Science, Service, Stewardship

An overview of the in-season discard estimation methodology currently being applied to monitor the Northeast Multispecies Fishery

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Overview of the presentation

- Requirements of Amendment 16.
  - Estimating discards.
  - Determining coverage levels.

- Determining an estimation procedure.
  - Selecting candidate estimators.
  - Identify the range of conditions likely to be observed in the fishery.
  - Properties of a good estimator.
  - Testing candidate estimators.

- Impacts of trimming (outlier removal) on discard estimation.

Requirements of Amendment 16

- NMFS must work within the framework determined by individual Fisheries Management Plans as set by the Management Councils.

- With regards to monitoring groundfish sectors, NMFS must work within the confines of the regulations as specified in Amendment 16.

- Amendment 16 contains language specific to how the groundfish fishery will be monitored and how discards will be estimated.

Requirements of Amendment 16: Estimating discards

(*A16, Section 4.2.3.5.3*)

- "Discards will not be counted when determining the sector's ACE/permit PSCs but will be counted against the ACE during the fishing year. When data is [sic] available from an adequate at-sea monitoring program (such as a federal observer program, a sector provided program, or other program that NMFS determines is adequate), in-season discard rates will be determined using a procedure specified by NMFS."

- "If a trip is observed, the discards reported by the observer or at-sea monitor on that trip till be counted as the discards for that trip. Unobserved trips will use a discard estimate calculated from the observed trips."

- "…if data from an adequate at-sea monitoring program is [sic] not available [discards] will be determined using a sector-specific discard rate. A sector-specific discard rate will be calculated for each stock and gear based on observer data from the previous year. If NMFS determines there are insufficient data to estimate discard rates at this fine of a scale, the fleetwide stock and gear discard rate would be used for those sector-gear combinations."

Requirements of Amendment 16: Estimating discards

Summary of Amendment 16 requirements for estimating discards:

- Discards will count against a sector's ACE.
- Discards from observed trips will be debited directly from a sector's ACE.
- Discards from unobserved trips will be estimated.
- If there is sufficient observer information available for the current fishing year the discard ratio will be estimated using in-season information.
  - Only when sufficient in-season information is not available will an "assumed" discard ratio be used.
- Discard estimation will be stratified by sector-gear-stock.
  - Discard ratios will be calculated for each sector. Within each sector, discards will be further broken down by gear types. For each gear type, discards will be estimated for each stock (14 allocated stocks, 16 sub-stocks).
  - 18 active sectors, 6^{+} gear types, 16 sub-stocks = 1728^{+} strata
    - *Not all strata will be active; approximately 700 active strata so far in 2010.*

Requirements of Amendment 16: Determining observer coverage levels

(*A16, Section 4.2.3.5.3*)

- "For observer or at-sea monitor coverage, minimum coverage levels must meet the coefficient of variation in the Standardized Bycatch Reporting Methodology. The required levels of coverage will be set by NMFS based on information provided by the Northeast Fisheries Science Center (NEFSC) and may consider factors other than the SBRM CV standard when determining appropriate levels."

- Past NEFOP observer coverage levels have been sufficient to estimate discards of the groundfish complex as well as most individual groundfish stocks at a levels of precision that exceeds the SBRM requirement (30% CV on total discards).

- What are the justifications for increased coverage beyond existing NEFOP coverage?

  - Given that discards will be deducted from a sector's ACE, there is greater incentive under A16 for vessel's to alter their behavior on observed trips.

  - Higher levels of coverage will be needed to reduce observer effects.
    - How much higher? Precedents?
      - SMP coverage (e.g., US/Canada, CA monitoring)

Requirements of Amendment 16: Determining observer coverage levels.

- Based on past monitoring of SMPs, anticipated compliance-based monitoring and budget constraints, NMFS made the decision to provide coverage sufficient to monitor the common pool at 30% and sectors at 38%.

- Includes the existing 8% NEFOP coverage of the groundfish fishery (approx.).

- Additional coverage will be accomplished using at-sea monitors (ASM).
  - ASMs record haul-by-haul catch estimates and length frequencies, but no additional biological sampling.

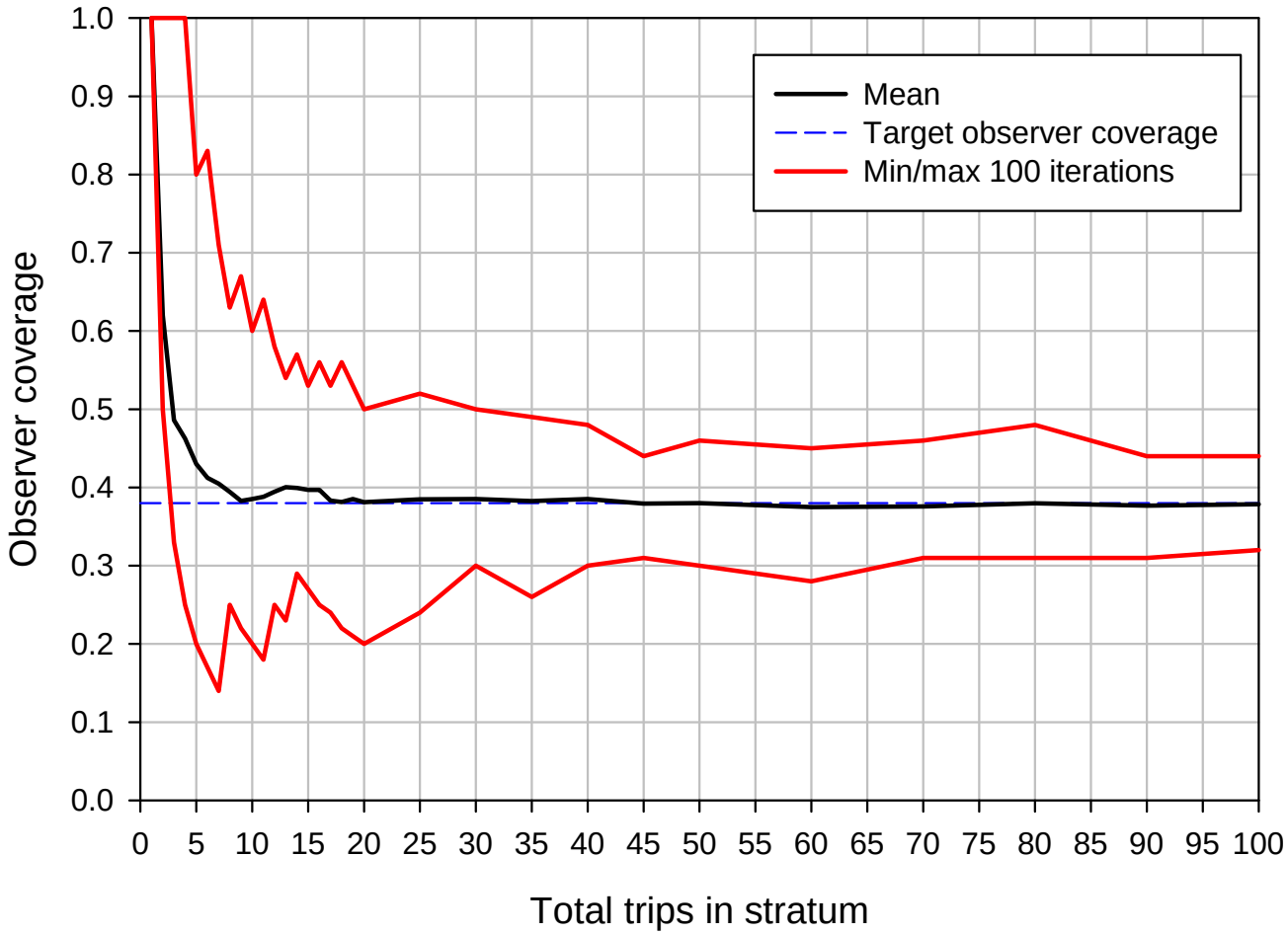
- Sectors could elect for additional ASM coverage beyond the NMFS funded levels.
  - None have opted for this in 2010.

Requirements of Amendment 16: Determining observer coverage levels.

- Will the observer coverage in 2010 be exactly 38% [30%]?
  - 38% [30%] of what?….Trips, sea days, total groundfish catch?
  - If the coverage assignment is unbiased, the coverage levels should be nearly identical regardless of the metric used.
  - The PTNS system is a trip-based system; it's the only metric known *a priori*.
    - It's not known for certain how long the trip will be or how much will be caught, but it is known that a trip will occur.
- The 38% [30%] coverage targets were based on anticipated need, available funding, and fishing practices in fishing years 2008-2009 (number of trips, average trip length).
  - The target coverage will not be met if:
    - More trips, longer trips: **realized** < **target**.
    - Fewer trips, longer trips: **realized** > **target**.
    - Random variability.
- Current observer coverage across the entire groundfish fishery is approximately 30% of the total trips.

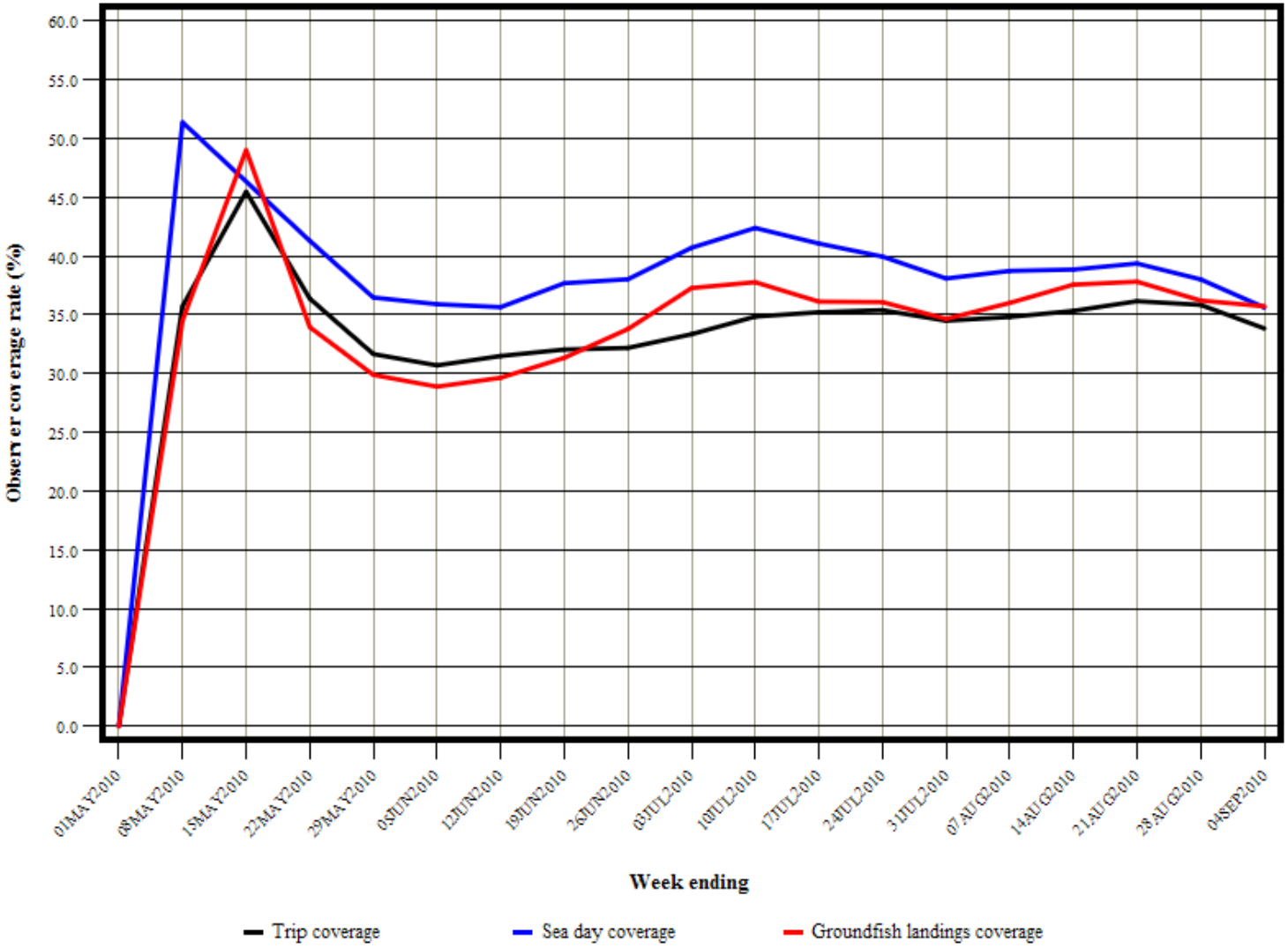
Requirements of Amendment 16: Determining observer coverage levels.

