Sector	LLB	GOM	45	2
Common	LLB	SNE	50	4
NEFS 10	LLB	GOM	104	4
Common	LLB	GOM	171	11
Fixed Gear Sector	LLB	GBK	178	15
NEFS 3	LLB	GOM	380	17

Table 5. Ratios of discards (d) to total species catch (t) in 2004 to 2008 Northeast Fisheries Observer Program (NEFOP) data used to create the base set used in the simulations. Ratios greater than 0.20 are shown in italics. Ratios are not shown for those species gear combinations not included in Table 2. *Note: the large dt ratio for Georges Bank yellowtail flounder in the gillnet fishery is based on only 12 trips.*

Stock		**Gear** Otter trawl dt ratio	**Gear** Gillnet dt ratio	**Gear** Longline dt ratio
Atlantic cod (*Gadus morhua*)	Gulf of Maine	*0.22*	0.09	*0.30*
	Georges Bank	0.16	0.10	0.15
Haddock (*Melanogrammus aeglefinus*)	Gulf of Maine	0.03	0.08	0.05
	Georges Bank	0.12	0.07	0.06
Pollock (*Pollachius virens*)		0.00	0.03	0.12
White hake (*Urophycis tenuis*)		0.02	0.03	0.14
Acadian redfish (*Sebastes fasciatus*)		0.14	0.09	0.07
Yellowtail flounder (*Limanda ferruginea*)	Cape Cod/Gulf of Maine	*0.31*	0.10	
	Georges Bank	0.10	*0.82*	
	Southern New England/mid-Atlantic	*0.26*	0.12	
Winter flounder (*Pseudopleuronectes americanus*)	Gulf of Maine	0.12	0.03	
	George Bank	0.04	0.14	
American plaice (*Hippoglossoides platessoides*)		0.16	0.19	
Witch flounder (*Glyptocephalus cynoglossus*)		0.06	0.04	

Table 6. Stock area boundaries by species used in all simulations.

Stock region	Species	Statistical areas used in simulations
Gulf of Maine	Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), winter flounder (Pseudopleuronectes americanus)	464, 465, 467, 511, 512, 513, 514, 515
	Yellowtail flounder (*Limanda ferrunginea*)	464, 465, 467, 511, 512, 513, 514, 515, 521
Georges Bank	Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*)	521, 522, 561, 562, 525, 526, 537, 538, 539
	Winter flounder (*Pseudopleuronectes americanus*), yellowtail flounder (*Limanda ferrunginea*)	522, 561, 562, 525
Southern New England/Mid-Atlantic	Yellowtail flounder (*Limanda ferrunginea*)	526, 537, 538, 539, 611, 612, 613, 614, 615, 616
Unit	Witch flounder (*Glyptocephalus cynoglossus*), pollock (*Pollachius virens*), white hake (*Urophycis tenuis*), American plaice (*Hippoglossoides platessoides*)	464, 465, 467, 511, 512, 513, 514, 515, 522, 561, 562, 525, 526, 537, 538, 539, 611, 612, 613, 614, 615, 616
	Acadian redfish (*Sebastes fasciatus*)	464, 465, 467, 511, 512, 513, 514, 515, 522, 561, 562, 525, 526

Table 7. Summary of base data sets extracted from data collected between 2004 to 2008 by the Northeast Fisheries Observer Program. Stock regions are as defined in Table 6. Grey shaded cells indicate those stock/gear combinations used as examples in this paper. *Definitions: dt ratio = ratio of discards to total catch; dk ratio = ratio of discard to retained catch; dk ratio CV = coefficient of variation of dk ratio; dk; dk slope = slope of dk rates over the year (increasing/decreasing rates). Summary information is not shown for flatfish species under the longline gear type because they are not species for which discards must be estimated (Table 2).*

Gear		**Atlantic cod (*Gadus morhua*)**		**Haddock (*Melanogrammus aeglefinus*)**		**Pollock (*Pollachius virens*)**	**White hake (*Urophycis tenuis*)**	**Acadian redfish (*Sebastes fasciatus*)**
		Gulf of Maine	**Georges Bank**	**Gulf of Maine**	**Georges Bank**			
Otter trawl (050; >= 6.0" mesh)	Trips	1030	1934	1030	1934	2863	2863	2411
	Trips w/ discards	572	1298	214	1186	350	587	821
	Vessels	195	277	195	277	416	416	319
	Days fished	324	353	324	353	364	364	361
	dt ratio	0.22	0.16	0.03	0.12	0.00	0.02	0.14
	dk ratio	0.0173	0.0198	0.0008	0.0274	0.0004	0.0005	0.0033
	dk ratio CV	0.039	0.074	0.158	0.044	0.076	0.068	0.049
	dk slope	0.00001400	-0.00001000	-0.00000690	-0.00000901	-0.00000008	0.00000012	-0.00000031
Gillnet (100; >= 6.0" mesh)	Trips	1582	799	1582	799	2517	2517	2117
	Trips w/ discards	1106	311	254	64	471	150	157
	Vessels	145	110	145	110	280	280	179
	Days fished	295	290	295	290	352	352	335
	dt ratio	0.09	0.10	0.08	0.07	0.03	0.03	0.09
	dk ratio	0.0298	0.0050	0.0009	0.0002	0.0034	0.0006	0.0003
	dk ratio CV	0.034	0.082	0.257	0.059	0.051	0.072	0.087
	dk slope	-0.00000745	-0.00004000	-0.00000345	0.00000007	0.00000112	0.00000013	0.00000003
Longline (010)	Trips	157	529	157	529	684	684	669
	Trips w/ discards	142	371	74	497	34	204	123
	Vessels	40	57	40	57	90	90	86
	Days fished	101	151	101	151	215	215	209
	dt ratio	0.30	0.15	0.05	0.06	0.12	0.14	0.07
	dk ratio	0.1546	0.0115	0.0189	0.0504	0.0001	0.0024	0.0004
	dk ratio CV	0.036	0.054	0.033	0.016	0.154	0.038	0.055
	dk slope	0.00147800	-0.00021000	-0.00012000	0.00002100	-0.00000714	0.00001800	0.00000166

Gear		**Yellowtail flounder (*Limanda ferrunginea*)**			**Winter flounder (*Pseudopleuronectes americanus*)**		**American plaice (*Hippoglossoides platessoides*)**	**Witch flounder (*Glyptocephalus cynoglossus*)**
		Cape Cod/Gulf of Maine	**Georges Bank**	**Southern New England/mid-Atlantic**	**Gulf of Maine**	**George Bank**		
Otter trawl (050; >= 6.0" mesh)	Trips	1549	1323	591	1030	1323	2863	2863
	Trips w/ discards	715	903	128	380	421	1565	1386
	Vessels	279	179	204	195	179	416	416
	Days fished	351	338	275	324	338	364	364
	dt ratio	0.31	0.10	0.26	0.12	0.04	0.16	0.06
	dk ratio	0.0052	0.0141	0.0025	0.0019	0.0031	0.0047	0.0022
	dk ratio CV	0.051	0.032	0.045	0.073	0.054	0.035	0.030
	dk slope	-0.00000457	0.00000613	-0.00002000	-0.00001000	0.00000320	0.00000167	0.00000028
Gillnet (100; >= 6.0" mesh)	Trips	2097	12	417	1582	12	2517	2517
	Trips w/ discards	318	2	4	232	2	297	108
	Vessels	176	10	133	145	10	280	280
	Days fished	331	11	195	295	11	352	352
	dt ratio	0.10	0.82	0.12	0.03	0.14	0.19	0.04
	dk ratio	0.0014	0.0003	0.0000	0.0006	0.0001	0.0001	0.0000
	dk ratio CV	0.059	0.030	0.203	0.097	0.024	0.052	0.094
	dk slope	-0.00000798	-0.00018000	0.00000019	-0.00000033	0.00001200	-0.00000029	-0.00000004

Table 8a. Summary of simulations comparing performance of the separate ratio method under a variety of temporal stratifications and fleet size when estimating discards of a species/fleet with low variability in discard rates (based on dk ratio CVs in Table 7). Example shown is for Gulf of Maine haddock (*Melanogrammus aeglefinus*) in the longline fishery. Grey shaded cells indicate which temporal stratification exhibited the optimal performance for a particular fleet size; blue cells indicate a tie.

dK CV level	Temporal stratification	Summary statistic	Fleet size: Small	Fleet size: Medium	Fleet size: Large
Low (haddock in the Georges Bank longline fishery)	Run summaries	Simulation runs	1000	1000	1000
		Total vessels	5	15	25
		Total trips	62	109	197
		Vessels observed	4.1	12.7	18.8
		Trips observed	19	33	59
		Days observed (dates of landing)	17.7	26.6	44.8
	Monthly	Median discard relative difference	-0.032	0.054	-0.013
		Mean discard relative difference	0.011	0.067	0.001
		Fraction of runs +/- 5.0% of true discards	0.151	0.188	0.253
		Interquartile range of the terminal relative difference	0.347	0.276	0.195
		Mean terminal CV	0.197	0.168	0.112
		Mean number of weeks with null dk	8.4	4.1	10.3
		Mean number of weeks with null variance	14.8	7.0	19.4
		Mean week when the 'quota' was first exceed	52.0	53.0	53.0
		Mean number of weeks when discard estimates were adjusted	1.6	0.6	1.9
		Average change when discard estimates were adjusted down (relative to terminal Discard estimate)	-0.0524	-0.0214	-0.0142
	Quarterly	Median discard relative difference	-0.061	0.054	-0.025
		Mean discard relative difference	-0.027	0.067	-0.011
		Fraction of runs +/- 5.0% of true discards	0.157	0.323	0.278
		Interquartile range of the terminal relative difference	0.309	0.264	0.183
		Mean terminal CV	0.203	0.186	0.123
		Mean number of weeks with null dk	4.9	3.5	4.9
		Mean number of weeks with null variance	10.2	5.7	10.5
		Mean week when the 'quota' was first exceed	52.1	53.0	53.0
		Mean number of weeks when discard estimates were adjusted down	2.4	1.2	2.4
		Average change when discard estimates were adjusted down (relative to terminal Discard estimate)	-0.040	-0.030	-0.012
	Year	Median discard relative difference	-0.010	0.011	-0.021
		Mean discard relative difference	0.018	0.027	-0.010
		Fraction of runs +/- 5.0% of true discards	0.153	0.190	0.278
		Interquartile range of the terminal relative difference	0.323	0.288	0.175
		Mean terminal CV	0.223	0.207	0.129
		Mean number of weeks with null dk	1.2	2.1	0.8
		Mean number of weeks with null variance	3.1	4.3	2.3
		Mean week when the 'quota' was first exceed	52.1	53.0	53.0
		Mean number of weeks when discard estimates were adjusted down	3.5	1.8	3.7
		Average change when discard estimates were adjusted down (relative to terminal Discard estimate)	-0.029	-0.044	-0.012

