C. Assessment of Gulf of Maine (GOM) winter flounder
Appendix C1

[SAW52 Editor's Note: The SARC-52 peer review panel concluded that no ASAP model run provided a suitable basis for management advice. A swept-area biomass method was accepted instead, and it is described in Appendix C1.]

Gulf of Maine winter flounder exploitation rates using 30+ cm biomass from survey area swept estimates

The NEFSC (RV Bigelow series), MDMF, and MENH surveys catch significant numbers of winter flounder per tow. The change in the NEFSC survey vessel and gear to the Bigelow in 2009 has resulted in higher catch efficiency relative to the Albatross series. In addition the sampling intensity has also increased in most of the inshore strata for the Gulf of Maine. The MENH survey covers a large area of this stock that was previous missing prior to 2000. More direct estimates of exploitable biomass through area swept estimates are possible with the recent improvements in fishery independent data sources. Exploitation rates can be inferred from using a range of assumed survey efficiencies (Q) along with consideration of survey stock area coverage and different assumed catches. Possible bounds on the likely recent exploitation rate could be determined. The range of the estimates using different assumptions may help show what the likely exploitation rates are under different catches. A knife edge approximation of exploitable biomass was assumed as legal sized 30+ cm numbers converted to weight from a length-weight equation. Exploitable biomass was estimated as:

Exploitable Biomass = 30+ cm biomass index per tow /1000 x total survey Area/tow footprint x 1/q

and exploitation rate as:

Exploitation rate = catch / 30+ cm biomass

This method could possibly be used to determine the likely exploitation rate and overfishing status for Gulf of Maine winter flounder. However determination on whether the stock is overfished cannot be made since biomass reference points are unknown.

There are several important facts to take into consideration when interpreting the exploitation rate table (Table C1);

1. No single survey covers the entire stock (Appendix C1 Figures C1 to C4)).
2. Winter flounder is a shallow water species with a stock boundary from north of Cape Cod to the Canadian border.

3. Much higher survey catch rates are seen inshore verse offshore strata. However a significant proportion of the stock may be offshore due to the much larger strata area (offshore NEFSC 26, 40, 39).
4. The MENH survey catches significant numbers of fish. However relatively few exploitable 30+ cm fish are seen in the survey (Appendix C1 Figure C5). Updated age data suggests slower growth rates in Maine waters.
5. The most recent three year average biomass was used for the spring and fall MDMF surveys, two years for Bigelow spring survey and only one year for the Bigelow fall survey. The combined biomass estimate was calculated from non-overlapping strata from all three surveys.
6. Most of the catch is taken from statistical area 514 (Cape Cod Bay, Mass Bay, Ipswich Bay, Stellwagen bank). MDMF exploitation estimates conservatively assume that the entire stock is within Massachusetts state waters.
7. A Q equal to 1 conservatively assumes that the survey gear is 100% efficient.
8. The combined estimate using non-overlapping strata from all three surveys covers most of the stock area (Appendix C1 Table C2, Figure C4).

Exploitable 30+ cm biomass and exploitation rates with the associated error distribution were re-estimated from 2004 to 2010 (Appendix C1 Table C3, Figure C6 and C7) using the Survey Area Graphical Analysis (SAGA) program. The 80 percent confidence intervals were plotted to evaluate the inter-annual variation. The Bigelow to Albatross conversion coefficients were not incorporated into the calculations. However the use of the estimated Miller et al (2010) conversion of 2.086 Kg/tow would result in similar biomass estimates between the Albatross and Bigelow series (Appendix C1 Figure C6). Questions with regards to the relative low catchability and inshore sampling coverage in the Albatross series, uncertainty in the conversion coefficients for larger fish and possible effects of changes in stock size over time can be avoided by limiting the analysis to the most recent Bigelow time series (spring 2009 & 2010, fall 2009 & 2010). An analysis limited to strata which overlapped both the NEFSC Bigelow and Massachusetts DMF survey suggests there is relatively little difference in gear efficiency between the surveys (Appendix C1 Figure C8). Adjusting of the area difference in the overlapping strata between the MDMF and NEFSC surveys brings the estimates closer together (Appendix C1 Figure C9). A small difference in the survey gear efficiency helps justify the use of non-overlapping strata among the surveys as a single biomass estimate. A comparison of the survey components used in the combined estimate (MDMF near-shore, NEFSC inshore, NEFSC offshore) between the spring and the fall surveys shows that a higher proportion of the stock close to shore during the spring (Appendix C1 Table C4, Figures C10 and C11). The lower overall 30+ biomass estimates in the spring may be a function of unavailable fish to the surveys that are residing inside the estuaries during the spawning season. However survey information in the fall is also limited since no sampling occurred in Cape Cod bay in the NEFSC Fall 2010 survey. Note the combined fall 2010 estimate is based on a different strata set among the surveys (Appendix C1 Figure C12). The MDMF strata in Cape Cod Bay were used to account for the missing strata in the NEFSC survey. Sensitivity of the biomass estimates to the inclusion of the large deep offshore strata (27, 38) can be seen in Appendix C1 Figure C13. These deep offshore strata (27, 38) were not included in the final estimates due to the lack of fish seen in the deep central Gulf of Maine (Appendix C1 Figure C14).

At the SMAST Fishermen's input meeting fishermen suggested that herding between the doors and ground cable is important for the catchability of winter flounder. This may be more important in the commercial fishery targeted flatfish tows were tow speeds tend to be about a knot slower than a survey tow. Area swept estimates using the doors for the footprint calculation was done as a sensitivity analysis (Appendix C1 Table C5). Using the new TOGA criteria instead of SHG was also done as a sensitivity comparison. The wing based TOGA biomass estimates were slightly higher than estimates based on SHG (Appendix C1 Table C6).

A proxy value of the overfishing threshold (F40%) was derived from a length-based yield per recruit (NFT 2011) analysis that assumes all fish above 30 cm are fully recruited to the fishery and that natural mortality is 0.3 (Appendix C1 Figure C15). Von Bertalanffy parameters were estimated from the spring and fall NEFSC survey age data (n = 2,035) from 2006 to 2010. Maturity at length information is estimated from the spring MDMF survey (L_{50}=29cm). The reference points were converted to exploitation rates to be consistent with the swept area biomass approach. An $F_{40\%}$ exploitation rate was estimated at 0.23 and $75\%F_{40\%}$ exploitation was 0.17 with M=0.3. Appendix C1 Table C7 and Figure C16 show estimated exploitation rates (catch over survey biomass) relative to the estimated exploitation based reference points over a range of catches using the combined surveys (spring and fall 2009 20010) assuming different efficiencies (0.2 to 1.0).

Uncertainty Estimates

Methods

The sampling distributions of biomass and fishing mortality are approximated by integrating over the factors which constitute the primary sources of uncertainty. These factors include the sampling variability in the Northeast Fisheries Science Center (NEFSC), Massachusetts Division of Marine Fisheries (MADMF), and Maine-New Hampshire (MENH) spring and fall bottom surveys for 2009 and 2010. The second major source of variability for the survey estimates is the variation in the size of the area swept by an average tow. The sample means and variances for each of these factors were used to parameterize their respective normal distributions. Sampling theory and boot-strapping analyses for other species suggests that the survey means should be asymptotically normal. We exploit this feature to simplify the estimation of the sampling distribution of biomass and exploitation rate.

The estimator of total stock size can be written as

$$B_{Tot} = A_{NEFSC}\frac{I_{NEFSC}}{e\,a_{NEFSC}} + A_{MADMF}\frac{I_{MADMF}}{e\,a_{MADMF}} + A_{MENH}\frac{I_{MENH}}{e\,a_{MENH}} \quad \text{(Eq. 1)}$$

Where **A** represents the total stratum area, **I** represents the mean index of abundance (kg/tow) for winter flounder greater than 30 cm, and **a** represents the average area swept per tow, and **e** represents the trawl efficiency (probability of capture given encounter). Each of the measures of survey abundance and swept area are measured with uncertainty. In this exercise it is assumed that the total stratum area A is constant and measured without error. The gear efficiency **e** is unknown but cannot be greater than one unless significant herding occurs. If herding does occur the maximum efficiency is approximately equal to the ratio of the trawl door width to the wing width. For the purposes of this exercise, gear efficiency was examined over a range of values between 0.6 and 1.0. The sampling distribution B_{tot} can be estimated by integrating over all possible sources of variation. In this exercise there are six normally distributed random variables to consider I_{NEFSC}, I_{MADMF}, I_{MENH}, a_{NEFSC}, a_{MADMF}, and a_{MENH}. The means and variances of these variables are summarized in Appendix C1 Table C8. The variance of the footprints for the MADMF and MENH survey were not measured. It was assumed that the CV of these estimates was equal to the estimates for the NEFSC survey. All NEFSC survey estimates were conducted on the FSV Bigelow.

The sampling distribution of each of the Fs described above was evaluated by integrating over each of the normal distributions for average weight I, survey footprint ***a***. The density **I** and footprint a parameters were evaluated over 40 equal probability intervals. The full evaluation of the six sources of variability required 40^6 = 4,096,000,000 evaluations. The proposed method is sometimes known as a Latin hypercube approach because it samples each of the distributions over equal probability intervals. In contrast, a parametric bootstrap sampling randomly from each of the component distributions may not adequately characterize the underlying variability. This of course could be tested and compared with the Latin hypercube approach.

Let Φ = Normal cumulative distribution function. The inverse of Φ, denoted as Φ^{-1} ,allows the evaluation of a set of values over a specified range, say α_{min} and α_{max} , over equal probability intervals. The value of the random variable X associated with the α level is defined as:

$$I_{\alpha}^{'} = \Phi^{-1}(\alpha \mid \bar{I}, S_I^2) \text{ (Eq. 2)}$$

The step size between successive values of α was set as δ = 1/40 (0.975-0.025), where α_{min} = 0.025 and α_{max} = 0.975. An equivalent approach was used for evaluation of the footprint parameter **a** where $a \sim N(\mu_a, \sigma_a^2)$.

This property can be illustrated for the biomass estimates by substituting Equation 2 into Eq. 1 and integrating over all possible step sizes. Let i, j, k, l, m, n represent the indices for survey and footprint components, and let a prime denote the value of each component that is derived by evaluating Eq. 2. corresponding the α probability level.

The expected value of $\boldsymbol{B_{tot}}$ is obtained by summing over the sampling distributions of ***X*** and ***a*** as follows:

$$E[B_{Tot}] = \sum_{i=1}^{40}\sum_{j=1}^{40}\sum_{k=1}^{40}\sum_{l=1}^{40}\sum_{m=1}^{40}\sum_{n=1}^{40}\left[A_{NEFSC}\frac{I_i'}{e\,a_j'} + A_{MADMF}\frac{I_k'}{e\,a_l'} + A_{MENH}\frac{I_m'}{e\,a_n'}\right]\delta^6$$

(Eq .3)

The sampling distribution of ***Btot*** can be constructed by noting that the each element within the brackets of the rhs of Equation 3 has a probability weight of δ =(1/40).

The sampling distribution of F is simply the assumed value of the quota divided by the estimate of the biomass in Equation 3. This approximation of the multidimensional integration provides reasonable assurance that the sampling distribution of the F and B will be appropriately estimated.

Results of Uncertainty Analyses

Summary statistics for the biomass estimates are provided in Appendix C1 Table C9 and plotted in Appendix C1 Figure *C*. Under the null hypothesis that the distribution is normally distributed, the sample statistics for skewness and kurtosis estimates have expected values of zero. Values of skewness greater than zero indicate positive skewing (i.e, a longer tail on the right or in a positive direction from the mean). Values of kurtosis greater than zero provide evidence that the sampling distribution is more peaked than a normal distribution with a comparable mean and variance.

Exploitation rate distributions relative to exploitation rate biological reference points are shown in Appendix C1 Figures C18 through C21. The probability of exceeding candidate biological reference points are provided graphically in Appendix C1 Figures C22 and C23.

Survey Area Swept 30+ cm Exploitation Rates Conclusions

The use of an efficiency value of 0.6 was supported by comparison of VPA estimates of efficiency for the Georges Bank winter flounder while making the assumption that the same fraction of each stock is available to the respective surveys. The NEFSC fall survey (expressed in Albatross equivalents) had an efficiency estimate of 0.3. Calibration experiments between the FSV Bigelow and the R/V Albatross revealed a biomass conversion coefficient of ~2. Thus an efficiency estimate for the Bigelow survey estimate in 2010 of 0.6 was supported. An analysis of catch rates in overlapping areas by the NEFSC and MADMF surveys demonstrated similar catchabilities for winter flounder by the two surveys.

The SARC concluded that the best estimate of 30+ cm biomass and recent (2010) exploitation is based on use of the TOGA tow criteria for the fall 2010 surveys assuming an efficiency of 0.6 (Appendix C1 Tables C6 and C10 and Figure C14). The overfishing status is based on the ratio of 2010 catch (195 mt) to survey based swept area estimate of biomass for winter flounder exceeding 30 cm in length (6,341 mt). Exploitation rate in 2010 was estimated at 0.03 (80% CI 0.02 - 0.05) and therefore overfishing is not occurring (F2010/F40 ratio = 0.13, Appendix C1 Figure C24). This conclusion is robust to the range of uncertainty in the biomass estimate (Appendix C1 Figures C18 through C21). The biomass estimate for 2010 is 16% lower than that for 2009 using the same survey methods but this difference is not statistically significant (Appendix C1 Figure C17).

Appendix C1 Table C1. A range of estimated 30+ cm biomass and exploitation rates for different surveys using a range of assumed qs (1, 0.8, 0.6, 0.4) and assumed catch (mt) or ABCs (238, 344, 500, 800). A combined estimate using non-overlapping strata is also shown. Exploitation rates exceeding 0.2 are highlighted.

Q = 0.4	Catch	Bigelow Spring	Bigelow Fall	MDMF Spring	MDMF Fall	Combined Spring	Combined Fall
30+ Biomass		3,520	10,271	2,895	3,713	7,074	11,390
ABC	238	0.07	0.02	0.08	0.06	0.03	0.02
3yr avg	344	0.10	0.03	0.12	0.09	0.05	0.03
	500	0.14	0.05	0.17	0.13	0.07	0.04
	800	0.23	0.08	0.28	0.22	0.11	0.07
Q = 0.6							
30+ Biomass		2,347	6,847	1,930	2,475	4,716	7,593
ABC	238	0.10	0.03	0.12	0.10	0.05	0.03
3yr avg	344	0.15	0.05	0.18	0.14	0.07	0.05
	500	0.21	0.07	0.26	0.20	0.11	0.07
	800	0.34	0.12	0.41	0.32	0.17	0.11
Q = 0.8							
30+ Biomass		1,760	5,135	1,448	1,856	3,537	5,695
ABC	238	0.14	0.05	0.16	0.13	0.07	0.04
3yr avg	344	0.20	0.07	0.24	0.19	0.10	0.06
	500	0.28	0.10	0.35	0.27	0.14	0.09
	800	0.45	0.16	0.55	0.43	0.23	0.14
Q = 1							
30+ Biomass		1,408	4,108	1,158	1,485	2,829	4,556
ABC	238	0.17	0.06	0.21	0.16	0.08	0.05
3yr avg	344	0.24	0.08	0.30	0.23	0.12	0.08
	500	0.36	0.12	0.43	0.34	0.18	0.11
	800	0.57	0.19	0.69	0.54	0.28	0.18

Appendix C1 Table C2 - Survey total area coverage, average tow footprint, kg/tow and expansion factors for non-overlapping strata used in the combined estimate.

