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Cumulative discard methodology review for groundfish discards in the Northeast United States groundfish fishery

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A working paper in support of the Cumulative Discard Methodology Peer Review

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Introduction

The Magnuson-Stevens Reauthorization Act required United States fishery managers to set annual catch limits (ACLs) for all overfished stocks by 2010 (2011 for all stocks). Monitoring of ACLs required that fishery catches (landings and discards) be monitored effectively in near real-time. Additionally, Amendment 16 (A16) to the Northeast Multispecies Fishery Management Plan allowed for the addition of up to 17 new groundfish sectors to begin operations on May 1, 2010 in the Northeast United States groundfish fishery. Each sector receives Annual Catch Entitlements (ACEs) of certain federally managed groundfish stocks. The ACEs are smaller subdivisions of the federal commercial groundfish ACLs which are sub-components of the overall groundfish ACLs.

The Northeast Multispecies Fishery Management Plan (Plan) covers twenty groundfish stocks in 22 management areas (Table 1). Concurrent with A16, a Discard Estimation Methodology Review was performed to develop a new method for estimating in-season discards resulting in the Cumulative Discard methodology that is currently in use. This Peer Review looks at one of the recommendations of the 2010 review, to evaluate the 2010 Cumulative Discard methodology with five years of data available.

Sectors are allowed to apply for and if approved receive exemptions (sector exemptions) from some rules implementing of Amendment 16. Many sector exemptions have been approved to date including two related to monitoring. The “redfish exemption” exempts sector trips from having to fish their entire trip using 6 ½” trawl gear, allowing them to fish down to 5 ½” trawl gear with area restrictions. The “small mesh exemption” allows vessels to target small mesh species using small mesh trawl gear on a sector trip. Both exemptions require vessels to declare their intent to fish under an exemption at the start of their trip. Additional information on these sector exemptions can be found in the sector operations plan final rule at http://www.greateratlantic.fisheries.noaa.gov/regs/2015/May/15mul20152016sectoropsfr.pdf.

The current monitoring method is used to estimate discards for stocks in each of the 22 management areas. For each stock/management area, each part of each trip (“sub-trip”) is stratified into several hundred strata based on sector membership, gear and mesh size, and declared sector exemption. Trips are randomly selected for observer coverage. Within each stratum the observed discards of the stock are summed across sub-trips and are divided by the sum of the observed commercial kept catch to generate a stratum discard rate. This rate is applied to the sum of the commercial kept catch for all unobserved sub-trips in the stratum to estimate commercial discard for on unobserved trips. This is added to the observed discard to estimate discards for the stock as a whole. This applies to the entire groundfish fishing year which runs from May 1st through April 30th.

At the beginning of the fishing year, a transition discard rate is employed to generate an estimate of stock discards until five groundfish subtrips have been observed. If any time during the fishing year estimated stock catch were to exceed the sector ACE, the sector would be prohibited from fishing in the stock/management area until the sector leases in more ACE or ACE otherwise becomes available.

The current sector, gear/mesh, and sector exemption stratification is the ‘baseline’ stratum. This review implements a method of generating alternative sets of strata and compares four alternatives to the baseline stratification schema.

This working paper describes the data and methodology used to respond to the Terms of Reference of the 2016 Cumulative Discard Methodology Peer Review (Appendix 1).

Methods

Data sources

In-season monitoring of the groundfish fishery relies upon two main sources of data:

1) Northeast Fisheries Observer Program Fisheries Observer Program (NEFOP) Reports: The NEFOP deploys fisheries observers on commercial fishing trips in New England and Mid-Atlantic waters. Most vessel operators are required to alert the Observer Program of their intent in the groundfish fishery prior to sailing. For the monitoring program, audited observer data from groundfish trips are made available to the Analysis and Program Support Division within 3 days of the end of an observed trip. For this analysis, data were drawn from both Observer Database System and At-Sea Monitoring databases. Information from trips that were reported by observers and at-sea monitors to have been groundfish trips were included in this analysis. It is important to note that only hauls that were observed for discards were used to calculate a ratio of stock discarded to observed kept all species.

2) Data for total pounds of all species kept on groundfish trips were sourced from the Data Matching and Imputation System (DMIS). DMIS data are dealer-reported landings reports matched to trip or subtrip-based information from Vessel Trip Reports (VTR) and Vessel Monitoring System (VMS) activity code declarations. VTRs are the source for area fished, landing date, and fishing gear used.

Sector exemptions, sector membership and the number of actively fishing permits have changed since ACL accounting was implemented in 2010. In order to reflect the groundfish fishery moving forward, the following modifications were made to both the historical observer and DMIS data:

1) Trips under historical sector memberships were updated to FY16 sector memberships based on moratorium right id (MRI)
2) Trips under MRIs currently in confirmation of permit history (CPH) were removed
3) Trips under MRIs that have been cancelled were removed
4) Trips under sectors that are currently lease-only were removed
5) FY15 sector exemption declarations were added to the data
6) Trips by open-access groundfish vessels were removed
7) Subtrips with disallowed groundfish gear were removed, including trawl gear with less than 5.75” mesh

A Moratorium Right Id (MRI) is a fishing privilege in the limited access groundfish fishery. It represents a share of the fishery in effect. Limited-access groundfish vessels must fish under an MRI. Each MRI receives a Potential Sector Contribution (PSC) of fish, their share of the quota for each of the 22 groundfish stocks.

CPH is a manner of storing an MRI for an indefinite time without having a vessel to apply it to. The MRI still receives PSC. Sectors can lease out PSC to other sectors from MRIs that are in CPH the same as with MRIs on active vessels.

Estimation of stock discards and precision

The cumulative discard method in the groundfish fishery is currently based on a ratio estimate pooled over all groundfish trips for an entire fishing year. Using the separate ratio method, the total discarded pounds of species *j* is defined as:

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

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

where: $\hat{D}_{1,j}$ 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*

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

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

And the coefficient of variation (CV) of $\widehat{D}_{bt}$ is defined as:

(4) $$CV(\widehat{D}_{1,j}) = \frac{\sqrt{V(\widehat{D}_{1,j})}}{\widehat{D}_{1,j}}$$

where $V(\widehat{D}_{1,j})$ is the variance of estimated discards of species *j* on groundfish trips;

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

For Terms of Reference 1 and 2: '…summarize the variability in discard rate by measurable strata' simulations as described in Galuardi, Linden and McAfee (2016) were run on 2015 data for different stratifications (see Table 2): by combining all vessels (baseline) vs. vessel length category; by separate sectors (baseline) vs. combining sectors together; by combining Broad Stock Areas (BSAs) (baseline) vs. separating BSAs; and by both separate sectors and combined BSAs (baseline) vs. both combining sectors and separating BSAs. Table 3 displays partial results of the baseline runs.

Throughout this analysis the five trip transition rate is used unless otherwise specified. Note that a 365 day moving average or other alternative transition rate can be analyzed in the same way.

