ECOSYSTEM CONSIDERATIONS

2.1 Target Biological Reference Points, Worldwide Cross System Comparisons, and Aggregate Production Model Results for GARM Stocks.

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1.0 Introduction:

This working paper addresses TOR 2: Ecosystem Data for use in stock assessments, (3. Identify candidate measures of system-level productivity). It provides analyses to determine if the Northeast Shelf LME (Large Marine Ecosystem) can support the reference point biomasses (summed BRPs) required for the GARM species (see NEFSC 2002) as well as the other demersal fish resources in the region. There has been some concern expressed by various stakeholders as to whether the US Northeast Shelf LME can support biomass at optimal levels (e.g., B_{MSY}) simultaneously for all 19 groundfish (GARM stocks), and more broadly, the entire fish community. The purpose of this working paper is to summarize current information on the BRPs for GARM species and other demersal fish components of the US Northeast Shelf LME. Here we summarize information for the demersal components of the LME and compare it to recent energy budget analyses for the region (Link et al. 2006). We then compare the data to other ecosystems by using energy budget density units (t/km2) as the common currency.

In addition an aggregate surplus production model will be fit using the ASPIC production model for all 19 GARM groundfish stocks. This approach will provide an estimate of the overall carrying capacity for this group of stocks as a whole. Estimates of BRPs (e.g., aggregate carrying capacity, B_{MSY}, MSY, F_{MSY}) will be calculated for the GARM stocks. The aim will be to calculate aggregate BRPs to compare to summations of single stocks BRPs.

2.0 Methods

Detailed descriptions of methods used in these analyses are available in working papers 3.1 and 3.2 (GARM BRP Meeting). The current analysis focuses only on the GARM stocks.

Results and Discussion

The estimated total MSY for the GARM species is 144,977[*]mt and B_{MSY} for this groundfish complex is 1,065,068 mt (Table 1). The current total biomass for the GARM stocks is 696,207 mt and the ratio of total current biomass to B_{MSY} for this group is 0.65 (Table 1). This analysis suggests that the GARM species are currently at 65% of their B_{MSY} target. The species with the largest B_{MSY} targets and lowest B/B_{MSY} ratios are GB cod, ocean pout, and white hake (Table 1). These are several of the major GARM stocks that still require rebuilding.

In terms of density units (t/km2), the total MSY for the GARM stocks is 0.59 t/km2 (Table 2). The summed value for GARM, elasmobranch, and other demersal components compares favorably, in terms of scale, with the values for these categories from other recent analyses for the entire LME (for example 11.77 t/km2 for demersal fishes; Link et al. 2006) (Table 3). The current target demersal biomass that the US Northeast Shelf LME needs to support is about 3.6 million mt (Table 3). This equates to a unit area biomass of 14.62 t/km2, about 24% higher than the 11.77 t/km2, estimated from a recent analysis for the 1996-2000 time period (Link et al. 2006) and compared to 10.6-17.04 t/km2 from historical studies for the

Georges Bank ecosystem (Cohen et al 1982; Sissenwine et al 1984). The other components of the ecosystem, excluding GARM species and elasmobranchs, comprise about 1/3 of the total biomass (Table 3).

The average demersal biomass for the nine temperate and boreal systems (from various ecosystem modeling studies) was 15.2 t/km2, with a range between 2.1-44.9 t/km2 (Table 4). The target biomass for the demersal component is moderately lower than the average for the nine systems and is higher than six of the individual systems (Table 4). However, for many of these other ecosystems the demersal component is depleted.

Landings of GARM stocks ranged from 49,000 mt to 289,000 mt during 1950-2005 (Table 5). Since landings either did not occur or were not recorded for several stocks during 1950-1959, only landings from 1960-2007 were used in the ASPIC analysis. Spring survey indices for the GARM stocks showed a major decline from over 80 kg/tow in 1973 to a series low of 10 kg/tow in 1994, recovering to over 50kg/tow in 2002 and fluctuating around this value through 2007(Figure 1). Most of the GARM stocks, although experiencing some declines from the 1970s to the early 1990s, were well represented in the survey catch during spring (Figure 2). Autumn survey indices also showed a pronounced decline during the late 1960s through the early 1990s, ranging from 110 kg/tow in 1964 to a series low of about 12 kg/tow in 1994, and recovering to about 50 kg/tow recently (Figure 3). GARM stocks were also well represented in the autumn survey catch in the 1963-2007 time-series (Figure 4).

Initial values from the previous ASPIC run (WP 3.2) for the GARM stocks were used to start a final ASPIC run, the model converged rapidly to a B1/K value of 1.0, an MSY of 139, and a K value of 1900 (Table 6). Residuals for both the spring and autumn series for this ASPIC run were reasonable and the biomass trajectory during 1960-2008 appeared plausible (Figures 5-7). Estimates of biological reference points were MSY= 139,000 mt, B_{MSY} = 950,000 mt, and F_{MSY} = 0.15 (Table 6; Figure 8). Bootstrap results for MSY and B_{MSY} suggest that the ASPIC model fit was reasonably precise for both parameters. 80% CIs for MSY are 128,800-141,900 mt and 836,000-1,059,000 mt for B_{MSY}. Relative bias for MSY was estimated at 3.0% and at 4.5% for B_{MSY}.

The estimates of MSY and B_{MSY} (139,000 mt and 950,000 mt) from ASPIC are similar to management targets (144,977 mt and 1,065,068) for the GARM single stock groups (Table 6). The new results for the GARM stocks are considerably lower for MSY and B_{MSY} than the previous estimates (Table 6). The system wide fishing rate on the GARM complex was estimated at F=0.15 (Table 6). When compared to the distribution of fully recruited Fs for the GARM stocks, the aggregate F_{MSY} is relatively much lower (Figure 8).