Table 8b. Summary of simulations comparing performance of the separate ratio method under a variety of temporal stratifications and fleet size when estimating discards of a species/fleet with medium variability in discard rates (based on dk ratio CVs in Table 7). Example shown is for Gulf of Maine haddock (*Melanogrammus aeglefinus*) in the gillnet fishery. Grey shaded cells indicate which temporal stratification exhibited the optimal performance for a particular fleet size.

dK CV level	Temporal stratification	Summary statistic	Fleet size: Small	Medium	Large
Medium (haddock in the Gulf of Maine gillnet fishery)	Run summaries	Simulation runs	1000	1000	1000
		Total vessels	5	15	25
		Total trips	35	145	365
		Vessels observed	3.8	11.0	20.2
		Trips observed	11	44	110
		Days observed (dates of landing)	10.8	40.3	89.0
	Monthly	Median discard relative difference	-0.399	0.026	0.006
		Mean discard relative difference	-0.222	0.127	0.046
		Fraction of runs +/- 5.0% of true discards	0.037	0.085	0.140
		Interquartile range of the terminal relative difference	0.845	0.687	0.420
		Mean terminal CV	0.250	0.325	0.274
		Mean number of weeks with null dk	6.0	5.9	3.1
		Mean number of weeks with null variance	12.9	14.2	7.4
		Mean week when the 'quota' was first exceed	46.2	51.1	50.3
		Mean number of weeks when discard estimates were adjusted down	0.8	3.7	6.1
		Average change when discard estimates were adjusted down (relative to terminal Discard estimate)	-0.285	-0.048	-0.025
	Quarterly	Median discard relative difference	-0.195	0.037	0.005
		Mean discard relative difference	-0.021	0.085	0.021
		Fraction of runs +/- 5.0% of true discards	0.038	0.084	0.145
		Interquartile range of the terminal relative difference	1.041	0.584	0.378
		Mean terminal CV	0.574	0.369	0.266
		Mean number of weeks with null dk	3.0	2.0	1.2
		Mean number of weeks with null variance	7.1	5.2	3.2
		Mean week when the 'quota' was first exceed	45.4	51.4	50.6
		Mean number of weeks when discard estimates were adjusted down	1.7	6.8	8.5
		Average change when discard estimates were adjusted down (relative to terminal Discard estimate)	-0.230	-0.045	-0.017
	Year	Median discard relative difference	-0.026	-0.001	0.004
		Mean discard relative difference	-0.018	0.033	0.014
		Fraction of runs +/- 5.0% of true discards	0.063	0.099	0.130
		Interquartile range of the terminal relative difference	1.048	0.531	0.378
		Mean terminal CV	0.631	0.378	0.277
		Mean number of weeks with null dk	0.4	0.3	0.1
		Mean number of weeks with null variance	1.6	0.9	0.5
		Mean week when the 'quota' was first exceed	44.6	51.5	50.6
		Mean number of weeks when discard estimates were adjusted down	1.9	8.3	10.8
		Average change when discard estimates were adjusted down (relative to terminal Discard estimate)	-0.082	-0.034	-0.020

Table 8c. Summary of simulations comparing performance of the separate ratio method under a variety of temporal stratifications and fleet size when estimating discards of a species/fleet with high variability in discard rates (based on dk ratio CVs in Table 7). Example shown is for witch flounder (*Glyptocephalus cynoglossus*) in the trawl fishery. Grey shaded cells indicate which temporal stratification exhibited the optimal performance for a particular fleet size.

dK CV level	Temporal stratification	Summary statistic	Fleet size		
			Small	Medium	Large
High (witch flounder in the trawl fishery)	Run summaries	Simulation runs	1000	1000	1000
		Total vessels	5	15	25
		Total trips	16	100	170
		Vessels observed	3.2	11.2	16.2
		Trips observed	5	30	51
		Days observed (dates of landing)	4.9	29.1	47.3
	Monthly	Median discard relative difference	0.764	-0.011	0.003
		Mean discard relative difference	3.224	0.083	0.037
		Fraction of runs +/- 5.0% of true discards	0.012	0.097	0.116
		Interquartile range of the terminal relative difference	5.686	0.554	0.396
		Mean terminal CV	n/a	0.186	0.202
		Mean number of weeks with null dk	6.8	14.2	7.3
		Mean number of weeks with null variance	11.1	29.9	17.8
		Mean week when the 'quota' was first exceed	39.4	51.1	49.9
		Mean number of weeks when discard estimates were adjusted down	0.3	5.1	6.3
		Average change when discard estimates were adjusted down (relative to terminal Discard estimate)	-3.759	-0.092	-0.029
	Quarterly	Median discard relative difference	0.831	-0.005	-0.017
		Mean discard relative difference	2.970	0.006	0.008
		Fraction of runs +/- 5.0% of true discards	0.015	0.100	0.144
		Interquartile range of the terminal relative difference	5.226	0.488	0.369
		Mean terminal CV	0.307	0.288	0.233
		Mean number of weeks with null dk	4.8	5.0	2.6
		Mean number of weeks with null variance	9.7	11.7	6.7
		Mean week when the 'quota' was first exceed	39.6	51.4	50.2
		Mean number of weeks when discard estimates were adjusted down	0.5	7.6	9.0
		Average change when discard estimates were adjusted down (relative to terminal Discard estimate)	-0.142	-0.061	-0.024
	Year	Median discard relative difference	-0.030	-0.017	-0.010
		Mean discard relative difference	0.726	-0.004	0.009
		Fraction of runs +/- 5.0% of true discards	0.077	0.128	0.152
		Interquartile range of the terminal relative difference	1.115	0.481	0.348
		Mean terminal CV	0.603	0.310	0.238
		Mean number of weeks with null dk	1.4	0.6	0.1
		Mean number of weeks with null variance	3.6	1.7	0.4
		Mean week when the 'quota' was first exceed	40.3	51.4	50.3
		Mean number of weeks when discard estimates were adjusted down	0.7	9.1	9.1
		Average change when discard estimates were adjusted down (relative to terminal Discard estimate)	-0.133	-0.031	-0.015

Table 9. Summary of simulations comparing performance of the separate ratio method under a variety of temporal stratifications when discard rates are computed daily and weekly. Example shown is for white hake (*Urophycis tenuis*) in the longline fishery.

Stock	**Computational frequency of the discard estimate**	**Summary statistic**	**Temporal stratification**		
			Month	**Quarter**	**Year**
White hake longline fishery	Run summaries	Simulation runs			1000
		Total vessels			50
		Total trips			100
		Vessels observed			22.8
		Trips observed			30
		Days observed (dates of landing)			27.3
	Daily	Median discard relative difference	0.034	-0.005	-0.018
		Mean discard relative difference	0.090	0.021	0.003
		Fraction of runs +/- 5.0% of true discards	0.083	0.094	0.108
		SD discard relative difference	0.500	0.404	0.408
		Mean terminal CV	0.358	0.366	0.385
		Mean number of days with null DK	15.4	7.5	2.0
		Mean number of days with null variance	31.6	16.8	4.5
		Number of runs when the 'quota' was exceeded	597	510	488
		Mean day when the 'quota' was first exceed	354.1	354.9	355.0
		Mean number of days when discard estimates were adjusted down	7.4	8.6	10.0
		Average change when discard estimates were adjusted down (relative to terminal Discard estimate)	-0.066	-0.023	-0.014
	Weekly	Median discard relative difference	0.034	-0.005	-0.018
		Mean discard relative difference	0.090	0.021	0.003
		Fraction of runs +/- 5.0% of true discards	0.083	0.094	0.108
		SD discard relative difference	0.500	0.404	0.408
		Mean terminal CV	0.358	0.366	0.385
		Mean number of weeks with null DK	8.9	4.3	0.6
		Mean number of weeks with null variance	16.8	9.7	1.4
		Number of runs when the 'quota' was exceeded	570	497	475
		Mean week when the 'quota' was first exceed	51.9	51.9	51.9
		Mean number of weeks when discard estimates were adjusted down	2.1	3.0	3.9
		Average change when discard estimates were adjusted down (relative to terminal Discard estimate)	-0.117	-0.039	-0.023