- An example of random variability in observer coverage levels:



Requirements of Amendment 16: Determining observer coverage levels.

- Example of coverage metrics for one sector in fishing year 2010.



Determining an estimation procedure

- Given that discards will need to be estimated for unobserved trips we need to select an estimator that will perform well across the range of ‘conditions’ likely to be experienced in fishing year 2010.

  - Three steps:
    1. Select candidate estimators to evaluate.
    2. Identify the range of conditions likely to be observed in the fishery.
       - What are the test conditions we are going to subject the candidate estimators to?
    3. Identify the properties that we are looking for in a good estimator.

Determining an estimation procedure: selecting candidate estimators

- How did we select candidate estimators for consideration?

- How have discards been estimated in the groundfish fishery in previous years?
  - Catch monitoring in the US/Canada shared resource area for cod, haddock and yellowtail flounder:
    - Ratio calculated as a 35 day moving window ratio of observed discard of species *j*/observed kept of species *j*.
      - Total discards are estimated by multiplying by the total kept of species *j* within each window.

  - Yellowtail bycatch in the scallop closed area fishery:
    - Methodology is similar to the US/Canada method.

  - SBRM and groundfish stock assessments:
    - Uses a combined ratio estimator to estimate discards at the fleet-level (gear, mesh, region).
    - In general, the ratio is calculated as the observed discard of species *j*/observed K of *all species*, calculated separately for each quarter.
      - Total discards are estimated by multiplying by the total kept of all species within each quarter.

Determining an estimation procedure: selecting candidate estimators

- Is there precedence in the groundfish fishery?
  - Yes, but are any of these 'optimal' for in-season quota monitoring of the groundfish fishery in FY 2010 (i.e., under sector management)?

- Several issues to consider, including:
  - The denominator used in the ratio estimator (surrogate for fishing effort)
    - Discards per trip
    - Discards per days fished (or absent)
    - Kept of species (k_j)
    - Kept of all species (k_{all})
    - *Must be derivable for the population using other data sources (i.e., this is the same metric that will be used to expand the ratio to the unobserved fraction of trips).*

  - The form of the ratio estimator
    - Moving average
    - Combined ratio
    - Cumulative (separate) ratio (**not previously used, but has been examined*)
    - Permutations of the above?

Determining an estimation procedure: selecting candidate estimators

- The choice of a denominator was previously investigated by Wigley et al (2007).
    - **Discards per trip:** This does not capture the inter-variability in effort between trips.
    - **Discards per days fished [absent]:** This is adequate, but days fished (or absent) is not as verifiable as trip landings.
    - **Kept of species (k_j):** This is problematic when the discarded species is not landed.
    - **Kept of all species (k_{all}):** The most robust choice of a denominator.

- The form of the ratio estimator
    - **Moving average:** Has been used previously for in-season quota monitoring of the groundfish fishery, but the properties of this estimator were largely unknown.
    - **Combined ratio:** Is currently used in the SBRM process and for all groundfish stock assessments. This has undergone extensive review.
    - **Cumulative (separate) ratio:** Was considered in the SBRM process, but was not used. When sample sizes are large, it can be less precise than the combined ratio method.
        - Could it have preferable properties at small sample sizes?
    - Permutations of the above?
        - Smaller/larger window sizes.
        - Temporal stratification of the cumulative ratio.

Determining an estimation procedure: selecting candidate estimators

- Moving window estimator.

$$\hat{D}_{1,jhm} = \sum_{h=1}^{L} K_{hm} r_{s,jhm}$$

$$r_{s,jhm} = \frac{\sum_{i=1}^{m} \sum_{i=1}^{n_h} d_{jih}}{\sum_{i=1}^{m} \sum_{i=1}^{n_h} k_{ih}}$$

Where:

$D_{1,j}$ is the total estimated discarded pounds for species j;
K_h is the total kept pounds in stratum h;
$r_{s,jhm}$ is the separate ratio for species j in stratum h for window m;
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 observed trips in stratum h;
L is the number of strata h=1,…,L;
m is the size of the moving window (days).

Determining an estimation procedure: selecting candidate estimators

- Moving window estimator (*example of a 10-day moving window*)

Day	Observer Discard	Trip kept all	ratio		Fishery kept all		Estimated Discards
1	1,000	8,000	0.08974		8,000		1,000
2			0.08974		12,000		1,077
3			0.08974		7,000		628
4	500	10,000	0.08974		10,000		500
5			0.08974		18,000		1,615
6			0.08974		12,000		1,077
7			0.08974		6,000		538
8	800	9,000	0.08974		9,000		800
9	1,200	12,000	0.08974		12,000		1,200
10			0.08974		15,000		1,346
11			0.08974	x	14,000	=	1,256
12					8,000		
13					10,000		
14					21,000		
15	1,400	15,000			15,000		
16					14,000		
17					17,000		
18					7,000		
19					11,000		
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12			0.08065	x	8,000	=	645
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11			0.08974		14,000		1,256
12			0.08065		8,000		645
13			0.08065	x	10,000	=	806
14					21,000		
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11			0.08974		14,000		1,256
12			0.08065		8,000		645
13			0.08065		10,000		806
14			0.08065	x	21,000	=	1,694
15	1,400	15,000			15,000		
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11			0.08974		14,000		1,256
12			0.08065		8,000		645
13			0.08065		10,000		806
14			0.08065		21,000		1,694
15	1,400	15,000	0.09524	x	15,000	=	1,400
16					14,000		
17					17,000		
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19					11,000		
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11			0.08974		14,000		1,256
12			0.08065		8,000		645
13			0.08065		10,000		806
14			0.08065		21,000		1,694
15	1,400	15,000	0.09524		15,000		1,400
16			0.09444	x	14,000	=	1,322
17					17,000		
18					7,000		
19					11,000		
20					16,000		

Determining an estimation procedure: selecting candidate estimators

- Separate (cumulative) ratio estimator:

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

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

Where:

$D_{1,j}$ is the total estimated discarded pounds for species j;
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L is the number of strata h=1,…,L

Determining an estimation procedure: selecting candidate estimators

- Cumulative ratio estimator

Day	Observer Discard	Trip kept all	ratio		Fishery kept all	Cumulative total		Estimated Discards
1	1,000	8,000	0.12500		8,000	8,000		1,000
2			0.12500		12,000	20,000		2,500
3			0.12500		7,000	27,000		3,375
4	500	10,000	0.12500		10,000	37,000		4,625
5			0.08333		18,000	55,000		4,583
6			0.08333		12,000	67,000		5,583
7			0.08333		6,000	73,000		6,083
8	800	9,000	0.08333		9,000	82,000		6,833
9	1,200	12,000	0.08519		12,000	94,000		8,007
10			0.08974		15,000	109,000		9,782
11			0.08974	x	14,000	123,000	=	11,038
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Determining an estimation procedure: selecting candidate estimators

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12			0.08974	x	8,000	131,000	=	11,756
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Determining an estimation procedure: selecting candidate estimators

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13			0.08974	x	10,000	141,000	=	12,654
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15	1,400	15,000	0.08974	x	15,000	177,000	=	15,885
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14			0.08974		21,000	162,000		14,538
15	1,400	15,000	0.08974		15,000	177,000		15,885
16			0.09074	x	14,000	191,000	=	17,331
17					17,000			
18					7,000			
19					11,000			
20					16,000			

Determining an estimation procedure: selecting candidate estimators

- Combined ratio estimator:

$$\hat{D}_{2,j} = \sum_{h=1}^{L} K_h r_{c,j}$$

$$r_{c,j} = \frac{\sum_{h=1}^{L} N_h \sum_{i=1}^{n_h} \frac{d_{jih}}{n_h}}{\sum_{h=1}^{L} N_h \sum_{i=1}^{n_h} \frac{k_{ih}}{n_h}}$$

Where:

$D_{1,j}$ 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

Determining an estimation procedure: expected conditions

- What are the range of conditions likely to be observed in the fishery and for which the estimator will need to be robust to?
  - Variable levels of observer coverage
  - Range of strata sizes (sector-gear-stock)
    - Very small sample sizes to large sample sizes
  - Strong trends in fish discards
    - Seasonal migrations/availability
    - Influx of strong year classes
  - Discard variability
    - From area to area
    - From vessel to vessel
    - From trip to trip

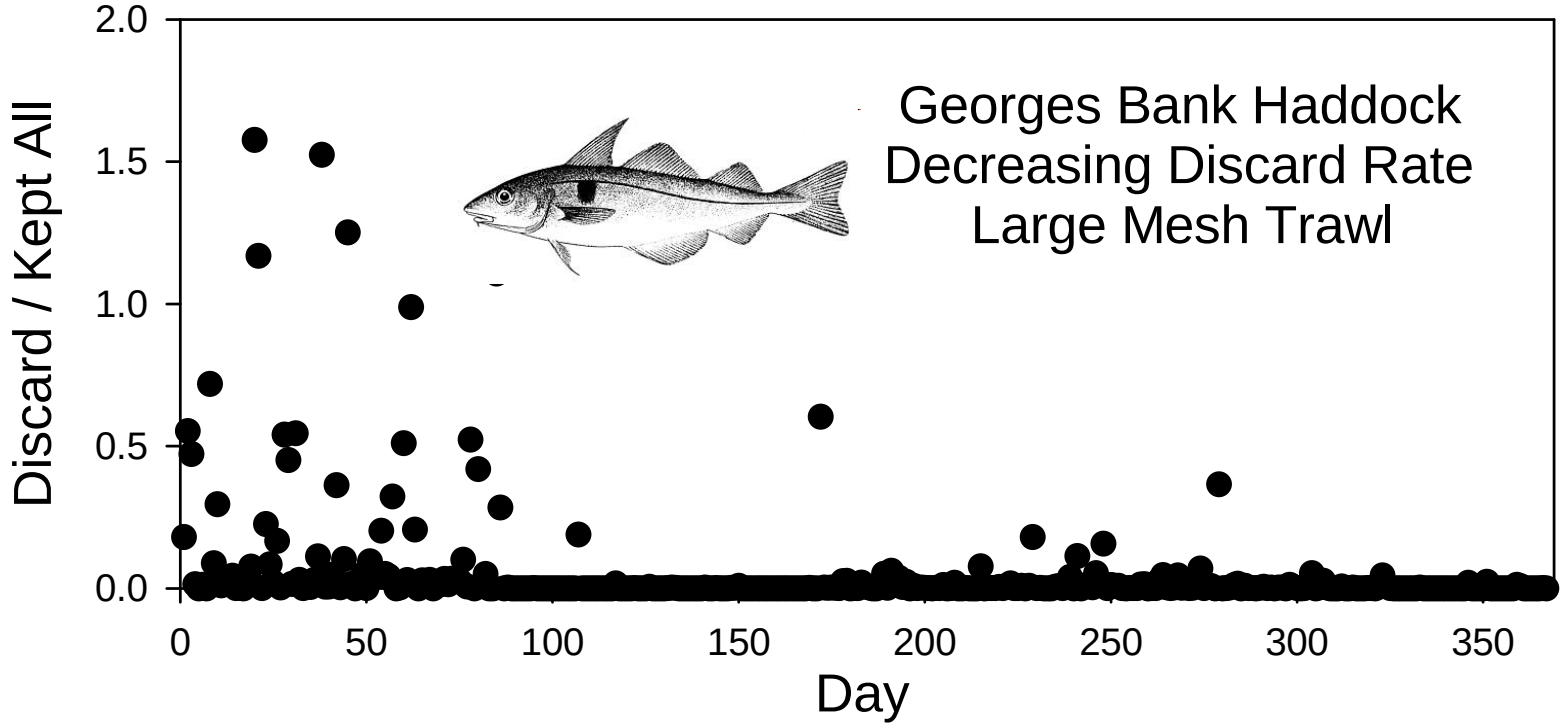
Determining an estimation procedure: expected conditions