	Combined Survey Estimate		
	NEFSC	ME/NH	MDMF
survey area (nm2)	2,990	3,475	309
Avg tow (area swept)	0.007	0.00462	0.003846
Total area/tow footprint	427,143	752,154	80,343
Tow duration	20 min	20 min	20 min
Numbers per tow	34-65	35	80
Proportion of 30+ biomass	0.59	0.09	0.33

Appendix C1 Table C3 - Survey total area coverage, average tow footprint, kg/tow expansion factors and tow during for the different surveys and survey components. NEFSC offshore (39,40,26) = 2322 nm^2, NEFSC inshore overlap (59,60,61,64,65,66) = 668 nm^2, MDMF overlap (27,28,29,30,34,35,36) = 484 nm^2,MDMF near shore (25,26,31,32,33) = 309 nm^2

A. Wing spread

	NEFSC							MDMF				MEHN
	Albatross			Bigelow				Gloria Michele				
	inshore overlap	offshore	combined	inshore overlap	offshore	Fall 2010	combined	state waters	near shore	Fall 2010	overlap	state waters
survey area (nm2)	668	2,322	2,990	668	2,322	2,638	2,990	793	309	633	484	3,475
Avg tow (area swept)	0.0112	0.0112	0.0112	0.007	0.007	0.007	0.007	0.003846	0.00385	0.003846	0.00385	0.00462
Total area/tow footprint	59,643	207,321	266,964	95,429	331,714	376,857	427,143	206,188	80,343	164,587	125,845	752,165
Tow duration	30 min	30 min	30 min	20 min	20 min	20 min	20 min	20 min	20 min	20 min	20 min	20 min

B. Door spread

	NEFSC				MDMF				MEHN
	Bigelow				Gloria Michele				
	inshore overlap	offshore	Fall 2010	combined	state waters	near shore	Fall 2010	overlap	state waters
survey area (nm2)	668	2,322	2,638	2,990	793	309	633	484	3,475
Avg tow (area swept)	0.0177	0.0177	0.0177	0.0177	0.0125	0.0125	0.0125	0.0125	0.0123
Total area/tow footprint	37,845	131,550	149,453	169,395	63,502	24,744	50,690	38,758	282,469
Tow duration	20 min	20 min	20 min	20 min	20 min	20 min	20 min	20 min	20 min

Appendix C1 Table C4 - A range of estimated 30+ cm biomass based on wing spread and exploitation rates for the combined survey estimate in spring 2009, spring 2010, fall 2009 and fall 2010 using a a range of qs assumptions (0.6, 0.8, & 1.0) and a range of assumed catch (mt) (238, 344, 400, 500, 800) based on an shg criteria of 136. The proportion of the biomass in each survey area is also shown. * Fall 2010 estimate is based on a different strata set since the NEFSC Fall survey did not cover Cape Cod bay strata.

Q=1				Total	Exploitation from assumed catch				
	NEFSC	MDMF	ME/NH	30+ biomass	238	344	400	500	800
Spring 2009	0.54	0.26	0.20	3,072	0.08	0.11	0.13	0.16	0.26
Spring 2010	0.45	0.33	0.21	2,587	0.09	0.13	0.15	0.19	0.31
Spring avg	0.49	0.30	0.21	2,829	0.08	0.12	0.14	0.18	0.28
Fall 2009	0.90	0.06	0.03	4,556	0.05	0.08	0.09	0.11	0.18
Fall 2010*	0.65	0.30	0.06	3,293	0.07	0.10	0.12	0.15	0.24

Q=0.8				Total	Exploitation from assumed catch				
	NEFSC	MDMF	ME/NH	30+ biomass	238	344	400	500	800
Spring 2009	0.54	0.26	0.20	3,840	0.06	0.09	0.10	0.13	0.21
Spring 2010	0.45	0.33	0.21	3,233	0.07	0.11	0.12	0.15	0.25
Spring avg	0.49	0.30	0.21	3,537	0.07	0.10	0.11	0.14	0.23
Fall 2009	0.90	0.06	0.03	5,695	0.04	0.06	0.07	0.09	0.14
Fall 2010*	0.65	0.30	0.06	4,116	0.06	0.08	0.10	0.12	0.19

Q=0.6				Total	Exploitation from assumed catch				
	NEFSC	MDMF	ME/NH	30+ biomass	238	344	400	500	800
Spring 2009	0.54	0.26	0.20	5,121	0.05	0.07	0.08	0.10	0.16
Spring 2010	0.45	0.33	0.21	4,311	0.06	0.08	0.09	0.12	0.19
Spring avg	0.49	0.30	0.21	4,716	0.05	0.07	0.08	0.11	0.17
Fall 2009	0.90	0.06	0.03	7,593	0.03	0.05	0.05	0.07	0.11
Fall 2010*	0.65	0.30	0.06	5,489	0.04	0.06	0.07	0.09	0.15

Appendix C1 Table C5 - A range of estimated 30+ cm biomass based on door spread and exploitation rates for the combined survey estimate in spring 2009, spring 2010, fall 2009 and fall 2010 using a a range of qs assumptions (0.6, 0.8, & 1.0) and a range of assumed catch (mt) (238, 344, 400, 500, 800) based on an shg criteria of 136. The proportion of the biomass in each survey area is also shown. * Fall 2010 estimate is based on a different strata set since the NEFSC Fall survey did not cover Cape Cod bay strata.

Q=1				Total	Exploitation from assumed catch				
	NEFSC	MDMF	ME/NH	30+ biomass	238	344	400	500	800
Spring 2009	0.43	0.16	0.40	1,516	0.16	0.23	0.26	0.33	0.53
Spring 2010	0.36	0.21	0.43	1,283	0.19	0.27	0.31	0.39	0.62
Spring avg	0.40	0.19	0.42	1,399	0.17	0.25	0.29	0.36	0.57
Fall 2009	0.87	0.05	0.08	1,877	0.13	0.18	0.21	0.27	0.43
Fall 2010*	0.64	0.23	0.14	1,328	0.18	0.26	0.30	0.38	0.60

A=0.8				Total	Exploitation from assumed catch				
	NEFSC	MDMF	ME/NH	30+ biomass	238	344	400	500	800
Spring 2009	0.43	0.16	0.40	1,895	0.13	0.18	0.21	0.26	0.42
Spring 2010	0.36	0.21	0.43	1,604	0.15	0.21	0.25	0.31	0.50
Spring avg	0.40	0.19	0.42	1,749	0.14	0.20	0.23	0.29	0.46
Fall 2009	0.87	0.05	0.08	2,347	0.10	0.15	0.17	0.21	0.34
Fall 2010*	0.64	0.23	0.14	1,660	0.14	0.21	0.24	0.30	0.48

				Total	Exploitation from assumed catch				
	NEFSC	MDMF	ME/NH	30+ biomass	238	344	400	500	800
Spring 2009	0.43	0.16	0.40	2,526	0.09	0.14	0.16	0.20	0.32
Spring 2010	0.36	0.21	0.43	2,139	0.11	0.16	0.19	0.23	0.37
Spring avg	0.40	0.19	0.42	2,332	0.10	0.15	0.17	0.21	0.34
Fall 2009	0.87	0.05	0.08	3,129	0.08	0.11	0.13	0.16	0.26
Fall 2010*	0.64	0.23	0.14	2,214	0.11	0.16	0.18	0.23	0.36

Appendix C1 Table C6 - A range of estimated 30+ cm biomass based on wing spread and exploitation rates for the combined survey estimate in spring 2009, spring 2010, fall 2009 and fall 2010 using a a range of qs assumptions (0.6, 0.8, & 1.0) and a range of assumed catch (mt) (238, 344, 400, 500, 800) based on an TOGA criteria of 132x. The proportion of the biomass in each survey area is also shown. * Fall 2010 estimate is based on a different strata set since the NEFSC Fall survey did not cover Cape Cod bay strata.

Q=1				Total	Exploitation from assumed catch				
	NEFSC	MDMF	ME/NH	30+ biomass	238	344	400	500	800
Spring 2009	0.56	0.25	0.19	3,212	0.07	0.11	0.125	0.16	0.25
Spring 2010	0.45	0.33	0.21	2,594	0.09	0.13	0.154	0.19	0.31
Spring avg	0.50	0.29	0.20	2,903	0.08	0.12	0.138	0.17	0.28
Fall 2009	0.90	0.06	0.03	4,567	0.05	0.08	0.088	0.11	0.18
Fall 2010*	0.69	0.26	0.05	3,804	0.06	0.09	0.105	0.13	0.21

Q=0.8				Total	Exploitation from assumed catch				
	NEFSC	MDMF	ME/NH	30+ biomass	238	344	400	500	800
Spring 2009	0.56	0.25	0.19	4,015	0.06	0.09	0.100	0.12	0.20
Spring 2010	0.45	0.33	0.21	3,243	0.07	0.11	0.123	0.15	0.25
Spring avg	0.50	0.29	0.20	3,629	0.07	0.09	0.110	0.14	0.22
Fall 2009	0.90	0.06	0.03	5,709	0.04	0.06	0.070	0.09	0.14
Fall 2010*	0.69	0.26	0.05	4,756	0.05	0.07	0.084	0.11	0.17

Q=0.6				Total	Exploitation from assumed catch				
	NEFSC	MDMF	ME/NH	30+ biomass	238	344	400	500	800
Spring 2009	0.56	0.25	0.19	5,354	0.04	0.06	0.075	0.09	0.15
Spring 2010	0.45	0.33	0.21	4,324	0.06	0.08	0.093	0.12	0.19
Spring avg	0.50	0.29	0.20	4,839	0.05	0.07	0.083	0.10	0.17
Fall 2009	0.90	0.06	0.03	7,612	0.03	0.05	0.053	0.07	0.11
Fall 2010*	0.69	0.26	0.05	6,341	0.04	0.05	0.063	0.08	0.13

Appendix C1 Table C7 – Exploitation ratios at various levels of catch and assumed trawl efficiency using 30+ cm swept area biomass from combined surveys.

	catch	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
Efficiency = 1	30+biomass																				
Spring 2009	3,212	0.016	0.031	0.047	0.062	0.078	0.093	0.109	0.125	0.140	0.156	0.171	0.187	0.202	0.218	0.233	0.249	0.265	0.280	0.296	0.311
Spring 2010	2,594	0.019	0.039	0.058	0.077	0.096	0.116	0.135	0.154	0.173	0.193	0.212	0.231	0.251	0.270	0.289	0.308	0.328	0.347	0.366	0.385
Spring avg	2,903	0.017	0.034	0.052	0.069	0.086	0.103	0.121	0.138	0.155	0.172	0.189	0.207	0.224	0.241	0.258	0.276	0.293	0.310	0.327	0.344
Fall 2009	4,567	0.011	0.022	0.033	0.044	0.055	0.066	0.077	0.088	0.099	0.109	0.120	0.131	0.142	0.153	0.164	0.175	0.186	0.197	0.208	0.219
Fall 2010	3,804	0.013	0.026	0.039	0.053	0.066	0.079	0.092	0.105	0.118	0.131	0.145	0.158	0.171	0.184	0.197	0.210	0.223	0.237	0.250	0.263
Fall avg	4,186	0.012	0.024	0.036	0.048	0.060	0.072	0.084	0.096	0.108	0.119	0.131	0.143	0.155	0.167	0.179	0.191	0.203	0.215	0.227	0.239
	catch	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
Efficiency = 0.8	30+biomass																				
Spring 2009	4,015	0.012	0.025	0.037	0.050	0.062	0.075	0.087	0.100	0.112	0.125	0.137	0.149	0.162	0.174	0.187	0.199	0.212	0.224	0.237	0.249
Spring 2010	3,243	0.015	0.031	0.046	0.062	0.077	0.093	0.108	0.123	0.139	0.154	0.170	0.185	0.200	0.216	0.231	0.247	0.262	0.278	0.293	0.308
Spring avg	3,629	0.014	0.028	0.041	0.055	0.069	0.083	0.096	0.110	0.124	0.138	0.152	0.165	0.179	0.193	0.207	0.220	0.234	0.248	0.262	0.276
Fall 2009	5,709	0.009	0.018	0.026	0.035	0.044	0.053	0.061	0.070	0.079	0.088	0.096	0.105	0.114	0.123	0.131	0.140	0.149	0.158	0.166	0.175
Fall 2010	4,756	0.011	0.021	0.032	0.042	0.053	0.063	0.074	0.084	0.095	0.105	0.116	0.126	0.137	0.147	0.158	0.168	0.179	0.189	0.200	0.210
Fall avg	5,232	0.010	0.019	0.029	0.038	0.048	0.057	0.067	0.076	0.086	0.096	0.105	0.115	0.124	0.134	0.143	0.153	0.162	0.172	0.182	0.191
	catch	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
Efficiency = 0.6	30+biomass																				
Spring 2009	5,354	0.009	0.019	0.028	0.037	0.047	0.056	0.065	0.075	0.084	0.093	0.103	0.112	0.121	0.131	0.140	0.149	0.159	0.168	0.177	0.187
Spring 2010	4,324	0.012	0.023	0.035	0.046	0.058	0.069	0.081	0.093	0.104	0.116	0.127	0.139	0.150	0.162	0.173	0.185	0.197	0.208	0.220	0.231
Spring avg	4,839	0.010	0.021	0.031	0.041	0.052	0.062	0.072	0.083	0.093	0.103	0.114	0.124	0.134	0.145	0.155	0.165	0.176	0.186	0.196	0.207
Fall 2009	7,612	0.007	0.013	0.020	0.026	0.033	0.039	0.046	0.053	0.059	0.066	0.072	0.079	0.085	0.092	0.099	0.105	0.112	0.118	0.125	0.131
Fall 2010	6,341	0.008	0.016	0.024	0.032	0.039	0.047	0.055	0.063	0.071	0.079	0.087	0.095	0.103	0.110	0.118	0.126	0.134	0.142	0.150	0.158
Fall avg	6,977	0.007	0.014	0.022	0.029	0.036	0.043	0.050	0.057	0.065	0.072	0.079	0.086	0.093	0.100	0.108	0.115	0.122	0.129	0.136	0.143
	catch	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
Efficiency = 0.4	30+biomass																				
Spring 2009	8,030	0.006	0.012	0.019	0.025	0.031	0.037	0.044	0.050	0.056	0.062	0.068	0.075	0.081	0.087	0.093	0.100	0.106	0.112	0.118	0.125
Spring 2010	6,486	0.008	0.015	0.023	0.031	0.039	0.046	0.054	0.062	0.069	0.077	0.085	0.093	0.100	0.108	0.116	0.123	0.131	0.139	0.146	0.154
Spring avg	7,258	0.007	0.014	0.021	0.028	0.034	0.041	0.048	0.055	0.062	0.069	0.076	0.083	0.090	0.096	0.103	0.110	0.117	0.124	0.131	0.138
Fall 2009	11,419	0.004	0.009	0.013	0.018	0.022	0.026	0.031	0.035	0.039	0.044	0.048	0.053	0.057	0.061	0.066	0.070	0.074	0.079	0.083	0.088
Fall 2010	9,511	0.005	0.011	0.016	0.021	0.026	0.032	0.037	0.042	0.047	0.053	0.058	0.063	0.068	0.074	0.079	0.084	0.089	0.095	0.100	0.105
Fall avg	10,465	0.005	0.010	0.014	0.019	0.024	0.029	0.033	0.038	0.043	0.048	0.053	0.057	0.062	0.067	0.072	0.076	0.081	0.086	0.091	0.096
	catch	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
Efficiency = 0.2	30+biomass																				
Spring 2009	16,061	0.003	0.006	0.009	0.012	0.016	0.019	0.022	0.025	0.028	0.031	0.034	0.037	0.040	0.044	0.047	0.050	0.053	0.056	0.059	0.062
Spring 2010	12,972	0.004	0.008	0.012	0.015	0.019	0.023	0.027	0.031	0.035	0.039	0.042	0.046	0.050	0.054	0.058	0.062	0.066	0.069	0.073	0.077
Spring avg	14,517	0.003	0.007	0.010	0.014	0.017	0.021	0.024	0.028	0.031	0.034	0.038	0.041	0.045	0.048	0.052	0.055	0.059	0.062	0.065	0.069
Fall 2009	22,837	0.002	0.004	0.007	0.009	0.011	0.013	0.015	0.018	0.020	0.022	0.024	0.026	0.028	0.031	0.033	0.035	0.037	0.039	0.042	0.044
Fall 2010	19,022	0.003	0.005	0.008	0.011	0.013	0.016	0.018	0.021	0.024	0.026	0.029	0.032	0.034	0.037	0.039	0.042	0.045	0.047	0.050	0.053
Fall avg	20,930	0.002	0.005	0.007	0.010	0.012	0.014	0.017	0.019	0.022	0.024	0.026	0.029	0.031	0.033	0.036	0.038	0.041	0.043	0.045	0.048