Results and Discussion

Four alternative stratification cases were examined and compared to the baseline case;

Vessel Length Category – this alternative retains the same stratification as the baseline except case for adding vessel length category strata. This categorized vessels into four groups; less than 30 feet, from 30 feet to less than 50 feet, from 50 feet to less than 75 feet, and greater than or equal to 75 feet. The baseline case does not stratify by vessel length

Combine Sectors Together – this alternative retains the same stratification as the baseline case except for combining all sectors into one stratum, separate from the common pool. The baseline stratifies by individual sector and common pool.

Separate Broad Stock Area (BSA) - See Figure 1. This alternative retains the same stratification as the baseline case except adding BSA strata. The baseline does not stratify by BSA. Note that a number of groundfish stocks occur in only one BSA and so are not generally impacted by this stratification.

Combine Sectors Together and Separate BSA – this alternative retains the same stratification as the baseline case except for both combining all sectors into one stratum and adding BSA strata.

Combined Coefficients of Variation (CVs) by stock were calculated using Galuardi (2016) using the approached described by Cochran 1977 and are summarized in Table 2. CVs varied from the baseline by as much as 36.4% higher to 25.9% lower. Three stocks – SNE/MA yellowtail flounder (SNE yellowtail), GB winter flounder, and SNE/MA winter flounder all had combined CVs consistently greater than 30. In particular SNE yellowtail returned CVs in the high 70s and low 80s. These high values were driven by two strata, common pool using bottom otter trawl and gillnet gear using extra-large mesh which came under the SNE ELM Gillnet sector exemption. When trips from these two strata were removed from the SNE yellowtail run the combined CV dropped into the 20s.

Of the four stratifications examined, categorizing by vessel length appears to have the most promise with five CVs substantially improved (reduced by greater than 10%) and three worsened (increased by more than 10%). This could reflect differences in fishing behavior between the larger off-shore vessels and the smaller inshore vessels. Combining all sectors together showed the worst results. This could reflect the varied behavior of different sectors.

With respect to the BSA stratification note that nine of the stocks/management areas are limited to one BSA. This results in no change in the CV vs. the baseline case. The single BSA stocks were not counted when calculating % counts of CVs increasing and decreasing for the BSA stratification. Inferential statistics to determine statistically significant differences among the CVs should be included as part of a future analysis.

Table 3 displays bootstrapped median catch and resulting confidence intervals (CIs) around the catch along with the FY15 quota for each stock. Results tended varied somewhat from the CV results. The vessel length category stratification again looked promising with some ten CIs shrinking by more than 10% and three increasing by more than 10%. The BSA stratification did not perform as well six increased CIs and two CIs being reduced.

With respect to the BSA stratification, note that seven of the stocks are limited to one BSA. This would be expected to result in only small changes in the median catch and CI vs. the baseline case solely due to the randomness of the bootstrap.

Paired t-tests, Wilcoxon signed-rank tests, and sign tests were run testing if the proportional width of the CI (CI width / median catch) of the baseline was greater than or equal to that of each alternative. The GB cod and haddock east and west management areas were excluded to avoid double-counting. For the vessel length categorization, combine sectors together, and combine sectors together with BSA alternatives all 20 stocks were used. For the BSA alternative single BSA stocks were excluded resulting in 13 stocks used. For all tests for all alternatives we could not reject the null hypothesis that the baseline CI widths were greater than or equal to the alternative widths – there were no statistically significant differences. More work should be done to explore other ways of evaluating alternative stratifications.

One caveat to note for the catch is that a number of FY15 groundfish trips were removed from the analysis to reflect the FY16 active vessel population. Trips by vessels that went into Confirmation of Permit History (CPH), vessels that entered a lease-only sector, etc., were eliminated from the population which reduces the total number of groundfish trips being assumed for the fishing year. However in all likelihood much of the quota share associated with those vessels may be fished by other vessels. It is unlikely that those catch are completely eliminated. Therefore these catch estimates may underestimate how much fish the fleet could catch in FY16 and going forward.

We made an introductory look to in-season catch estimation. Charts of estimated catch of selected stocks with confidence intervals are presented in Figures 2 through 4. The red dashed line near the top is the FY15 quota. Note that although these charts are all from the baseline scenario it is straightforward to plot any catch estimates for any of the stratification alternatives and transition rate alternatives.

Figure 2 of Georges Bank winter flounder baseline catch was rather typical of allocated stock charts. Even though from Table 3 the CVs for the baseline are greater than 30, the width of the ending 95% confidence interval of about 7.5 mt is small relative to the 869 mt final median catch, so on the chart the confidence bands are difficult to see. Figure 3 shows baseline Atlantic halibut with a 365 day moving average transition rate which had a greater proportion of discards to kept halibut. Here the confidence bands are clear.

Figure 4 shows estimated catch of a discard stock, baseline northern windowpane flounder with a 365 day moving average transition rate. The upper confidence bands cross over the quota line. This method enables estimates of the probability of a "false positive" closure, i.e., a closure to the randomness of the data even though the median estimated catch is under the quota. See the Figure 6 discussion below. The probability of a "false negative" also can be estimated using this method, where the median is above the quota line but the lower confidence bands are below the quota line. In this case the fishery could remain open even though the true population catch is above the quota.

We made an introductory look at the realized CV as a function of observer coverage in Figure 5 for baseline white hake catch. The observer coverage of 17.3% resulted in an estimated CV of 0.15, the lower left-hand intersection of the two blue lines. Observer coverage of 31.1% results in a CV of 0.30 when weighing the individual strata coverage by their total estimated discard. Discards are estimated by stratum. Weighing observer coverage by estimated discard means that strata with larger discard receive proportionally more coverage such that all discard has equal observer coverage. The low actual CV and observer coverage for white hake in the example implies that actual observer coverage was concentrated in strata with low CVs relative to discards. This represents one hypothetical way measuring how well observer coverage is distributed across strata and could potentially result in more stable predicted observer coverage requirements. Again note that one can create this same chart for stratification alternatives and transition alternatives.

Finally we looked at confidence intervals of catch as a function of observer coverage in Figure 6. This displays cumulative northern windowpane baseline catch over the year. The lines shaded from light to dark are 95% confidence intervals for coverage ranging from the actual FY15 rate of 20.5% through 60%. Higher coverage rates were simulated by drawing additional samples from the existing observed trips. As one would expect the end of year 95% confidence interval shrinks, from (76.7 mt – 117.0 mt) to (83.5 mt – 103.5 mt). At the actual coverage rate of 20.5% the first day of a potential premature closure is expected January 23rd and the probability of a premature closure is 38.3%. At a coverage rate of 60% the first day of a potential premature closure is April 7th and the probability of a premature closure is 21.7%.

Expected catch with confidence intervals can be run for other coverage rates such as target NEFOP coverage, target FY16 total coverage (NEFOP and at-sea monitor (ASM)), and coverage required for a 97.5% probability of remaining below the quota. Note this was a different run of the northern windowpane baseline from the catch displayed in Table 4; the results are slightly different presumably due to bootstrap randomness. Further work should include reviewing how many bootstrap runs are necessary for parameter estimates with a required precision.