- Likely strata sizes

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

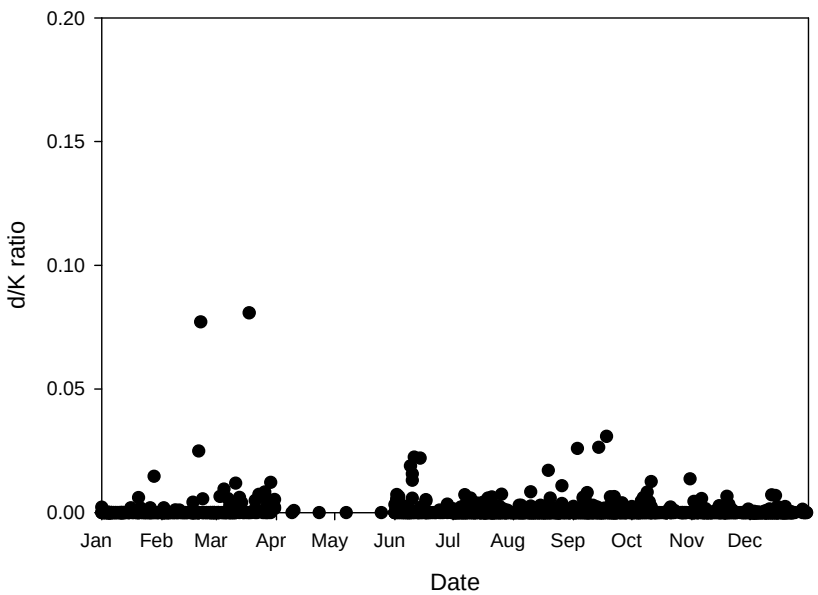
Determining an estimation procedure: expected conditions

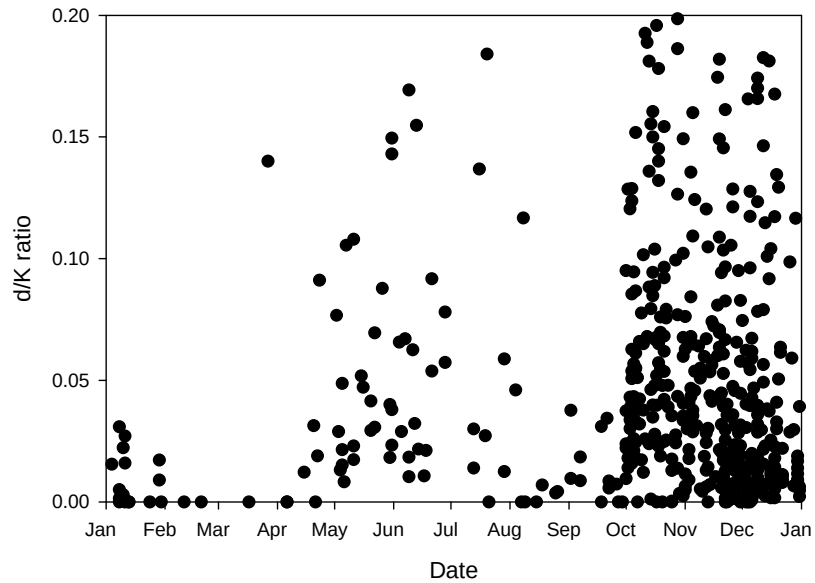
- Strong trends in fish discards



Determining an estimation procedure: expected conditions

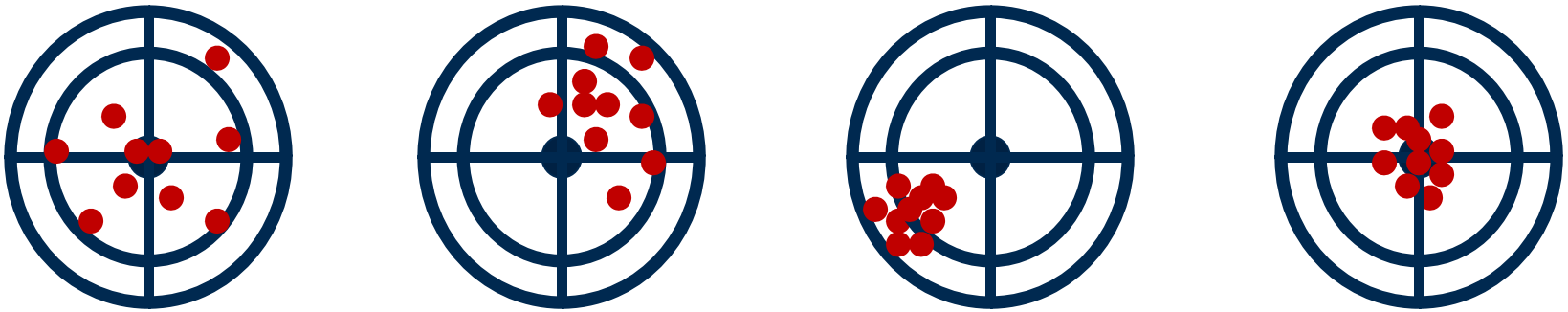
- Discard variability
  - Amount of variability will vary by sector, gear and stock.
  - Causes can include differences in fishing behavior between vessels, different gear configurations, fishing location, time of day, wind direction, water temperature, etc.
  - High variability within strata can make estimation of a stratum-specific discard ratio difficult.
    - Particularly when strata sizes are small and sampling coverage is low.





Determining an estimation procedure: properties of a good estimator

- What are the properties of a good estimator?
  - Across the range of conditions likely to be observed in the population, the estimator should be:
    - **Unbiased:** the expected value of the estimator (or the mean of the estimator) is equal to the true value.
    - **Consistent:** As the observed sample size approaches the population size, the estimator gets closer to the true value.
    - **Efficient:** The precision of the estimator is minimized.
    - **Robust:** Not sensitive to small sample sizes and variability in the discard ratios.



Determining an estimation procedure: testing candidate estimators

- Examined the performance of the candidate estimators through a suite of simulation exercises.

- The results of the simulation exercises were reviewed by an independent peer-review panel to ensure the objectivity and integrity of the selected method.
  - Peer reviewed working papers and review reports are available at:
    - **http://www.nefsc.noaa.gov/groundfish/Discard.html**

Determining an estimation procedure: testing candidate estimators

- Testing through simulation.
  - Simulations allow us to construct a population where the 'true' discards are known.
  - Population data sets can be constructed to reflect the range of conditions across which we want to test candidate estimators.
  - Test candidate estimators on identical populations and population samples (observed trips).

Observed data set

- Size controlled by the observer coverage rate (e.g., 0.3)
- Each simulation iteration contained a differed set from the population

This is repeated for each of the 1000 iterations

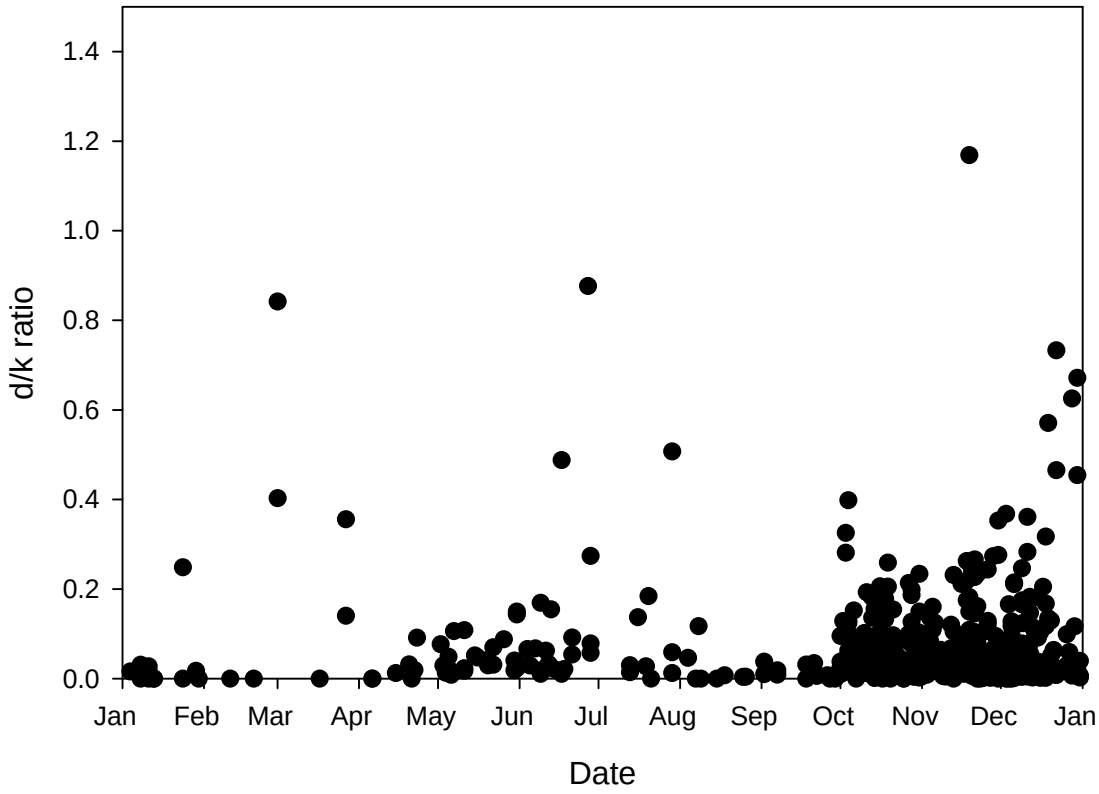
Uniform random sampling without replacement

Population data set

- Constrained by:
  - Region (statistical area groupings analogous to stock area)
  - Gear type (otter trawl and gillnet only)
  - Number of trips *or* fleet size (number of unique vessels)

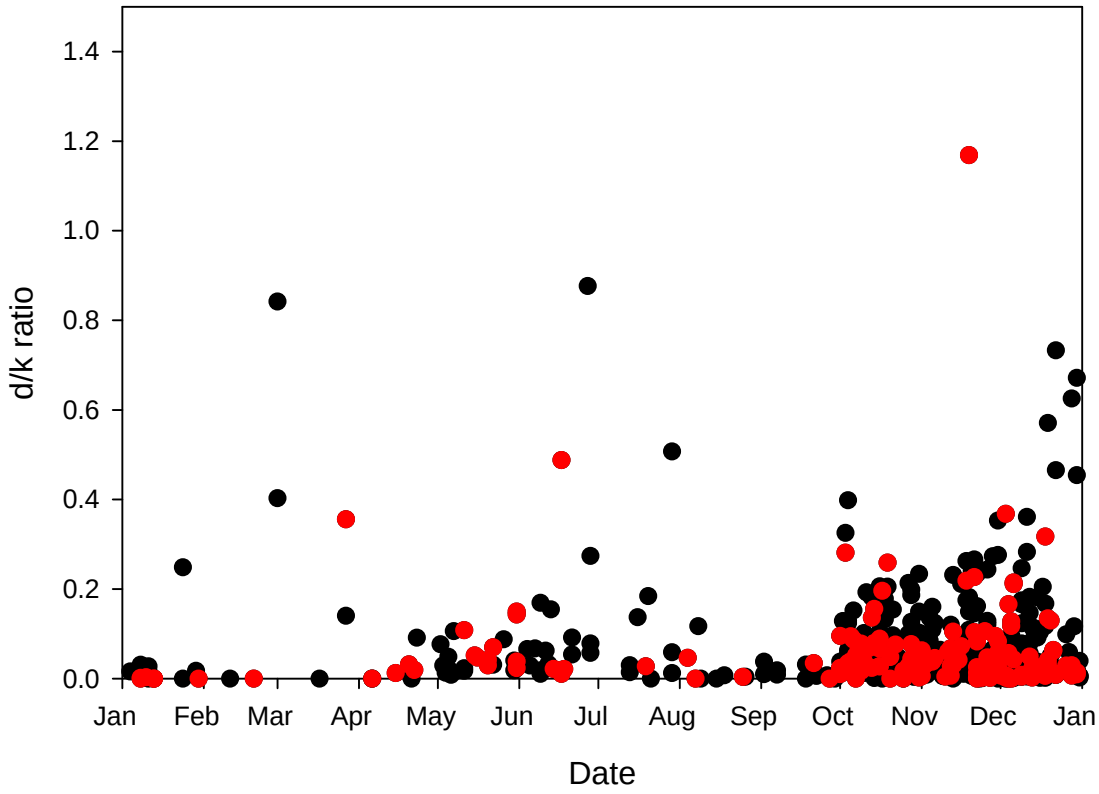
Determining an estimation procedure: testing candidate estimators