Appendix C1 Table C8 - Summary of model input data for estimation of swept area biomass estimates for GOM winter flounder.

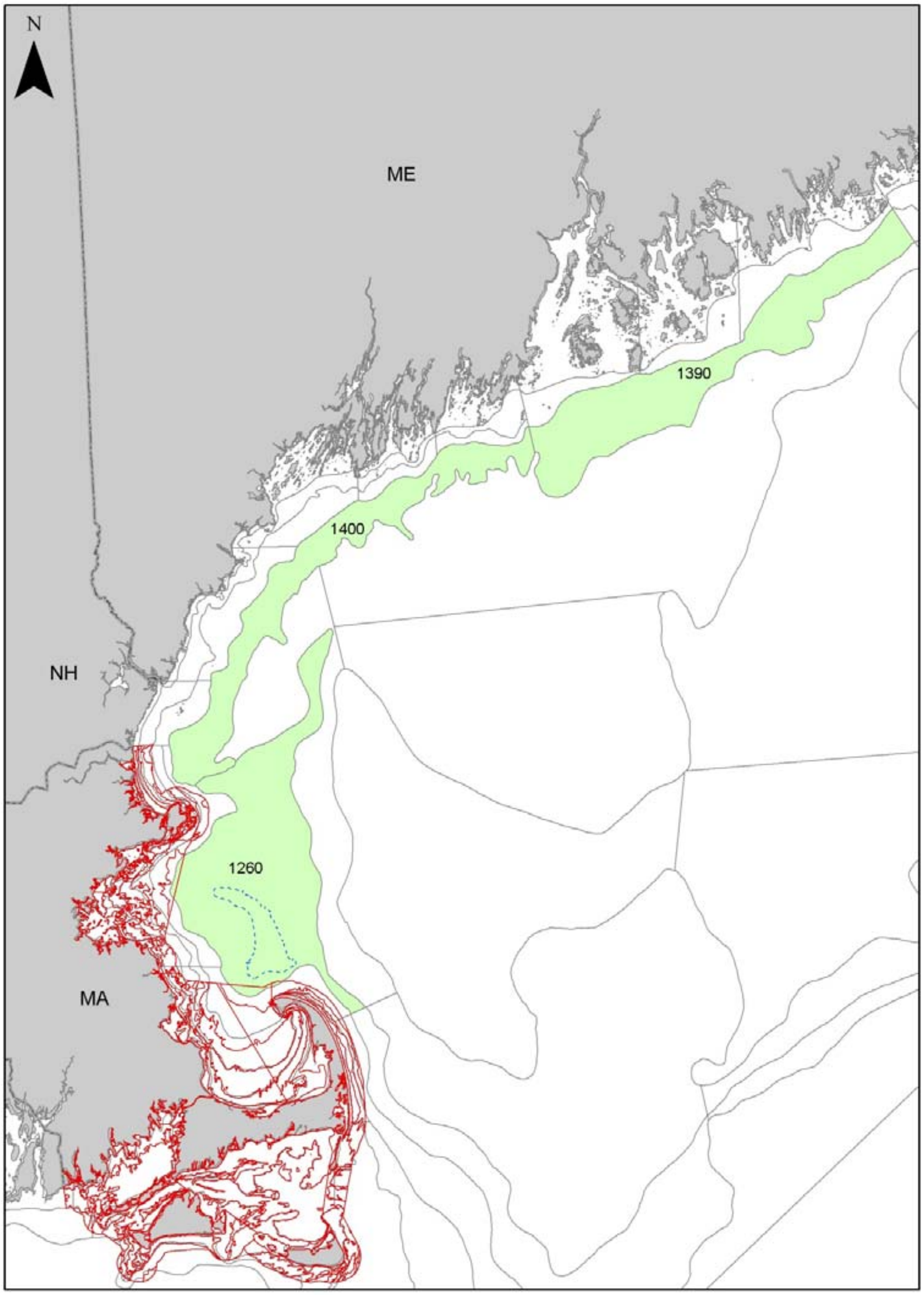
Survey	Season	Year	Total Survey Area in nm^2	Area per tow in nm^2 (SE)	Survey in kg/tow (SE)
NEFSC	Spring	2009	2990	0.006974755 (0.000835526)	4.18909 (1.68859)
MADMF			309	0.003846 (0.0004607)	10.0972 (1.63578)
ME-NH			3475	0.00462 (0.000553443)	0.81315 (0.13173)
NEFSC	Fall	2009	2990	0.006974755 (0.000835526)	9.6447 (4.10327)
MADMF			309	0.003846 (0.0004607)	3.59066 (0.627)
ME-NH			3475	0.00462 (0.000553443)	0.21176 (0.03698)
NEFSC	Spring	2010	2990	0.006974755 (0.000835526)	2.74878 (0.60754)
MADMF			309	0.003846 (0.0004607)	10.7822 (2.8331)
ME-NH			3475	0.00462 (0.000553443)	0.73656 (0.19354)
NEFSC	Fall	2010	2638	0.006974755 (0.000835526)	7.00897 (2.97247)
MADMF			633	0.003846 (0.0004607)	5.96533 (0.855255)
ME-NH			3475	0.00462 (0.000553443)	0.240953 (0.03455)

Appendix C1 Table C9 - Summary of estimated sampling distribution of biomass estimates for Gulf of Maine winter flounder for varying seasons, years and assumed survey efficiency estimates.

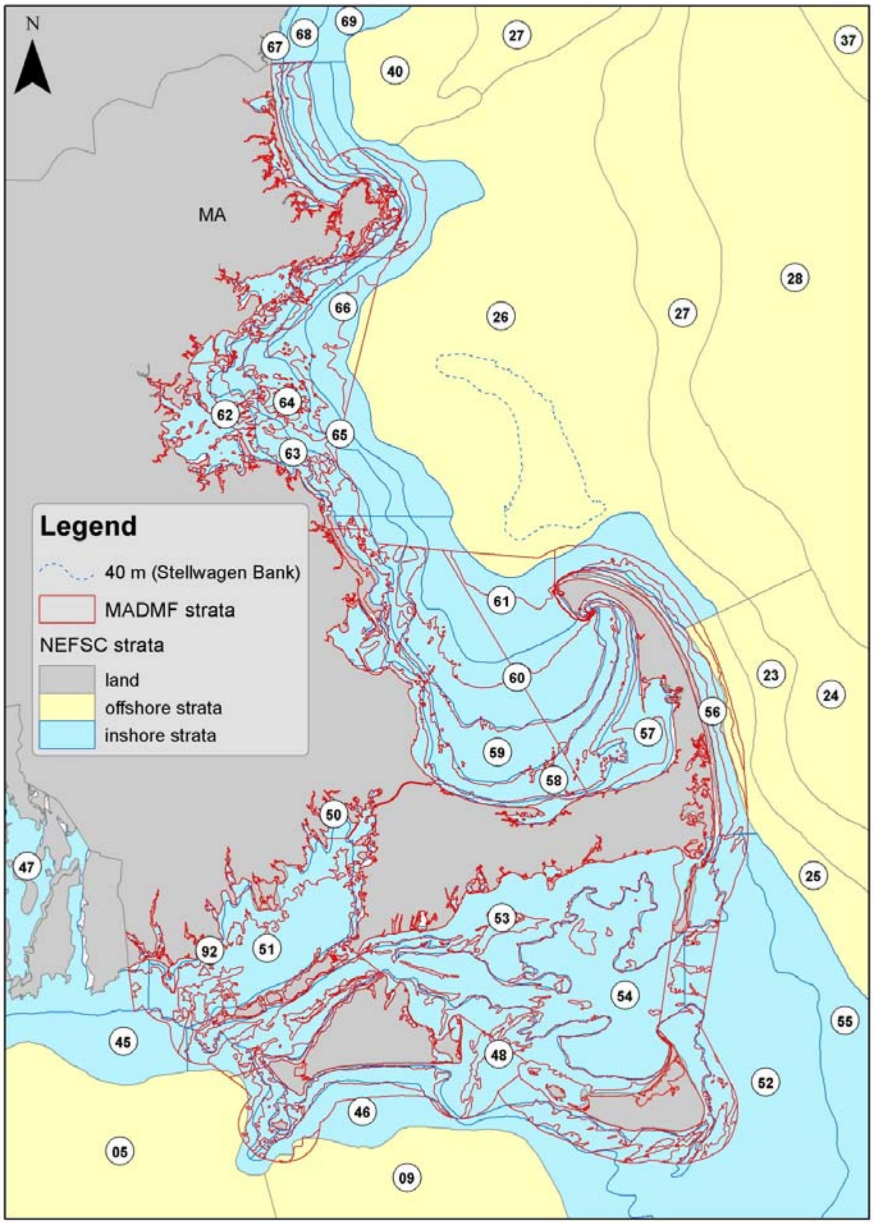
	Fall2009			***Spring2009***			***Spring2010***			***Fall2010***		
	0.6	***0.8***	***1***	***0.6***	***0.8***	***1***	***0.6***	***0.8***	***1***	***0.6***	***0.8***	***1***
Min	2,260	1,680	1,330	2,890	2,150	1,700	2,590	1,920	1,520	2,610	1,940	1,540
Max	15,690	12,400	9,930	8,240	6,230	5,010	6,540	4,940	3,970	11,870	8,990	7,240
Range	13,430	10,720	8,600	5,350	4,080	3,310	3,950	3,020	2,450	9,260	7,050	5,700
Mean	7,761	5,826	4,659	5,203	3,899	3,116	4,375	3,278	2,620	6,468	4,849	3,877
SD	2,643	1,995	1,599	913	686	550	612	460	368	1,721	1,295	1,037
CV	0.341	0.342	0.343	0.176	0.176	0.176	0.14	0.14	0.141	0.266	0.267	0.268
Skewness	0.231	0.248	0.249	0.242	0.246	0.249	0.191	0.195	0.195	0.237	0.242	0.245
Kurtosis	-0.471	-0.434	-0.432	-0.332	-0.32	-0.313	-0.178	-0.165	-0.157	-0.432	-0.422	-0.414
Percentiles												
1%	2,700	2,020	1,610	3,380	2,530	2,020	3,070	2,300	1,840	3,150	2,350	1,880
5%	3,560	2,670	2,130	3,770	2,820	2,250	3,400	2,550	2,030	3,750	2,800	2,240
10%	4,300	3,220	2,570	4,030	3,020	2,410	3,600	2,690	2,150	4,230	3,160	2,530
20%	5,360	4,020	3,210	4,390	3,290	2,630	3,840	2,880	2,300	4,910	3,680	2,940
25%	5,800	4,350	3,470	4,530	3,400	2,710	3,940	2,950	2,360	5,190	3,890	3,110
30%	6,200	4,650	3,710	4,670	3,500	2,800	4,030	3,020	2,410	5,450	4,090	3,270
40%	6,940	5,200	4,160	4,920	3,690	2,950	4,200	3,140	2,510	5,930	4,450	3,550
50%	7,650	5,740	4,590	5,160	3,870	3,090	4,350	3,260	2,610	6,390	4,790	3,830
60%	8,370	6,280	5,020	5,410	4,050	3,240	4,510	3,380	2,700	6,860	5,140	4,110
70%	9,150	6,870	5,490	5,670	4,250	3,400	4,690	3,510	2,810	7,370	5,530	4,420
75%	9,590	7,200	5,760	5,820	4,360	3,490	4,790	3,590	2,870	7,650	5,740	4,590
80%	10,080	7,570	6,050	5,990	4,490	3,590	4,890	3,670	2,930	7,970	5,980	4,780
90%	11,350	8,530	6,820	6,430	4,820	3,850	5,180	3,890	3,110	8,800	6,600	5,280
95%	12,350	9,290	7,430	6,780	5,090	4,070	5,420	4,070	3,250	9,450	7,090	5,680
99%	14,010	10,570	8,470	7,410	5,560	4,450	5,860	4,400	3,520	10,560	7,930	6,350

Appendix C1**Table C10. Summary of sampling distribution for exploitation rates for the Fall 2010 with an assumed efficiency of 0.6 and the 2010 catch of 195 mt for Gulf of Maine winter flounder.**