Figures

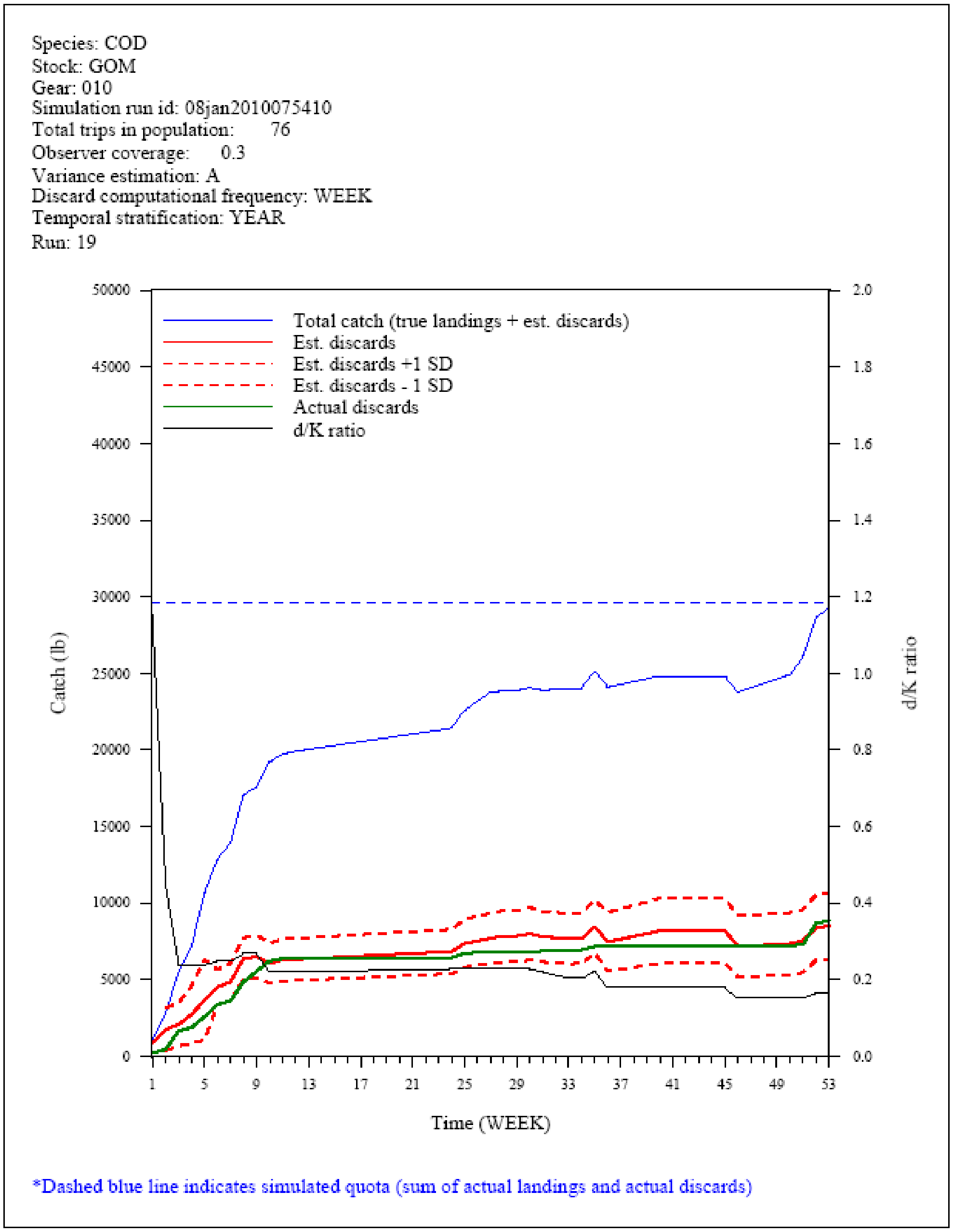

Figure 1. Example output of one iterations using the separate ratio method with yearly temporal stratification to estimate discards of Gulf of Maine Atlantic cod (*Gadus morhua*) in the longline fishery. In this example discards are computed weekly.

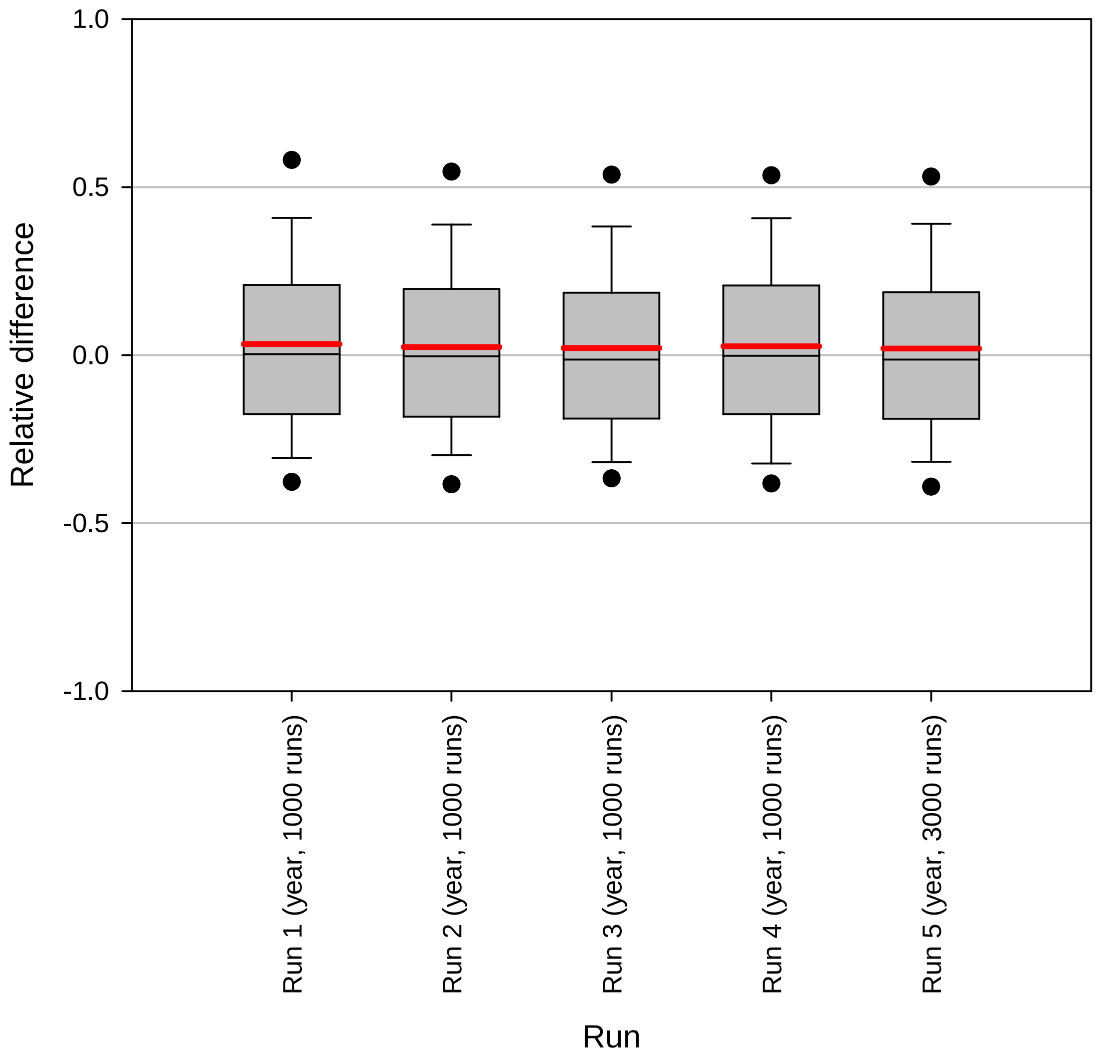

Figure 2. Box plots illustrating the relative stability of simulation results based on 1000 iterations of the separate ratio with yearly temporal stratification to estimate discards of Gulf of Maine Atlantic cod (*Gadus morhua*) in the longline fishery. All simulations were performed on the same population set; simulations 1 – 4 were run 1000 times, run 5 was run 3000 times. *Boxes show the 25th, 50th and 75th percentile; whiskers show the 10th and 90th percentiles and dots show the 5th and 95th percentiles. Bold red line represents the mean.*

