Discard Estimation using Observer Data

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Introduction

The Northeast Fisheries Observer Program (NEFOP) has provided data on fish kept and discarded at sea from numerous vessels for over a decade. These data are commonly used to estimate the total discards of a species or stock by a given fleet. Many different methods can be used for this estimation. This paper explores six of the methods using actual observer data to create a known universe of trips and randomly sampling from this universe. The distributions of relative differences between the estimates and the known total discards are used as the means to rank the utility of the different methods to estimate discards. This simulation study does not examine all possible discard estimation methods, but rather focuses on specific methods that have been used in, or suggest for, stock assessments in the Northeast US.

Methods

Four different universes of observed trips were created based on two species of interest, yellowtail flounder and fluke, and using either the species of interest only as the kept portion or using the sum of all species as the kept portion. When all species were used as the kept portion, the observer trips were limited to Georges Bank using trawl gear in years 2004 through 2006. When only the species of interest was used as the kept portion, all gears and areas were used for year 2006. These universes were selected rather arbitrarily with the intent of having a sufficiently large number of trips within the universe and some consistency in time or space for the discard rates. Summary statistics for these four universes show that there were between 650 and 1200 trips with total discards between 80,000 and 500,000 pounds (Table 1). The distribution of discards per trip was highly skewed in all four universes, with the mean greater than the third quartile in each case. These sample sizes and amount of discards were thought to be sufficient as the basis for the exercise. Plots of the discards versus kept for the four universes show the common pattern of large spread in the data and many observations with high discards but low or no kept and vice versa (Figure 1).

Samples were drawn randomly without replacement from each universe using a process known as Bernoulli sampling. To create a sample, each trip was assigned a zero or one based on a random Bernoulli variable with probability of assignment to one set at 10%. Only those trips assigned a one were included in that sample. This means that sample size

varied from sample to sample following a binomial distribution with sample size N and probability of being selected 10%, but over the 500 samples each individual trip should be represented with equal probability. This random selection process was chosen to mimic the current practice of targeting 10% observer coverage but acknowledges that the exact proportion of trips covered will vary about this target from year to year depending on numerous factors, such as ability to correctly predict where a trip will occur, incomplete trips, changing regulations, etc.

Six methods for estimating discards from each random sample were examined. Five of the six used a discard to kept ratio estimator to multiply the total kept, which was assumed known exactly for this exercise. The sixth used the average discard per trip to multiply the total number of trips, which was assumed known exactly for this exercise. For all six methods, the relative difference between the estimated and actual discards was computed as 100 * (Destimated – Dactual) / Dactual and the bias for the method computed as the average relative difference from the 500 samples.
In the following descriptions of the methods, all of the estimators are calculated for each random sample, so this subscript is not used. Let
D# = an estimate of total discards (#=1-6)
D = the universe total discards
K = the universe total kept
N = the universe total number of trips
d = the discards of an individual sampled trip
k = the kept of an individual sampled trip
n = the number of trips sampled
npos = the number of trips sampled where both d and k are greater than zero

The first method to estimate discards was the most commonly used method in New England groundfish stock assessments, called “ratio of sums”
D1 = r1 * K, where r1 = sum of d / sum of k.

The second method to estimate discards is based on the distribution of discard to kept for each trip, called “mean log ratio with correction”
D2 = r2 * K, where r2 = exp[avg(ln(d/k)) + var(ln(d/k))/2].

The third method to estimate discards is a variation on D2 that modifies the estimate based on the proportion of positive trips in the sample, called “mean log ratio with correction and prop pos”
D3 = r2 * K * (npos/n), where r2 is defined above.

The fourth method to estimate discards is similar to D2 but does not use the lognormal correction factor, called “mean log ratio without correction”
D4 = r4 * K, where r4 = exp[avg(ln(d/k))].

The fifth method to estimate discards is simply the average of the observed discard to kept ratios, called “mean ratio”
D5 = r5 * K, where r5 = avg(d/k).

The sixth and final method to estimate discards is trip based instead of using a discard to kept ratio, called “mean discard per trip”
D6 = r6 * N, where r6 = avg(d) = sum of d / n.

Results and Discussion

The results for the six methods were consistent over the four universes in that methods 2 through 5 were consistently highly biased while methods 1 and 6 were not (Table 2). The probability density functions of relative difference estimates from the 500 random samples clearly show that methods 2 through 5 are not good estimators for total discards with some density plots not even encompassing the value zero (Figures 2-5). Estimates of discards were highly correlated among the six methods, especially between methods 1 and 6 (see for example Figure 6).

