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US Northeast Shelf LME Total Fish Biomass, Target Biological Reference Points for Fish, and Worldwide Cross System Comparisons.

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(GARM3 System Capacity Analyses)

Introduction:

This Working paper addresses TOR 3 of section F: 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 and pelagic 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 species), 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 fish components of the US Northeast Shelf LME. This includes important commercial pelagic and elasmobranch species as well as an estimate of the biomass of all other fish in this ecosystem. Here we summarize information for the demersal and pelagic 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/km^2) as the common currency.

Methods

Available data on BRPs (MSY and Bmsy) for the 19 GARM species as well as for small pelagics, elasmobranchs, and medium pelagic fishes were summarized from various sources (NEFSC 2002, NEFSC 2007; Table 1). In some cases there are no BRPs available from analytical models and for these species only proxy values for Bmsy (kg/tow) were accessible (Table 1). To convert proxy values for Bmsy to biomass estimates, a swept area biomass approach was utilized. A standard swept area conversion based on tow duration, net area etc (0.0112; NEFSC 2003) was used to convert proxy Bmsy values to swept area biomass along with an estimate of the total US Northeast Shelf area of 246,662 km^2 (Link et al. 2006; Table 2). These estimates were used with species specific q's for swept area biomass available from a previous study (Link et al 2006). Specifically swept area biomass (mt) was divided by an average q (spring and autumn) to give an estimate of Bmsy (Table 2). This process was repeated for all the species with proxy Bmsy values (Table 3). In addition for several species/stocks that lacked an estimate of MSY, average landings for an appropriate time period (as defined by available information) were used as a proxy to MSY (Table 3). Additionally current biomass was obtained from the most recent stock assessment for each stock (NEFSC 2002; NEFSC 2007; Table 3). These values were used with Bmsy estimates to calculate a B/Bmsy ratio (Table 3).

To account for the rest of the demersal biomass in the US Northeast Shelf LME, SURVAN analyses with and without GARM and elasmobranch species from categories that included piscivores, benthivores, and omnivores (c.f. Link et al 2006 for details) were completed. Swept area biomass estimates (spring and autumn, 2002-2006) from survey runs for GARM and elasmobranch stocks only were subtracted from the corresponding survey run with all the species included, and then averaged to estimate the remaining swept area biomass in the demersal system (Table 4). These seasonal values for each category were then divided by the appropriate q for that category to obtain seasonal estimates of biomass for other non GARM species, which were averaged for the final estimate of the remaining demersal fish biomass (Table 4). The estimated remaining biomasses for each category were summed to produce the total biomass for each category (Table 6). These estimates were divided by the total area of the US Northeast LME (246,662 km^2) to produce per unit area estimates for the species and groups (Table 6).

The data for the demersal component of the US Northeast Shelf LME were summed for all the demersal categories including the GARM species, elasmobranchs, demersal omnivores, demersal piscivores, and demersal benthivores. These latter three categories were used in previous analyses (Link et al 2006) and included all the remaining demersal biomass except GARM species, spiny dogfish, and skates (Table 7). Medium pelagics were included with demersal because this category includes striped bass, bluefish, and weakfish (Table 7).

A similar table was prepared for the small pelagic fish component of the LME. Categories for this table followed the same convention as in Link et al (2006). The commercial pelagic category utilized estimates of BRPs for Atlantic mackerel, Atlantic herring and butterfish from previous studies (Table 3). Data from Link et al (2006) (1996-2000) were used to calculate a weighted average for each of the other pelagic categories (other pelagic, squid, meso pelagic, and anadromous) over the entire LME (values for each eco-region were weighted by their respective area); (Table 8). The data for the pelagic component of the US Northeast Shelf LME is summarized in Table (9).

Summary information from other LMEs and systems were obtained from a variety of other sources, mostly energy budget modeling studies (Aydin et al. 2007; Blanchard et al. 2002; Bundy 2004; Greenstreet et al 1997; Harvey et al 2003; Savenkoff et al. 2001; Savenkoff et al. 2004; Zeller and Reinert 2004). Data for demersal and pelagic fishes from these systems were summarized to produce estimates of total density (t/km^2) in each region. A comparison table for all these systems was produced, values were averaged, and estimates for the US Northeast Shelf LME (proposed and current) were included for comparison (Table 10).