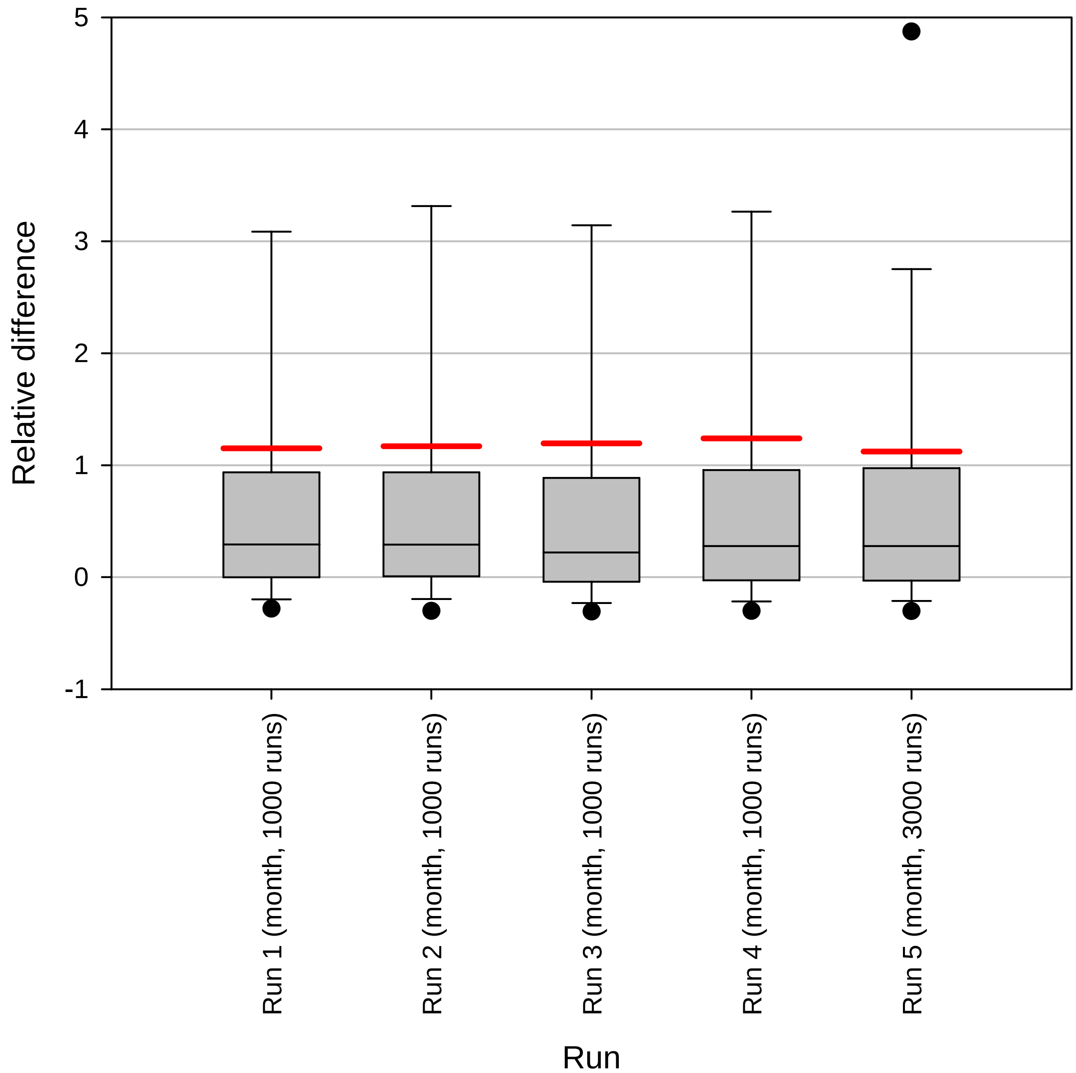

Figure 3. Relative stability of simulation results based on 1000 iterations of the separate ratio with monthly temporal stratification to estimate discards of Gulf of Maine Atlantic cod (*Gadus morhua*) in the longline fishery. All simulations were performed on the same population set; simulations 1 – 4 were run 1000 times, run 5 was run 3000 times. *Boxes show the 25th, 50th and 75th percentile; whiskers show the 10th and 90th percentiles and dots show the 5th and 95th percentiles. Bold red line represents the mean.*

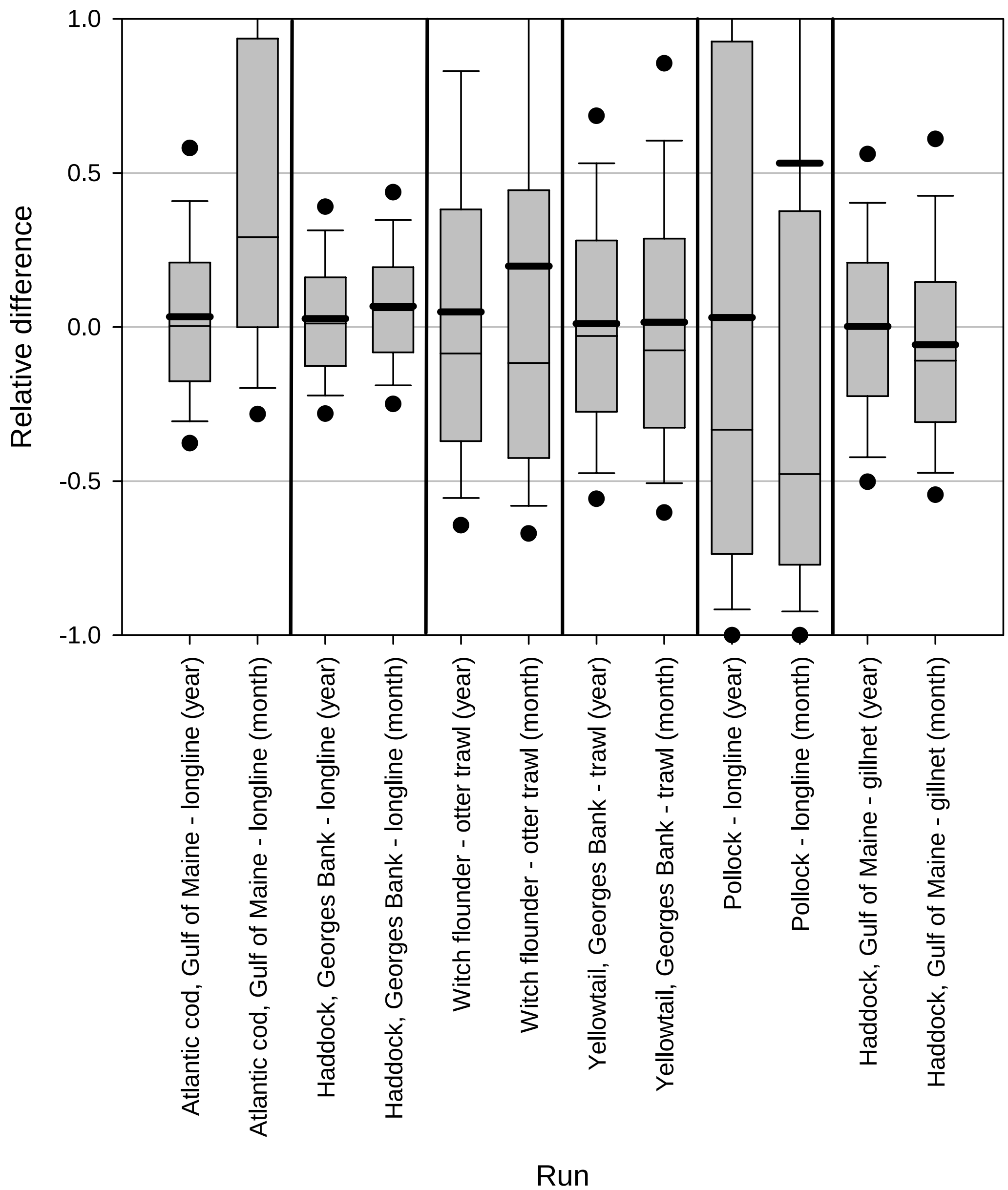

Figure 4. Box plots comparing the distribution of terminal (end of year) discard estimates from simulations of the separate ratio run using both yearly and monthly temporal stratification run on six different stock/gear populations. In each case, the yearly and monthly simulations were performed on identical populations with identical set of observed trips. *Boxes show the 25th, 50th and 75th percentile; whiskers show the 10th and 90th percentiles and dots show the 5th and 95th percentiles. Bold red line represents the mean. *Note: vertical axis was truncated to highlight the interquartile range.*

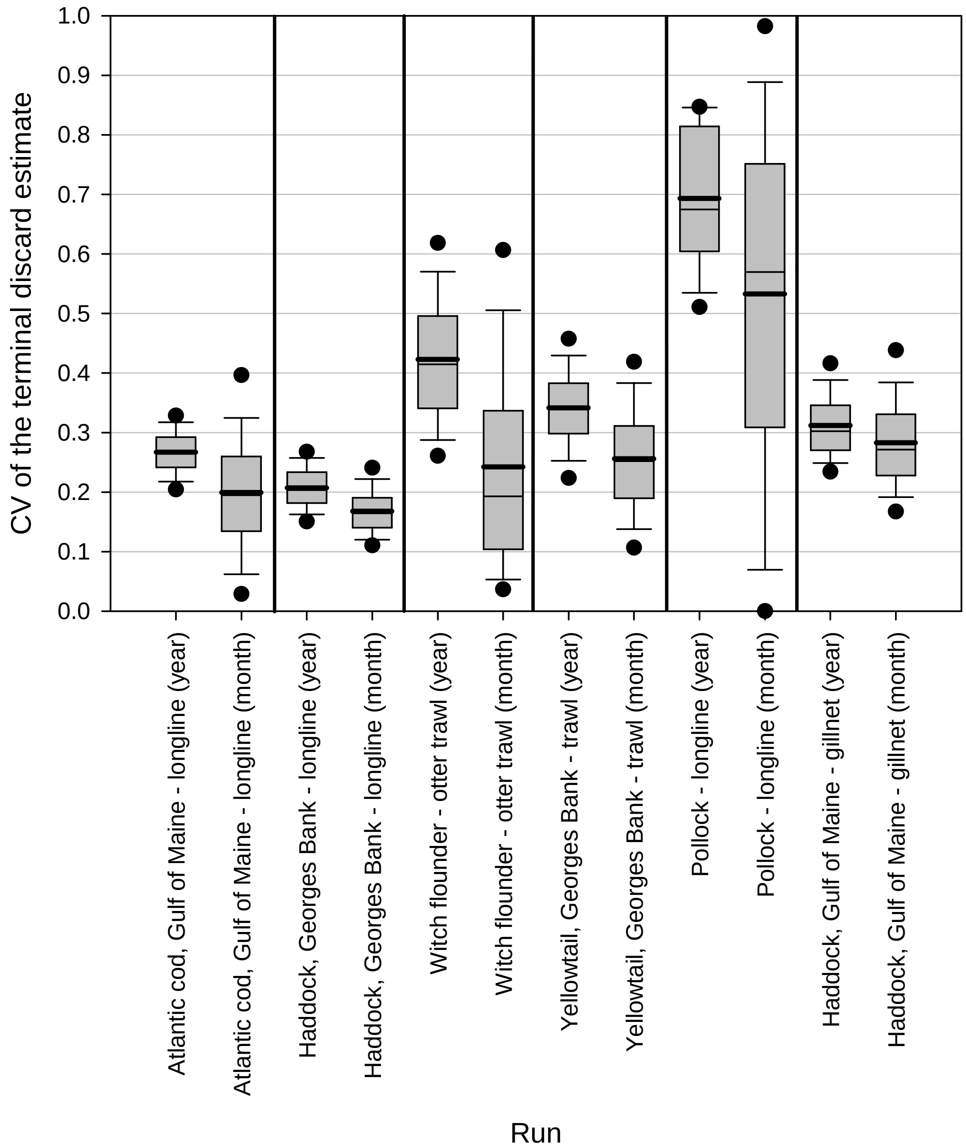

Figure 5. Box plots comparing the distribution of coefficients of variation (CV) from the terminal (end of year) discard estimates outputted from simulations of the separate ratio run using both yearly and monthly temporal stratification run on six different stock/gear populations. In each case, the yearly and monthly simulations were performed on identical populations with identical set of observed trips. *Boxes show the 25th, 50th and 75th percentile; whiskers show the 10th and 90th percentiles and dots show the 5th and 95th percentiles. Bold red line represents the mean.*