The reason for the poor performance of methods 2 through 5 could be due to the limited nature of the samples that are used in the estimation. Methods 2 through 4 use the logarithm of trip specific discard and kept values, meaning any trip that has zero kept or discarded cannot enter the calculations. Method 5 uses an average of trip specific discard to kept and so any trips with zero kept cannot be used. This should not be an issue in universes 3 and 4 because they use the kept of all species, which is almost never zero. This can be seen in Table 2 where the bias is much lower for universes 3 and 4 than universes 1 and 2. However, the distribution of d/k in method 5 may be, and usually is, highly skewed, and the average of a highly skewed distribution may not possess desirable properties. To test the hypothesis that methods 2 through 5 are biased, the proportion positive in the binomial distribution used to generate the random samples was increased to 0.99, meaning that 99% of the trips in the universe would be included in each sample. In universe 1, this resulted in much less spread of the relative difference distributions for all six methods, as expected, but the bias was still high for methods 2 through 5 and the probability density functions for relative difference did not overlap zero at all (Figure 7). Methods 2 through 5 do not converge to unbiased estimates as the sample size increases and thus should not be used for estimation of discards.

Methods 1 and 6 perform almost identically in three of the four universes, and only differ in universe 2, which has the highest amount of variability in the raw data. Method 6 should be preferred if the ability to estimate N is the same as the ability to estimate K. Due to the inability to track specific trips to areas, requiring the use of an allocation scheme for landings to areas, it is currently easier to estimate K than N in many cases. This argues for using method 1 over method 6, although the estimates were highly correlated in these simulations.

Note that even for these two best performing methods, the deviation of any one particular sample from the true value could be quite high (plus or minor 50%). This high degree of variability could be explained by the lack of any attempt to define a homogenous pool for estimation based on criteria such as gear, mesh size, time of year, and regulations. In this

sense, these simulations are a worst case scenario for observer coverage of 10%. Note that 10% observer coverage is the overall goal of NEFOP in recent years, although specific fisheries have higher targets, such as special access programs. In earlier years of NEFOP, 10% observer coverage was not possible due to funding limitations. However, because the simulations used pure random sampling to generate the values used in the estimates and the K and N were assumed known exactly, actual estimates could be worse than these results if in fact observer bias exists or K and N can only be estimated approximately. Furthermore, observer coverage less than 10% would be expected to have wider spread of relative differences than these results.

Although results from universes 1 and 3, as well as 2 and 4, cannot be compared directly due to differences in area, time, gear, and sample size, the overall trends of less spread and more symmetry in the distributions of relative differences in the kept all species cases supports their use. In practice, this could lead to situations where a single observed discard of a species becomes magnified tremendously to a large discard for a fleet landing large amounts of other species, for example, the scallop dredge fishery. Analysts will need to continue to be careful that discard rates are not extrapolated beyond the range of the species of interest when conducting discard estimations using any method.

Conclusions

Methods 1 and 6, “ratio of sums” and “mean discard per trip”, respectively, are recommended for estimation of discards, while methods 2 through 5 are not. Use of all species kept appears to produce less biased results than kept of only the species of interest. However, this conclusion warrants further research.

Acknowledgments

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Table 1. Summary statistics for the four universes generated for this exercise. N denotes the number of trips, K the total kept pounds, D the total discarded pounds, pos the number of trips where both the kept and discarded pounds were greater than zero, and prop pos the proportion of positive trips (=pos/N). The final rows of the table present summary statistics for the distribution of discard pounds per trip.

	Universe			
	1	2	3	4
Parameter	Yellowtail	Fluke	YT Kept All	Fluke Kept All
Area	All	All	Georges Bank	Georges Bank
Gear	All	All	Trawl	Trawl
Year	2006	2006	2004-2006	2004-2006
Kept what	Yellowtail	Fluke	All Species	All Species
N	659	704	1167	1167
K	905,667	323,065	23,679,168	23,679,168
D	84,577	298,213	285,449	478,239
pos	433	376	802	624
prop pos	65.7%	53.4%	68.7%	53.5%
d/trip distribution				
min	0.0	0.0	0.0	0.0
1st qu.	1.5	3.0	0.0	0.0
median	19.0	60.8	14.0	5.0
mean	128.3	423.6	244.6	409.8
3rd qu.	105.7	319.1	188.3	309.5
max	7506.0	22360.5	10804.0	22360.5

Table 2. Bias for each method of discard estimation in the four universes based on 500 random samples.