Conclusions

Results from this study suggest that on an ecosystem basis, current biomass management targets (B_{MSY}s) for GARM stocks are reasonable. The current targets compare favorably with the results of recent and historical studies in the region and are also in general agreement with results of many studies for other worldwide ecosystems. New summed BRPs for the GARM stocks are similar to BRPs from an aggregate surplus production model for these stocks. Aggregate model results suggest that the overall fishing mortality rate should be relatively low (F=0.15) to obtain MSY for this complex of GARM stocks.

Notes on GARM stock recovery and long-term advice

A 2nd Tier quota could be considered during recovery and for long-term maintenance of the GARM stock complex. Based on the results of the aggregate production model for the GARM stocks, system recovery is predicated on a low fishing rate (F_{MSY} = 0.15).
Weak stock management is an issue because there are several stocks in each eco-region that will constrain the overall recovery of this FMP complex (i.e. halibut, GB cod, GB Yt, white hake, SNE Yt). Unless stocks can somehow be targeted independently, a much lower fishing effort than is currently being employed will be required for full system recovery.

3.0 Panel Discussion/Comments

Conclusions

The Panel agreed that the exploration of ecosystem productivity for understanding future management scenarios is an important effort and should be pursued. It was noted that the sum of the GARM single species targets is close to the multispecies estimate of system productivity considering only those stocks. However, a concern was raised with the analysis that the single species reference points correct for survey catchability (through the assessment models) but the multispecies biomass dynamics model does not correct for the survey catchability of each species. This makes the direct comparison of the system biomass and reference points to single species estimates problematic and should be investigated in future.

Notwithstanding the problem noted above, the ecosystem estimates of productivity appears to be slightly less than the sum of species productivity and this implies that some tradeoffs between species may occur. If this is the case, it is likely that these tradeoffs are relatively minor under current conditions because many of the species are depleted. As rebuilding proceeds on more species, these tradeoffs may become more apparent and the difference between system potential productivity and single species summed potential may increase. The proposed analysis of the allocation of productivity among stocks (such as through a linear programming approach) is worth pursuing. Overall, a more complete management strategy evaluation or scenario analysis approach should be developed for this ecosystem. It was also noted that if differential exploitation of species can not be well managed then the overall fishing mortality rate for the entire system must be quite low ($F_{ecosystem}$ = 0.15) in order to obtain maximum sustainable yield for this ecosystem.

The Panel noted that in the new assessments, many of the biomass reference points for GARM species are lower than in previous assessments. The concern was raised that this may be an artifact of the depleted level of many resources. In most cases, reference points are estimated from the historic series of stock and recruitment. However, recent observations tend to be at low stock sizes (with low recruitment) or after commencement of high exploitation. This may result in lower estimated productivity. As rebuilding proceeds and recruitment at higher stock sizes are observed, it is likely that estimates of potential productivity (and the biomass reference points) will increase. This pattern has already been observed for some stocks (haddock, scallops), though the majority have not yet rebuilt sufficiently to confirm the pattern.

Table 1. Biological Reference Points (MSY, B_{MSY}), current biomass (from new assessments) and ratio of current biomass to B_{MSY} for GARM species.*

	GARM Stocks	MSY (mt)	Bmsy (mt)	Current B (mt)	B/Bmsy
1	GOM cod	10,431	60,104	33,878	0.56366
2	GB cod	31,159	148,084	17,672	0.11934
3	GOM haddock	1,360	5,900	5,846	0.99085
4	GB haddock	32,746	158,873	315,976	1.98886
5	Redfish	10,139	271,000	234,609	0.86572
6	Pollock [1]	6,491	33,201	12,517	0.37701
7	CC-GOM Yt	1,720	7,790	1,922	0.24673
8	GB Yt	9,400	43,200	9,526	0.22051
9	SNE-MA Yt	6,100	27,400	3,508	0.12803
10	Am plaice	4,011	21,940	11,106	0.50620
11	Witch fldr	2,352	11,447	3,434	0.29999
12	GOM Winter fldr	912	3,769	1,099	0.29159
13	GB Winter fldr	4,160	16,000	4,964	0.31025
14	SNE-MA Winter fldr	9,742	38,761	3,368	0.08689
15	GOM-GB Windowpane fldr [1]	700	5,599	2,550	0.45544
16	SNE-MA Windowpane fldr [1]	500	3,484	3,152	0.90471
17	Ocean Pout [1]	3,754	103,262	9,970	0.09655
18	White hake [1]	5,800	56,254	19,810	0.35215
19	Halibut	3,500	49,000	1,300	0.02653
total		**144,977**	**1,065,068**	**696,207**	**0.65367**

1 B_{MSY} based on area swept biomass and estimated Q for demersal species

Table 2. Biological Reference Points (MSY, and B_{MSY}, mt) for GARM stocks. expressed in energy budget density units (t/km^2) (based a total area of the continental shelf of 246,662 km^2) for direct comparison to other worldwide systems.*