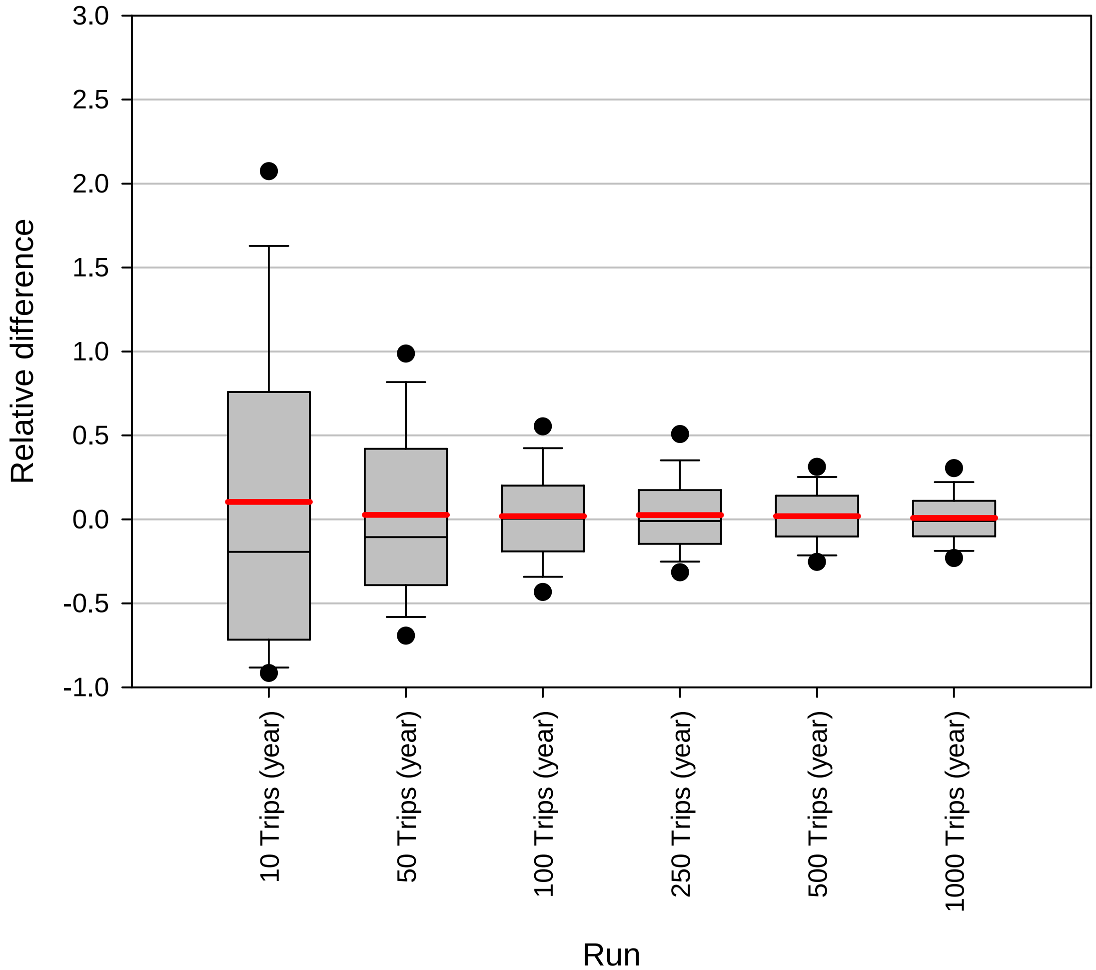

Figure 6. Box plots showing the distribution of terminal (end of year) discard estimates from simulations of the separate ratio run using yearly temporal stratification under a variety of population sizes (number of trips). Example shown is for discards of Gulf of Maine Atlantic cod (*Gadus morhua*) in the gillnet fishery. *Boxes show the 25th, 50th and 75th percentile; whiskers show the 10th and 90th percentiles and dots show the 5th and 95th percentiles. Bold red line represents the mean.*

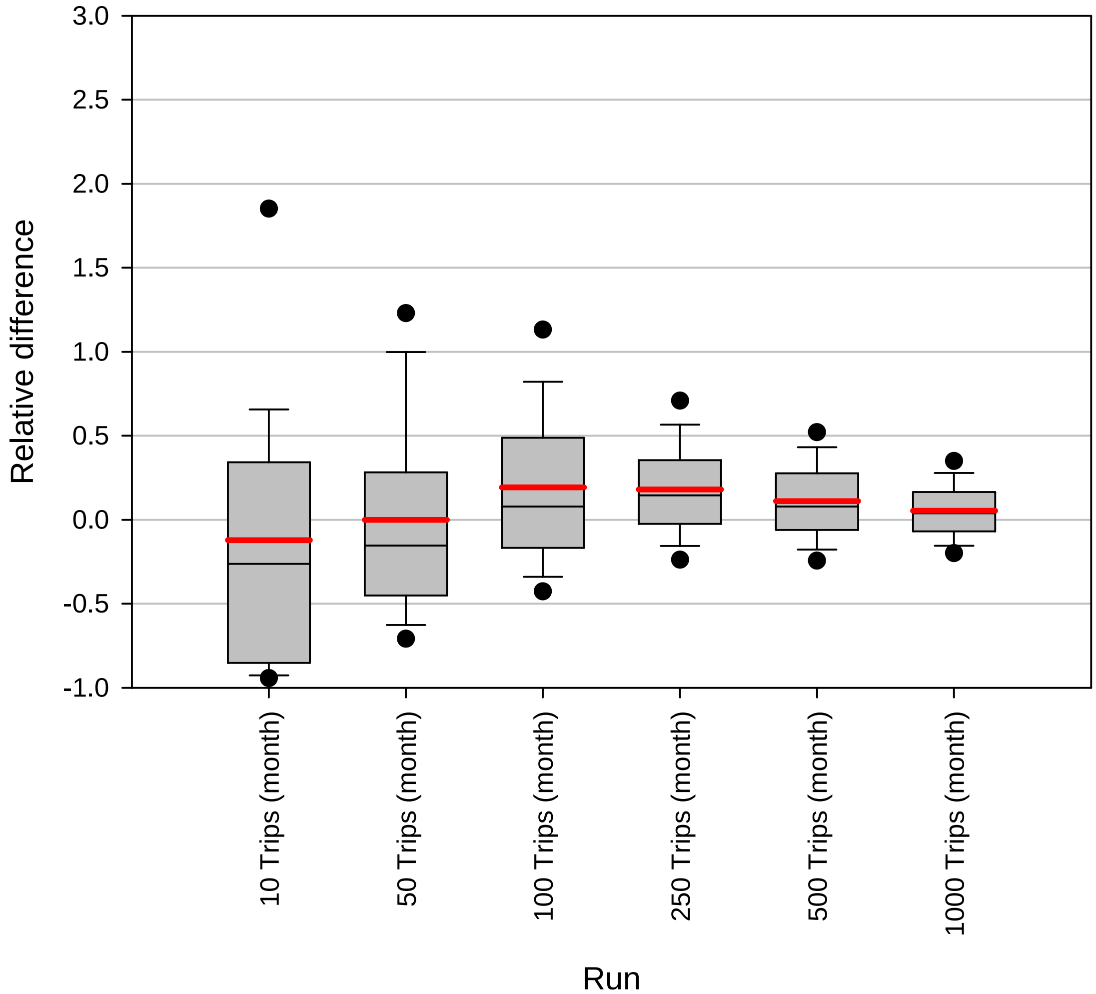

Figure 7. Box plots showing the distribution of terminal (end of year) discard estimates from simulations of the separate ratio run using monthly temporal stratification under a variety of population sizes (number of trips). Example shown is for discards of Gulf of Maine Atlantic cod (*Gadus morhua*) in the gillnet fishery. *Boxes show the 25th, 50th and 75th percentile; whiskers show the 10th and 90th percentiles and dots show the 5th and 95th percentiles. Bold red line represents the mean.*

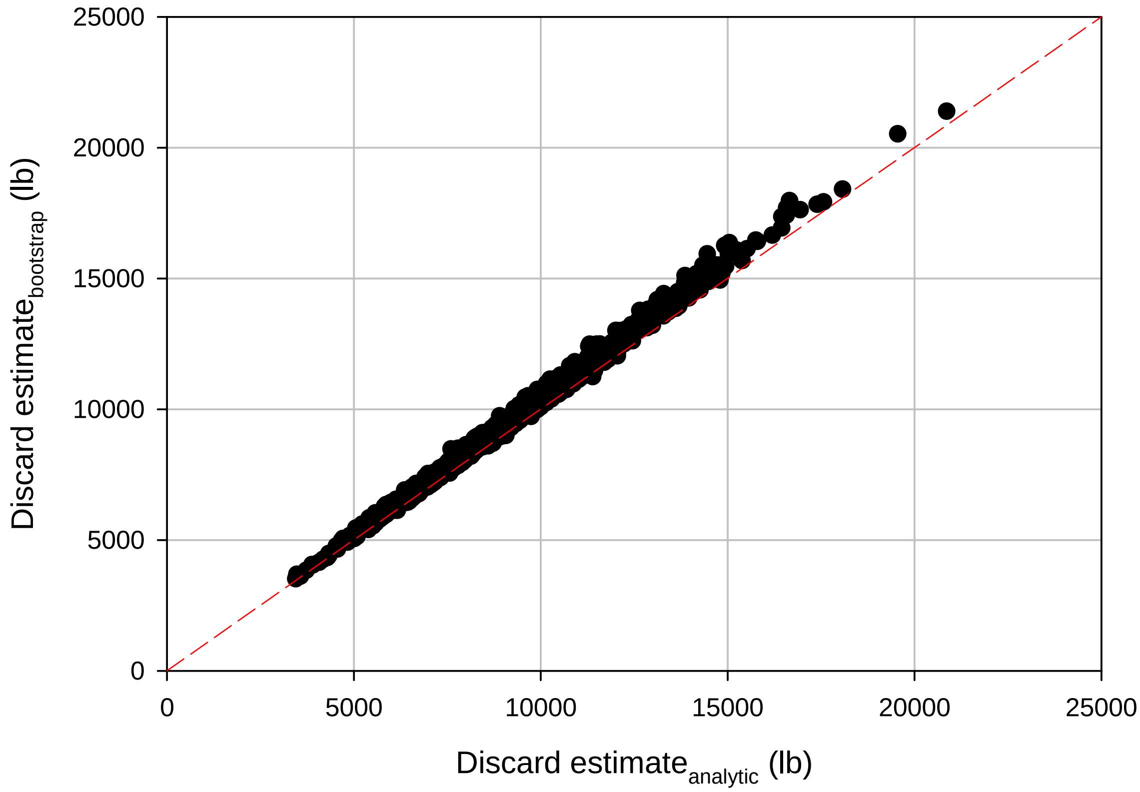

Figure 8a. Comparison of bootstrap estimates of terminal (end of year) discard to the analytic estimates for Gulf of Maine Atlantic cod (*Gadus morhua*) in the longline fishery. Population was fixed at 15 vessels (76 trips). The simulation was run 1000 times with 500 bootstrap iterations.