	Universe			
Method	1	2	3	4
1	2%	13%	0%	0%
2	320%	728%	152%	398%
3	177%	338%	73%	167%
4	23%	-47%	-71%	-50%
5	233%	307%	-8%	24%
6	1%	0%	0%	0%

Figure 1. Plots of discarded pounds versus kept pounds for the four universes (see Table 1 for definition of each universe). Each dot denotes a trip. The red line is a loess smooth through the data.

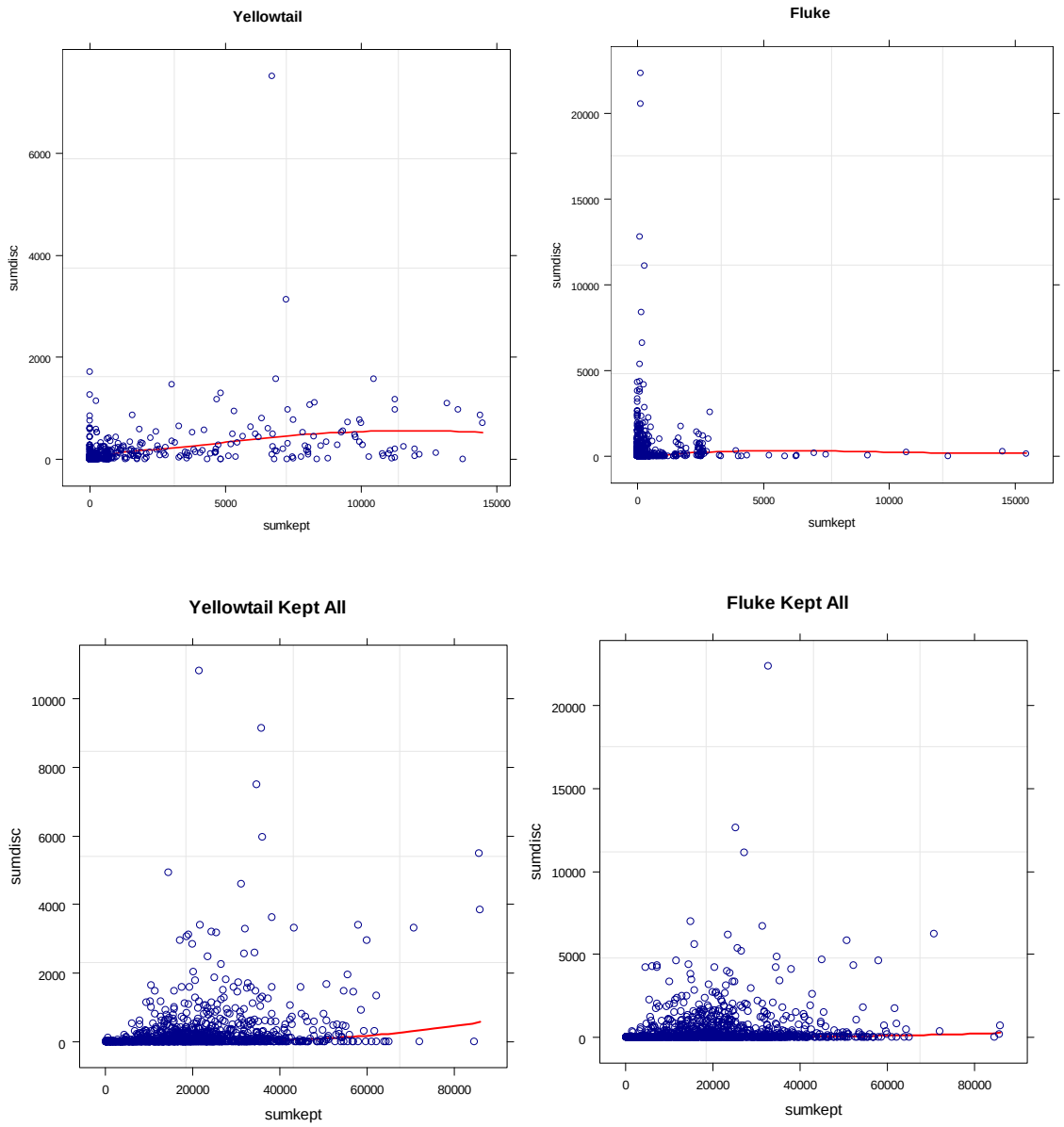

Figure 2. Probability density functions of the relative difference between estimated and true discards for the six methods of estimating discards in universe 1. The red vertical line denotes zero bias while the thicker vertical blue line denotes the average relative difference or bias for the method.