	GARM Stocks	MSY (mt)	t/km^2	Bmsy (mt)	t/km^2
1	GOM cod	10,431	0.0423	60,104	0.243669672
2	GB cod	31,159	0.1263	148,084	0.600352385
3	GOM haddock [1]	1,360	0.0055	5,900	0.023919391
4	GB haddock	32,746	0.1328	158,873	0.644092437
5	Redfish	10,139	0.0411	271,000	1.098670325
6	Pollock [1]	6,491	0.0263	33,201	0.134601304
7	CC-GOM Yt	1,720	0.0070	7,790	0.031581704
8	GB Yt	9,400	0.0381	43,200	0.175138591
9	SNE-MA Yt	6,100	0.0247	27,400	0.111083273
10	Am plaice	4,011	0.0163	21,940	0.088947701
11	Witch fldr	2,352	0.0095	11,447	0.046407672
12	GOM Winter fldr	912	0.0037	3,769	0.015280031
13	GB Winter fldr	4,160	0.0169	16,000	0.064866145
14	SNE-MA Winter fldr	9,742	0.0395	38,761	0.15714229
15	GOM-GB Windowpane fldr [1]	700	0.0028	5,599	0.022699096
16	SNE-MA Windowpane fldr [1]	500	0.0020	3,484	0.014124603
17	Ocean Pout [1]	3,754	0.0152	103,262	0.418637989
18	White hake [1]	5,800	0.0235	56,254	0.228061256
19	Halibut	3500	0.0142	49,000	0.198652568
total	total	**144,977**	**0.5878**	**1,065,068**	**4.31792843**

* To complete this analysis in time for the GARM meeting it was necessary to get stock size and BRP estimates before they were finalized. Some of the values in Tables 1 and 2 (above) are not identical to the final values given in the individual species chapters and in the Executive Summary.

Table 3. Total biomass (mt) and energy budget density units (t/km^2) for GARM stocks, elasmobranchs, other demersal components, and medium pelagics (c.f. Link et al 2006) for the US Northeast Shelf LME.

Category	Biomass (mt)	t/km^2
GARM species	1065068.00	4.32
Elasmobranchs	1155731.00	4.69
demersal omnivores	15291.40	0.06
demersal piscivores	262902.49	1.07
demersal benthivores	850566.28	3.45
medium pelagics	256677.00	1.04
Total	**3606236.17**	**14.62**

Table 4. Energy budget density units (total t/km^2) and average (t/km^2) for nine worldwide systems for demersal fishes with proposed US Northeast Shelf LME BRP targets and current density.

System	Demersal B (t/km^2)
Gulf of Alaska	26.478
Bering Sea	44.852
Barents Sea	4.313
North Sea	8.868
Baltic Sea	2.130
Faroes	10.605
Newfoundland-Labrador	10.990
Gulf of St Lawrence	21.780
Scotian Shelf	6.849
Average	**15.207**
Northeast Shelf LME Target	**14.620**
Northeast Shelf LME Current	**13.123**

Table 5. Catch (t, recent years include discards) of GARM stocks during 1950-2007

Year	GOM cod	GB cod	GOM hadd	GB hadd	Yt	Window	A Plaice	Winter	Witch	Pollock	Redfish	O-pout	White_hake	Halibut	Total
1950	5062	15400		41273	13887						34307		5492	135	115557
1951	3567	14800		47318	10862						30077		5300	180	112104
1952	3011	10900		43252	10437						21377		5200	143	94320
1953	3121	8100		35926	8040						16791		5100	121	77200
1954	3411	8800		46388	7614						12988		5000	146	84346
1955	3171	9300		40851	9020						13914		4900	86	81243
1956	2693	10500	7307	51144	9526						14388		4800	72	100431
1957	2562	10400	6166	48561	14626						18490		4700	93	105598
1958	4670	11100	7367	37322	21339						16047		4600	85	102531
1959	3795	12100	4660	36051	18864						15521		4500	69	95559
1960	3448	10853	4924	40877	19939		1310		1255		11375		4400	73	98454
1961	3216	14731	5353	46650	25822		1522		1024		14101		4300	97	116816
1962	2989	23486	5110	54004	29000		1971		977		14134	0	4200	160	136031
1963	2595	27189	4789	54846	49490		2333		1374	6241	10046	20	4100	199	163222
1964	3226	25165	5853	64086	53580		3799	10302	1418	9008	8313	2123	3995	255	191124
1965	3780	38333	4654	150362	52371		3635	11194	2664	9000	8057	877	3434	320	288681
1966	4008	53134	5870	121274	44416		3867	15095	3314	9847	8569	13380	2051	300	285124
1967	5676	36752	5502	51469	53338		4473	12735	3682	8534	10864	7361	1498	531	202416
1968	6360	43136	3557	40923	55674		3777	10072	3054	5222	6777	16538	1699	282	197072
1969	8157	37939	2697	22252	67362		3939	11715	3852	9822	12455	30101	1815	178	212285
1970	7812	25652	1543	11300	51588		4329	12519	3261	11976	16741	9938	2799	147	159603
1971	7380	28179	1316	10862	37356		3061	12766	6115	15203	20034	7932	3801	132	154137
1972	6776	25059	955	5866	42351		2245	10883	5515	13013	19095	4849	4127	118	140852
1973	6069	28923	609	5429	33226		2087	9721	3162	13076	17360	6664	4462	97	130887
1974	7639	27331	878	4450	36657		2127	7459	2140	12393	10471	4866	5255	84	121749
1975	8903	25008	1343	5606	24702	2722	2596	8216	2357	13871	10572	994	5010	118	112017
1976	10172	19926	2013	4484	22369	2991	3536	6764	1882	13382	10696	1200	5641	101	105156
1977	12426	27367	3335	10994	19584	2770	7231	10372	2493	16273	13223	1987	7196	89	135340
1978	12426	35661	5071	22516	19500	3282	9610	12031	3525	22305	14083	2413	6630	148	169200
1979	11680	39162	4406	19647	21757	3086	11360	8883	2895	18452	14755	2181	5641	175	164080
1980	13528	48684	6542	27638	21727	2523	14442	17291	3147	23539	10183	2366	6630	181	198421
1981	12534	47543	6289	25011	17760	2864	13186	22460	3449	22820	7915	2994	8428	211	193464
1982	16713	61088	6961	17627	32320	4841	15567	23545	4954	20285	6903	4761	9112	215	224892
1983	16037	53404	7672	12009	36709	5836	13721	20750	6162	18397	5328	4897	9471	215	210607
1984	12187	39766	4109	10394	18890	6130	10761	22535	6760	20748	4793	5016	10195	149	172433
1985	12713	42298	3073	7943	9410	7736	7306	19539	6191	21328	4282	4665	10898	128	157511
1986	12768	26876	1878	6846	9666	7004	4796	12877	4635	26650	2929	4098	9270	83	130377
1987	11236	32112	860	6997	7856	6006	4312	15006	3497	23583	1894	4809	8362	54	126583
1988	9746	41976	430	6689	7170	6406	3839	13874	3322	17815	1177	4055	6976	136	123612
1989	12669	34340	282	4915	11687	6684	3536	11437	2144	12693	669	8729	7955	80	117821
1990	17737	44413	439	5574	26466	7520	3932	9801	1561	11674	639	10746	8154	77	148733
1991	20423	38810	435	6997	11246	7595	6060	10120	1994	10153	2039	6350	8215	93	130531
1992	11884	29686	331	6244	9740	2980	7034	7553	2439	10721	978	1994	12602	73	104257
1993	9607	24620	223	4668	6003	2449	6118	6782	2825	10290	1046	1578	10342	67	86618
1994	8951	15754	217	4827	6248	1856	5624	4737	3009	7585	546	1477	7108	50	67989
1995	7419	9068	476	2442	2989	1953	5444	4994	2412	4858	631	639	5791	21	49138
1996	7650	9718	360	4131	3941	1788	4829	5843	2294	4759	689	680	4108	27	50816
1997	5731	11784	988	3833	5127	1887	4634	6581	1981	5991	432	555	3391	30	52946
1998	4515	9888	954	5665	6347	1194	4383	5756	2046	7994	586	690	3724	18	53758
1999	4769	10991	565	6357	7801	630	3929	5272	2398	5815	383	804	4462	40	54216
2000	5939	9771	903	8711	10903	612	4583	7170	2617	5772	488	367	4375	36	62247
2001	8400	13584	1147	11788	11624	414	4800	8117	3327	6430	728	549	5998	41	76947
2002	7286	11368	1166	13258	8832	413	3764	6517	3413	5735	494	588	3763	37	66635
2003	7537	8901	1237	12827	9097	820	2802	6777	3458	6829	564	452	5081	60	66441
2004	5817	6292	1403	18253	8705	695	2023	5550	3226	7512	523	296	4229	42	64565
2005	5636	4404	1716	21814	5286	1270	1556	4152	2802	8687	665	205	3136	55	61383
2006	4536	4610	1172	15989	3151	1148	1338	3262	1950	7390	648	188	2256	48	47685
2007	5628	5956	1368	16815	2709	1422	1226	3254	1172	9400	1160	179	2163	85	52537