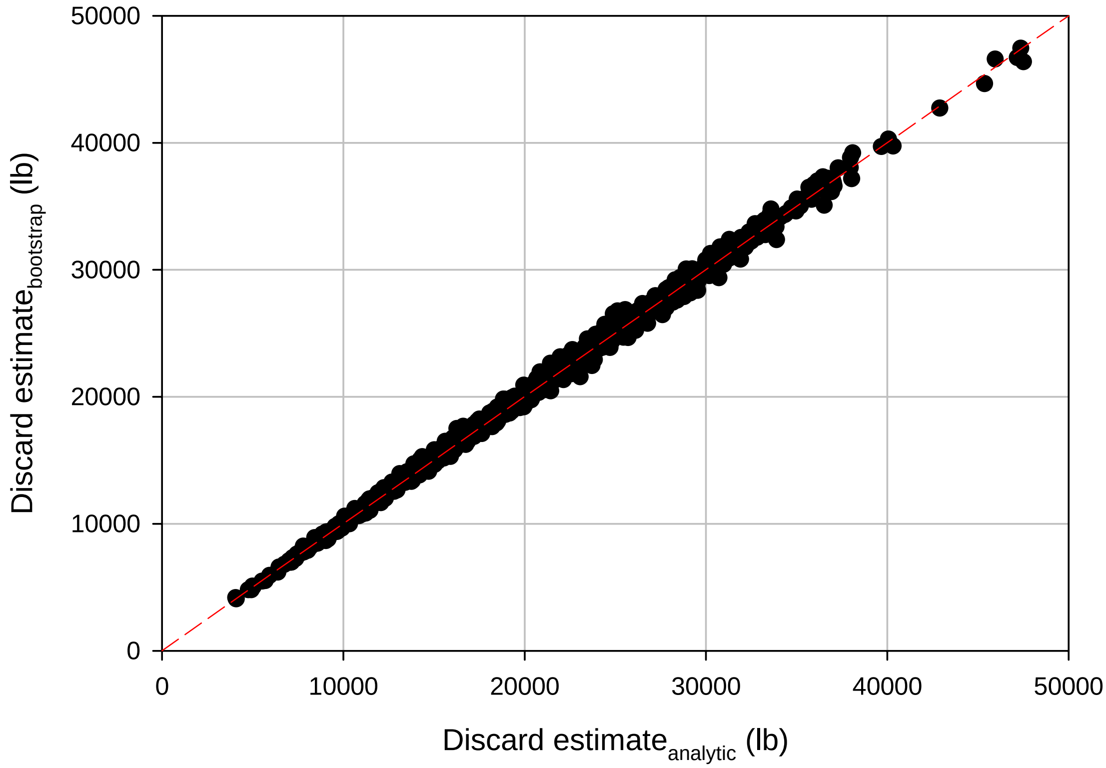

Figure 8b. Comparison of bootstrap estimates of terminal (end of year) discard to the analytic estimates for Georges Bank yellowtail flounder (*Limanda ferruginea*) in the longline fishery. Population was fixed at 15 vessels (113 trips). The simulation was run 1000 times with 500 bootstrap iterations.

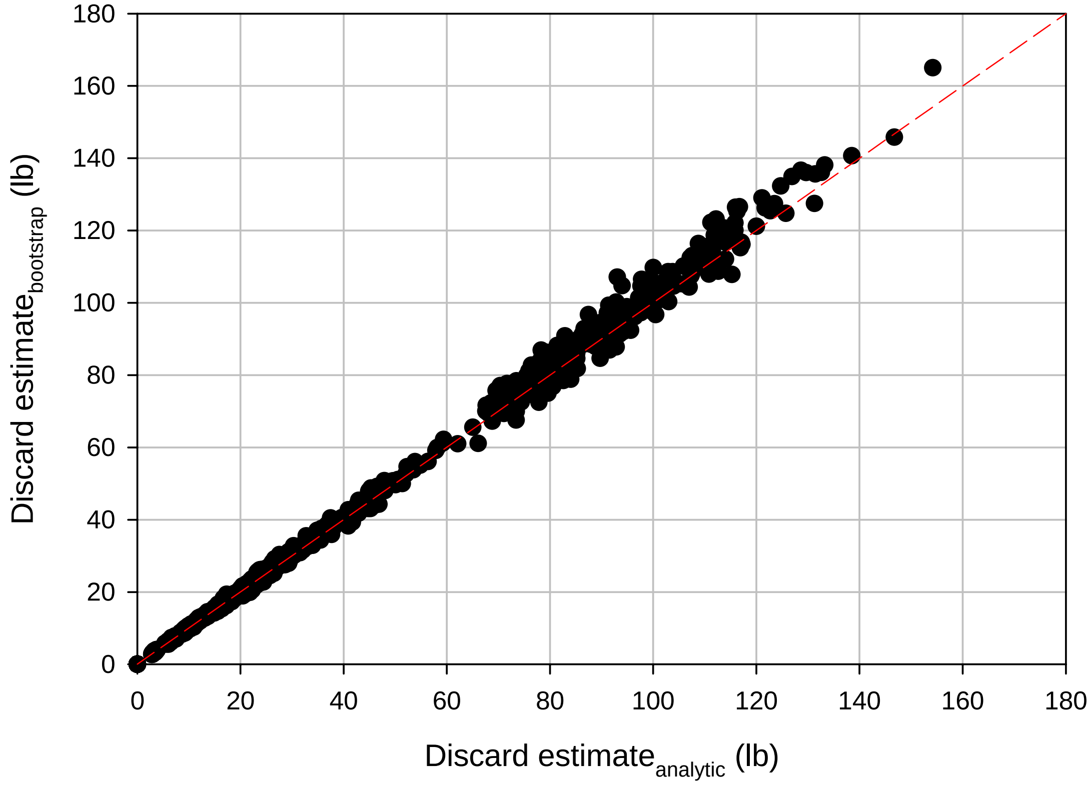

Figure 8c. Comparison of bootstrap estimates of terminal (end of year) discard to the analytic estimates for pollock (*Pollachius virens*) in the longline fishery. Population was fixed at 15 vessels (215 trips). The simulation was run 1000 times with 500 bootstrap iterations.

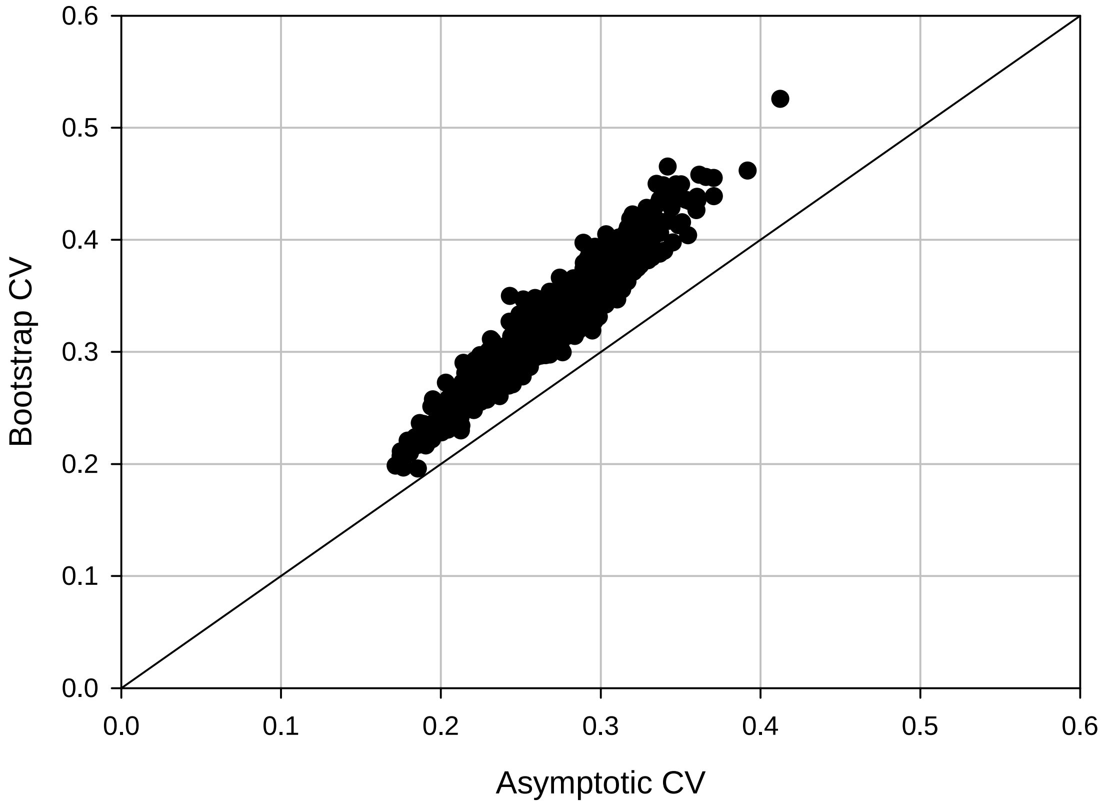

Figure 9a. Comparison of the bootstrap coefficients of variation (CV) on the terminal (end of year) discard estimates to the analytic (asymptotic) estimates for Gulf of Maine Atlantic cod (*Gadus morhua*) in the longline fishery. Population was fixed at 15 vessels (76 trips). The simulation was run 1000 times with 500 bootstrap iterations.