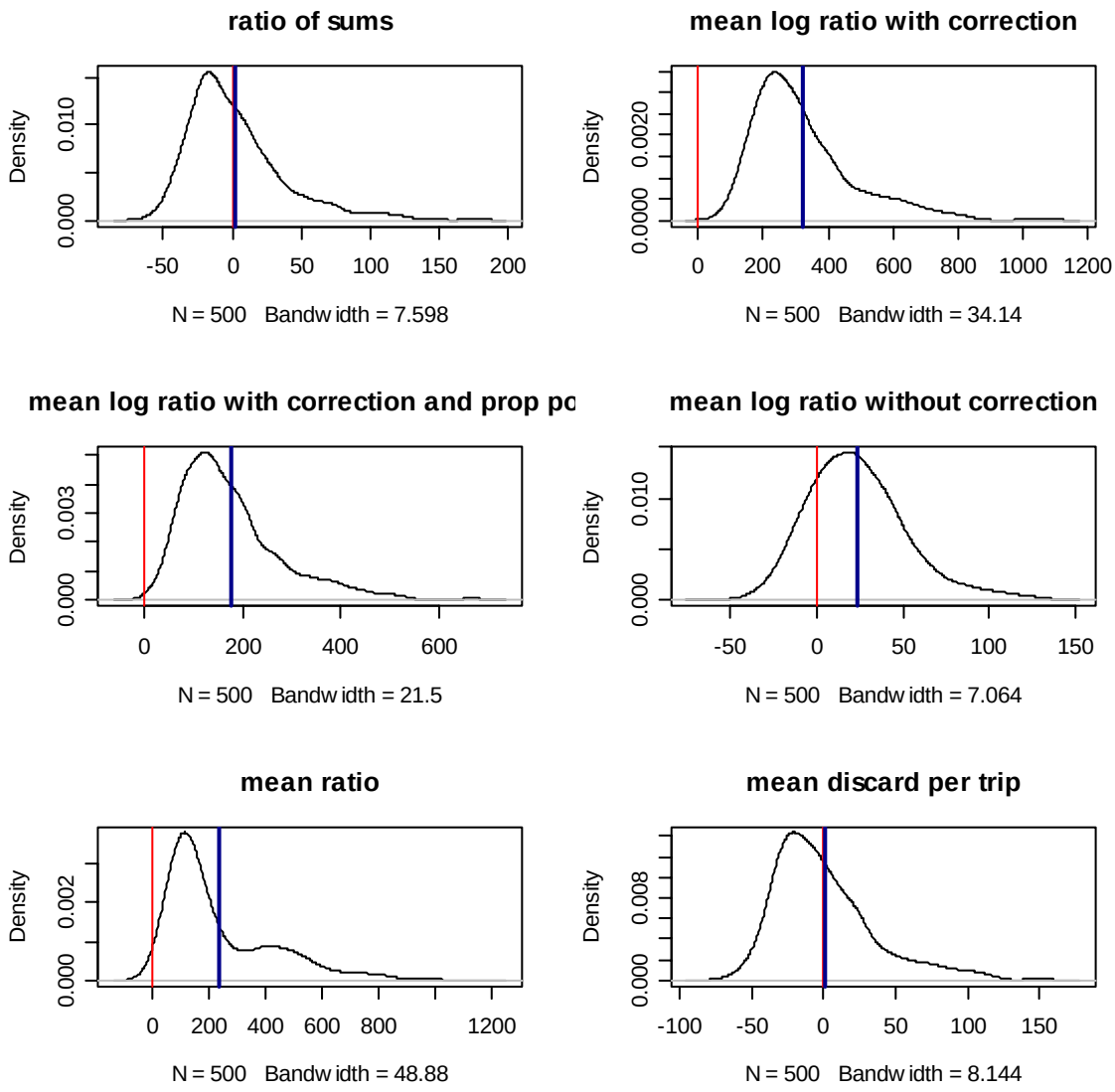

Figure 3. Probability density functions of the relative difference between estimated and true discards for the six methods of estimating discards in universe 2. The red vertical line denotes zero bias while the thicker vertical blue line denotes the average relative difference or bias for the method.