- Testing through simulation.
  - Start with a population (529 trips)



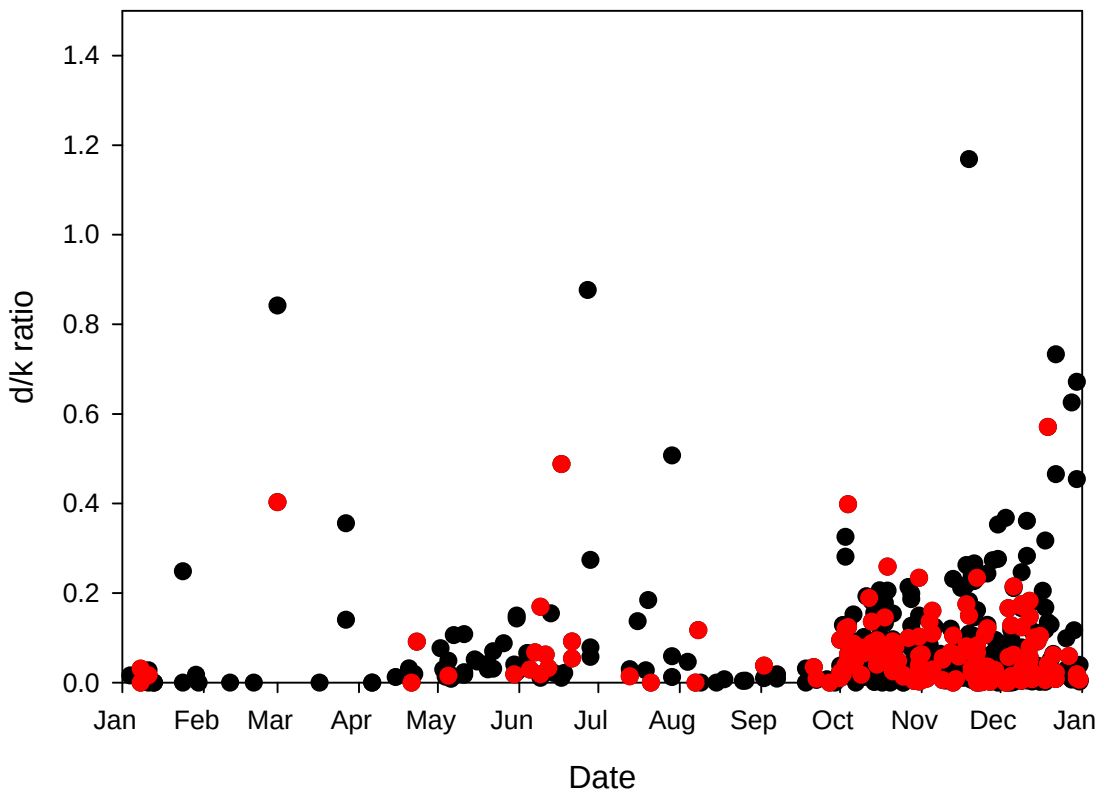
Determining an estimation procedure: testing candidate estimators

- Testing through simulation.
  - Draw a sample of 30% of the total trips (529*0.30≈159 trips).



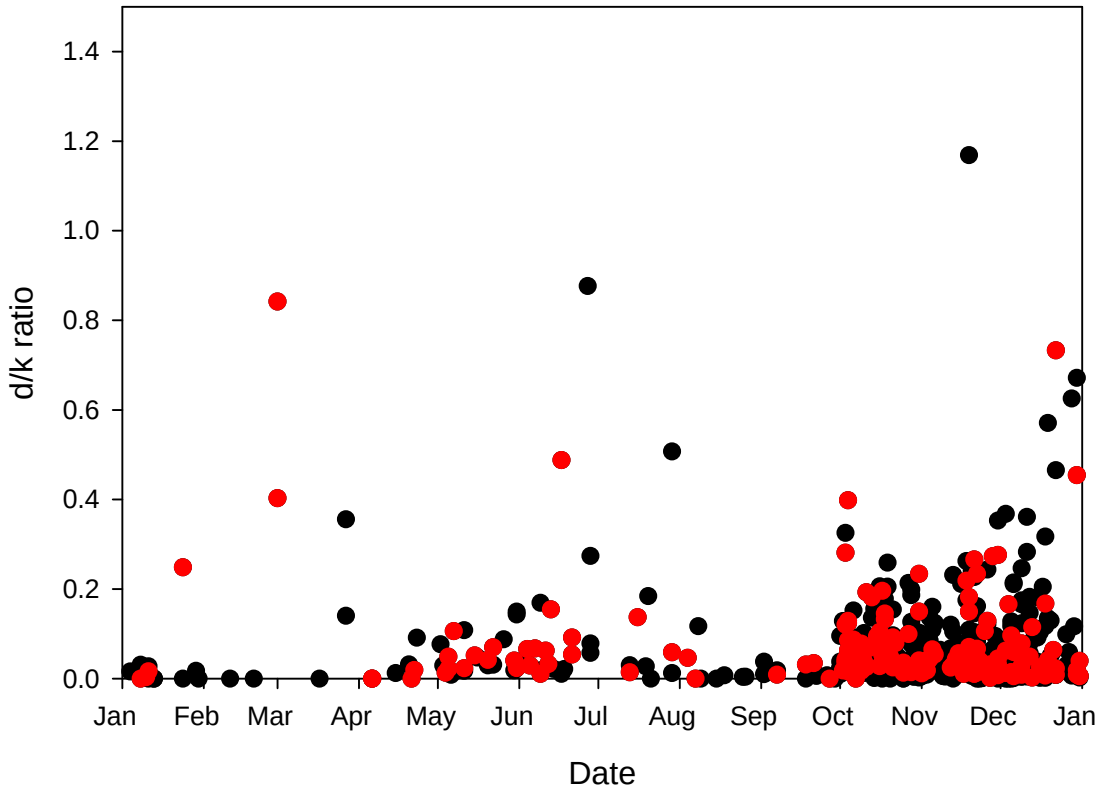
Determining an estimation procedure: testing candidate estimators

- Testing through simulation.
  - Draw a second sample of 30% of the total trips (529*0.30≈159 trips).



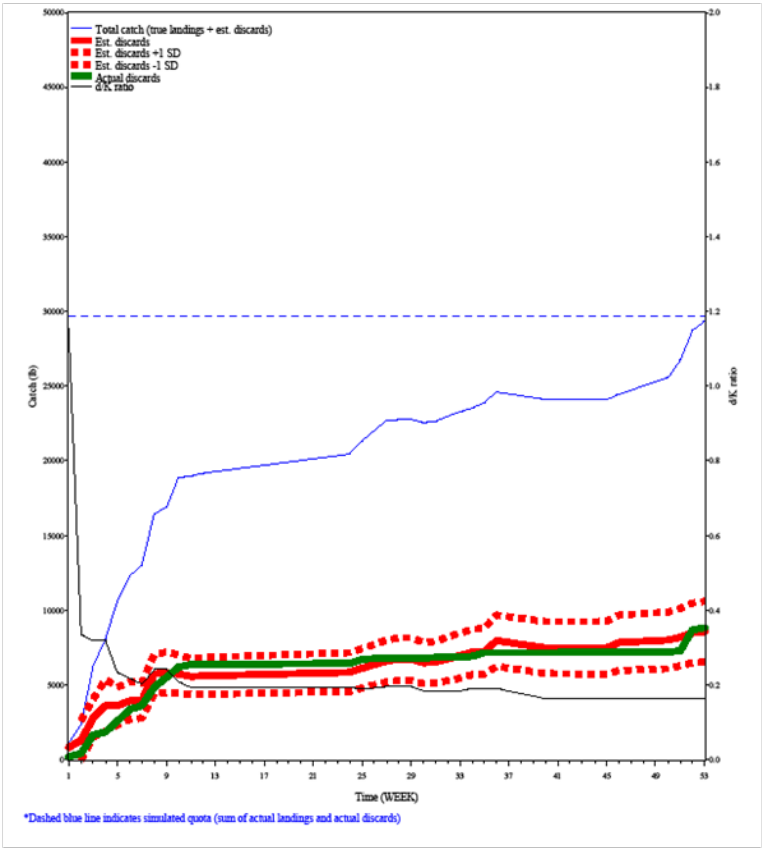
Determining an estimation procedure: testing candidate estimators

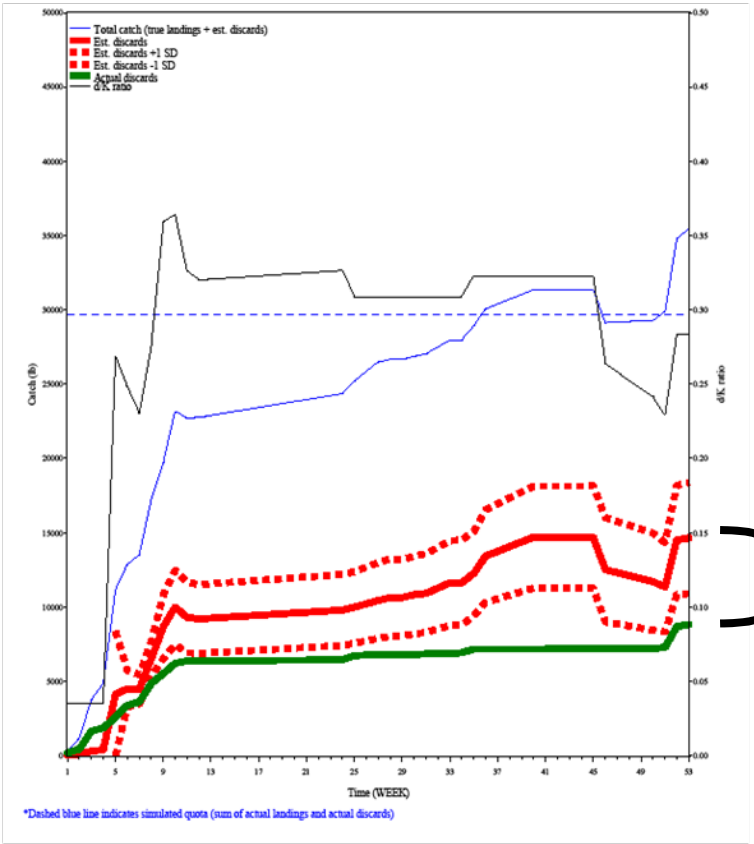
- Testing through simulation.
  - Draw a third sample of 30% of the total trips (529*0.30≈159 trips).
  - Repeat for a total of 1000 times



Determining an estimation procedure: testing candidate estimators

- Simulations were repeated from 1000 to 5000 times to achieve a distribution of the discard estimates derived from random sampling of the population.
  - Examples of individual simulation runs:





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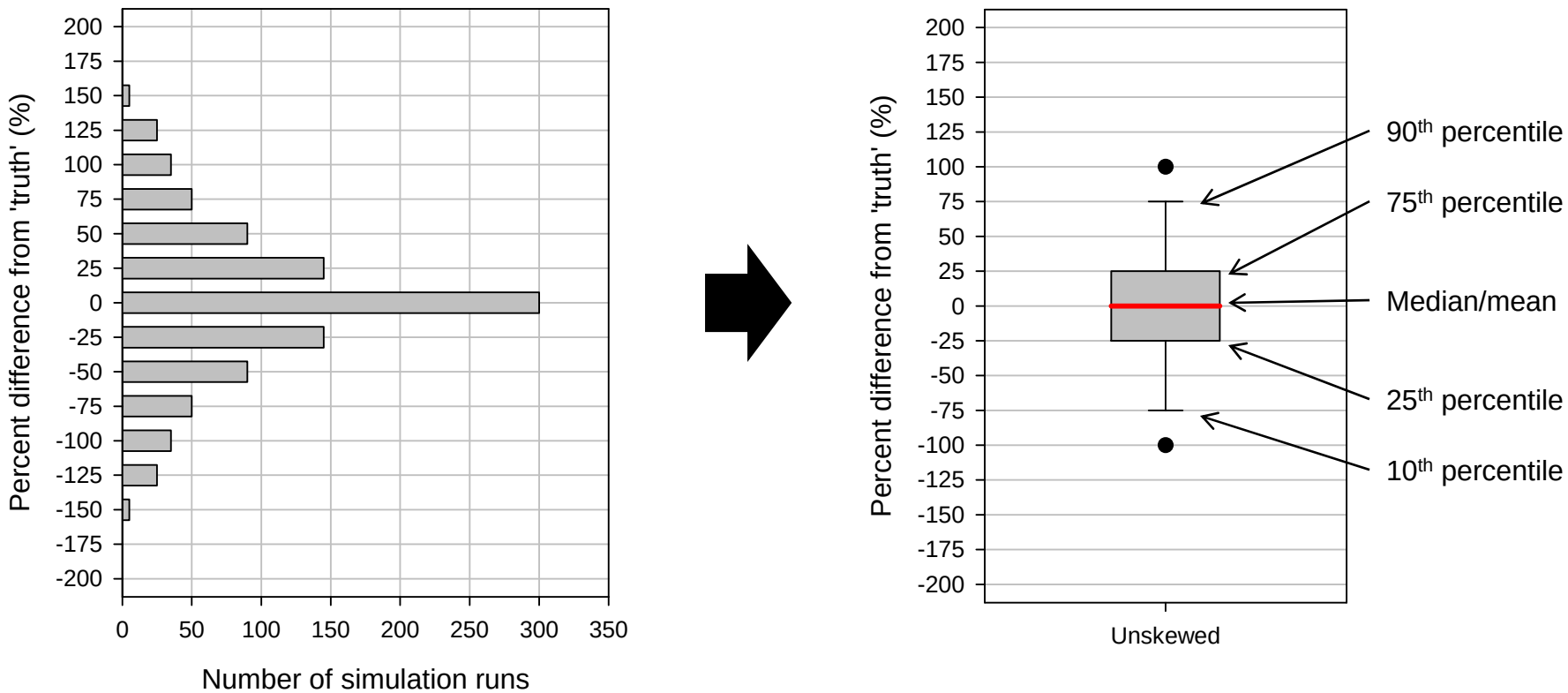
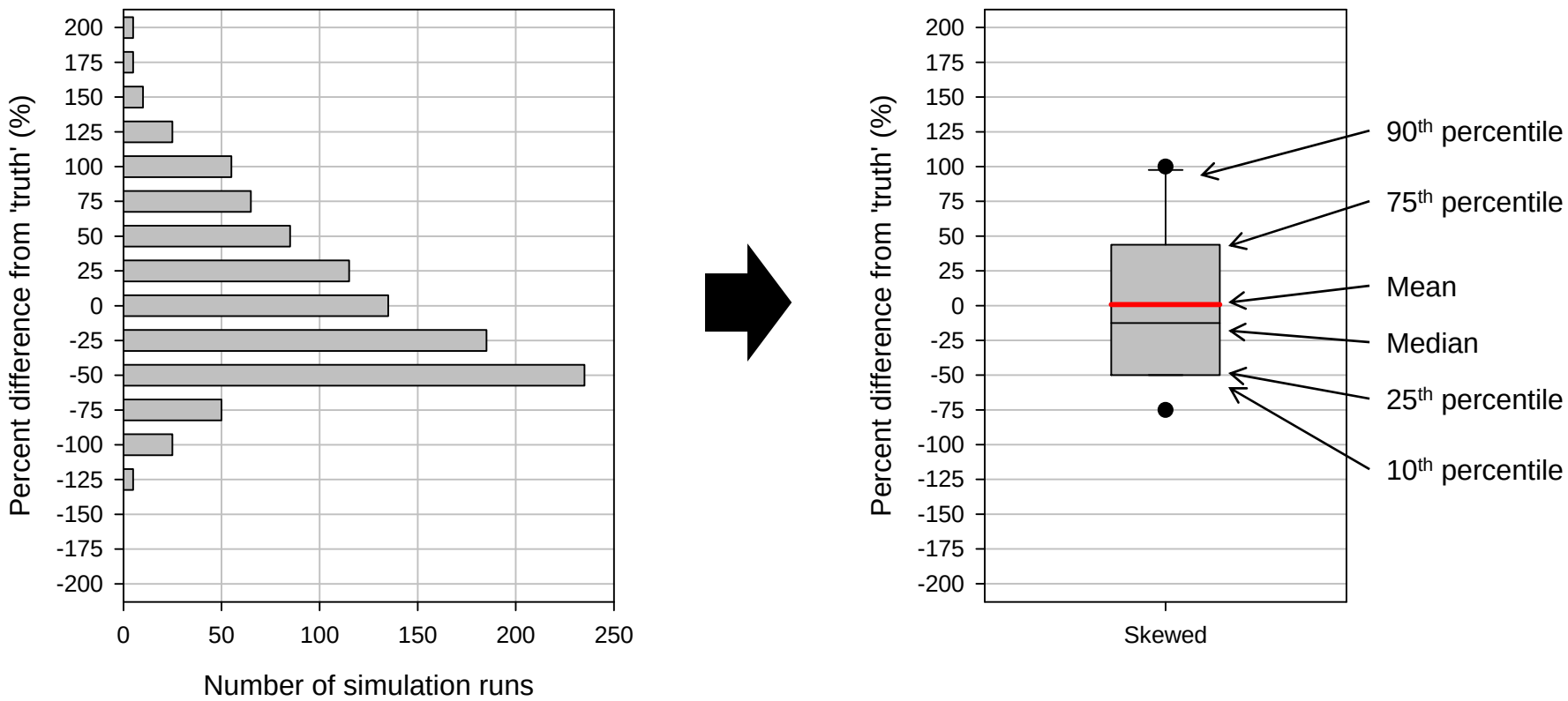
Determining an estimation procedure: testing candidate estimators

- Interpreting the simulation outputs.
  - Example 1: **Uniform** distribution of simulation runs compared to the true discards in the population.



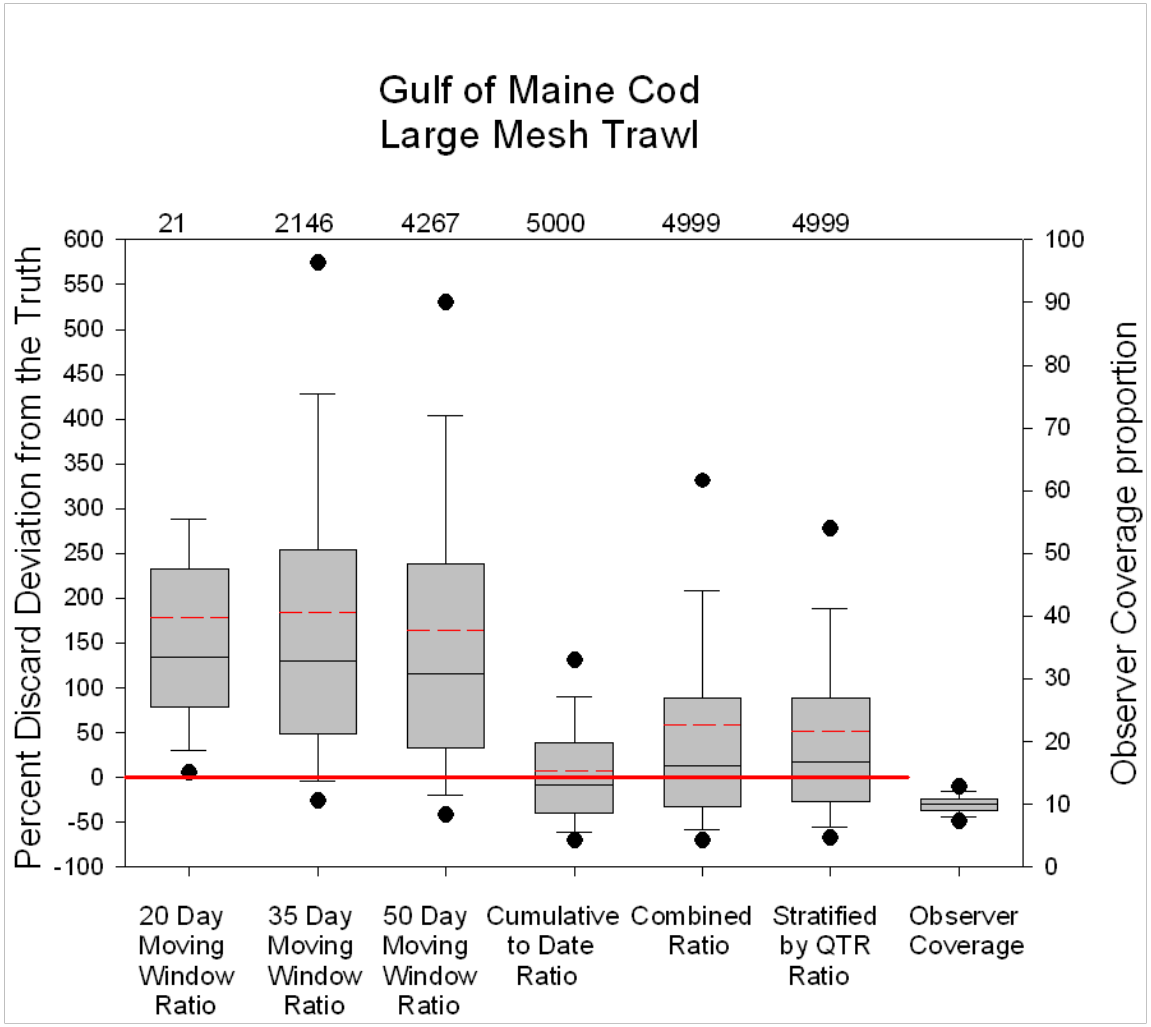
Determining an estimation procedure: testing candidate estimators

- Interpreting the simulation outputs.
  - Example 2: **Skewed** distribution of simulation runs compared to the true discards in the population.



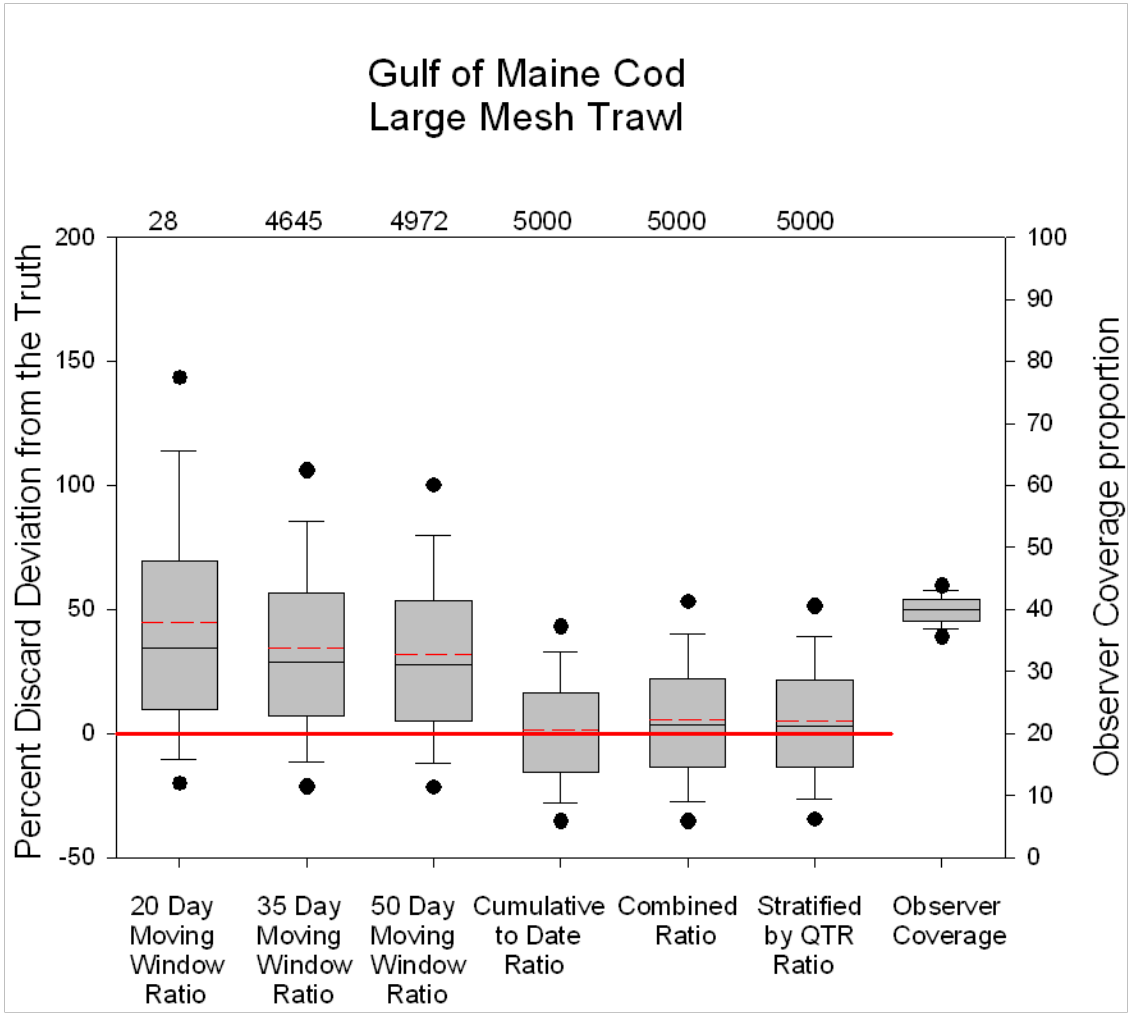
Determining an estimation procedure: testing candidate estimators