Table 6. Results for BRPs from aggregate production model (ASPIC), and summed single species BRPs for GARM stocks based on new and recent stocks assessments.

GROUP	MSY	Bmsy	Fmsy	K
New GARM SS Target	145	1065	na	na
New GARM Aggregate Results	139	950	0.15	1900
Old GARM SS Target	197	1424	na	na
Old GARM Aggregate Results	126	758	0.17	1513

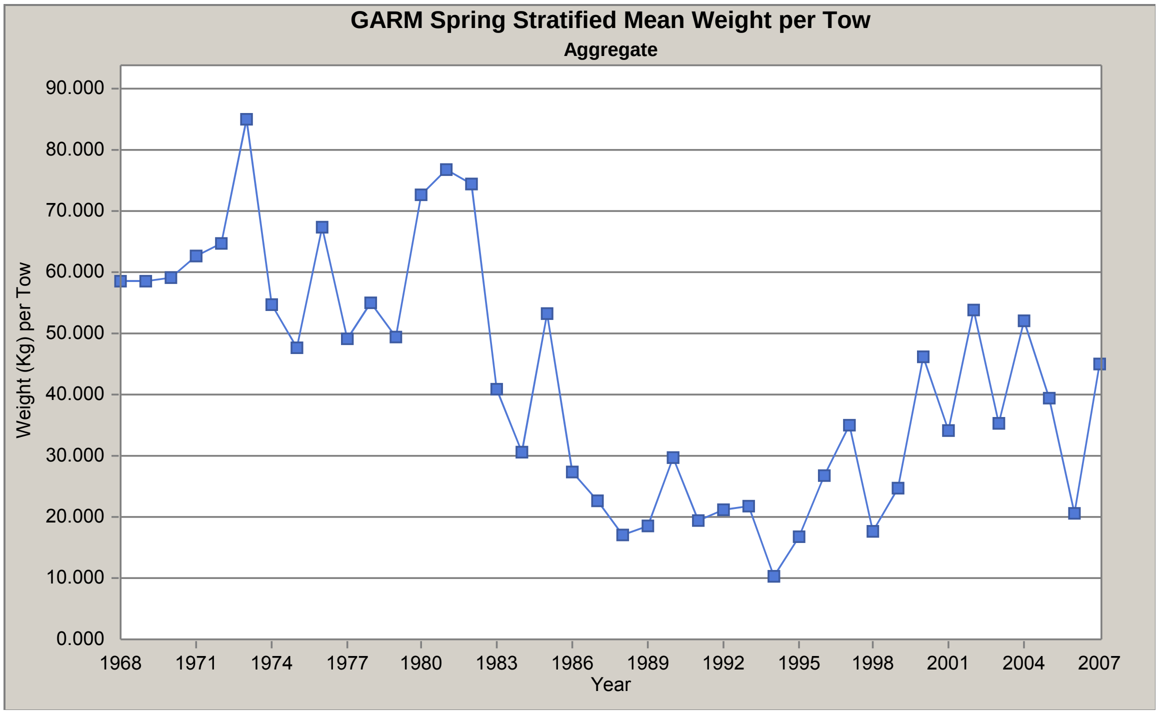

Figure 1. Spring stratified mean weight per tow (kg) for all GARM stocks during 1968-2007.