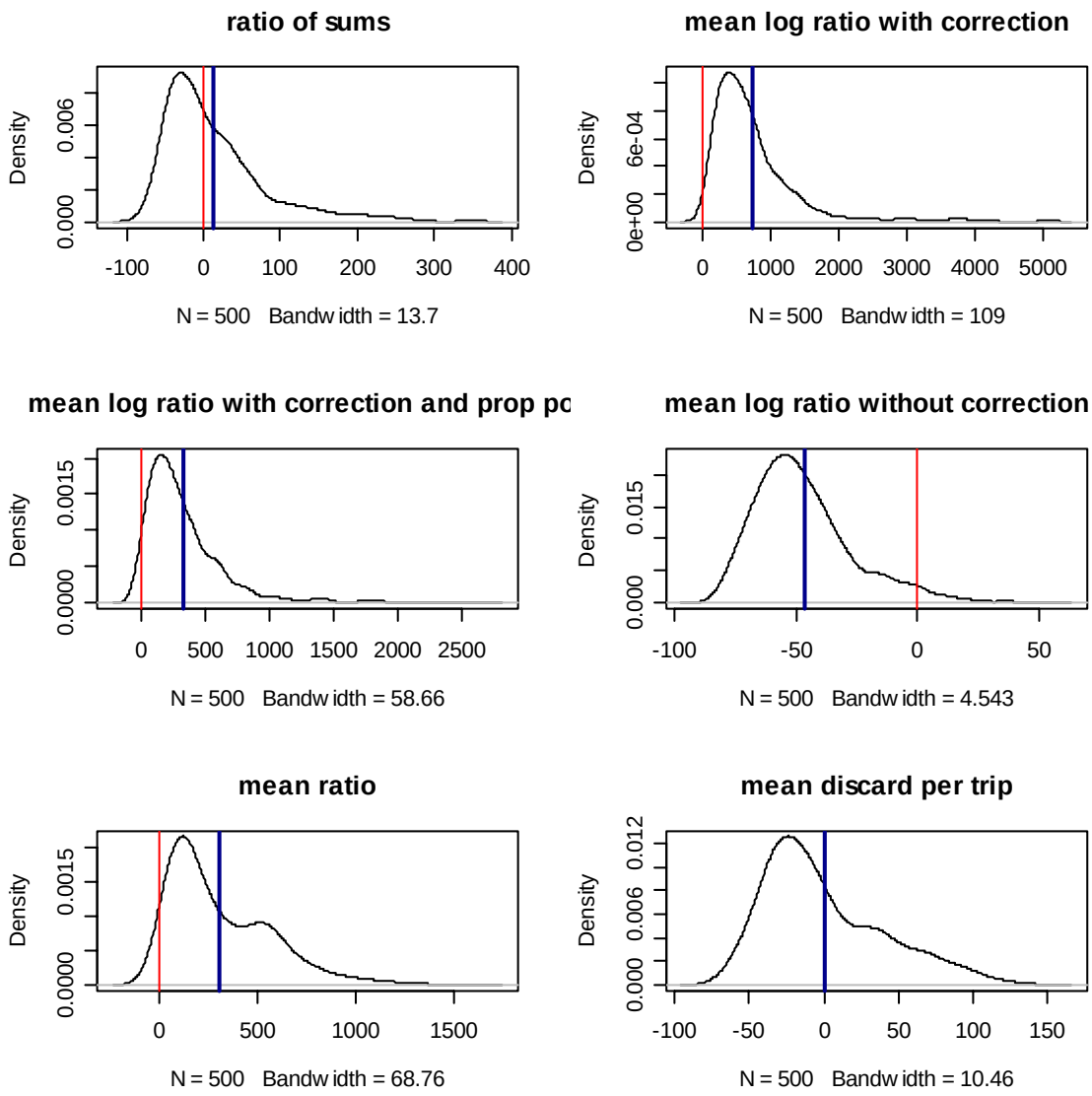

Figure 4. Probability density functions of the relative difference between estimated and true discards for the six methods of estimating discards in universe 3. The red vertical line denotes zero bias while the thicker vertical blue line denotes the average relative difference or bias for the method. Note that the zero bias line is not visible in the plot of method 4.