- Comparison of candidate estimators at **10% observer coverage**.
  - Stratum size is 100 trips



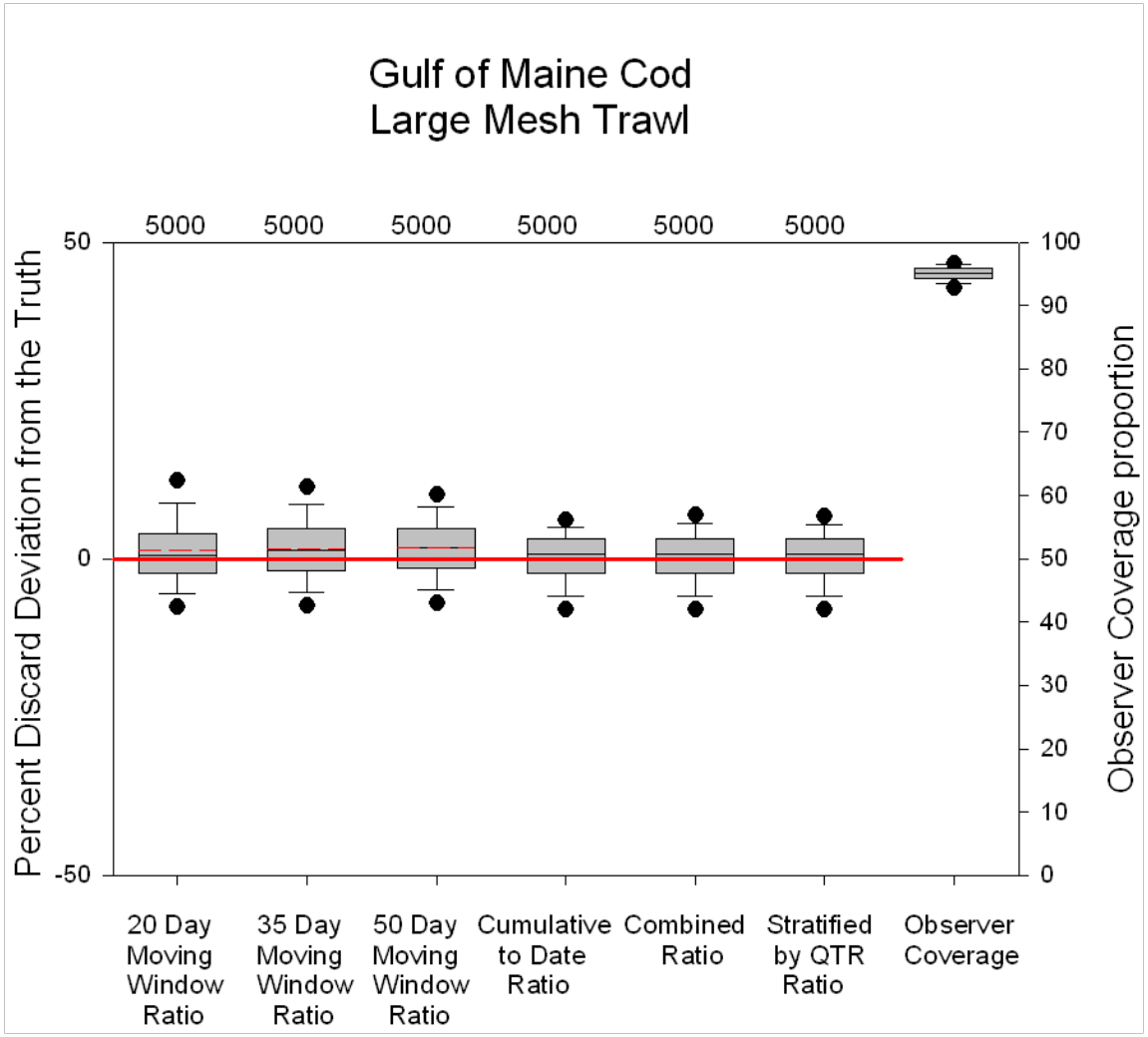
Determining an estimation procedure: testing candidate estimators

- Comparison of candidate estimators at **40% observer coverage**.
  - Stratum size is 100 trips



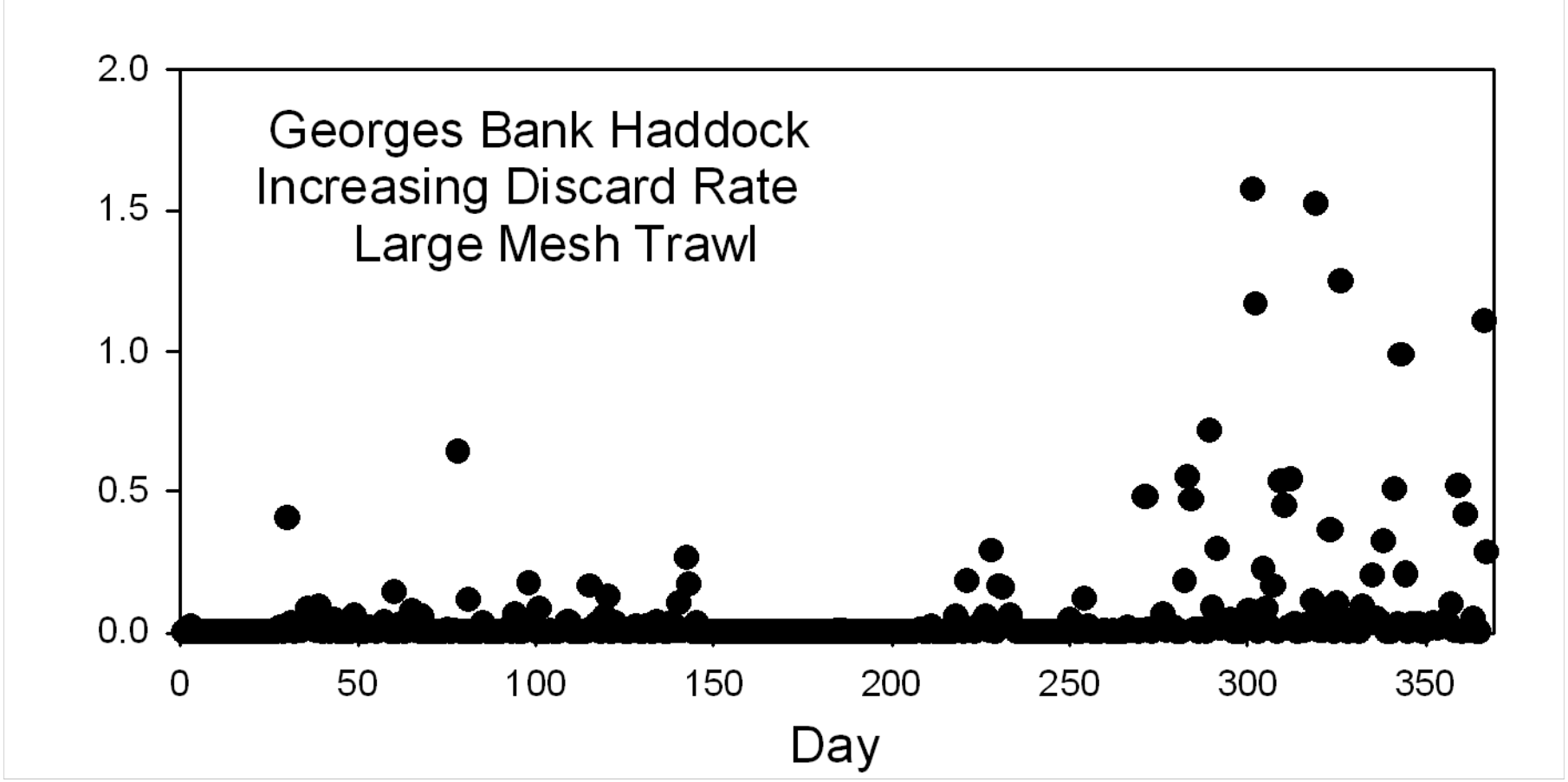
Determining an estimation procedure: testing candidate estimators

- Comparison of candidate estimators at **95% observer coverage**.
  - Stratum size is 100 trips



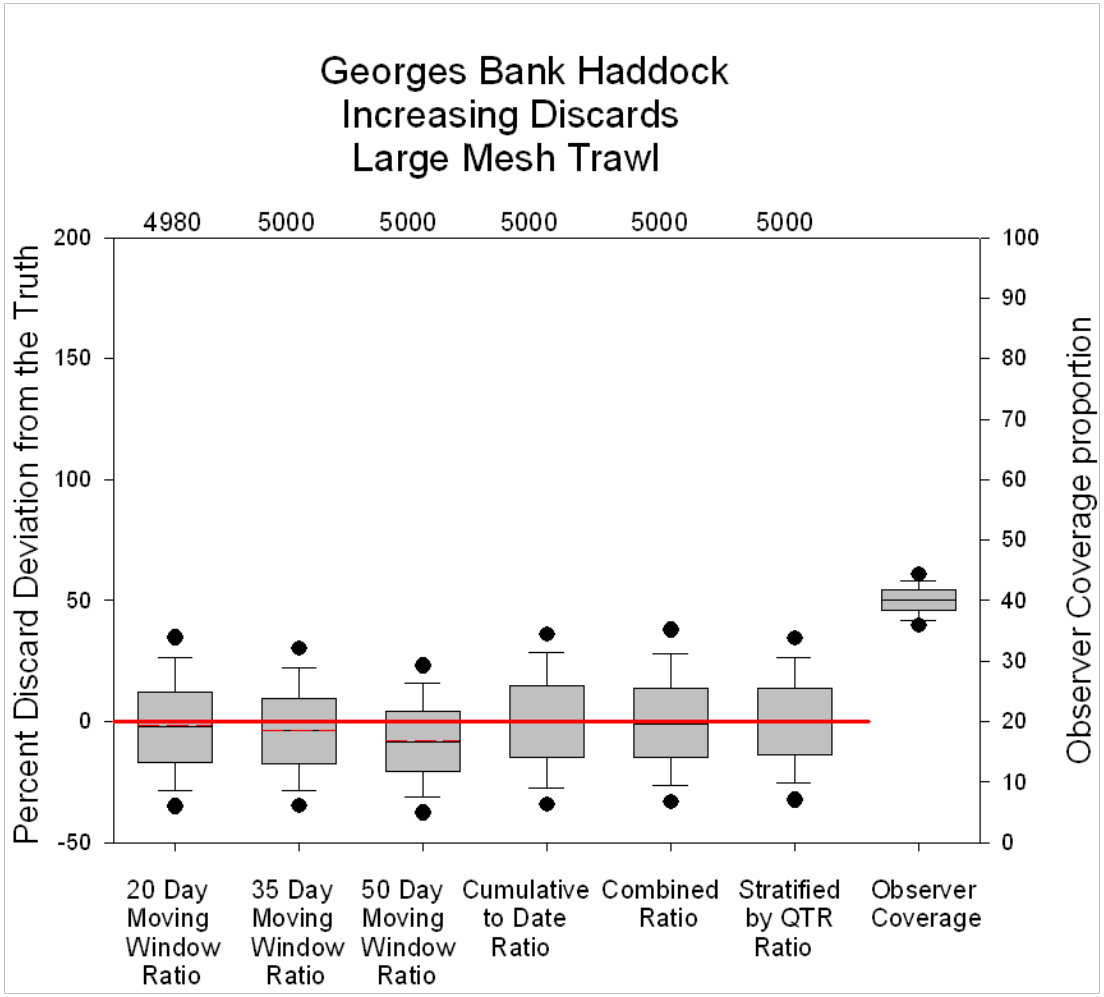
Determining an estimation procedure: testing candidate estimators

- Comparison of candidate estimators when discards are increasing throughout the fishing year.