Results and Discussion

The estimated total MSY for the GARM species is 196,784 mt and Bmsy for this groundfish complex is 1,424,788 mt (Table 3). Commercially important small pelagic fishes had a total MSY of 354,175 mt and total Bmsy of 1,295,978 mt, while the summed MSY for elasmobranchs of interest was 17,973 mt with a Bmsy of 1,155,731 mt (Table 3). The current total biomass for the three groups was 4,968,220 mt with the pelagic biomass comprising the largest fraction of these three groups at 3,377,800 mt (Table 3). The ratios of total current biomass to Bmsy for the three groups are 0.59, 2.61, and 0.65, respectively (Table 3). This analysis suggests that the GARM species are currently at 59% of their Bmsy target. The species with the largest Bmsy targets and lowest B/Bmsy ratios are GB cod, GOM cod, GOM haddock, ocean pout, and white hake (Table 3). These are the major GARM species that still require rebuilding. Several stocks such as GOM haddock, ocean pout, and white hake seem to have proxy Bmsy reference points that are relatively high when converted to estimates of absolute biomass.

In terms of density units (t/km^2), the total MSY for the GARM stocks is 0.8 t/km^2, 1.4 t/km^2 for the small pelagics, and 0.07 t/km^2 for the elasmobranchs (Table 5). For Bmsy the three groups have similar unit area densities, with the GARM stocks at 5.78 t/km^2, pelagics at 5.24 t/km^2, and elasmobranchs at 4.69 t/km^2 (Table 5). The density value for commercial pelagic fishes and the summed value for GARM and elasmobranchs 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/km^2 for demersal fishes and 8.28 t/km2 for pelagic fishes; Link et al. 2006).

The current target demersal biomass that the US Northeast Shelf LME needs to support is about 4.0 million mt (Table 7). This equates to a unit area biomass of 16.079 t/km^2, about 25% higher than the 11.77 t/km^2, estimated from a recent analysis for the 1996-2000 time period (Link et al. 2006) and compared to 10.6-17.04 t/km^2 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 7). It was assumed that the biomass in these other demersal categories is relatively stable and can be summed with the reference biomass of the other categories to allow for an assessment of the entire demersal fish system.

The current target pelagic biomass is about 2.1 million mt, a unit area equivalent of 8.4 t/km^2 (Table 9). This value is about 27% lower than the total pelagic biomass estimated for the 1996-2000 period (11.43 t/km^2; Link et al. 2006) and compared to 9.1-17.3 t/km^2 from historical studies for Georges Bank (Cohen et al 1982; Sissenwine et al 1984). The other four pelagic components, excluding the commercial pelagic category, comprise about 40% of the total pelagic biomass.

The average demersal biomass for the nine temperate and boreal systems (from various ecosystem modeling studies) was 15.2 t/km^2, with a range between 2.1-44.9 t/km^2, while the average for small pelagics was 17.556 t/km^2 with a range between 7.4-27.9 t/km^2; Table 10). Total target fish biomass (t/km^2) for the Northeast LME is below the average for the nine other temperate marine systems (24.479 t/km^2 versus 32.763 t/km^2; Table 10). The target biomass for the demersal component is moderately higher than the average for the nine systems and is higher than six of the individual systems (Table 10). However, for many of these other ecosystems the demersal component is depleted.

The target pelagic biomass for the Northeast LME is well below the average for the nine other systems (Table 10). This estimate is lower than all but one of the pelagic system estimates for the other systems. The current demersal biomass is about 26% below the reference biomass, while the current pelagic biomass is larger by a factor of two than the target biomass for pelagics. This is because the biomass of Atlantic mackerel and herring are currently considerably larger than the sum of their respective Bmsy reference points, for the pelagic component. The current total biomass is about 4 t/km^2 larger than the proposed US Northeast Shelf LME biomass (Table 10)