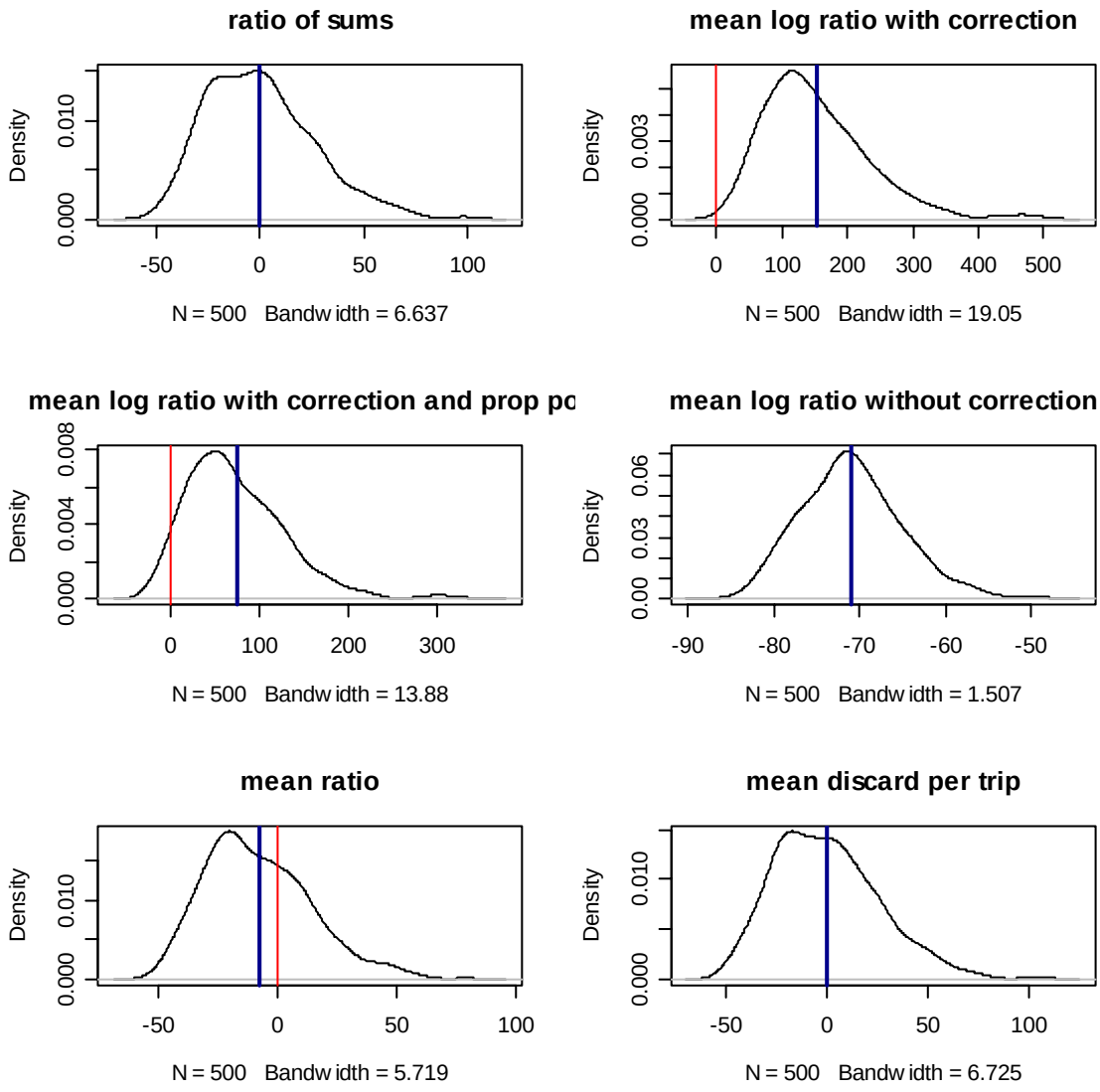

Figure 5. Probability density functions of the relative difference between estimated and true discards for the six methods of estimating discards in universe 4. The red vertical line denotes zero bias while the thicker vertical blue line denotes the average relative difference or bias for the method.