In general this methodology appears to provide potential for examining many alternative stratifications across the groundfish stocks. The results on this review indicate many directions for future analyses that could lead to improvement in precision of catch estimates and more information for managing the fishery.

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

Table 2

CVs by Groundfish Stock and Stratification Alternative

Fishing Year 2015 Trips; Five Trip Transition Method

Stock	CV					Percent Difference from Baseline			
	Baseline	Vessel Length Category	Combine Sectors Together	Separate Broad Stock Area (BSA)	Combine Sectors Together and Separate BSA	Vessel Length Category	Combine Sectors Together	Separate Broad Stock Area (BSA)	Combine Sectors Together and Separate BSA
GB Cod East	0.30	0.22	0.25	0.30	0.25	-24.2%	-14.8%	0.0%	-14.8%
GB Cod West	0.13	0.14	0.14	0.15	0.14	3.1%	7.5%	12.7%	7.9%
GB Cod	0.12	0.12	0.13	0.13	0.14	2.8%	12.6%	12.5%	13.7%
GOM Cod	0.22	0.21	0.23	0.22	0.23	-4.7%	4.0%	0.0%	4.0%
GB Haddock East	0.24	0.26	0.23	0.24	0.23	8.8%	-3.8%	0.0%	-3.8%
GB Haddock West	0.11	0.11	0.13	0.11	0.12	1.4%	19.3%	-1.7%	12.5%
GB Haddock	0.10	0.12	0.13	0.11	0.12	15.8%	25.2%	12.6%	19.6%
GOM Haddock	0.13	0.10	0.11	0.13	0.11	-25.2%	-20.5%	0.0%	-20.5%
GB Yellowtail Flounder	0.27	0.31	0.26	0.27	0.26	14.8%	-5.2%	0.0%	-5.2%
SNE/MA Yellowtail Flounder	0.78	0.82	0.77	0.78	0.77	5.6%	-0.7%	0.0%	-0.7%
CC/GOM Yellowtail Flounder	0.10	0.09	0.12	0.10	0.13	-14.9%	18.0%	1.2%	27.7%
Plaice	0.08	0.08	0.07	0.07	0.07	1.9%	-6.6%	-6.5%	-6.1%
Witch Flounder	0.09	0.09	0.09	0.08	0.08	1.3%	-1.1%	-5.5%	-5.6%
GB Winter Flounder	0.38	0.36	0.39	0.38	0.39	-3.2%	2.6%	0.0%	2.6%
GOM Winter Flounder	0.11	0.13	0.14	0.11	0.14	9.3%	21.6%	0.0%	21.6%
SNE/MA Winter Flounder	0.33	0.31	0.32	0.32	0.31	-5.1%	-2.0%	-1.2%	-4.1%
Redfish	0.14	0.11	0.14	0.13	0.11	-25.9%	0.3%	-10.9%	-22.1%
White Hake	0.15	0.15	0.15	0.16	0.15	-2.7%	-1.7%	5.2%	1.1%
Pollock	0.10	0.11	0.10	0.09	0.09	6.5%	3.2%	-9.7%	-5.5%
Northern Windowpane	0.16	0.19	0.17	0.14	0.17	23.2%	8.7%	-10.3%	8.8%
Southern Windowpane	0.24	0.24	0.24	0.24	0.24	-2.2%	-1.8%	0.0%	-1.8%
Ocean Pout	0.21	0.17	0.21	0.22	0.22	-16.9%	-0.9%	6.1%	5.5%
Halibut	0.12	0.11	0.15	0.11	0.11	-6.9%	23.2%	-8.6%	-3.7%
Wolffish	0.10	0.11	0.14	0.08	0.09	2.7%	36.4%	-17.9%	-8.2%
Count/% Count of CV Decrease	NA	NA	NA	NA	NA	5 / 21%	2 / 8%	3 / 20%*	3 / 13%
Count/% Count of CV Increase	NA	NA	NA	NA	NA	3 / 13%	7 / 29%	3 / 20%*	5 / 21%

Yellow - CV > 0.30: Red - Greater than 10% increase; Green - Reduction of more than 10%

*% of stocks which include more than one BSA

Table 3

Bootstrap Catch by Groundfish Stock and Stratification Alternative

Fishing Year 2015 Trips; Five Trip Transition Method

Stock	Fishing Year 2015 Quota	Baseline		Vessel Length Category*		
		Median	95% Confidence Interval	Median	95% Confidence Interval	Increase in CI vs. Baseline
	(mt)	(mt)	(mt)	(mt)	(mt)	(%)
GB Cod East	124	82.5	(81.5 - 84.0)	82.8	(81.8 - 84.6)	9.7%
GB Cod West	1,663	1,512.5	(1,506.2 - 1,521.1)	1,512.1	(1,505.9 - 1,520.7)	-0.5%
GB Cod	1,787	1,595.1	(1,588.7 - 1,603.9)	1,594.7	(1,588.6 - 1,603.8)	-0.1%
GOM Cod	207	169.9	(165.0 - 176.1)	169.6	(165.8 - 174.5)	-21.4%
GB Haddock East	17,760	1,033.7	(981.2 - 1,137.8)	1,024.5	(975.4 - 1,118.0)	-9.0%
GB Haddock West	**3,999**	3,901.0	**(3,738.5 - 4,090.6)**	3,915.8	**(3,748.1 - 4,120.2)**	5.7%
GB Haddock	21,759	4,939.6	(4,763.0 - 5,144.1)	4,949.7	(4,747.7 - 5,182.6)	14.1%
GOM Haddock	958	648.9	(639.3 - 664.8)	648.3	(640.2 - 660.0)	-22.2%
GB Yellowtail Flounder	202.9	38.8	(37.8 - 40.5)	41.2	(39.4 - 44.1)	75.8%
SNE/MA Yellowtail Flounder	579	277.4	(263.8 - 308.5)	278.2	(264.7 - 303.0)	-14.5%
CC/GOM Yellowtail Flounder	458	351.7	(348.4 - 356.1)	350.8	(347.8 - 354.9)	-8.0%
Plaice	1,408	1,316.4	(1,302.4 - 1,332.9)	1,315.8	(1,301.7 - 1,332.2)	0.0%
Witch Flounder	610	499.9	(492.9 - 508.4)	500.0	(492.6 - 508.6)	2.9%
GB Winter Flounder	1,891	868.6	(865.9 - 872.4)	868.6	(866.0 - 871.7)	-11.8%
GOM Winter Flounder	392	113.6	(113.1 - 114.5)	113.4	(112.9 - 114.2)	-14.8%
SNE/MA Winter Flounder	1,306	681.7	(677.0 - 694.4)	682.2	(677.4 - 690.5)	-24.5%
Redfish	11,034	1,899.0	(1,882.8 - 1,917.6)	1,898.5	(1,885.5 - 1,911.9)	-23.9%
White Hake	4,343	1,405.3	(1,401.3 - 1,410.0)	1,522.4	(1,518.9 - 1,526.5)	-12.0%
Pollock	13,720	2,325.4	(2,313.2 - 2,339.6)	2,327.6	(2,316.3 - 2,342.2)	-1.7%
Northern Windowpane	**98**	95.5	**(73.0 - 124.2)**	100.8	**(80.0 - 124.0)**	-14.1%
Southern Windowpane	**102**	**156.2**	**(108.3 - 278.9)**	**173.7**	**(126.7 - 341.3)**	25.8%
Ocean Pout	195	56.7	(37.6 - 88.4)	58.2	(39.2 - 81.8)	-16.3%
Halibut	64	52.6	(45.5 - 62.7)	50.2	**(43.6 - 59.3)**	-8.7%
Wolffish	62	1.4	(1.1 - 1.8)	1.3	(1.0 - 1.8)	-0.3%