Summary

The total target biomass for the US Northeast Shelf ecosystem is 6.1 million mt, 67% demersal species and 33% pelagic species. The GARM stocks, commercial pelagic fishes, and elasmobranchs have similar Bmsy biomass targets at 5.78, 5.24, and 4.69 t/km^2, respectively. The LME biomass targets for pelagic and demersal fishes are similar in scale to biomass estimates from previous studies of the region. The total Bmsy target biomasses for the Northeast LME for demersal and pelagic fish resources are similar to the current Northeast LME biomass and similar to the average biomass of many other temperate marine systems. The target biomass for the Northeast LME is below the average for the nine other temperate marine systems (24.485 versus 32.763 t/km^2). The target biomass for the demersal component is moderately higher than the average for the demersal group from nine other systems, while the target pelagic biomass is well below the average for pelagic fish from these systems.

Conclusions

Results from this study suggest that on an ecosystem basis, current biomass management targets (Bmsys) for GARM, pelagic, and elasmobranch fishes are not unreasonable. The current targets compare favorably with the results of current and historical studies in the region and are also in general agreement with results of many studies for other worldwide ecosystems. Whether current harvest removal targets (MSYs) are attainable is the subject of other studies for the GARM3.

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Table 1. Available Biological Reference Points or proxies (MSY, Bmsy, SSBmsy, and catch/tow) for GARM species, pelagics, and elasmobranchs (NEFSC 2007).

	Garm Species	MSY	Bmsy	SSBmsy	Bmsy proxy
1	GOM cod	16,600		82,830	
2	GB cod	35,200		217,000	
3	GOM haddock	5,100			22.2 kg/tow
4	GB haddock	52,300	250,300		
5	Redfish	8,235	236,700		
7	Pollock	17,640			3.0 kg/tow
7	CC-GOM Yt	2,300		12,600	
8	GB Yt	12,900		58,800	
9	SNE-MA Yt	14,200		69,500	
10	Am plaice	4,900		28,600	
11	Witch fldr	4,375		25,248	
12	GOM Winter fldr	1,500	4,100		
13	GB Winter fldr	3,000	9,400		
14	SNE-MA Winter fldr	10,600	30,100		
15	GOM-GB Windowpane fldr	1,000			0.94 kg/tow
16	SNE-MA Windowpane fldr	900			0.92 kg/tow
17	Ocean Pout	1,500			4.91 kg/tow
18	White hake	4,234			7.70 kg/tow
19	Halibut	300	5,400		
	Pelagics				
1	Herring	194,000	629,000		
2	Mackerel	148,000		644,000	
3	Butterfish	12,175	22,978		
	Elasmobranchs				
1	Spiny Dogfish				
2	Skates				19.929 kg/tow

Table 2. Example data for converting white hake proxy reference point (kg/tow) to and estimate of proxy Bmsy (SAB=swept area biomass, Q= catchability coefficient, spr=spring, av=average).

White Hake							
Strata Set		Trawl Swept Area	Bmsy Proxy (kg/tow)		Q for biomass	spr	0.2023
21-30,33-40		0.0112	7.7			fall	0.183
Strata						av	0.19265
21	424						
22	454		Swept Area Biomass				
23	1016		SAB (kg)	17809688			
24	2569						
25	390		SAB (mt)	17809.69			
26	1014						
27	720						
28	2249		Proxy Bmsy (mt)				
29	3245		92445.82				
30	619						
33	861						
34	1766						
35	533						
36	4069						
37	2108						
38	2560						
39	730						
40	578						
sum	25905						

Table 3. Biological Reference Points (MSY, Bmsy), current biomass (from NEFSC 2007) and ratio of current biomass to Bmsy for GARM species, pelagics, and elasmobranchs.