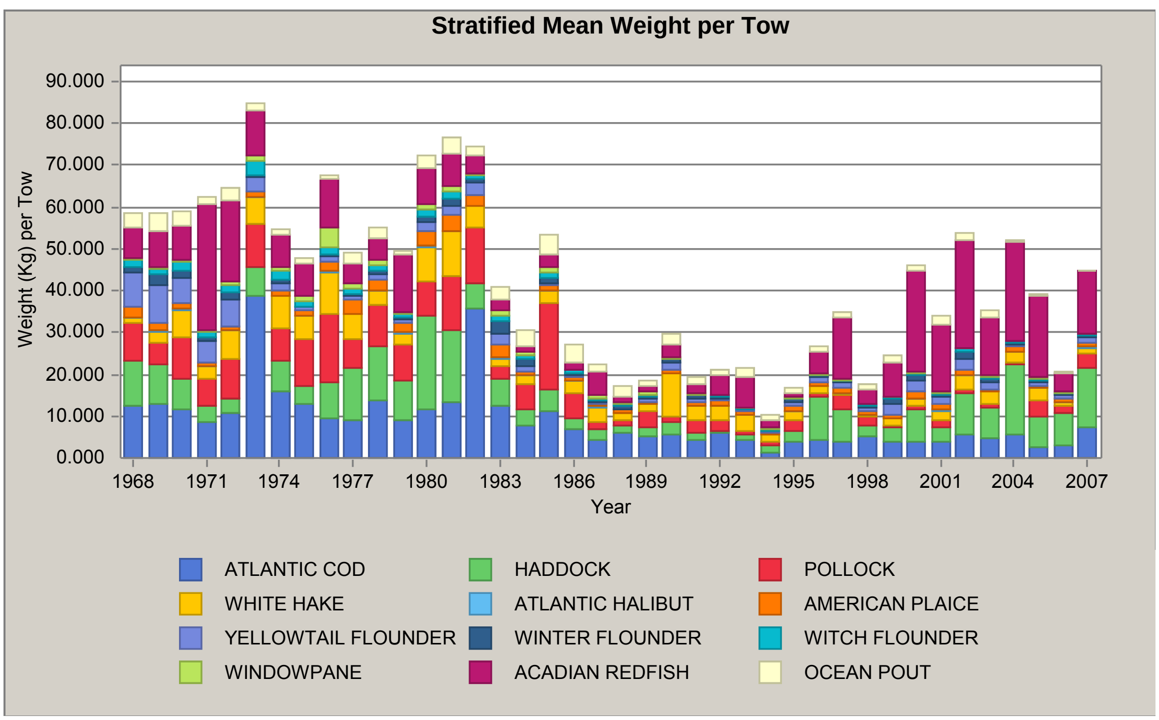

Figure 2. Catch composition of spring stratified mean weight per tow (kg) for all GARM stocks during 1968-2007.

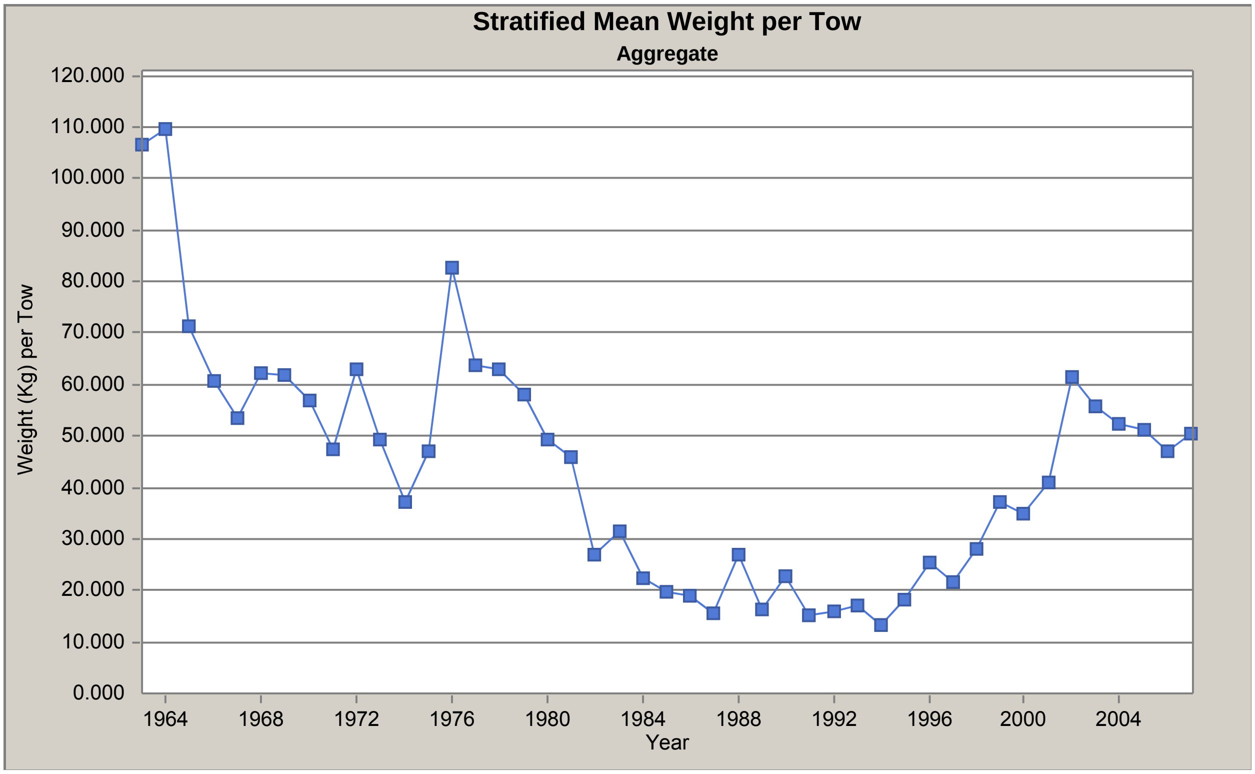

Figure 3. Autumn stratified mean weight per tow (kg) for all GARM stocks during 1963-2007.