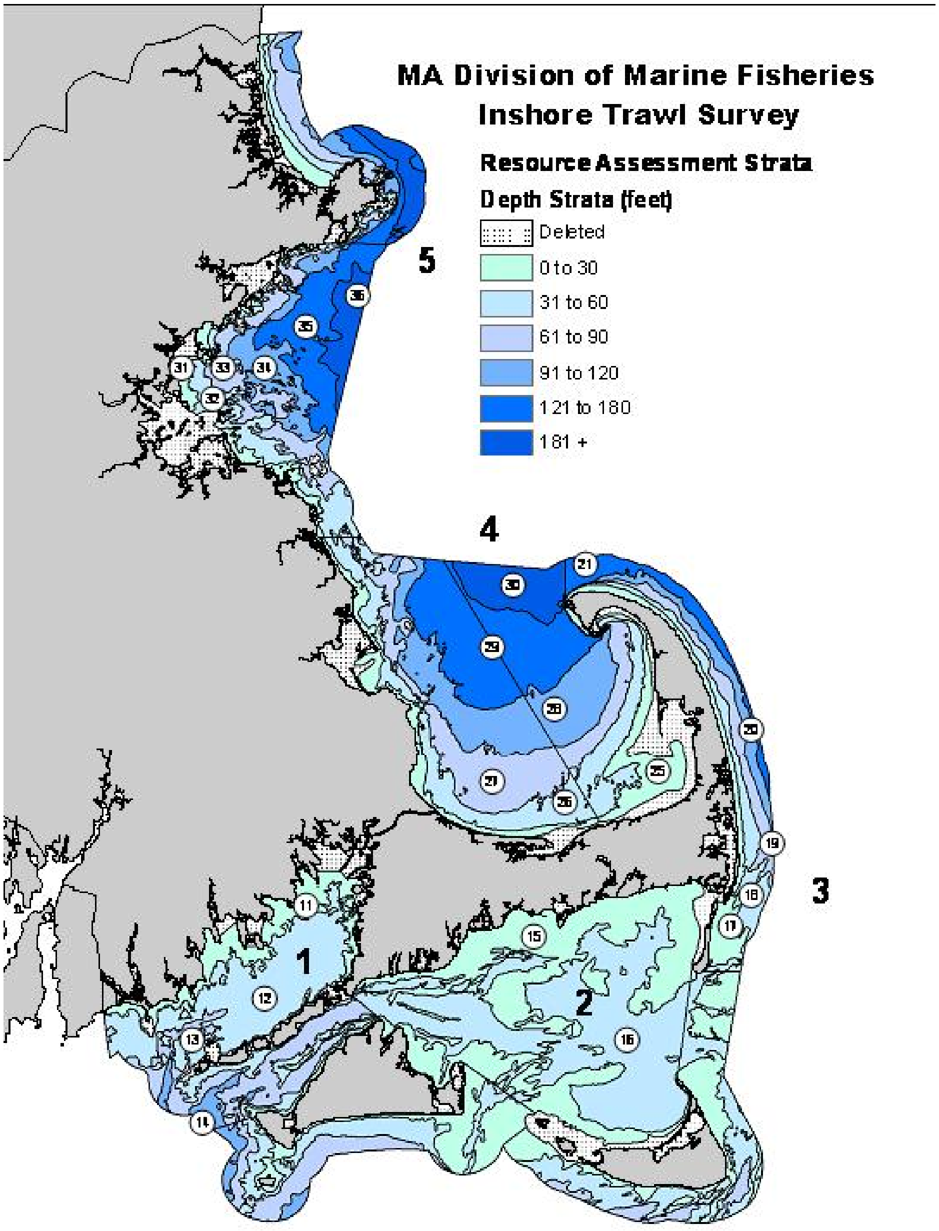
Minimum	**0.015**
Maximum	**0.076**
Range	**0.061**
Mean	**0.032**
Standard Dev	**0.010**
C.V.	**0.302**
Skewness(G1)	**1.057**
Kurtosis(G2)	**1.021**
Method = EMPCDF	
1 %	**0.018**
5 %	**0.020**
10 %	**0.022**
20 %	**0.024**
25 %	**0.025**
30 %	**0.026**
40 %	**0.028**
50 %	**0.030**
60 %	**0.032**
70 %	**0.035**
75 %	**0.037**
80 %	**0.039**
90 %	**0.046**
95 %	**0.051**
99 %	**0.061**



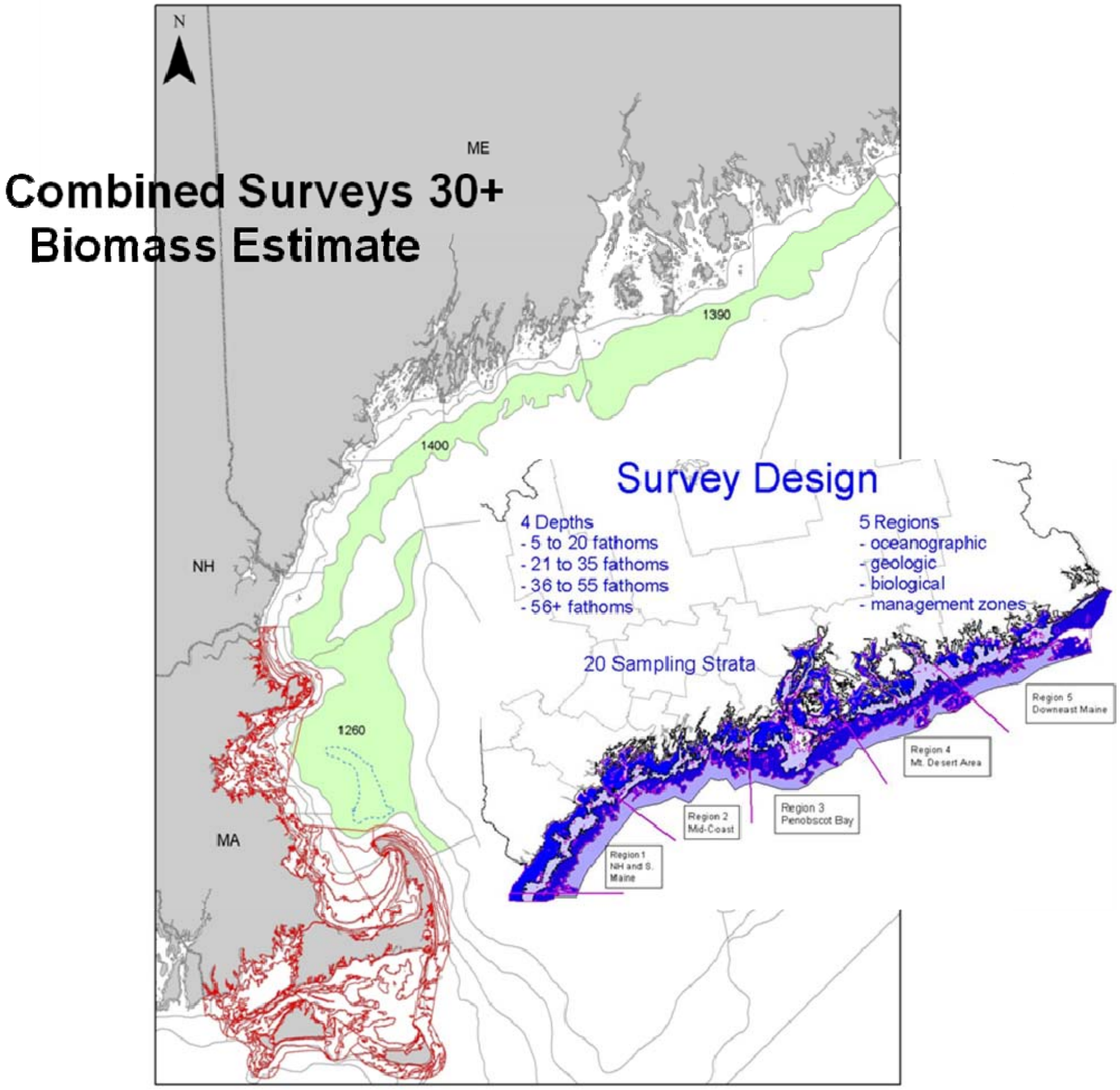
Appendix C1 Figure C1 - Gulf of Maine winter flounder inshore and offshore survey coverage map. Green shaded areas are the NEFSC offshore strata used for the 30+ biomass estimate.



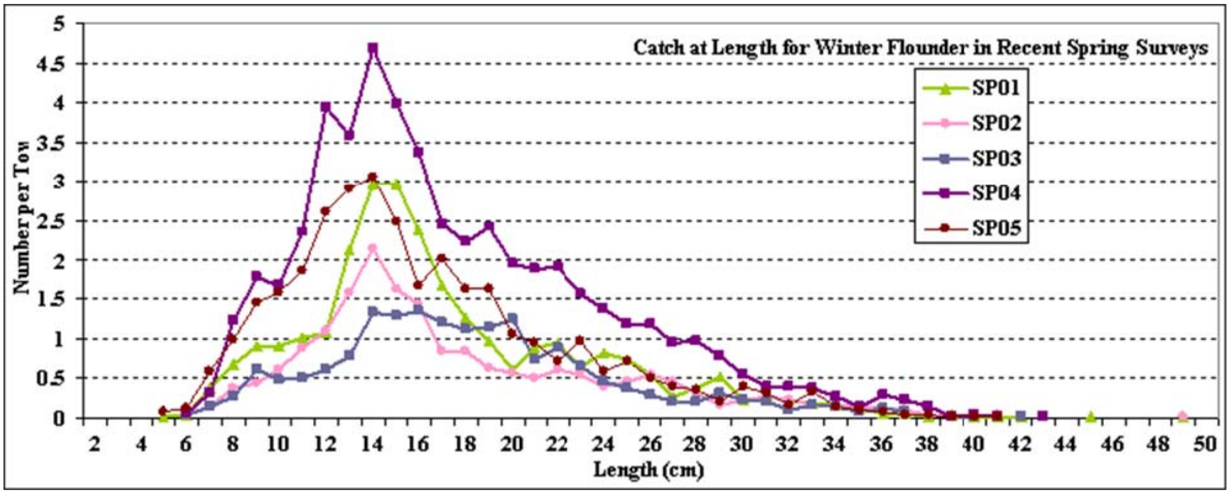
Appendix C1 Figure C2 - Gulf of Maine winter flounder inshore survey overlap between the NEFSC and MDMF surveys.



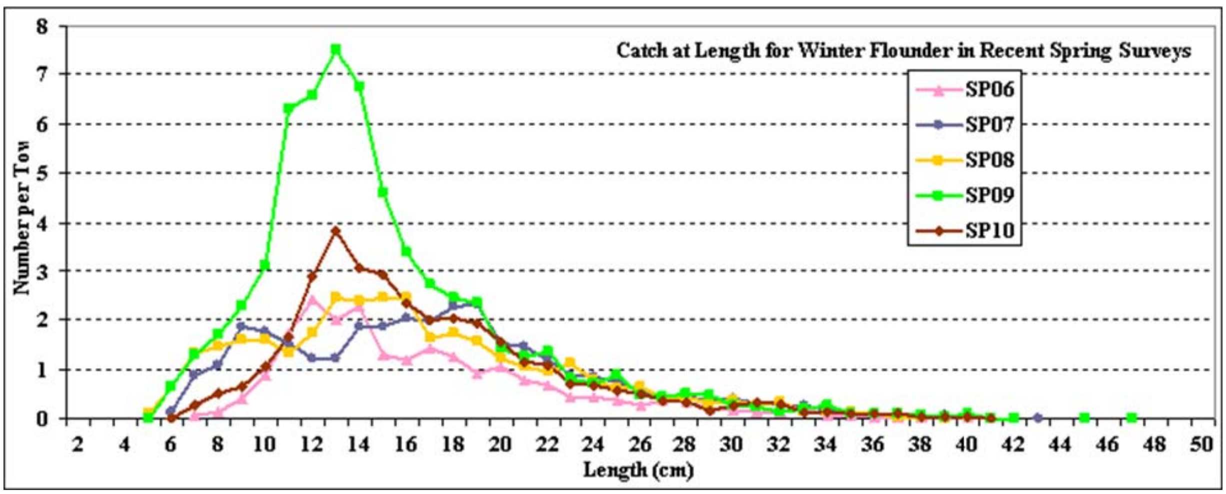
Appendix C1 Figure C3 - MDMF survey strata. The gulf of Maine winter flounder stock uses strata north of Cape Cod.



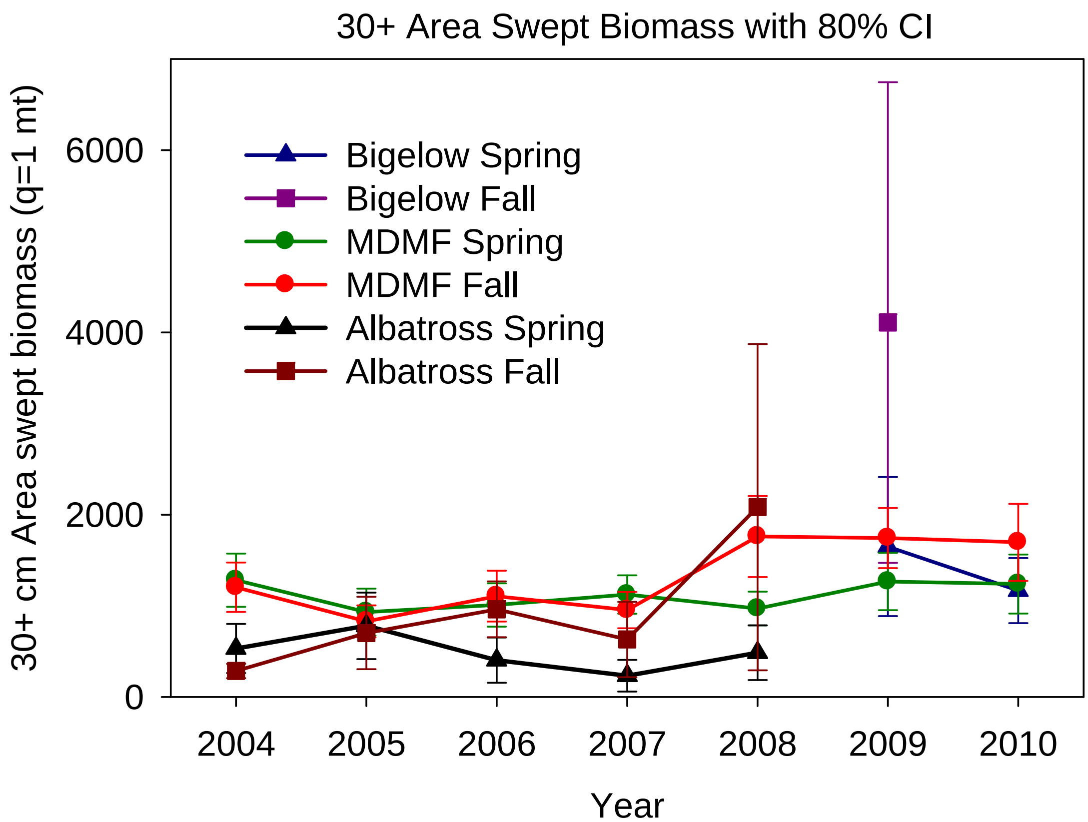
Appendix C1 Figure C4 - NEFSC, MDMF, and MENH survey areas used in the combined survey 30+ cm biomass estimate.