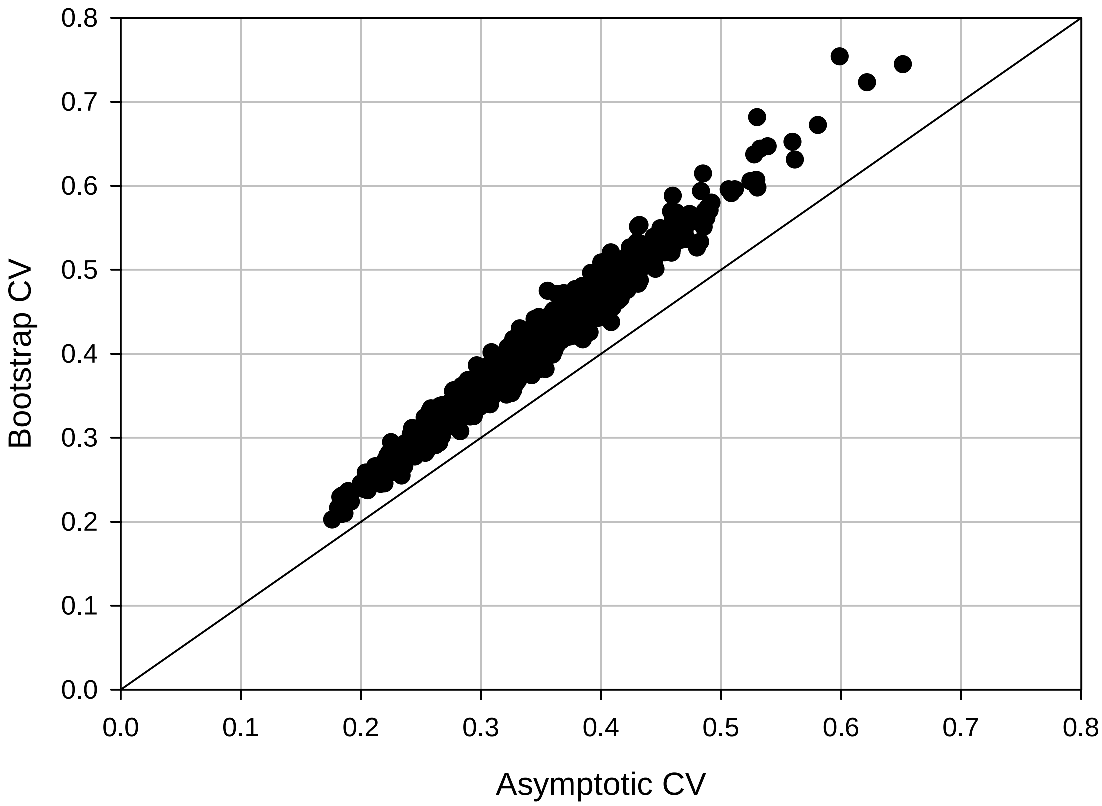

Figure 9b. Comparison of the bootstrap coefficients of variation (CV) on the terminal (end of year) discard estimates to the analytic (asymptotic) estimates for Georges Bank yellowtail flounder (*Limanda ferruginea*) in the longline fishery. Population was fixed at 15 vessels (113 trips). The simulation was run 1000 times with 500 bootstrap iterations.

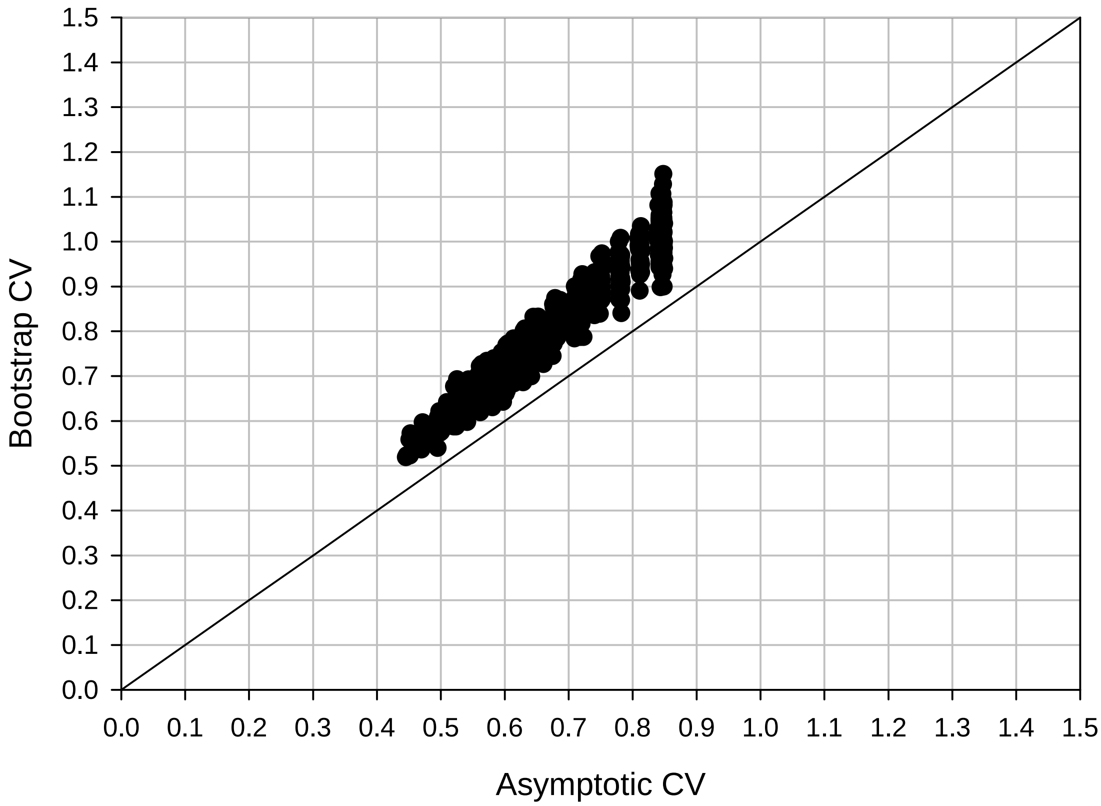

Figure 9c. Comparison of the bootstrap coefficients of variation (CV) on the terminal (end of year) discard estimates to the analytic (asymptotic) estimates for pollock (*Pollachius virens*) in the longline fishery. Population was fixed at 15 vessels (215 trips). The simulation was run 1000 times with 500 bootstrap iterations.

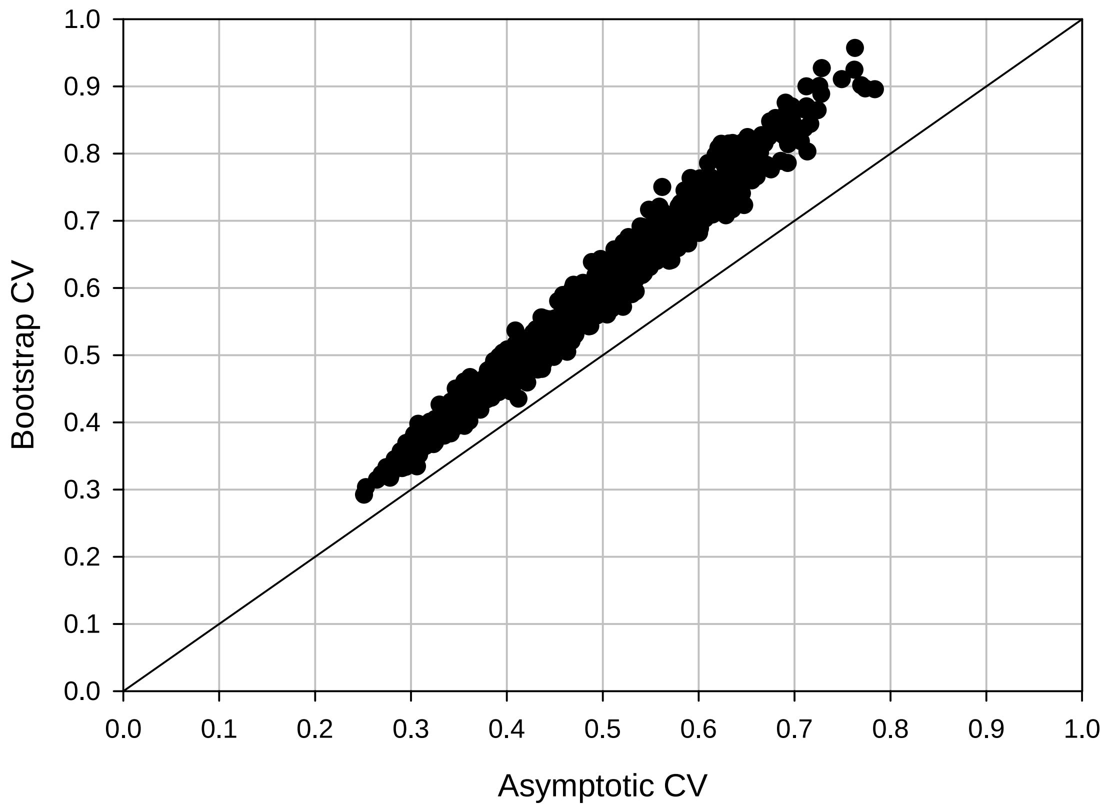

Figure 9d. Comparison of the bootstrap coefficients of variation (CV) on the terminal (end of year) discard estimates to the analytic (asymptotic) estimates for pollock (*Pollachius virens*) in the longline fishery. Population was fixed at 650 trips. The simulation was run 1000 times with 500 bootstrap iterations.