Table 3 continued…

Bootstrap Catch by Groundfish Stock and Stratification Alternative

Fishing Year 2015 Trips; Five Trip Transition Method

Stock	Fishing Year 2015 Quota	Baseline		Combine Sectors Together*		
		Median	95% Confidence Interval	Median	95% Confidence Interval	Increase in CI vs. Baseline
	(mt)	(mt)	(mt)	(mt)	(mt)	(%)
GB Cod East	124	82.5	(81.5 - 84.0)	82.3	(81.1 - 84.0)	10.7%
GB Cod West	1,663	1,512.5	(1,506.2 - 1,521.1)	1,513.0	(1,506.3 - 1,521.0)	-1.0%
GB Cod	1,787	1,595.1	(1,588.7 - 1,603.9)	1,595.2	(1,588.8 - 1,605.2)	8.0%
GOM Cod	207	169.9	(165.0 - 176.1)	168.5	(164.4 - 174.1)	-12.5%
GB Haddock East	17,760	1,033.7	(981.2 - 1,137.8)	1,061.4	(988.5 - 1,142.4)	-1.7%
GB Haddock West	**3,999**	3,901.0	**(3,738.5 - 4,090.6)**	3,907.0	**(3,728.5 - 4,147.5)**	19.0%
GB Haddock	21,759	4,939.6	(4,763.0 - 5,144.1)	4,946.1	(4,733.5 - 5,217.9)	27.1%
GOM Haddock	958	648.9	(639.3 - 664.8)	646.7	(639.1 - 657.0)	-29.7%
GB Yellowtail Flounder	202.9	38.8	(37.8 - 40.5)	38.4	(37.6 - 39.7)	-17.5%
SNE/MA Yellowtail Flounder	579	277.4	(263.8 - 308.5)	277.2	(263.8 - 307.5)	-2.2%
CC/GOM Yellowtail Flounder	458	351.7	(348.4 - 356.1)	351.0	(346.4 - 356.8)	33.7%
Plaice	1,408	1,316.4	(1,302.4 - 1,332.9)	1,311.6	(1,298.6 - 1,326.9)	-7.1%
Witch Flounder	610	499.9	(492.9 - 508.4)	497.7	(490.8 - 506.0)	-2.3%
GB Winter Flounder	1,891	868.6	(865.9 - 872.4)	868.4	(865.8 - 872.8)	8.0%
GOM Winter Flounder	392	113.6	(113.1 - 114.5)	113.4	(112.8 - 114.2)	-0.8%
SNE/MA Winter Flounder	1,306	681.7	(677.0 - 694.4)	681.5	(676.8 - 693.0)	-7.0%
Redfish	11,034	1,899.0	(1,882.8 - 1,917.6)	1,893.3	(1,876.7 - 1,912.3)	2.5%
White Hake	4,343	1,405.3	(1,401.3 - 1,410.0)	1,518.6	(1,515.2 - 1,522.5)	-16.1%
Pollock	13,720	2,325.4	(2,313.2 - 2,339.6)	2,313.7	(2,303.7 - 2,325.7)	-16.6%
Northern Windowpane	**98**	95.5	**(73.0 - 124.2)**	82.8	**(61.9 - 114.2)**	2.3%
Southern Windowpane	**102**	**156.2**	**(108.3 - 278.9)**	**156.8**	**(109.9 - 308.6)**	16.4%
Ocean Pout	195	56.7	(37.6 - 88.4)	57.7	(37.8 - 89.5)	1.6%
Halibut	64	52.6	(45.5 - 62.7)	42.5	**(36.9 - 52.3)**	-10.1%
Wolffish	62	1.4	(1.1 - 1.8)	1.3	(1.0 - 1.7)	-4.4%

Table 3 continued…

Bootstrap Catch by Groundfish Stock and Stratification Alternative

Fishing Year 2015 Trips; Five Trip Transition Method

Stock	Fishing Year 2015 Quota	Baseline		Separate Broad Stock Area (BSA)*		
		Median	95% Confidence Interval	Median	95% Confidence Interval	Increase in CI vs. Baseline
	(mt)	(mt)	(mt)	(mt)	(mt)	(%)
GB Cod East	124	82.5	(81.5 - 84.0)	82.4	(81.5 - 83.8)	-6.9%
GB Cod West	1,663	1,512.5	(1,506.2 - 1,521.1)	1,515.3	(1,508.3 - 1,526.6)	23.2%
GB Cod	1,787	1,595.1	(1,588.7 - 1,603.9)	1,597.9	(1,591.5 - 1,607.6)	6.1%
GOM Cod	207	169.9	(165.0 - 176.1)	169.7	(164.9 - 176.1)	0.9%
GB Haddock East	17,760	1,033.7	(981.2 - 1,137.8)	1,035.2	(980.6 - 1,141.4)	2.7%
GB Haddock West	**3,999**	3,901.0	**(3,738.5 - 4,090.6)**	3,983.1	**(3,815.1 - 4,147.8)**	-5.5%
GB Haddock	21,759	4,939.6	(4,763.0 - 5,144.1)	5,011.6	(4,801.0 - 5,255.7)	19.3%
GOM Haddock	958	648.9	(639.3 - 664.8)	648.7	(639.7 - 665.2)	0.0%
GB Yellowtail Flounder	202.9	38.8	(37.8 - 40.5)	38.8	(37.9 - 40.8)	13.1%
SNE/MA Yellowtail Flounder	579	277.4	(263.8 - 308.5)	276.6	(263.8 - 308.1)	-0.9%
CC/GOM Yellowtail Flounder	458	351.7	(348.4 - 356.1)	354.4	(350.4 - 359.2)	12.7%
Plaice	1,408	1,316.4	(1,302.4 - 1,332.9)	1,319.9	(1,307.3 - 1,334.7)	-9.9%
Witch Flounder	610	499.9	(492.9 - 508.4)	503.4	(496.1 - 511.7)	0.2%
GB Winter Flounder	1,891	868.6	(865.9 - 872.4)	868.6	(865.9 - 872.3)	-0.4%
GOM Winter Flounder	392	113.6	(113.1 - 114.5)	113.6	(113.0 - 114.4)	-2.4%
SNE/MA Winter Flounder	1,306	681.7	(677.0 - 694.4)	682.4	(677.8 - 694.4)	-4.9%
Redfish	11,034	1,899.0	(1,882.8 - 1,917.6)	1,930.7	(1,914.4 - 1,948.9)	-0.7%
White Hake	4,343	1,405.3	(1,401.3 - 1,410.0)	1,521.9	(1,518.2 - 1,526.1)	-9.4%
Pollock	13,720	2,325.4	(2,313.2 - 2,339.6)	2,332.2	(2,322.5 - 2,343.3)	-20.8%
Northern Windowpane	**98**	95.5	**(73.0 - 124.2)**	97.5	**(75.8 - 125.4)**	-3.0%
Southern Windowpane	**102**	**156.2**	**(108.3 - 278.9)**	**158.5**	**(110.6 - 299.5)**	10.7%
Ocean Pout	195	56.7	(37.6 - 88.4)	61.2	(39.2 - 96.2)	12.2%
Halibut	64	52.6	(45.5 - 62.7)	54.8	**(48.2 - 64.8)**	-3.9%
Wolffish	62	1.4	(1.1 - 1.8)	1.4	(1.1 - 1.6)	-31.4%