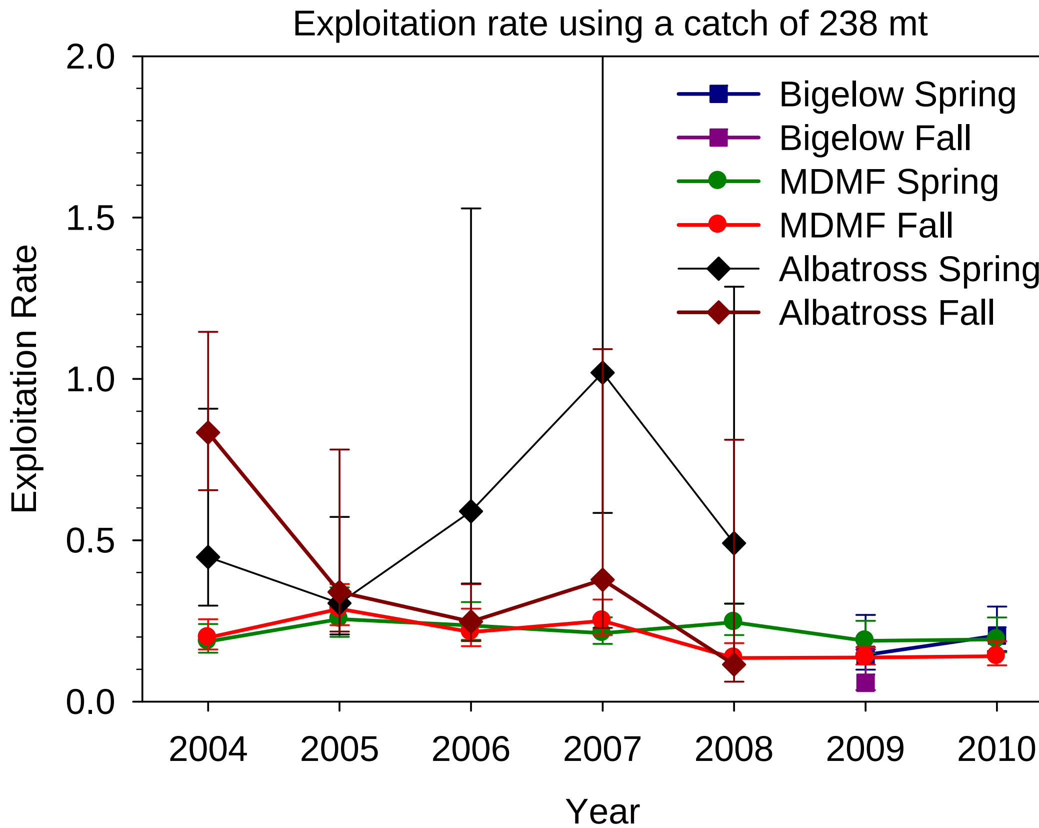
ME/NH Survey Spring



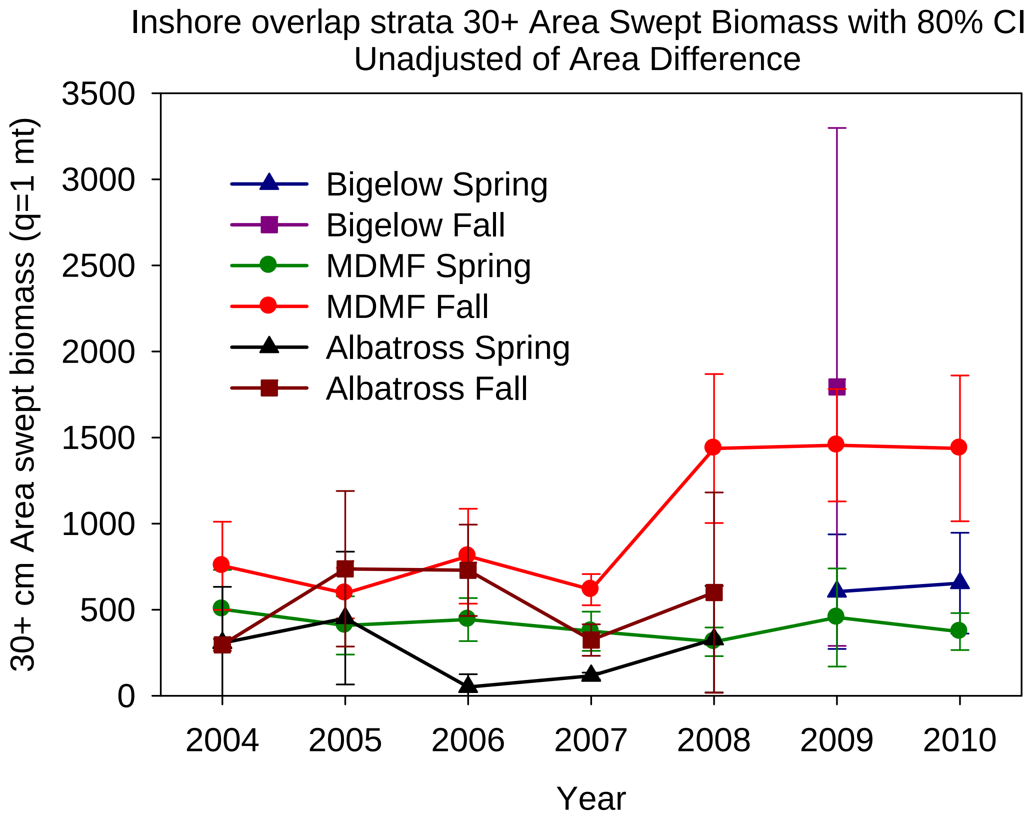
Appendix C1 Figure C5 - Numbers per tow at length from the inshore MENH survey. Relatively few fish 30 cm and greater are caught in the MENH survey.



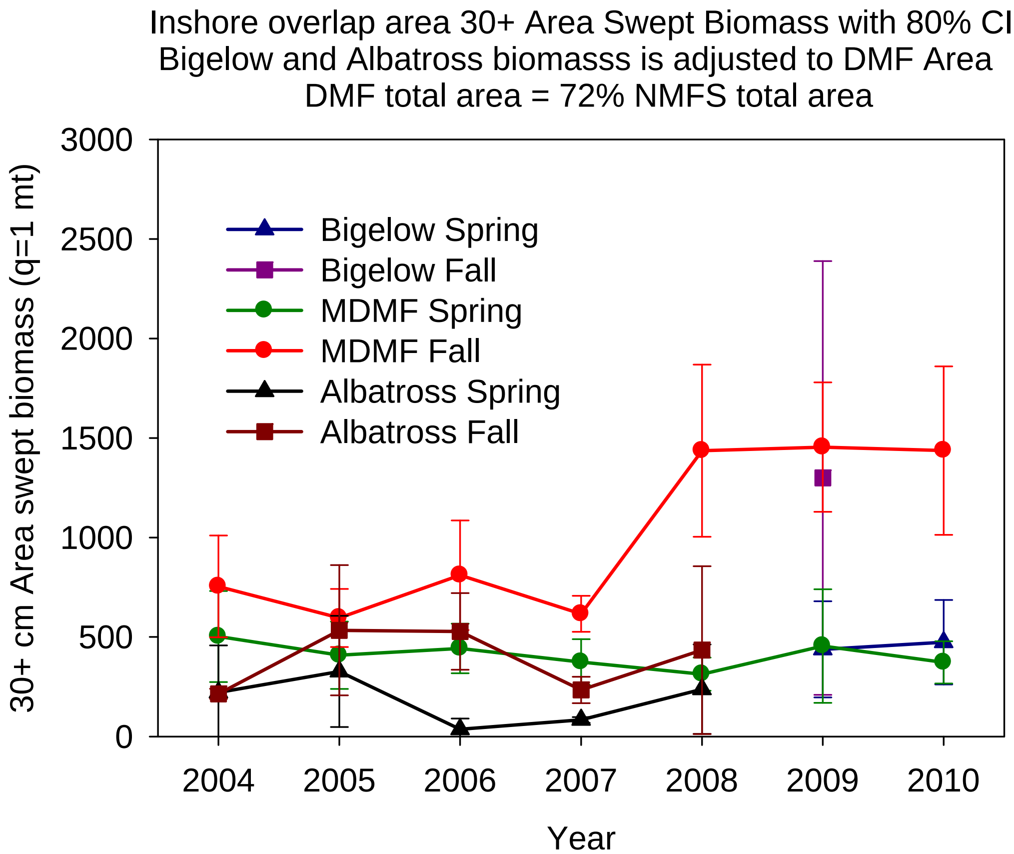
Appendix C1 Figure C6 - Minimum area swept exploitable biomass (30+cm) estimates by year with the associated 80% confidence intervals for the NEFSC (Albatross and Bigelow) and MDMF survey. Bigelow estimates were not adjusted to Albatross units.



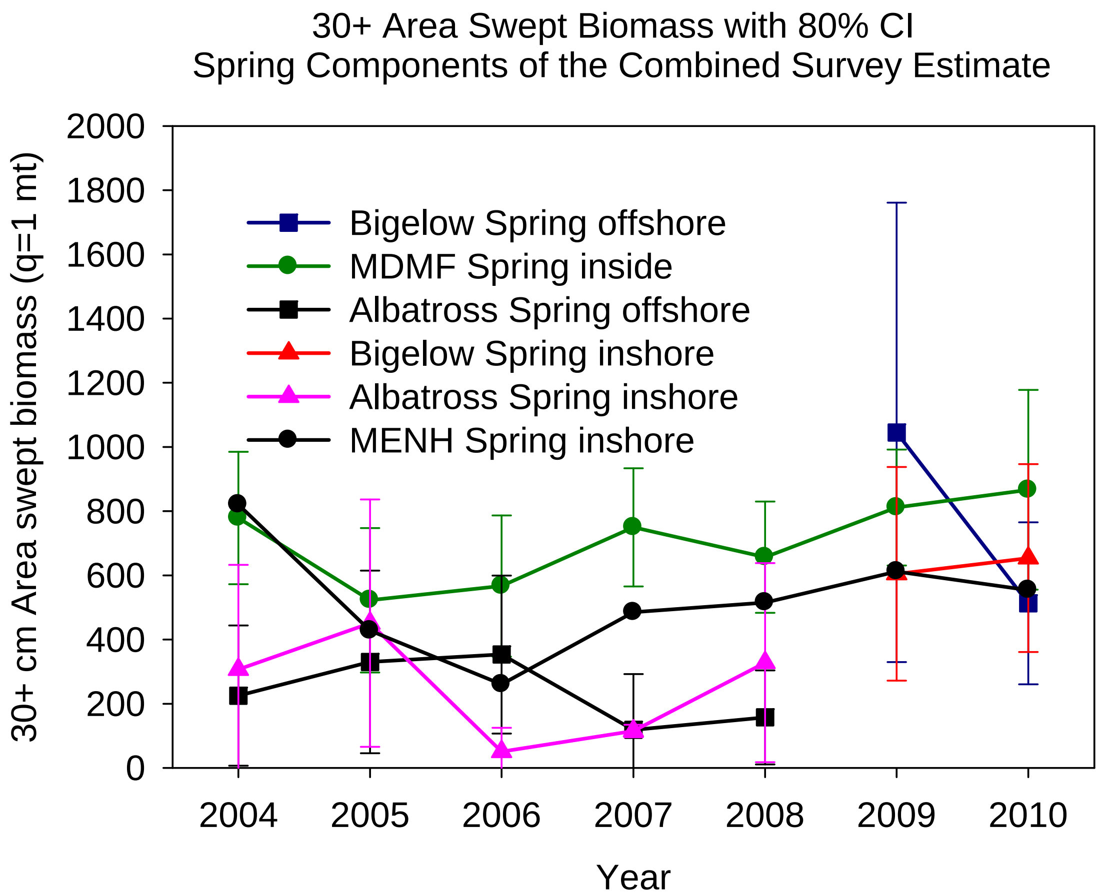
Appendix C1 Figure C7 - Exploitation rates assuming the ABC of 238 mt by year with the associated 80% confidence intervals for the NEFSC (Albatross and Bigelow) and MDMF surveys. Bigelow estimates were not adjusted to Albatross units.



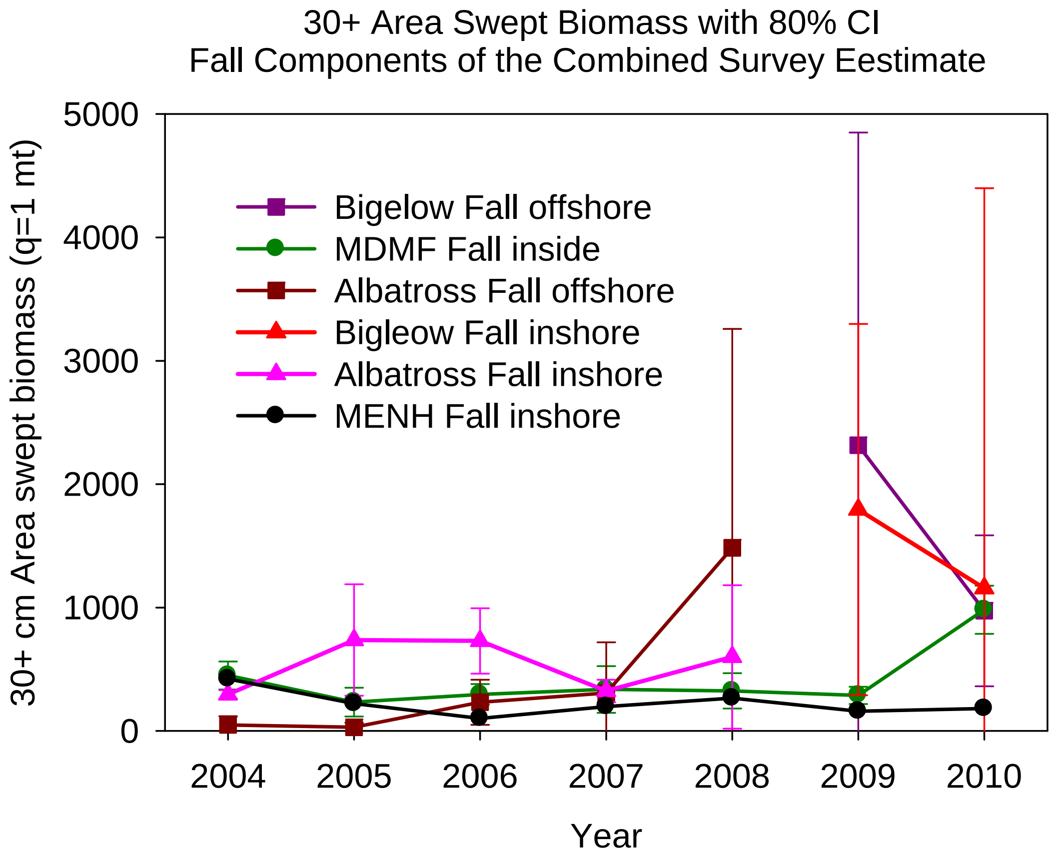
Appendix C1 Figure C8 - Minimum unadjusted area swept exploitable biomass (30+cm) estimates by year with the associated 80% confidence intervals limited to the overlap strata between the NEFSC (Albatross and Bigelow) and MDMF surveys. Bigelow estimates were not adjusted to Albatross units. NEFSC overlap strata equals 72% of the total DMF overlap area.