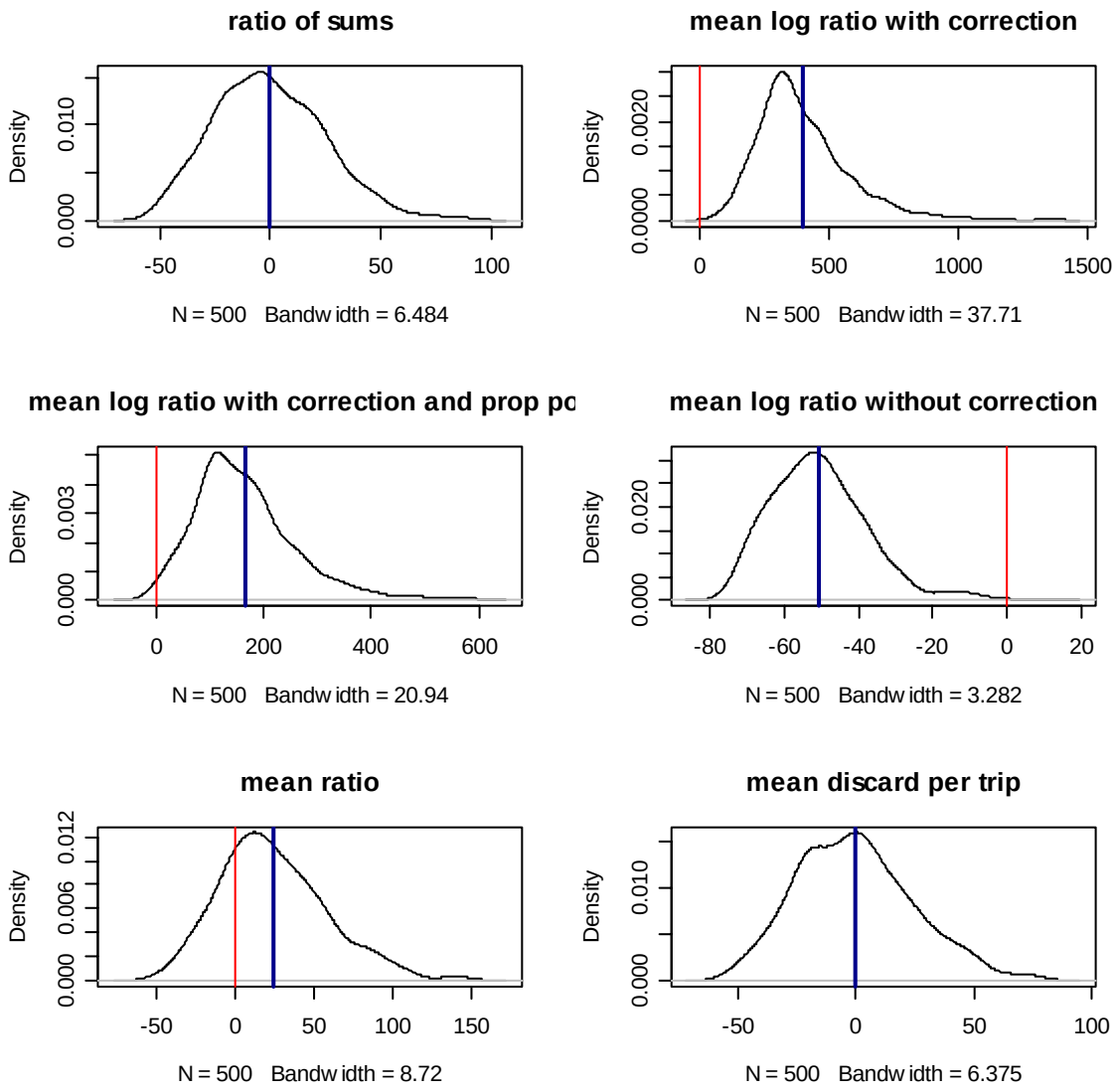

Figure 6. Relative difference estimates from 500 random samples of universe 4 from methods 1 and 6 (left plot) and methods 2 and 6 (right plot).