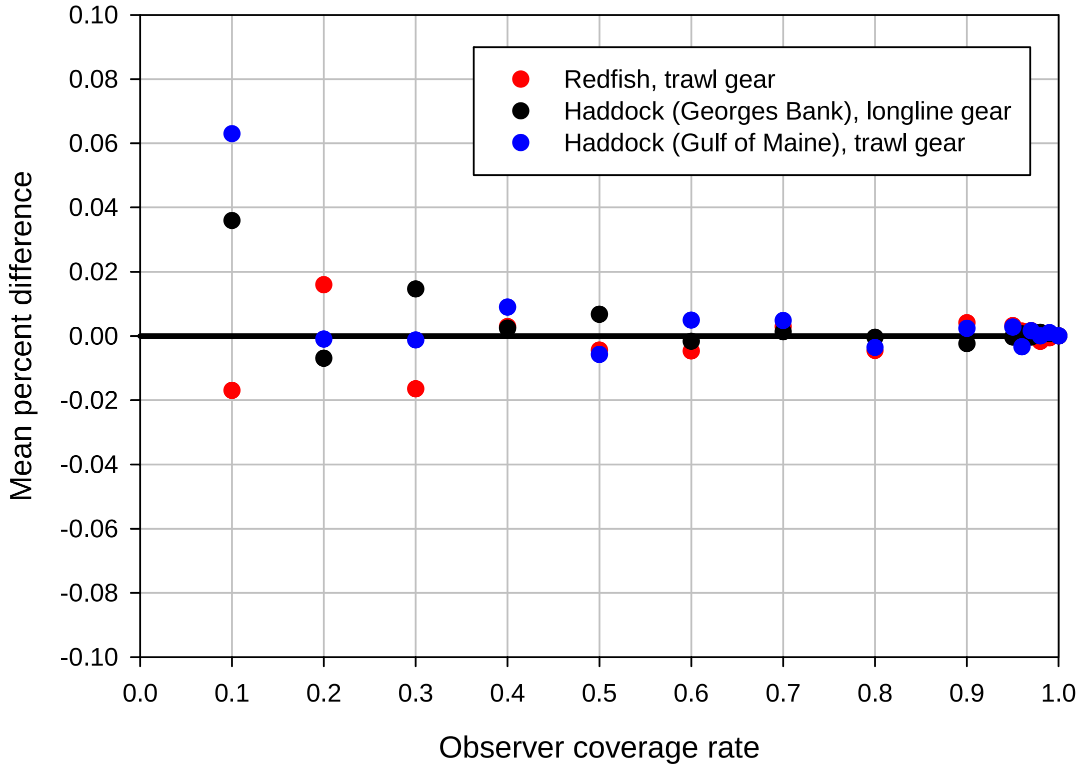

Figure 10. Influence of the observer coverage level on the measure of mean bias in discard estimates. Data are from simulations using the separate ratio with yearly temporal stratification with the trip size held constant at 200. Within each stock and gear combination, populations were held constant.

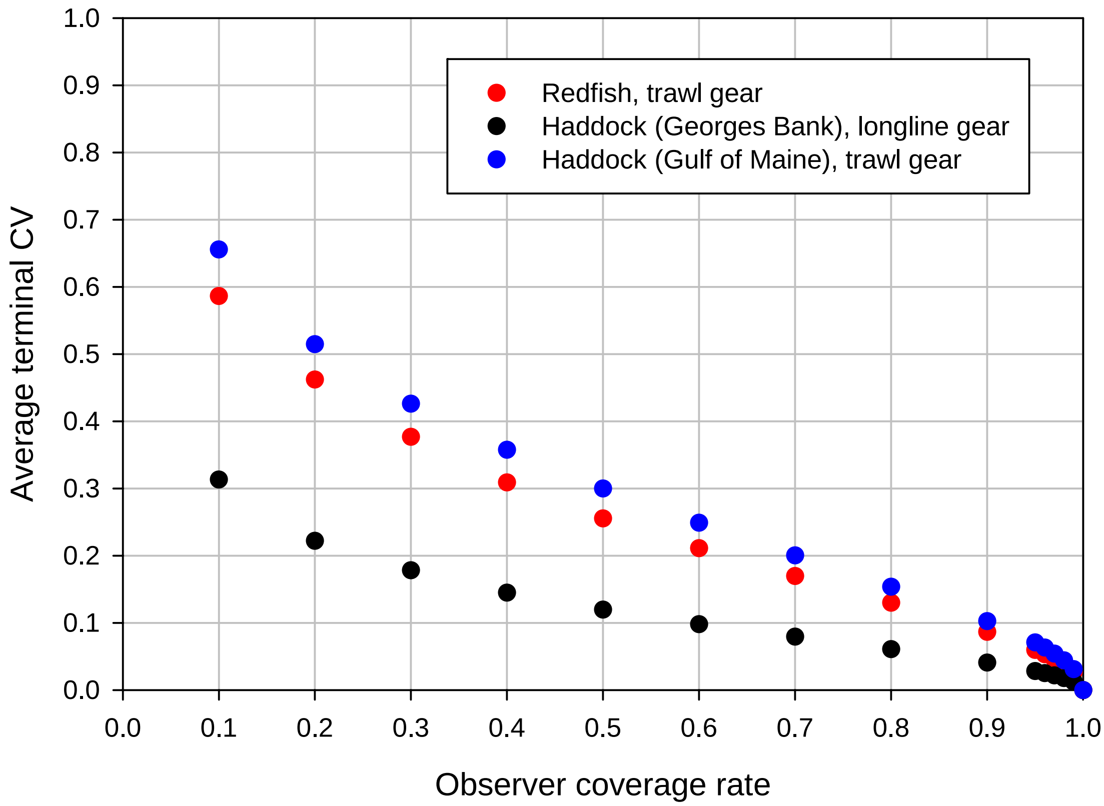

Figure 11. Influence of the observer coverage levels on the average coefficient of variation (CV) of terminal (end of year) discard estimates from 1000 iterations of the separate ratio with yearly temporal stratification. Coefficients of variation were calculated using the analytic (asymptotic) method. The trip size was held constant at 200 trips across all simulations.

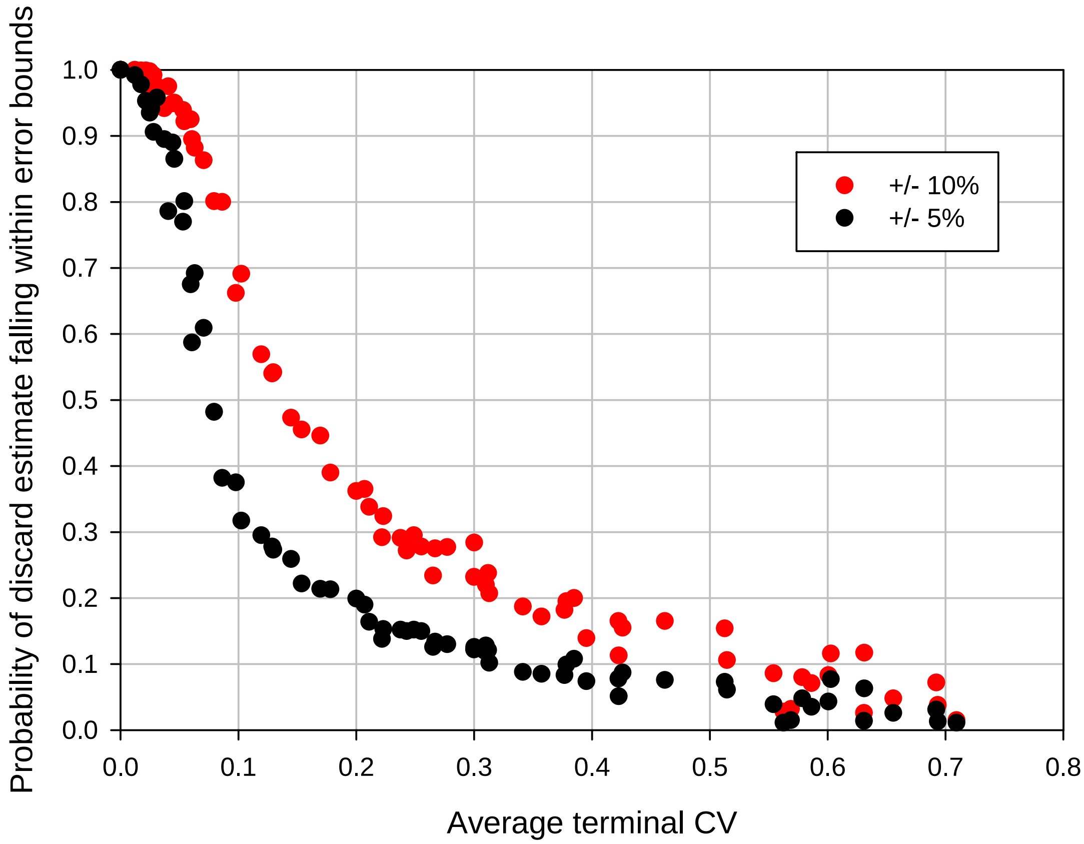

Figure 12. The relationship of average coefficient of variation (CV) of the terminal (end of year) discard estimate to the fraction of iterations within the simulation ± 5% and 10% of the true discards. The results include only the separate ratio simulations with yearly temporal stratification that included 1000 iterations. Coefficients of variation were calculated using the analytic (asymptotic) method.