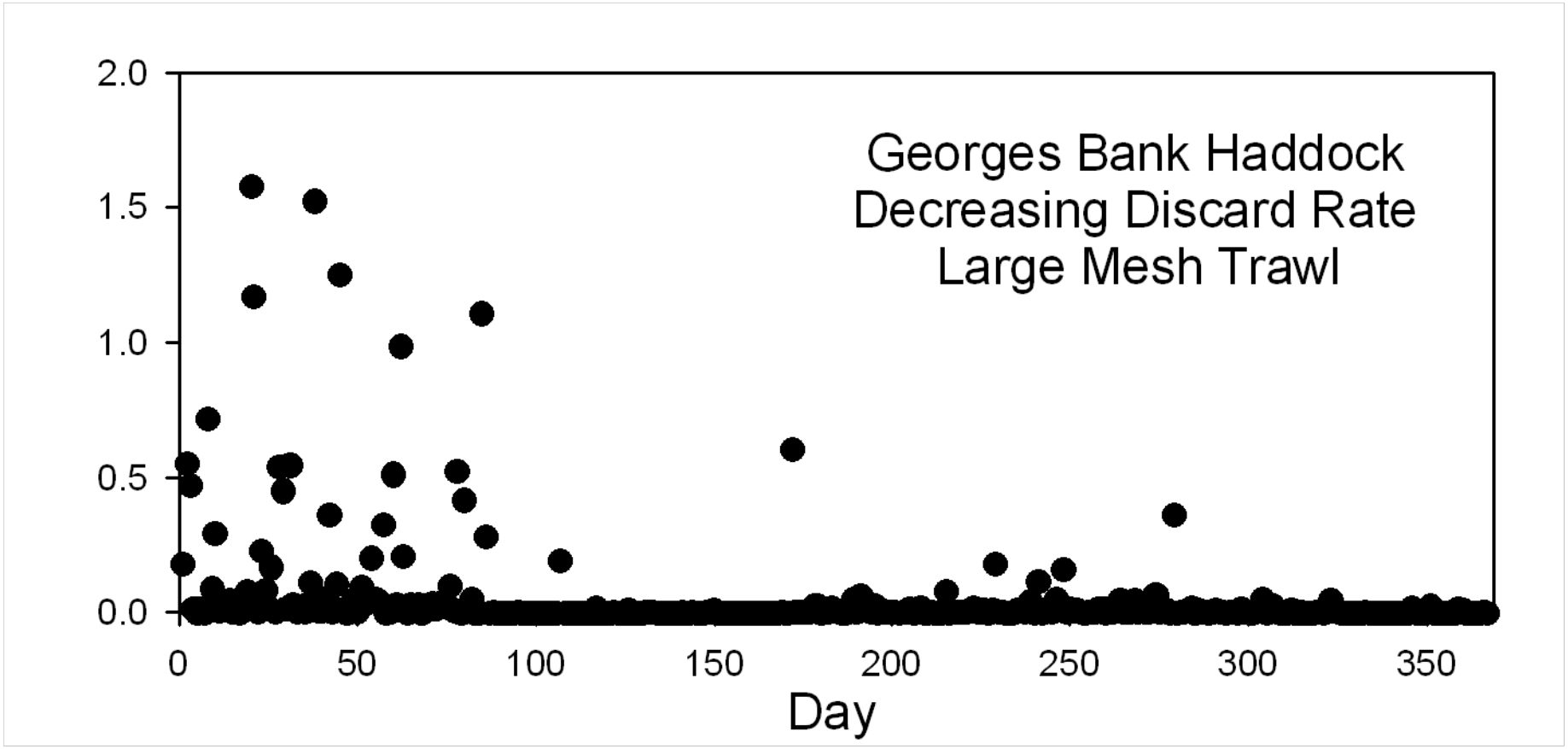
Determining an estimation procedure: testing candidate estimators

- Comparison of candidate estimators when discards are increasing throughout the fishing year.
  - Observer coverage fixed at 40% of 100 trips.



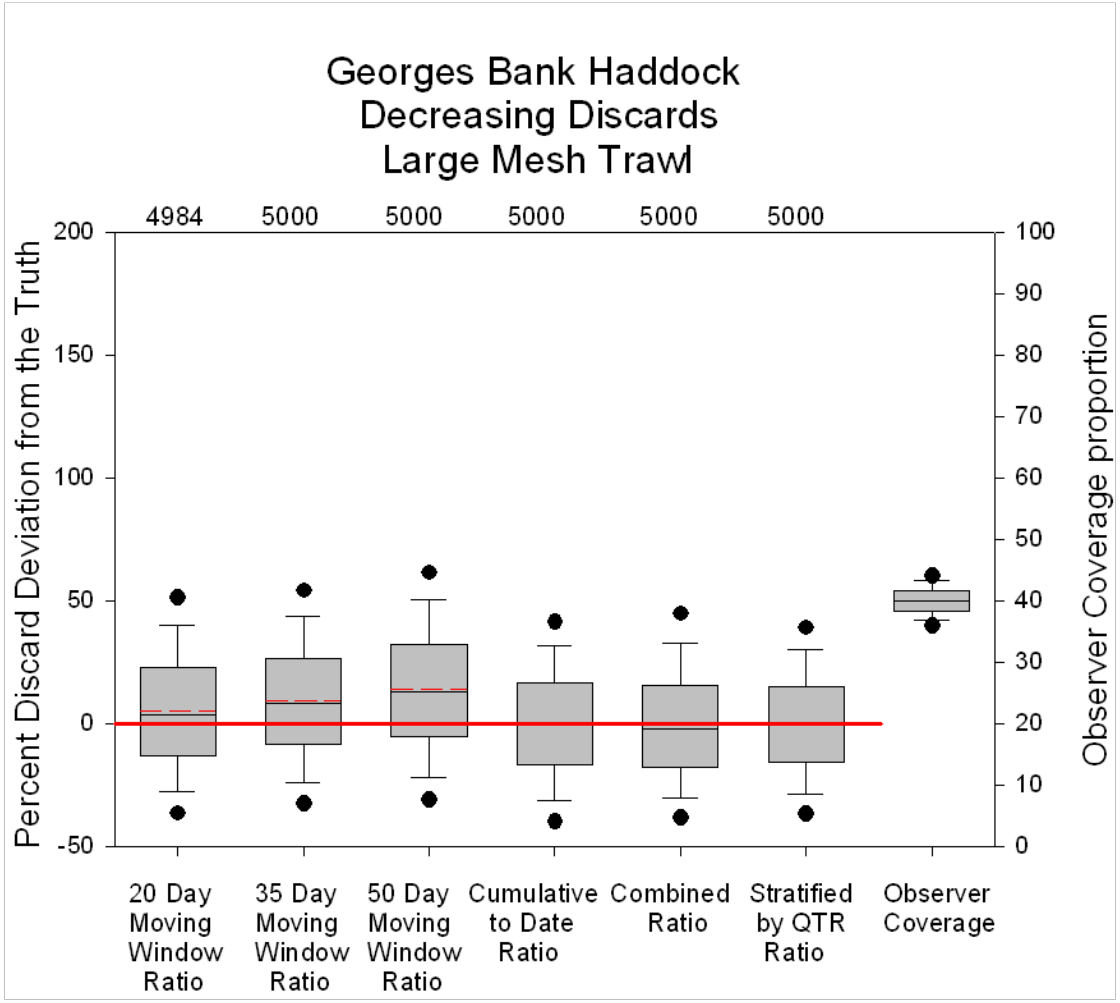
Determining an estimation procedure: testing candidate estimators

- Comparison of candidate estimators when discards are increasing throughout the fishing year.



Determining an estimation procedure: testing candidate estimators

- Comparison of candidate estimators when discards are decreasing throughout the fishing year.
  - Observer coverage fixed at 40% of 100 trips.



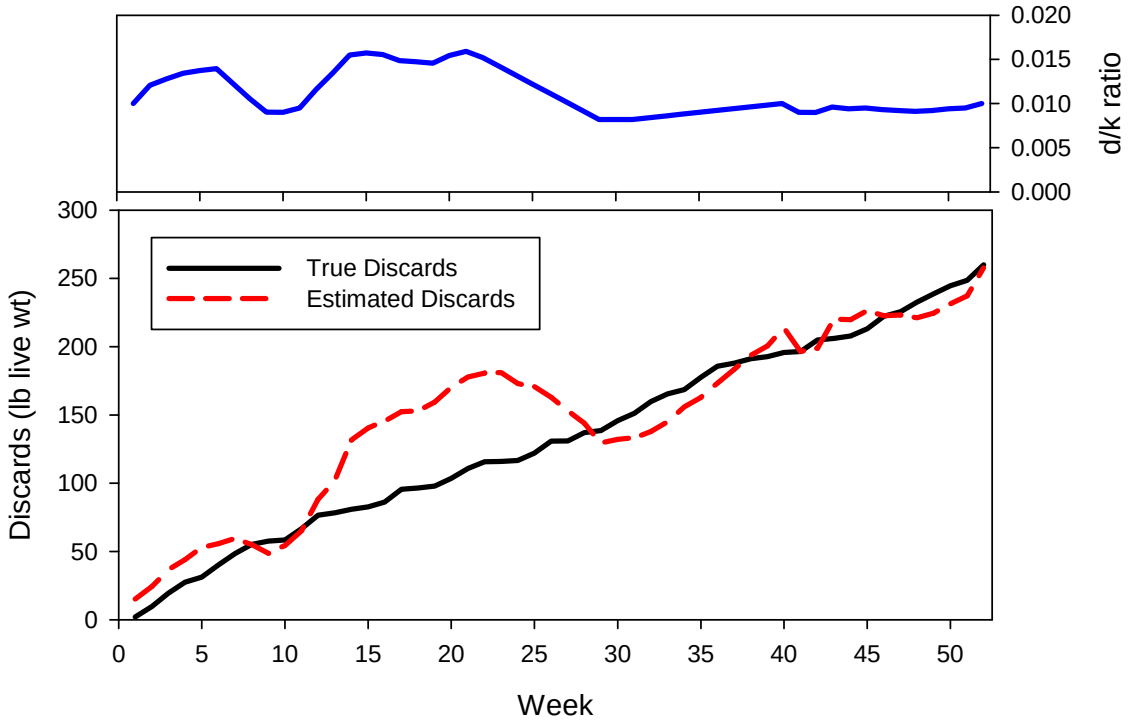
Determining an estimation procedure: testing candidate estimators

- These simulation exercises indicate that the moving average approach can lead to biased estimates of discards particularly when observer coverage is low (≤40%) and trends exist in the underlying discard patterns.