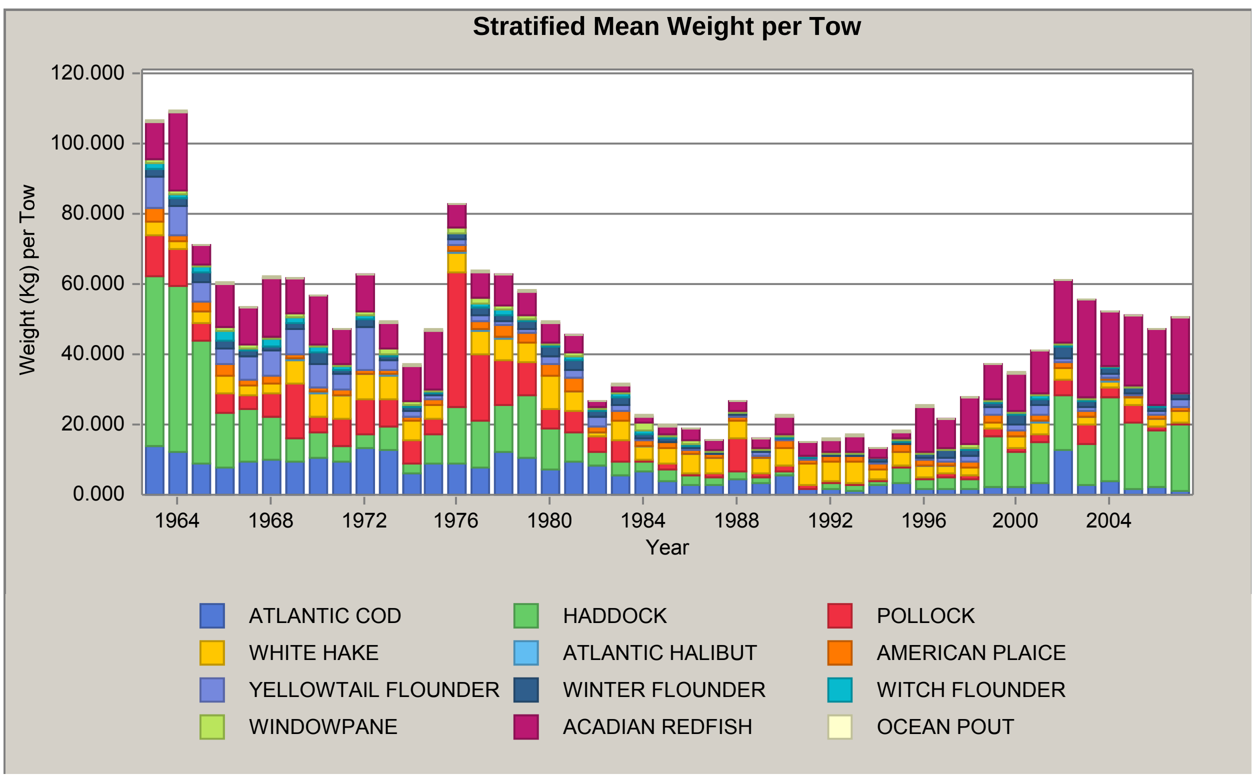

Figure 4. Catch composition of autumn stratified mean weight per tow (kg) for all GARM stocks during 1963-2007.