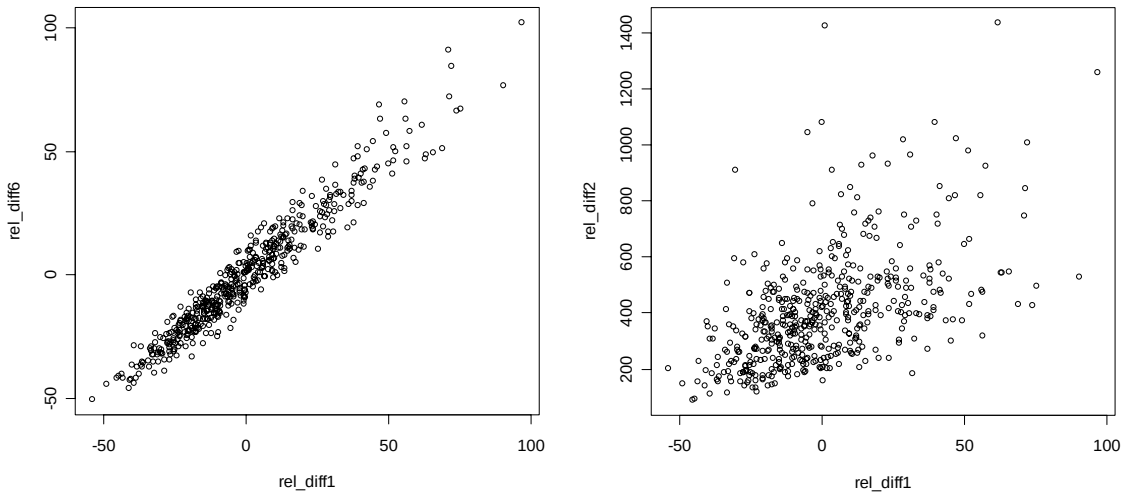
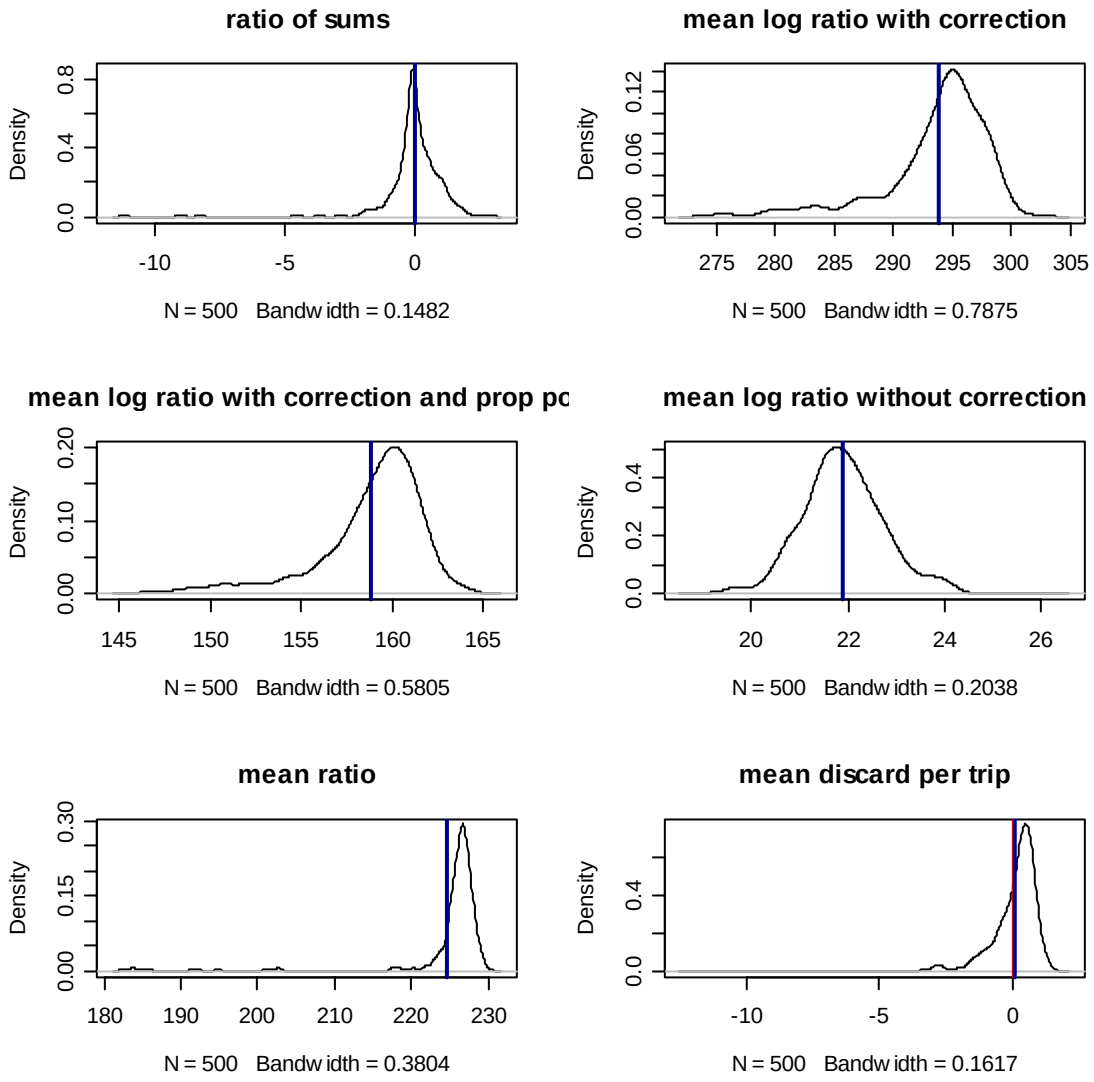
Figure 7. Probability density functions of the relative difference between estimated and true discards for the six methods of estimating discards in universe 1 when the sampling intensity in increased from 10% to 99%. The red vertical line denotes zero bias while the thicker vertical blue line denotes the average relative difference or bias for the method. Note that the zero bias line is not visible in the plots of methods 2 through 5.