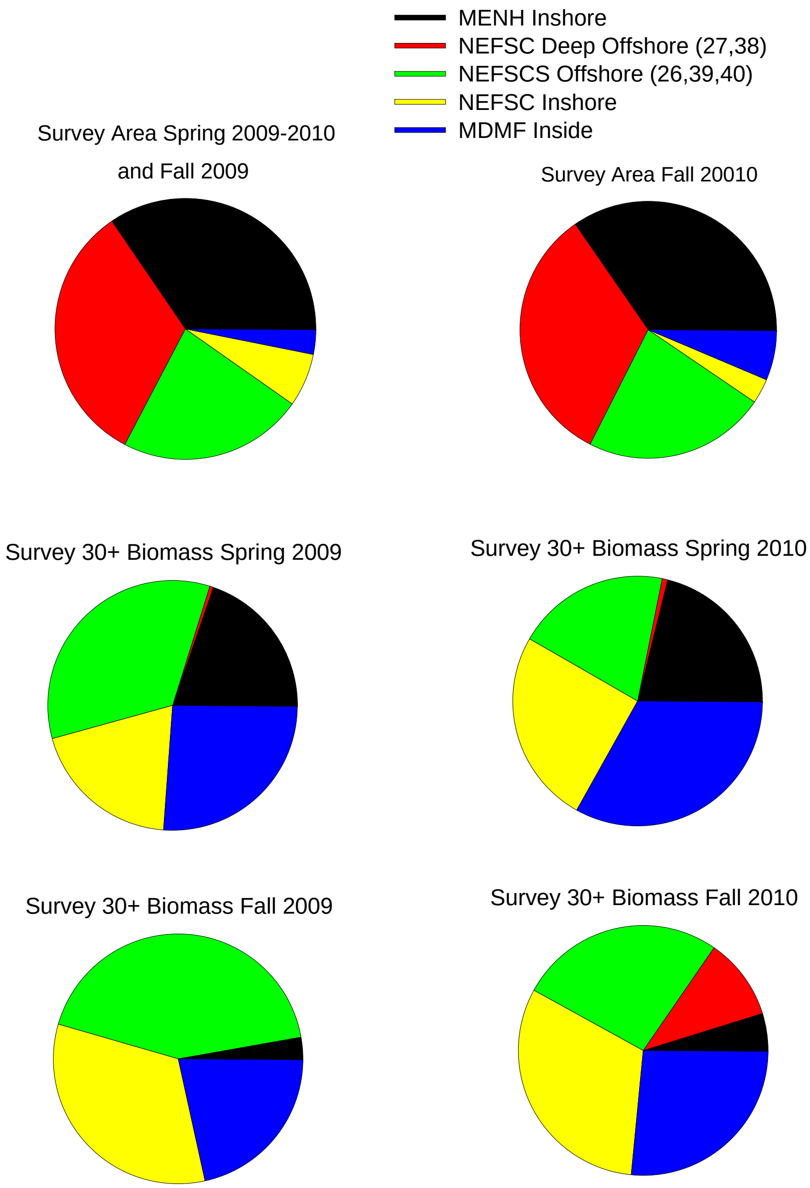
Appendix C1 Figure C9 - Minimum area adjusted area swept exploitable biomass (30+cm) estimates by year with the associated 80% confidence intervals limited to the overlap strata between the NEFSC (Albatross and Bigelow) and MDMF surveys. Bigelow estimates were not adjusted to Albatross units. NEFSC overlap strata equals 72% of the total DMF overlap area.



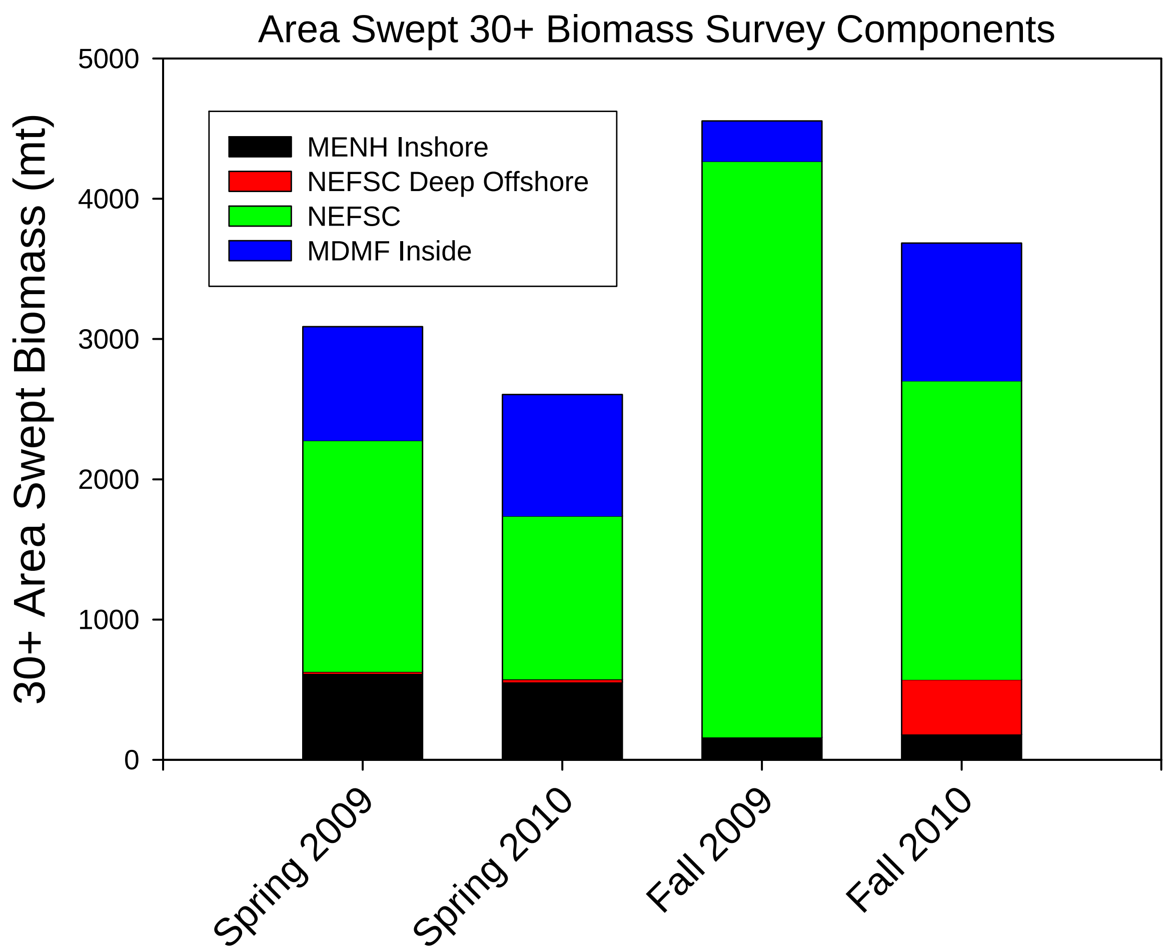
Appendix C1 Figure C10 - Spring minimum area swept exploitable biomass (30+cm) estimates by year with the associated 80% confidence intervals for the non-overlapping strata used in the combine biomass estimate. Bigelow estimates were not adjusted to Albatross units.



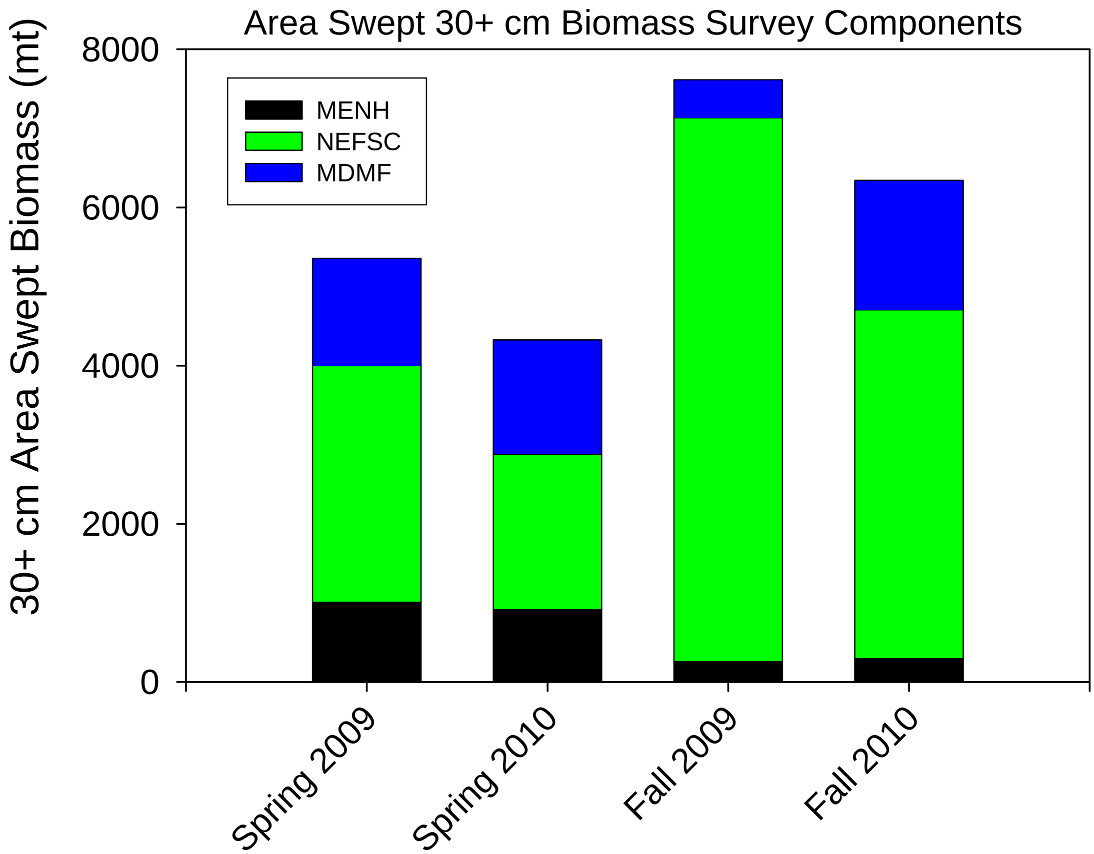
Appendix C1 Figure C11 - Fall minimum area swept exploitable biomass (30+cm) estimates by year with the associated 80% confidence intervals for the non-overlapping strata used in the combine biomass estimate. Bigelow estimates were not adjusted to Albatross units.



Appendix C1 Figure C12 –Pie charts of area coverage for each survey or NEFSC survey components (top). The Fall 2010 has a different area makeup due to the lack of coverage of Cape Cod Bay strata by the NEFSC survey. The estimated 30+ biomass for each component are shown for the spring 2009-2010 and fall 2009-2010 surveys.

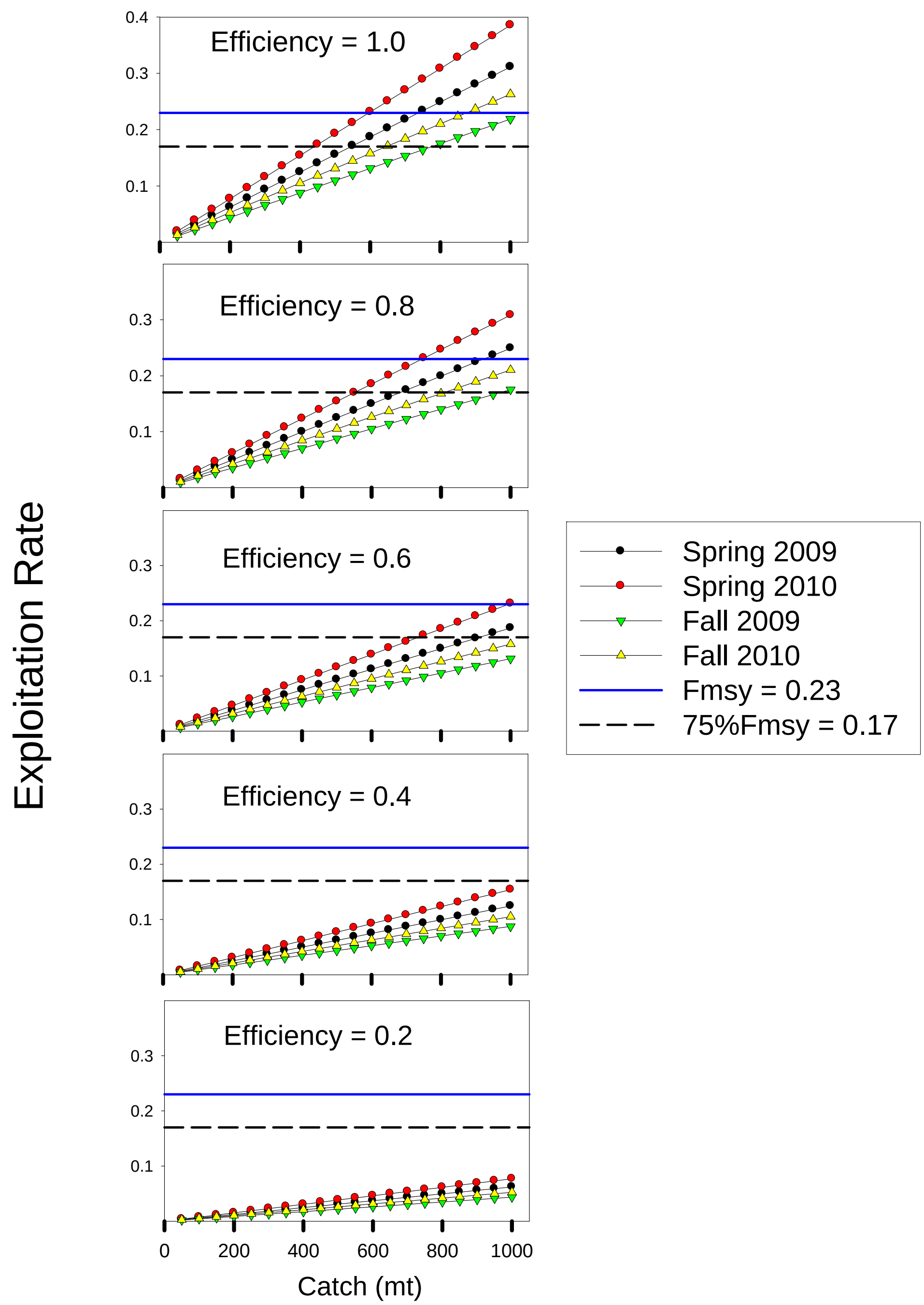


Appendix C1 Figure C13. 30+ area swept biomass estimates for the spring and fall surveys from 2009 to 2010 assuming efficiency is 1.0. The effect of using the NEFSC deep offshore strata (27, 38) can be seen in red. These strata were not used in the final estimates due to the lack of fish present in the deeper central part of the gulf of Maine.