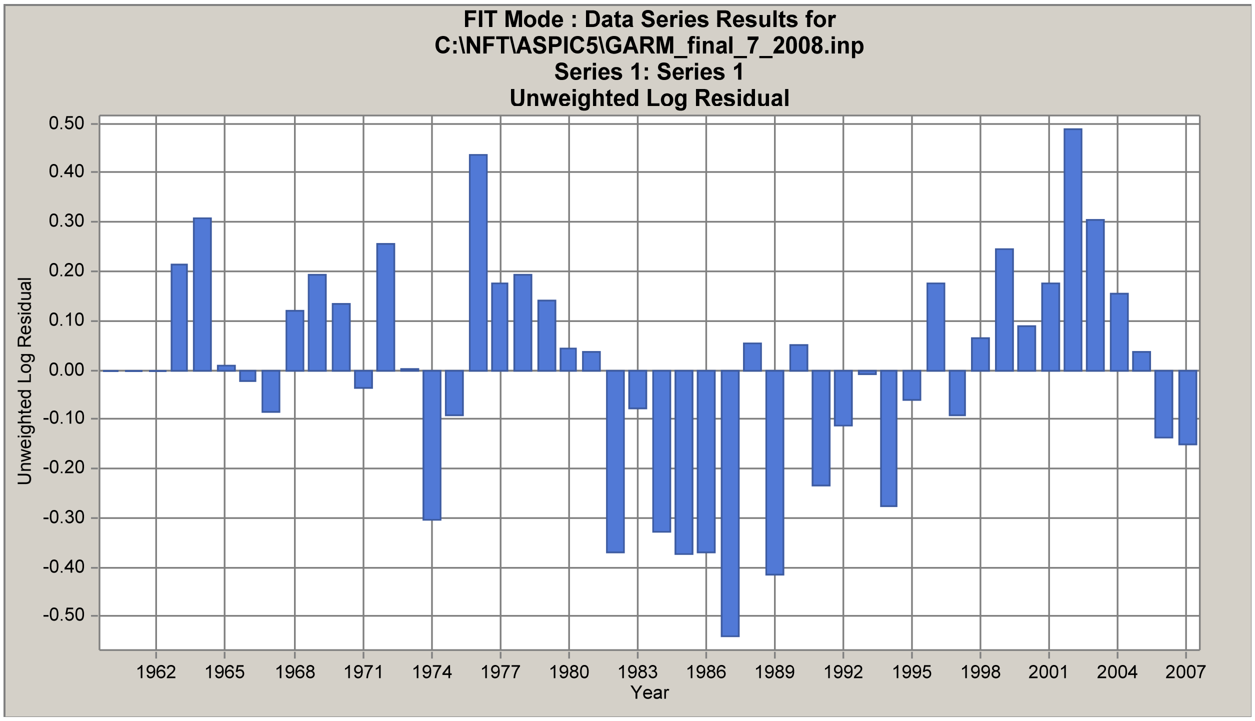

Figure 5. Residual plot from ASPIC model for autumn stratified mean weight per tow for the GARM stocks during 1963-2007.

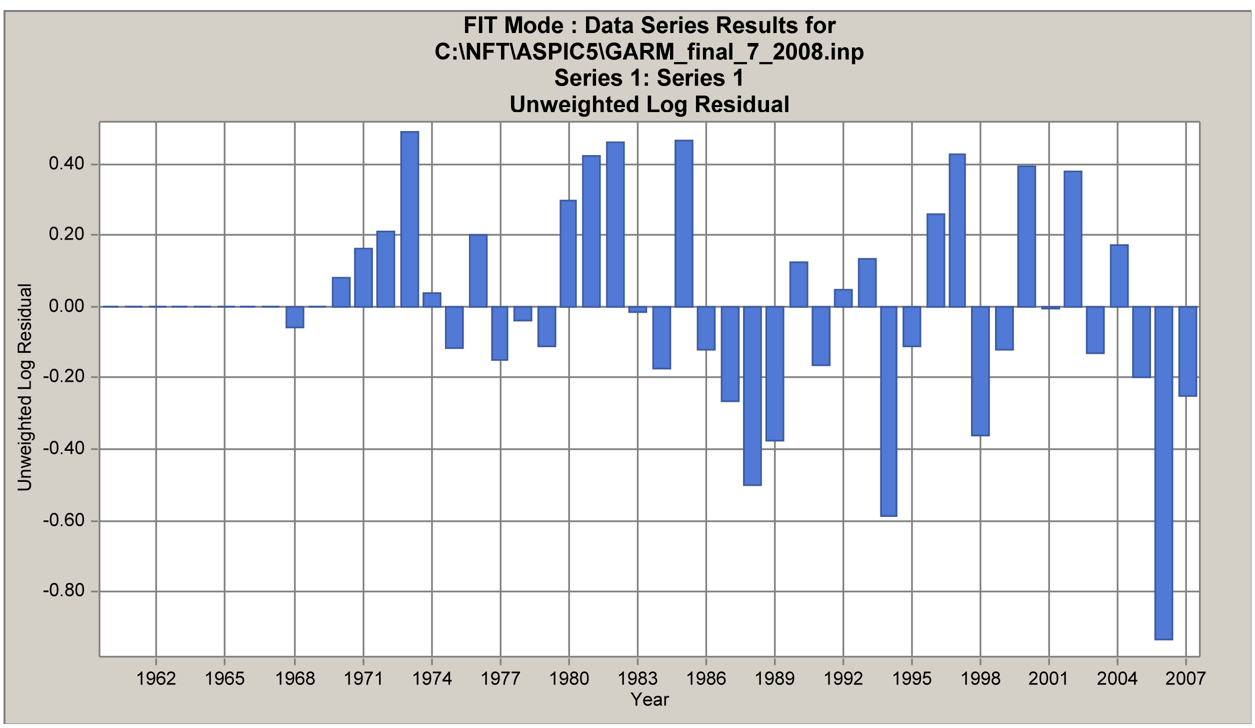

Figure 6. Residual plot from ASPIC model for spring stratified mean weight per tow for the GARM stocks during 1968-2007.