Table 3 continued…

Bootstrap Catch by Groundfish Stock and Stratification Alternative

Fishing Year 2015 Trips; Five Trip Transition Method

Stock	Fishing Year 2015 Quota	Baseline		Combine Sectors Together and Separate BSA*		
		Median	95% Confidence Interval	Median	95% Confidence Interval	Increase in CI vs. Baseline
	(mt)	(mt)	(mt)	(mt)	(mt)	(%)
GB Cod East	124	82.5	(81.5 - 84.0)	82.3	(81.1 - 83.9)	6.7%
GB Cod West	1,663	1,512.5	(1,506.2 - 1,521.1)	1,516.3	(1,509.4 - 1,526.0)	11.9%
GB Cod	1,787	1,595.1	(1,588.7 - 1,603.9)	1,599.0	(1,592.1 - 1,609.5)	14.5%
GOM Cod	207	169.9	(165.0 - 176.1)	168.6	(164.6 - 174.3)	-12.4%
GB Haddock East	17,760	1,033.7	(981.2 - 1,137.8)	1,061.7	(992.1 - 1,152.0)	2.1%
GB Haddock West	**3,999**	3,901.0	**(3,738.5 - 4,090.6)**	4,054.4	**(3,888.3 - 4,288.2)**	13.6%
GB Haddock	21,759	4,939.6	(4,763.0 - 5,144.1)	5,067.7	(4,865.0 - 5,339.9)	24.6%
GOM Haddock	958	648.9	(639.3 - 664.8)	647.0	(638.9 - 657.5)	-26.9%
GB Yellowtail Flounder	202.9	38.8	(37.8 - 40.5)	38.5	(37.6 - 39.7)	-19.5%
SNE/MA Yellowtail Flounder	579	277.4	(263.8 - 308.5)	276.9	(263.7 - 310.0)	3.5%
CC/GOM Yellowtail Flounder	458	351.7	(348.4 - 356.1)	351.9	(347.3 - 357.7)	33.5%
Plaice	1,408	1,316.4	(1,302.4 - 1,332.9)	1,313.2	(1,300.9 - 1,328.3)	-10.0%
Witch Flounder	610	499.9	(492.9 - 508.4)	500.4	(494.0 - 507.9)	-11.3%
GB Winter Flounder	1,891	868.6	(865.9 - 872.4)	868.6	(865.8 - 872.4)	2.9%
GOM Winter Flounder	392	113.6	(113.1 - 114.5)	113.4	(112.8 - 114.4)	9.3%
SNE/MA Winter Flounder	1,306	681.7	(677.0 - 694.4)	682.9	(677.9 - 693.2)	-12.0%
Redfish	11,034	1,899.0	(1,882.8 - 1,917.6)	1,901.7	(1,890.4 - 1,914.1)	-32.0%
White Hake	4,343	1,405.3	(1,401.3 - 1,410.0)	1,521.7	(1,518.1 - 1,526.0)	-8.8%
Pollock	13,720	2,325.4	(2,313.2 - 2,339.6)	2,325.5	(2,316.1 - 2,336.2)	-24.0%
Northern Windowpane	**98**	95.5	**(73.0 - 124.2)**	88.5	**(64.4 - 120.7)**	9.9%
Southern Windowpane	**102**	**156.2**	**(108.3 - 278.9)**	**157.8**	**(110.6 - 313.9)**	19.1%
Ocean Pout	195	56.7	(37.6 - 88.4)	61.5	(37.8 - 93.1)	8.7%
Halibut	64	52.6	(45.5 - 62.7)	53.4	**(46.8 - 63.7)**	-1.9%
Wolffish	62	1.4	(1.1 - 1.8)	1.4	(1.1 - 1.7)	-21.3%

Bold - potentially exceeded quota; shaded - greater than 10% increase; underlined - reduction of more than 10%

***None of the alternatives had smaller confidence interval width proportions (CI width divided by median catch) than the baseline at a 5% level of significance based on: paired t-test, Wilcoxon signed-rank test, and Sign test (binomial test). GB cod and haddock east and west area numbers excluded to avoid double-counting.**

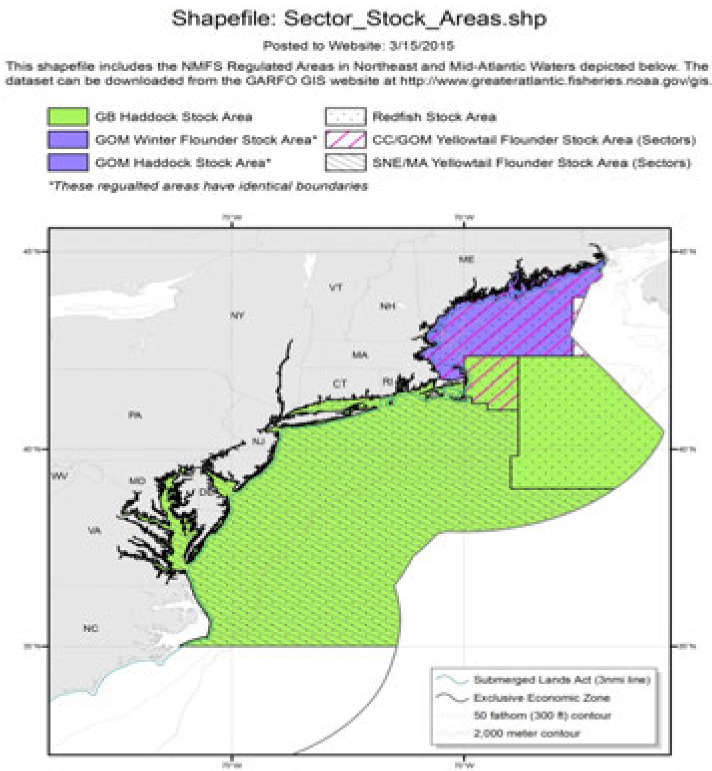

Figure 1 - Broad Stock Areas (BSAs)
The four large areas displayed are the four BSAs:
Gulf of Maine; Inshore Georges Bank, Georges Bank, and Southern New England