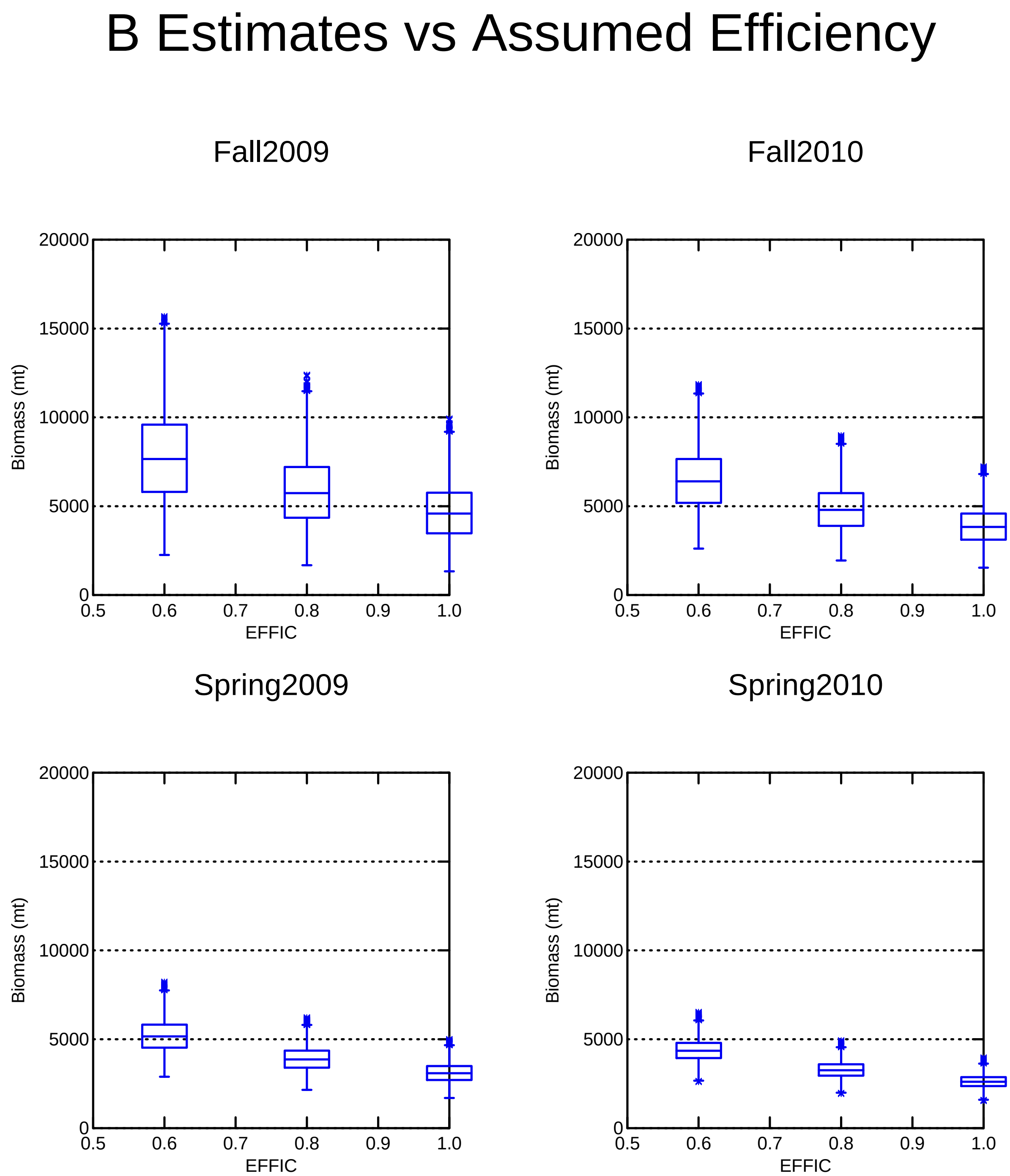


Appendix C1 Figure C14. The 30+ cm area swept biomass estimates for the spring and fall surveys from 2009 to 2010 assuming an efficiency of 0.6 which was used for overfishing status determination. The NEFSC survey used a TOGA tow criteria of 132x.

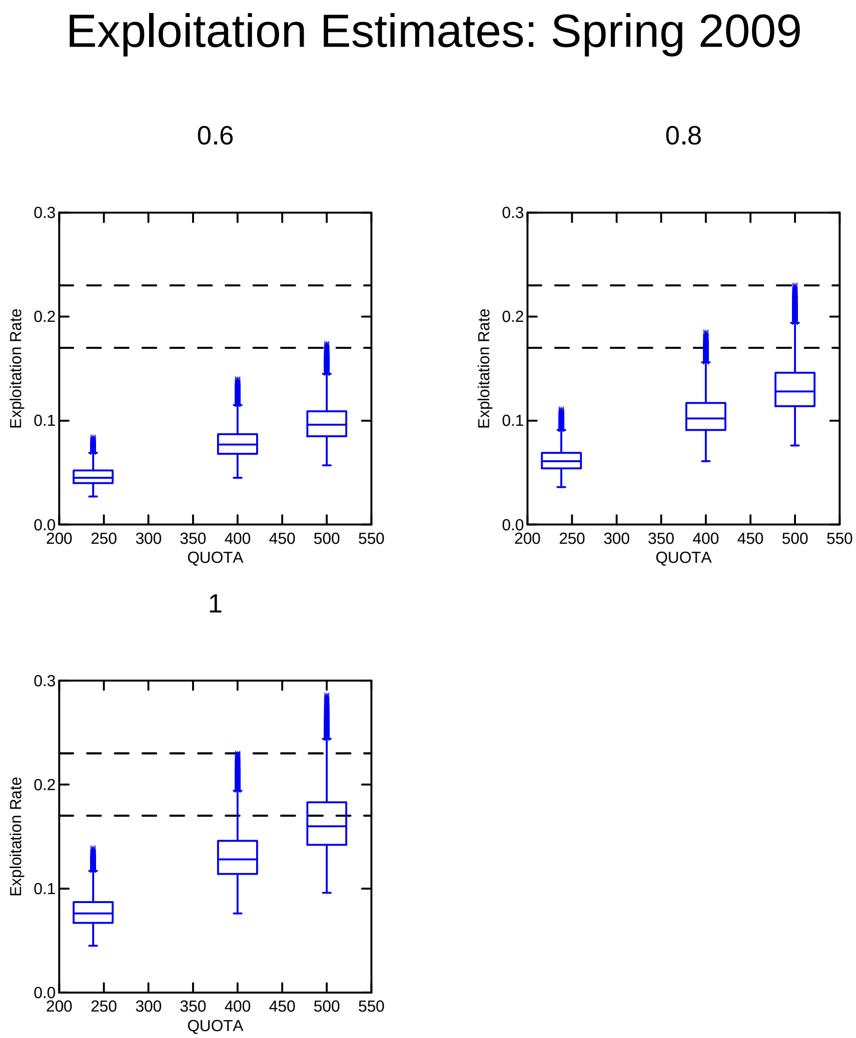
Appendix C1 Figure C15. Length based yield per recruit analysis using updated von Bertalanffy parameters estimated from the spring and fall 2006-2010 NEFSC surveys, maturity at length from the MDMF survey and assuming a natural mortality of 0.3. F40% was estimated at 0.31.



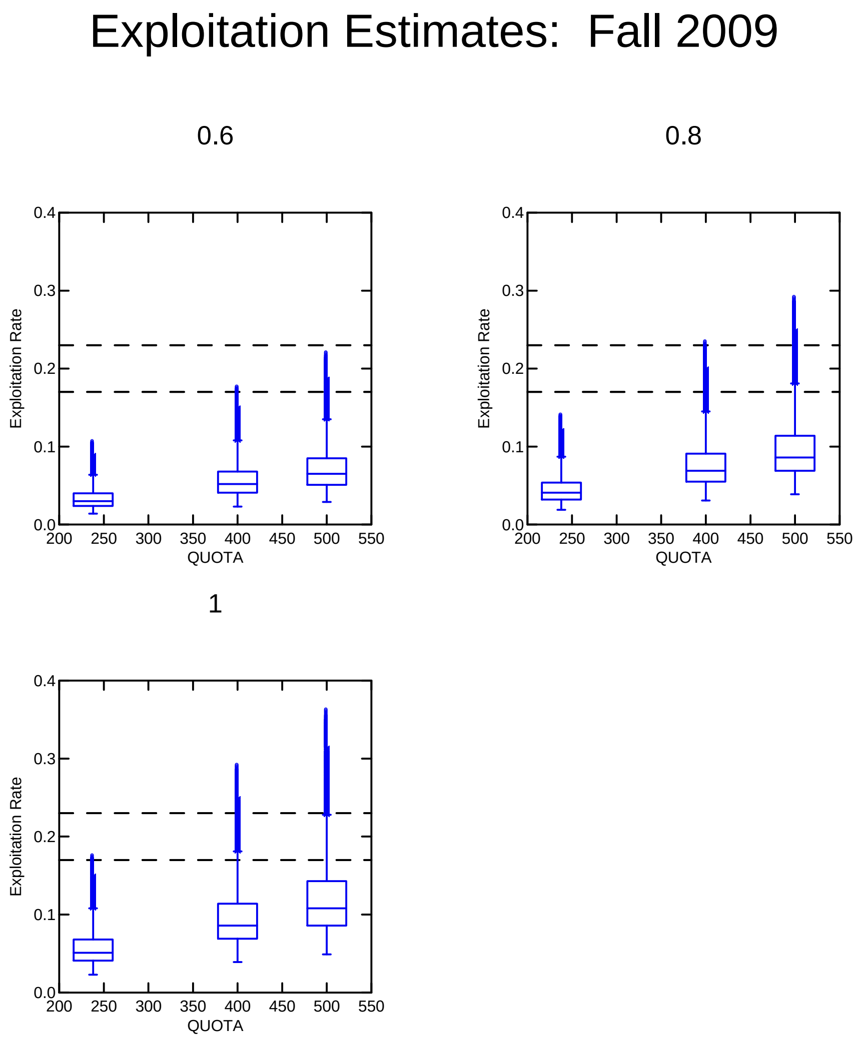
Appendix C1 Figure C16 - Exploitation rate (catch over survey biomass) for a range of catches using the combined surveys (spring and fall 2009 20010) assuming different efficiencies (0.2 to 1.0). Solid blue line is exploitation rate at Fmsy = 0.23 and the dashed black line is the exploitation rate at 75% F_{MSY} (0.17).



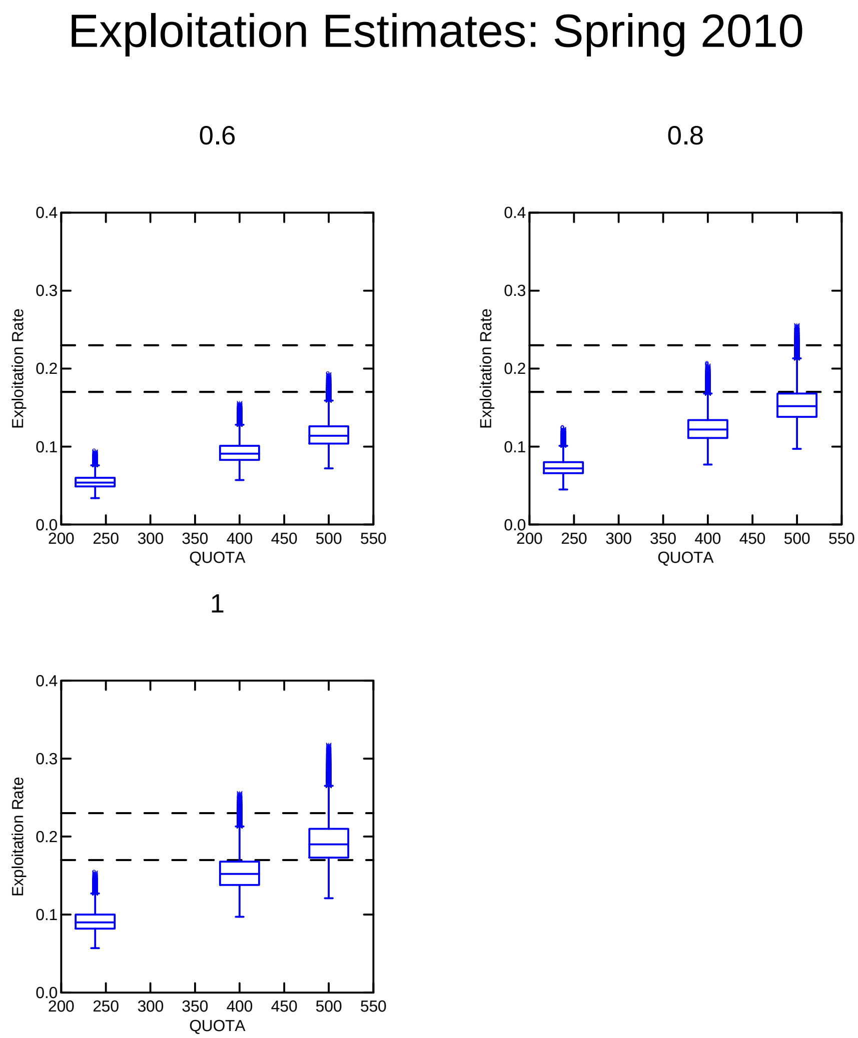
Appendix C1 Figure C17 - Sensitivity of swept area 30+ cm biomass estimates for Gulf of Maine winter flounder for varying seasons and years under three alternative assumed values of trawl efficiency for all three surveys.