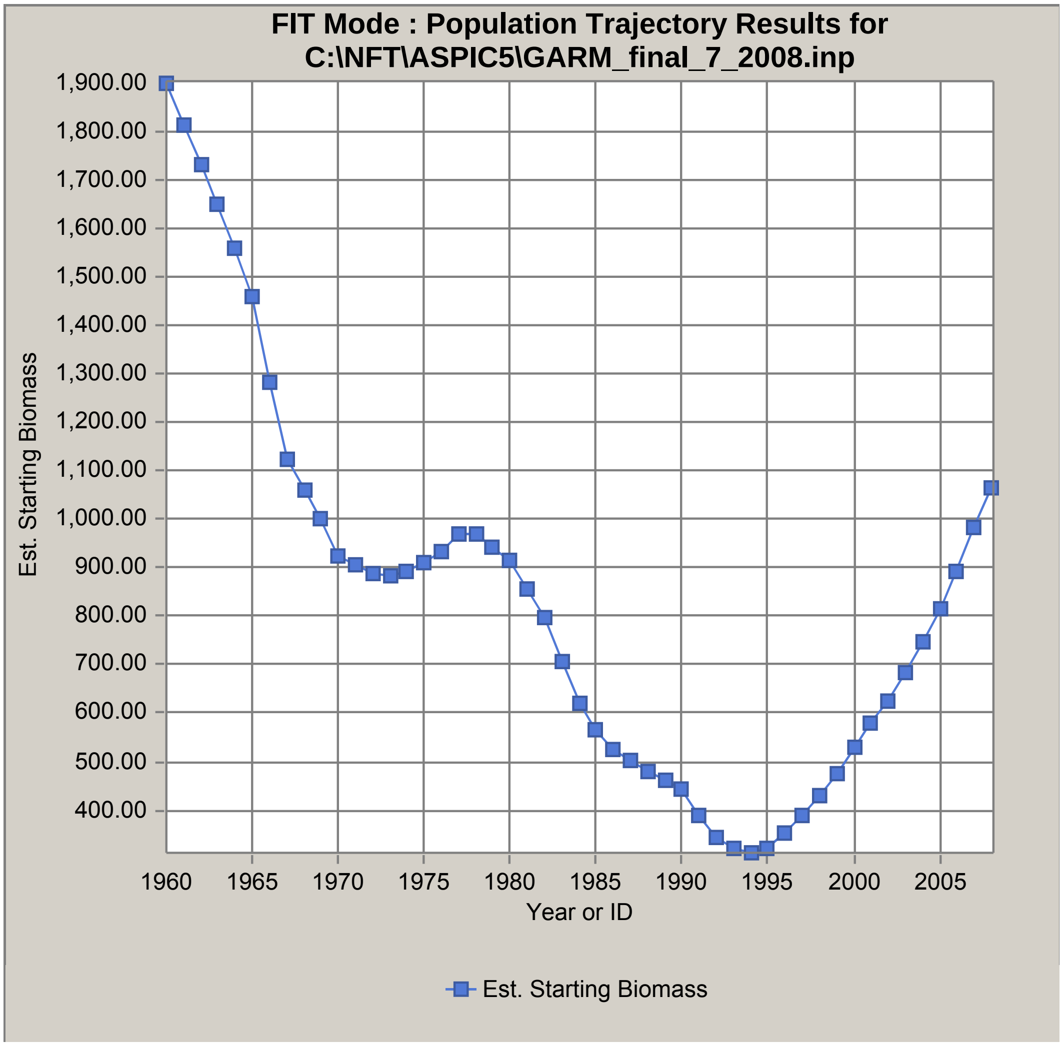

Figure 7. Biomass (000s mt) for GARM stocks from ASPIC model results during 1960-2007.

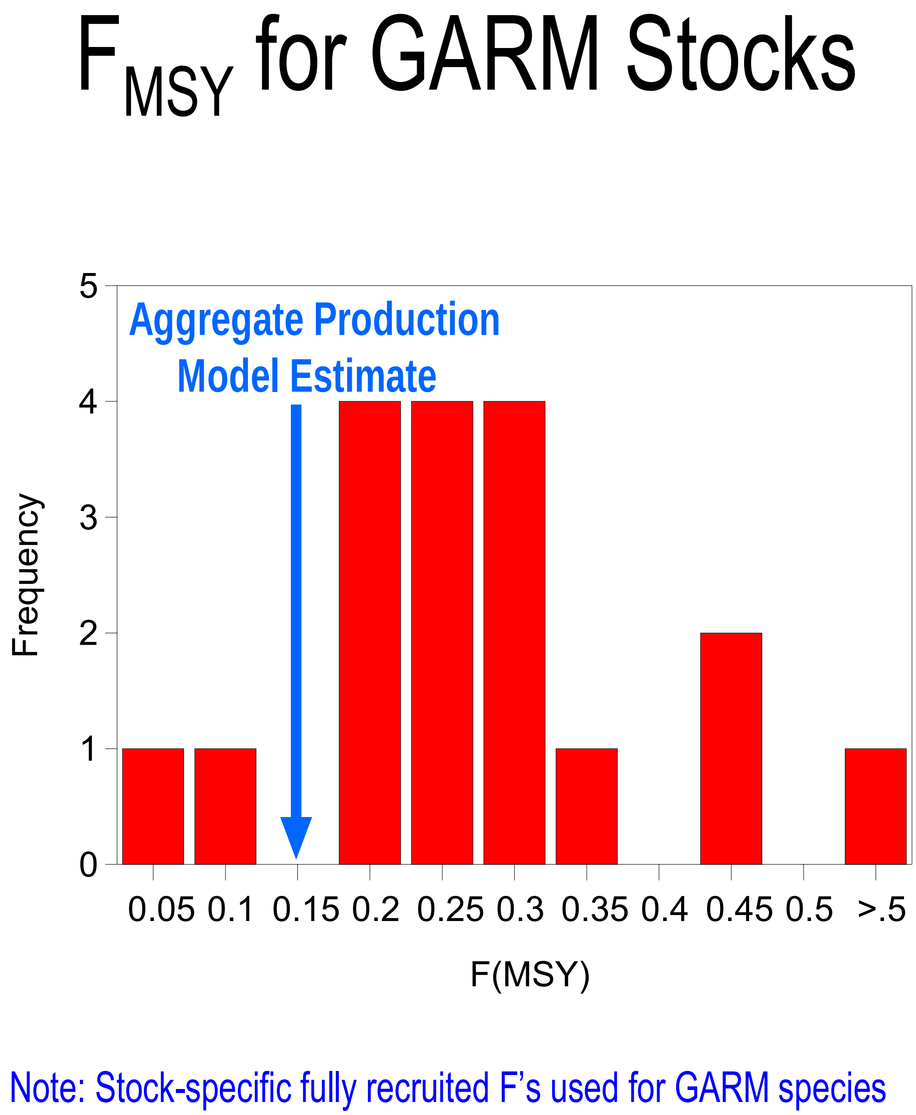

Figure 8. Comparison of GARM F_{MSY} from the aggregate ASPIC model with meta results for F_{MSY}s from the 19 GARM stocks.