- When comparing the cumulative, combined, and quarterly stratified approaches, the cumulative approach appeared to perform optimally under the conditions examined (i.e., unbiased and relatively precise)….**BUT**…

Determining an estimation procedure: testing candidate estimators

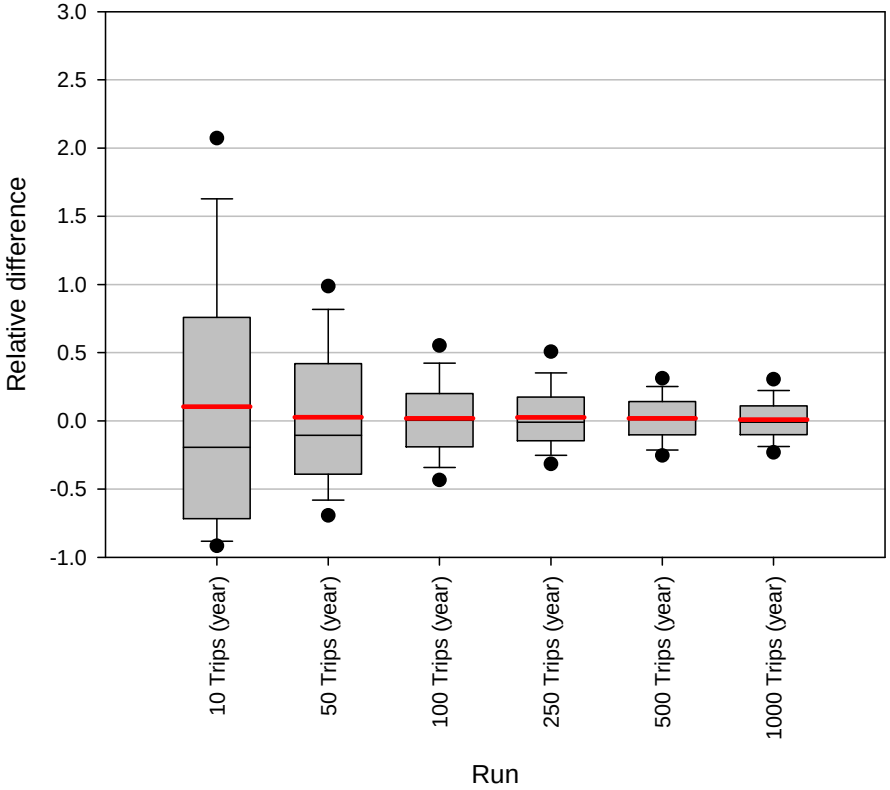
- When reviewing the candidate estimators internally there was considerable concern about the stability of the cumulative approach.
  - The dk ratio can be variable from week to week….
  - Which means…total stratum discards in past weeks will change over time.
  - Which could add to the difficulty that sectors will experience when attempting to determine ACE balances.
  - Are there ways to stabilize the discard estimates without compromising accuracy or precision?



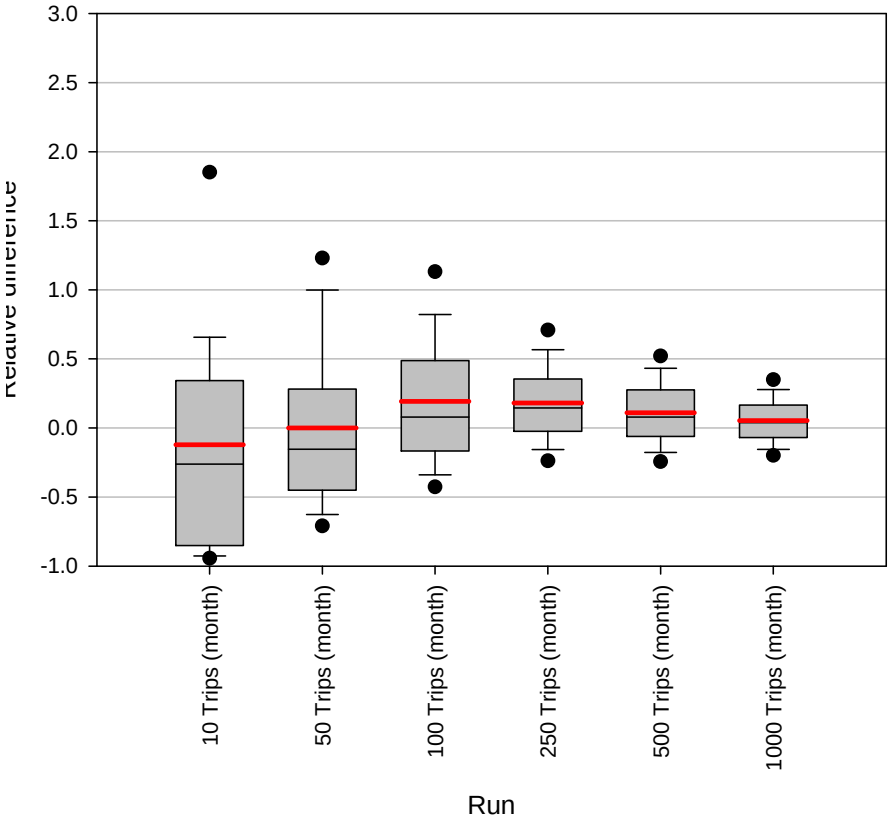
Determining an estimation procedure: testing candidate estimators

- Is there a way to stabilize the discard estimates but still use a variant of the cumulative ratio?
  - Temporally stratified cumulative ratio (e.g., annual, quarterly, monthly)

Comparison of the distribution of discard estimates as a function of population size (year time step)



Comparison of the distribution of discard estimates as a function of population size (month time step)



(haddock estimation in the Gulf of Maine gillnet fishery)

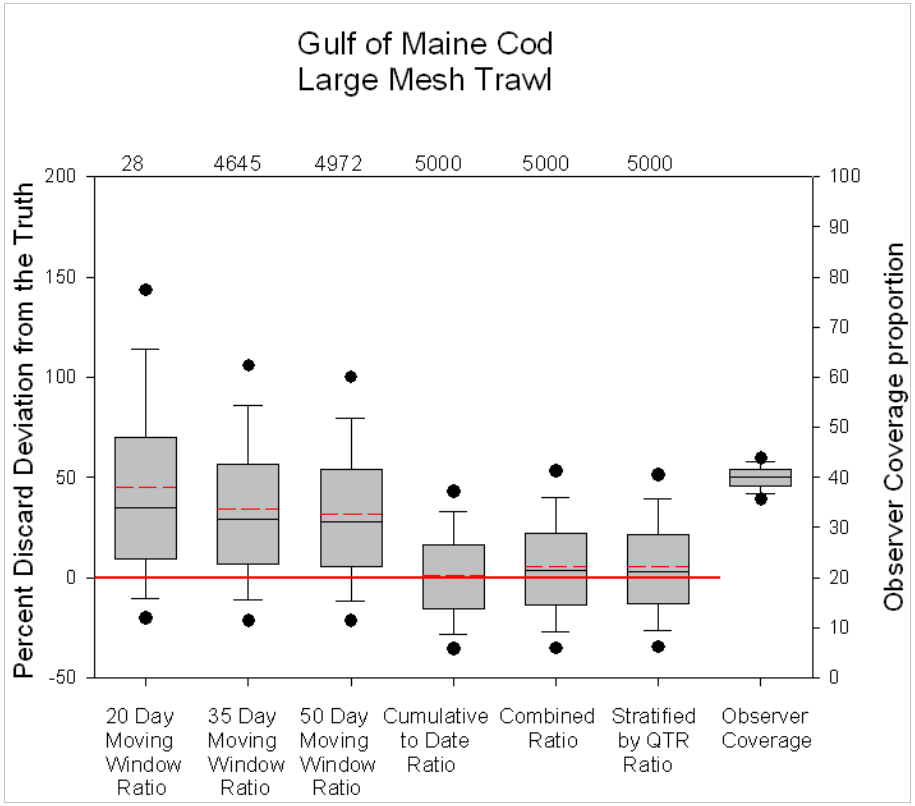
Determining an estimation procedure: testing candidate estimators

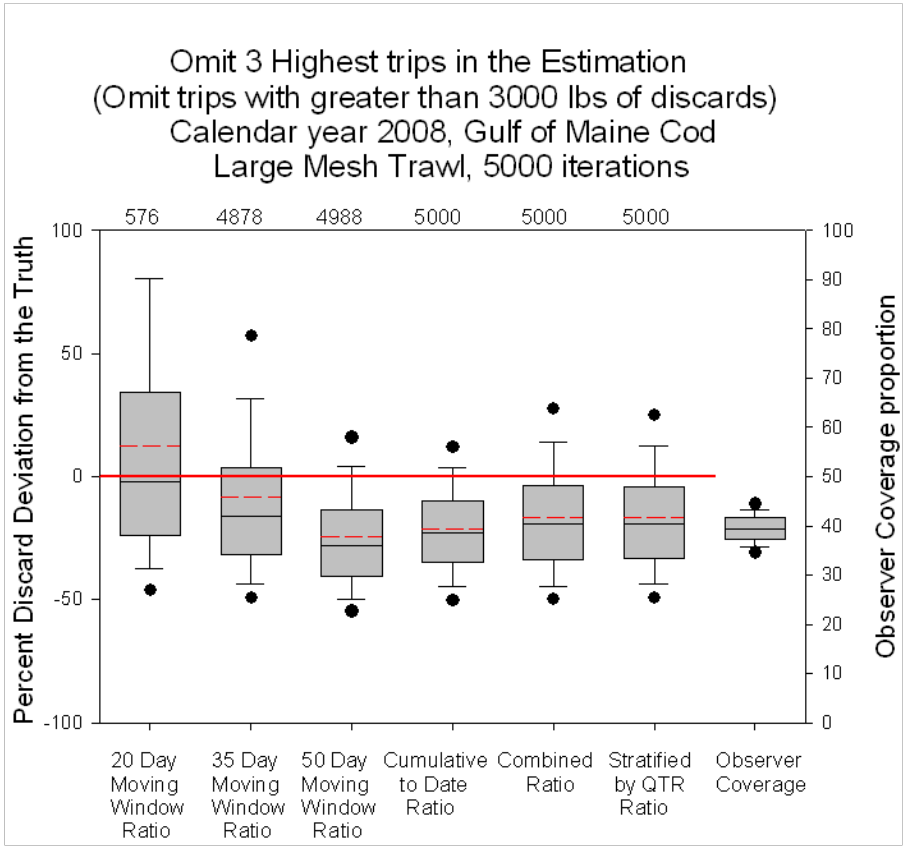
- The annual cumulative method provides an unbiased estimate of stratum discards that, among the candidate estimators examined, is the most robust to the conditions likely to be experienced in the groundfish fishery in 2010.

- While it may be operationally difficult to use this method for in-season monitoring because of the instability, it is the only method that will consistently achieve accurate estimates across the range of conditions that are likely to be observed in the groundfish fishery.

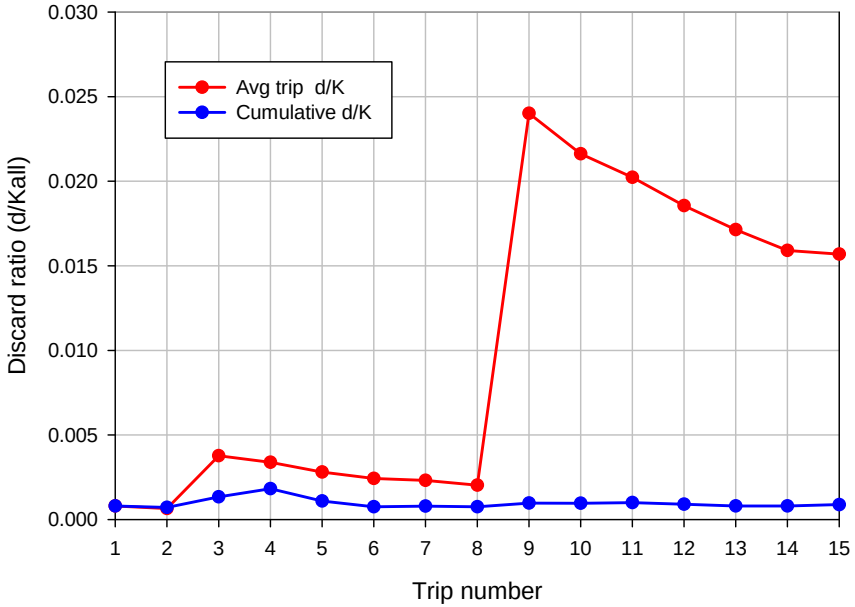
Impacts of trimming (outlier removal) on discard estimation

- What about the effects of ‘outliers’?
  - Won’t these bias the discard estimates?
- How does trimming high/low discard events impact the accuracy of the discard estimate?





Impacts of trimming (outlier removal) on discard estimation

- If the observer deployment is randomly stratified and unbiased, observed events should be representative of the population.
  - Large and small discarding events should be observed in proportion to how they are occurring in the population.

- The cumulative method buffers the discard ratio from being unduly influenced by trips with high discards.