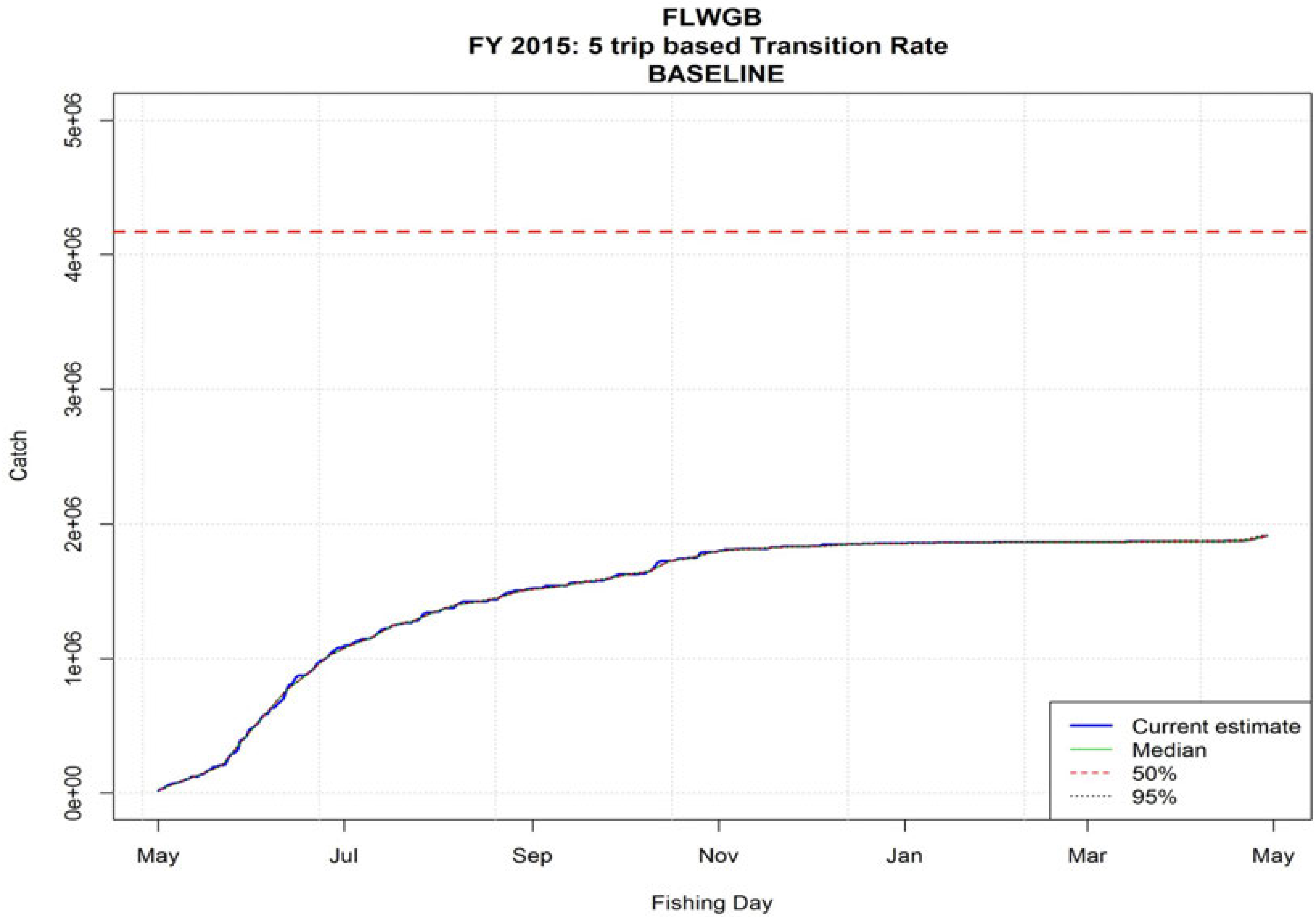

Figure 2 – Estimated Georges Bank Winter Flounder Catch

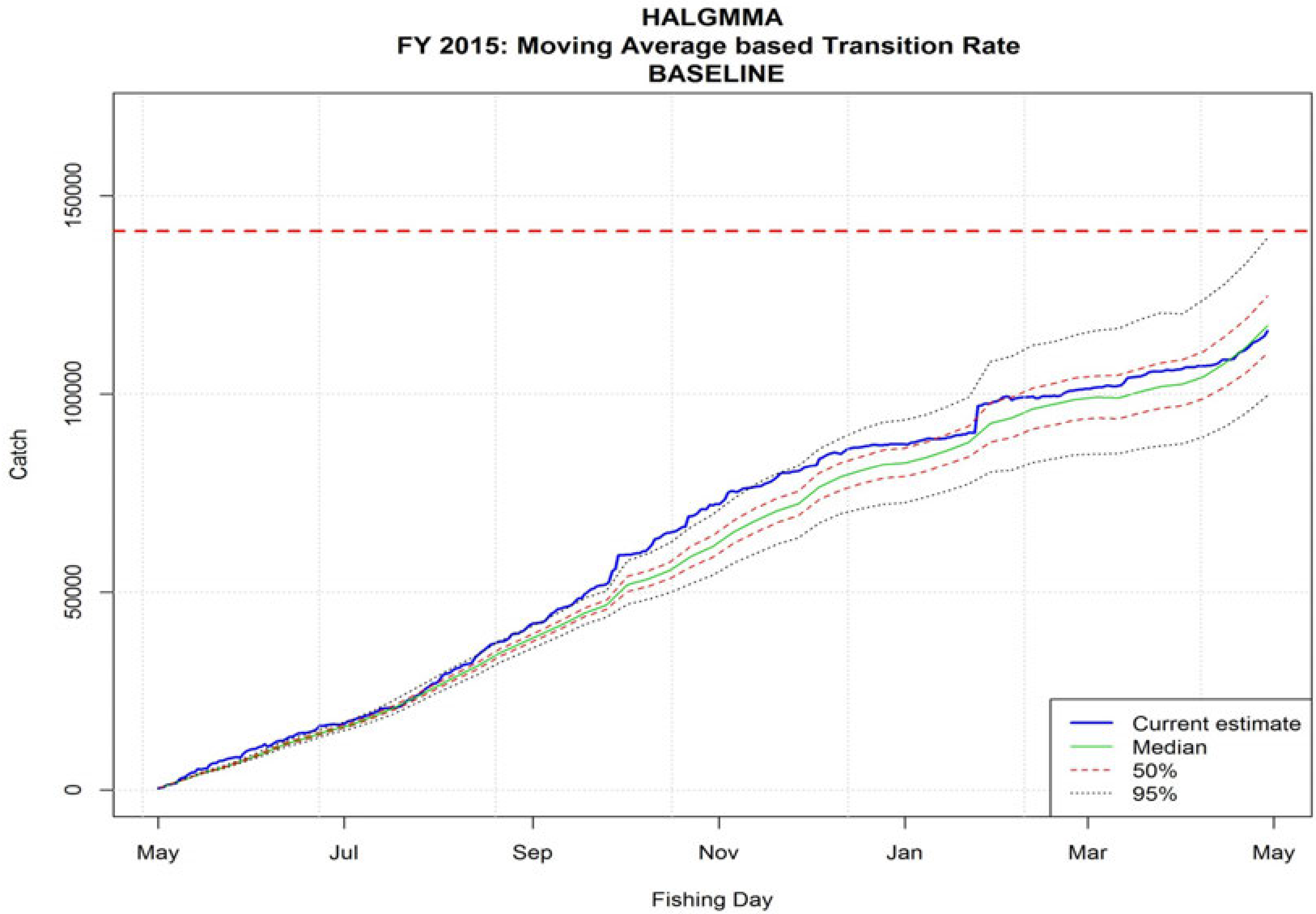

Figure 3 – Estimated Atlantic Halibut Catch

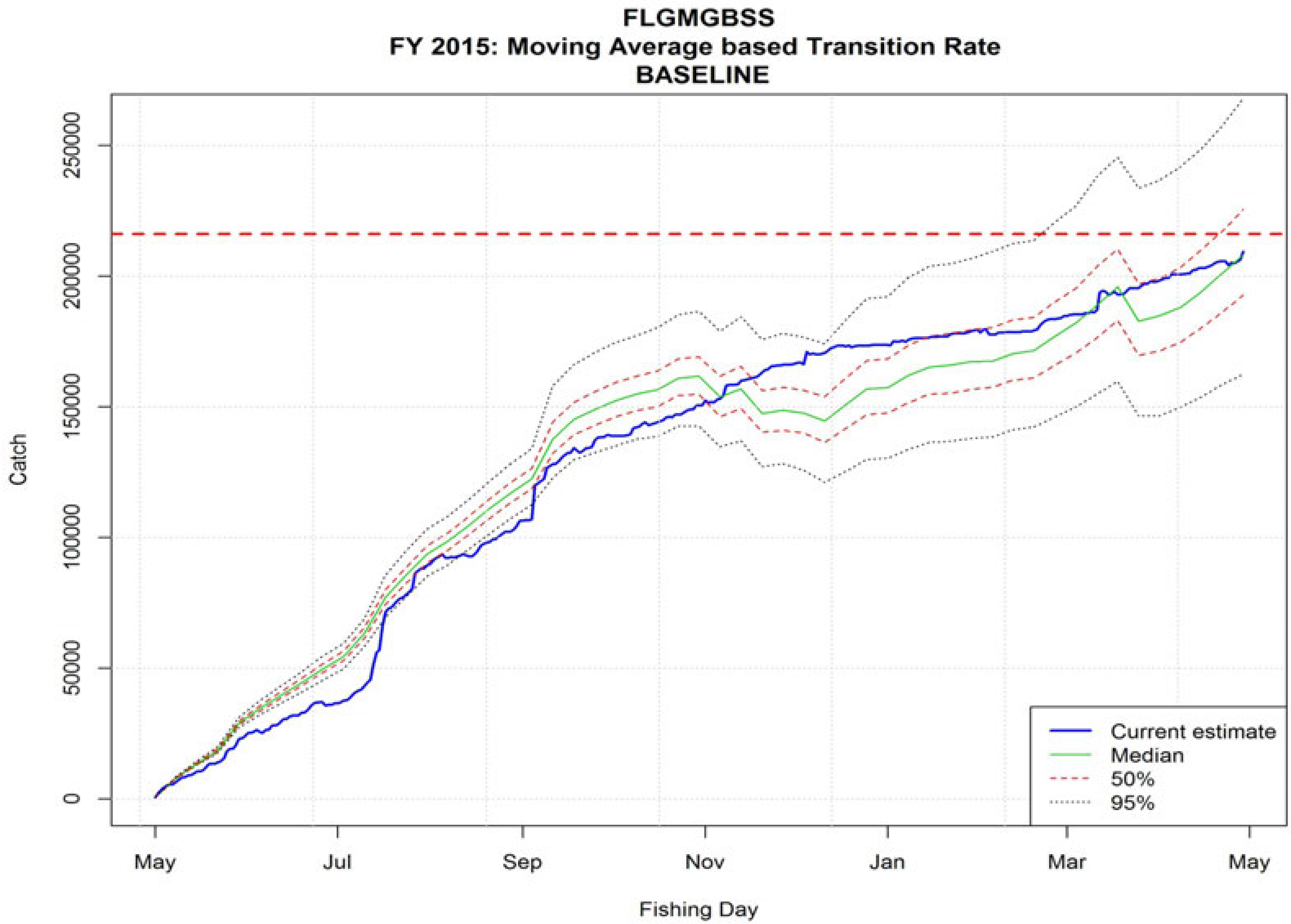

Figure 4 – Estimated Northern Windowpane Flounder Catch

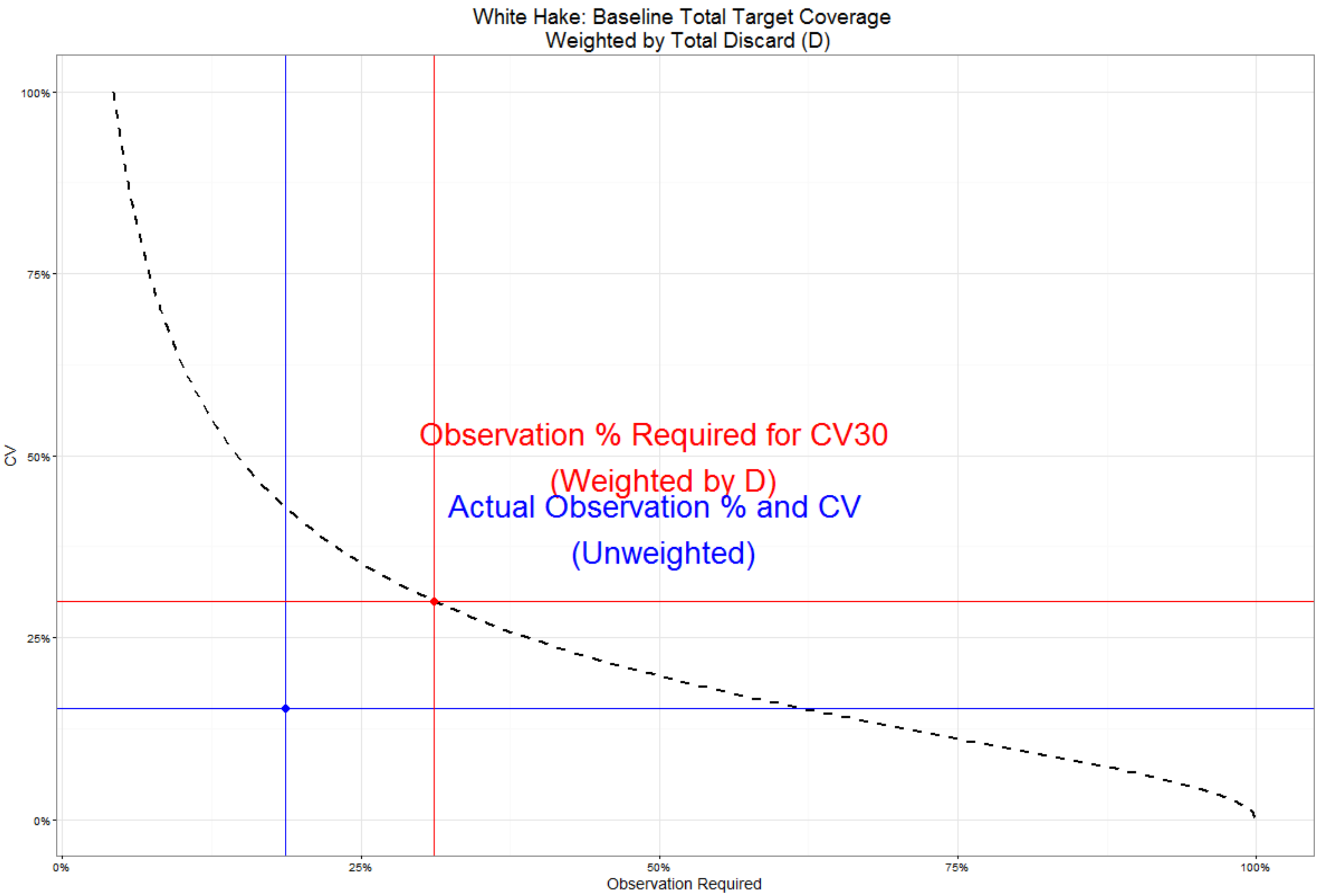

Figure 5 - White Hake Baseline Combined CV as a Function of Observer Coverage

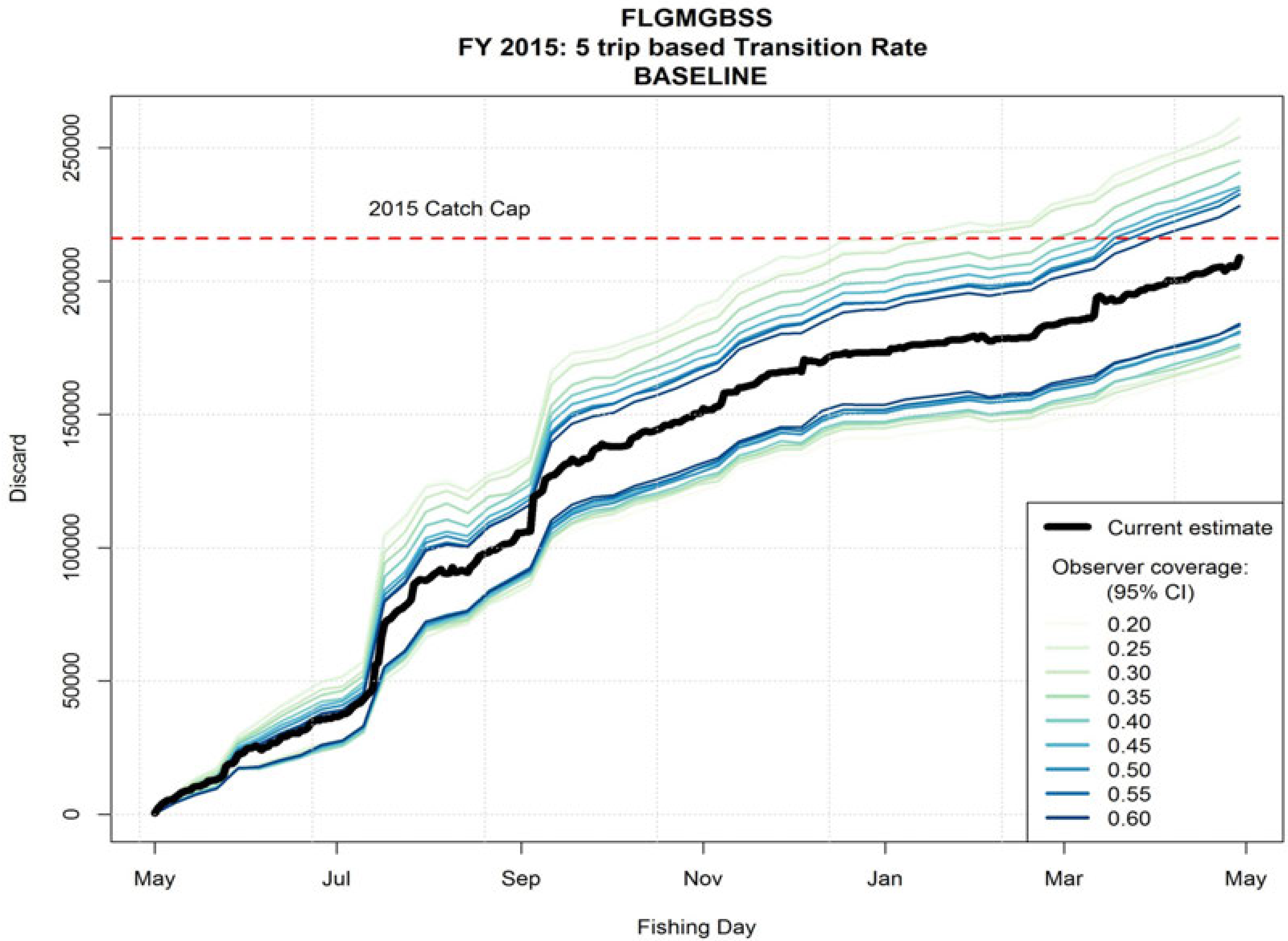

Figure 6 – Northern Windowpane Flounder 95% Confidence Intervals for Different Coverage Rates

Appendix A. Terms of reference

Terms of Reference- In-Season Discard Methodology Peer Review

GARFO Analysis and Program Support Division – July 2016

1. For each fishery subject to in-season discard monitoring utilizing the cumulative discard method, summarize the variability in discard rate by measurable strata: fishery, gear, area, season, volume of catch, etc.