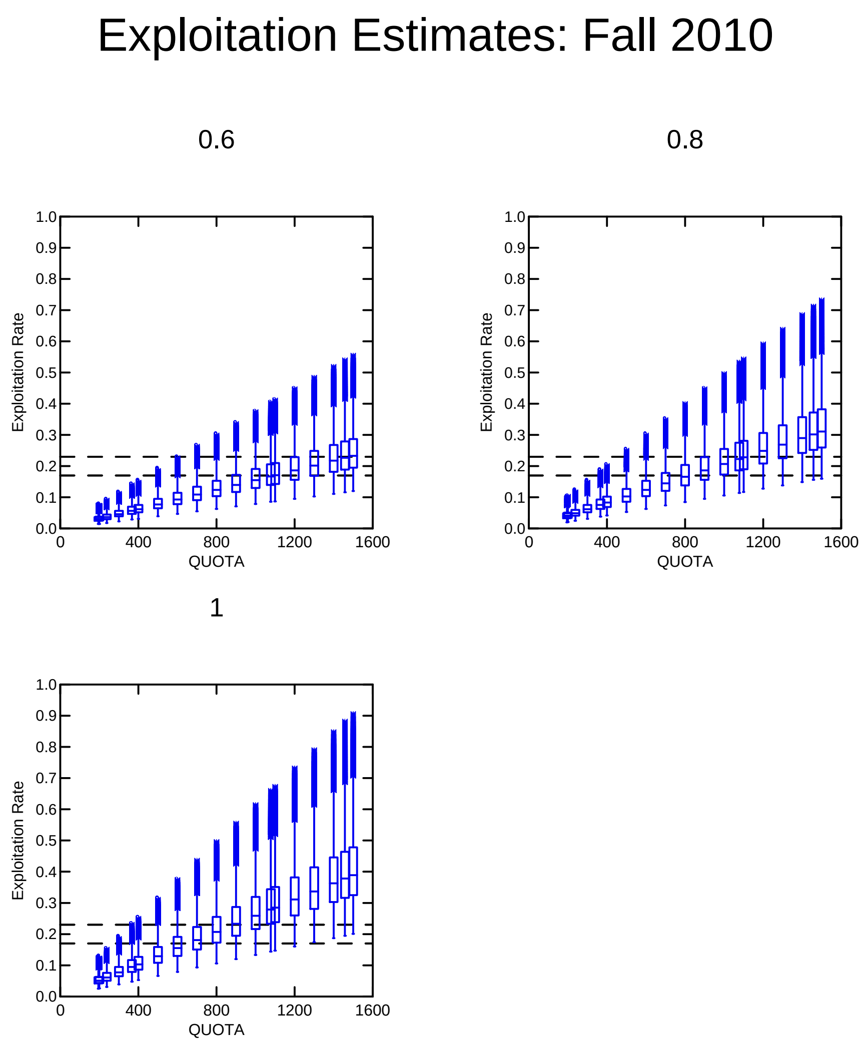
Appendix C1 Figure C18 - Estimated exploitation rates for Gulf of Maine winter flounder for spring 2009 based on three assumed estimates of gear efficiency (0.6, 0.8, and 1.0) and three assumed catch quotas of 238, 400, and 500 mt. Dashed lines represent length based estimates of F40% and 75% of F40% expressed as exploitation rates (0.23 and 0.17). SSB per recruit is derived using GOM winter flounder growth and maturation relationships and an assumed knife edge selection curve at 30 cm.



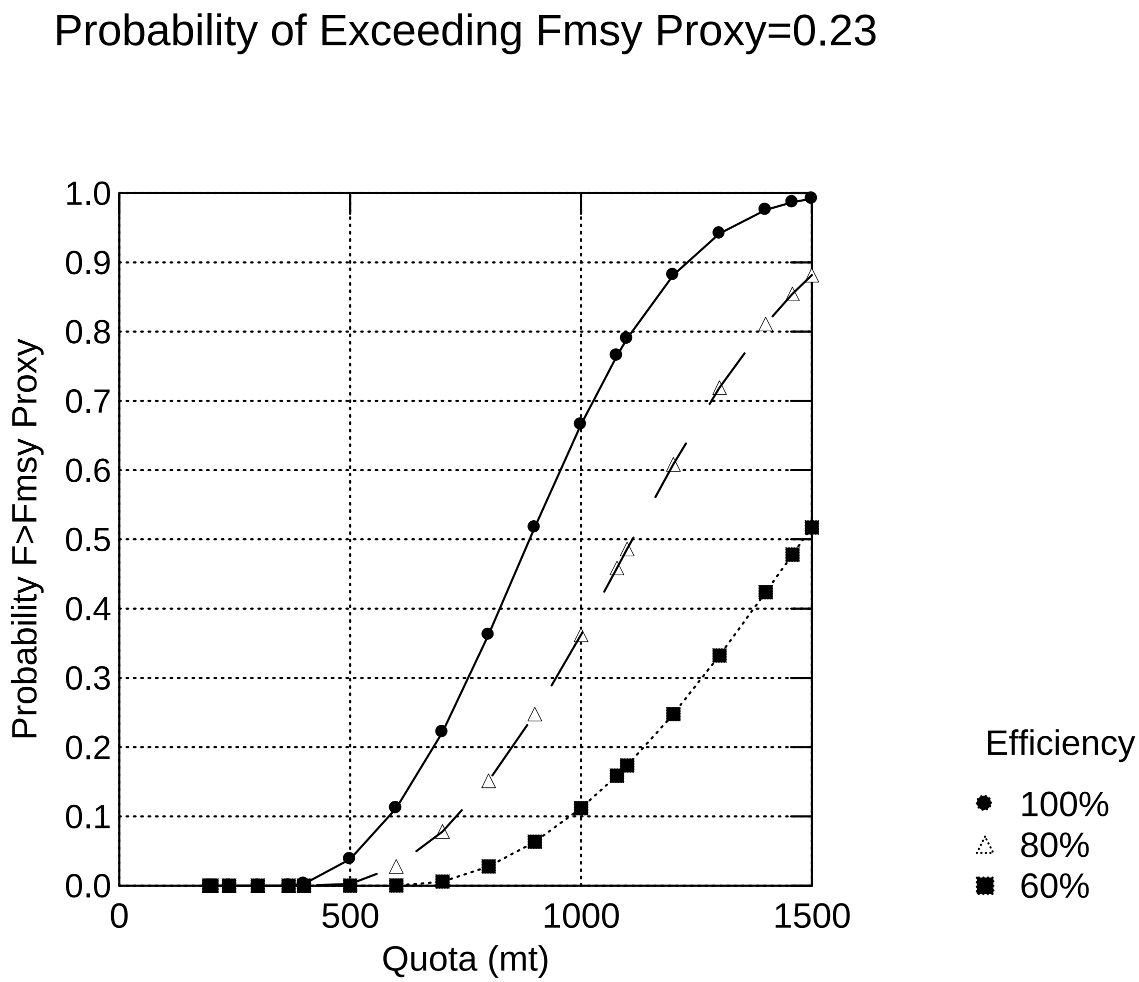
Appendix C1 Figure C19 - Estimated exploitation rates for Gulf of Maine winter flounder for Fall 2009 based on three assumed estimates of gear efficiency (0.6, 0.8, and 1.0) and three assumed catch quotas of 238, 400, and 500 mt. Dashed lines represent length based estimates of F40% and 75% of F40%expressed as exploitation rates (0.23 and 0.17). SSB per recruit is derived using GOM winter flounder growth and maturation relationships and an assumed knife edge selection curve at 30 cm.



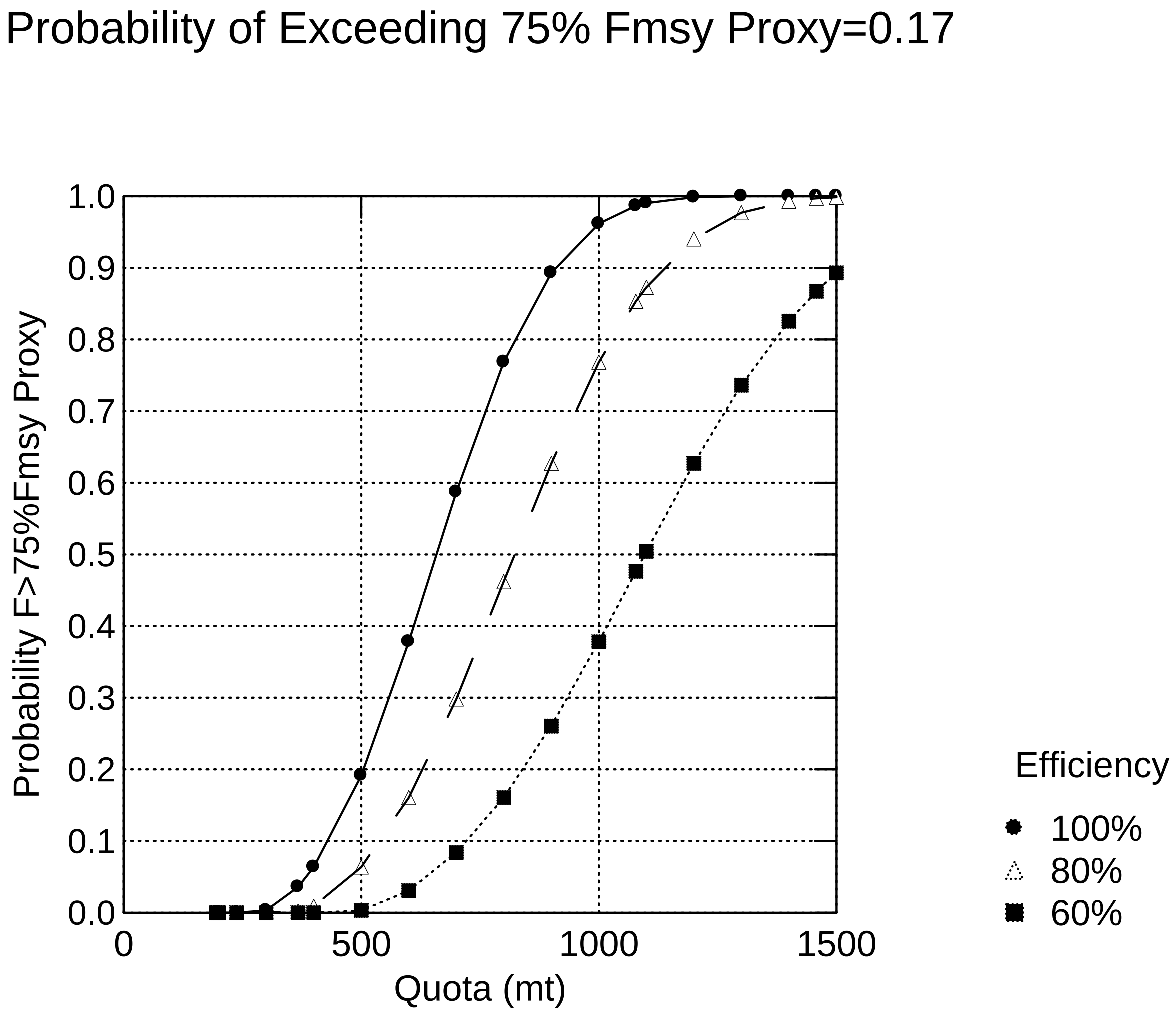
Appendix C1 Figure C20 - Estimated exploitation rates for Gulf of Maine winter flounder for Spring 2010 based on three assumed estimates of gear efficiency (0.6, 0.8, and 1.0) and three assumed catch quotas of 238, 400, and 500 mt. Dashed lines represent length based estimates of F40% and 75% of F40% expressed as exploitation rates (0.23 and 0.17). SSB per recruit is derived using GOM winter flounder growth and maturation relationships and an assumed knife edge selection curve at 30 cm.



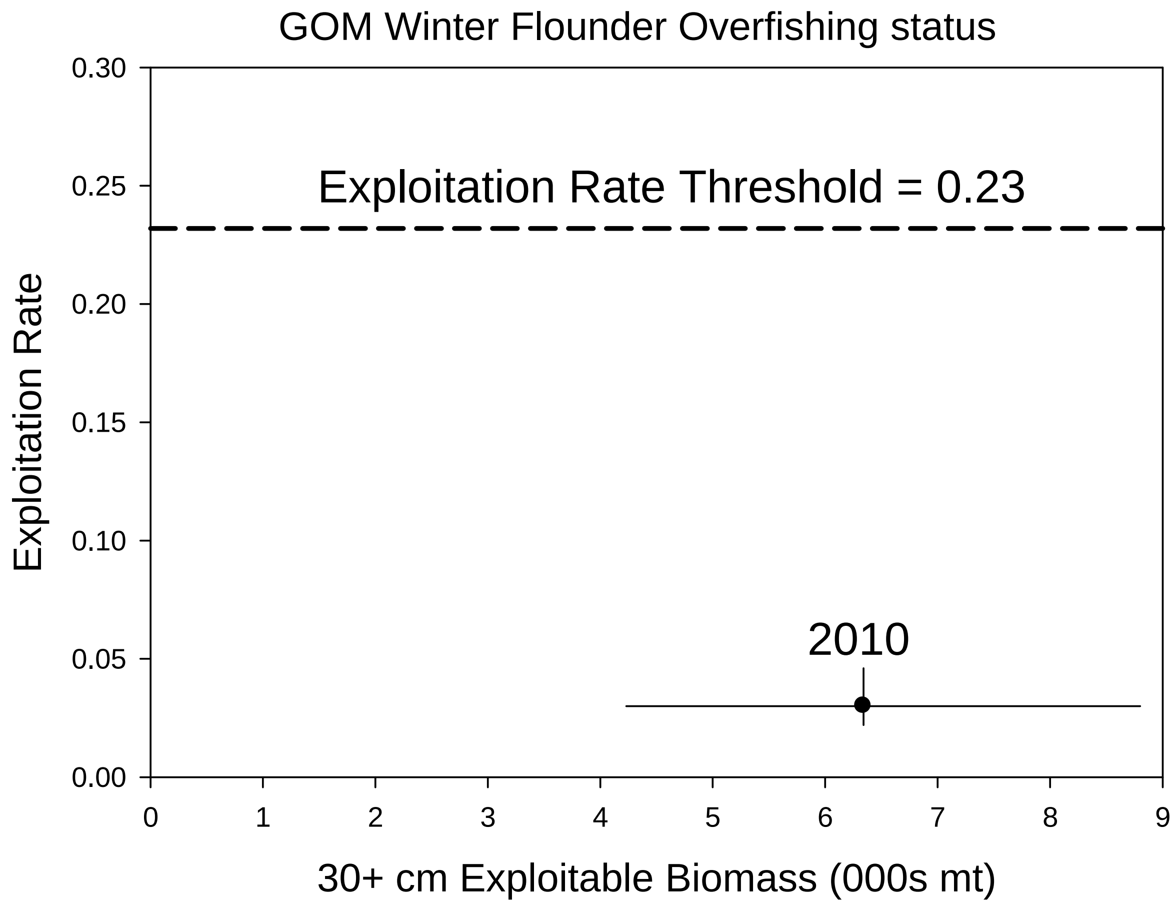
Appendix C1 Figure C21. Estimated exploitation rates for Gulf of Maine winter flounder for Fall 2010 based on three assumed estimates of gear efficiency (0.6, 0.8, and 1.0) and the 2010 catch of 195 mt, an assumed quota of 500 mt, 700 mt, 75% OFL of 1,078 mt and the OFL of 1,458 mt based on F40%. Dashed lines represent length based exploitation rate estimates of F40% (0.23) and 75% of F40% (0.17). SSB per recruit is derived using GOM winter flounder growth and maturation relationships and an assumed knife edge selection curve at 30 cm.



Appendix C1 Figure C22. Estimated probability of exceeding FMSY (F40 proxy) of 0.23 expressed as an exploitation rate assuming efficiencies of 60%, 80% and 100% base of the fall 2010 surveys across a range of quotas.



Appendix C1 Figure C23. Estimated probability of exceeding 75% of FMSY (F40 proxy) of 0.17 expressed as an exploitation rate assuming efficiencies of 60%, 80% and 100% base of the fall 2010 surveys across a range of quotas.



Appendix C1 Figure C24. Stock status for GOM winter flounder in 2010 with respect to MSY-based BRPs; error lines are 80% confidence intervals. F40% of 0.31 corresponds to an exploitation rate of 0.23.