2. Identify more optimal applications of the current cumulative method for in-season estimation of discards in comparison to existing cumulative discard methodology and stratification schemes. Alternatives identified will include

    a. Existing cumulative discard methodology and stratification scheme as a baseline

    b. Pooling data across current stratifications to increase information and precision. As an example, pooling across sectors and gears.

    c. Including seasonality as a stratification

    d. Allocate/restrict sampling requirements to those strata which in aggregate constitute a target fraction of total stock-specific discards. (i.e, excluding or minimizing sampling for strata with negligible discard totals)

3. Methods identified in TOR 2 will be compared using the following metrics

    a. Precision of the discard estimates for a given level of observer coverage

    b. Consistency of discard estimates calculated over the course of the fishing year.

    c. Precision and consistency of the CV discard metric for a given level of observer coverage

    d. Sensitivity to missing or erroneous data.

4. Examine methods for including data from past years to improve predicting the in-season estimation of discards.

5. Use archived data to simulate in-season behavior (with various time steps and discarding patterns) and recommend a preferred method for each fishery with consideration of the following:

    a. Feasibility, particularly the implications of stratum size and within-year pattern of precision.

b. The probability and timing of premature closure (i.e. false positive).

c. The probability and magnitude of exceeding a cap (i.e. e. false negative).