	GARM Species	MSY (mt)	Bmsy (mt)	Current B (mt)	B/Bmsy
1	GOM cod	16,600	82,830	28,904	0.34895569
2	GB cod	35,200	217,000	22,563	0.10397696
3	GOM haddock [1]	5,100	124,076	21,976	0.17711725
4	GB haddock	52,300	250,300	400,941	1.60184179
5	Redfish	8,235	236,700	200,244	0.84598226
6	Pollock [1]	17,640	49,802	40,937	0.8219951
7	CC-GOM Yt	2,300	12,600	1,100	0.08730159
8	GB Yt	12,900	58,800	8,000	0.13605442
9	SNE-MA Yt	14,200	69,500	690	0.00992806
10	Am plaice	4,900	28,600	14,149	0.49472028
11	Witch fldr	4,375	25,248	21,175	0.83868029
12	GOM Winter fldr	1,500	4,100	3,436	0.83804878
13	GB Winter fldr	3,000	9,400	4,301	0.45755319
14	SNE-MA Winter fldr	10,600	30,100	3,938	0.13083056
15	GOM-GB Windowpane fldr [1]	1,000	9,987	7,288	0.72974867
16	SNE-MA Windowpane fldr [1]	900	15,264	2.373	0.00015546
17	Ocean Pout [1]	1,500	102,635	10,993	0.10710771
18	White hake [1]	4,234	92,446	43,077	0.46596932
19	Halibut	300	5,400	288	0.05333333
total		**196,784**	**1,424,788**	**834,002**	**0.585352**
	Pelagics				
1	Herring	194,000	629,000	1,047,000	1.6645469
2	Mackerel	148,000	644,000	2,323,000	3.60714286
3	Butterfish	12,175	22,978	7,800	0.33945513
total		***354,175***	***1,295,978***	**3,377,800**	**2.606371**
	Elasmobranchs				
1	Spiny Dogfish [23]	10,470	418,549	453,000	1.08231055
2	Skates [12]	7,323	737,182	303,418	0.41159171
total		***17,793***	***1,155,731***	**756,418**	**0.654493**

1 Bmsy based on area swept biomass and estimated Q for demersal species

2 Msy based on average landings

3 Bmsy based on average of swept area biomass during 1970-2006

Table 4. Example calculation accounting for remaining biomass of piscivorous gadids during 2002-2006 (diff is the difference between estimates for all picivorous gadids and cod, pollock, white hake, and silver hake, sab=swept area biomass, Q= catchability coefficient, AV=average).

Cod, pollock, white hake, silver hake													
Total mean wt. per tow of piscivore Gadids (GARM): Autumn													
CRU#		MEAN WEIGHT					TOT.POP.WGT.		TOT.POP.WGT.		diff		
200209		7.11E+01					1.23E+08		1.23E+08		1.28E+05		
200306		4.46E+01					7.97E+07		79995177		2.77E+05		
200407		3.17E+01					5.36E+07		53603913		3.25E+04		
200510		2.88E+01					5.13E+07		51344679		2.60E+04		
200610		2.40E+01					4.27E+07		42805361		9.52E+04		
											sab kg	Q	biomass m
									fall		1.12E+05	0.183	611.1807
									spr		89837.88	0.2023	444.0825
									AV				527.6316

Table 5. Biological Reference Points (MSY, and Bmsy, mt) for GARM species, pelagics, and elasmobranchs 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 Species	***MSY (mt)***	***t/km^2***	***Bmsy (mt)***	***t/km^2***
GOM cod	16,600	0.0673	82,830	0.335803923
GB cod	35,200	0.1427	217,000	0.879747087
GOM haddock [1]	5,100	0.0207	124,076	0.503020735
GB haddock	52,300	0.2120	250,300	1.01474975
Redfish	8,235	0.0334	236,700	0.959613528
Pollock [1]	17,640	0.0715	49,802	0.201903984
CC-GOM Yt	2,300	0.0093	12,600	0.051082089
GB Yt	12,900	0.0523	58,800	0.238383082
SNE-MA Yt	14,200	0.0576	69,500	0.281762316
Am plaice	4,900	0.0199	28,600	0.115948234
Witch fldr	4,375	0.0177	25,248	0.102358776
GOM Winter fldr	1,500	0.0061	4,100	0.01662195
GB Winter fldr	3,000	0.0122	9,400	0.03810886
SNE-MA Winter fldr	10,600	0.0430	30,100	0.122029435
GOM-GB Windowpane fldr [1]	1,000	0.0041	9,987	0.040488637
SNE-MA Windowpane fldr [1]	900	0.0036	15,264	0.061882302
Ocean Pout [1]	1,500	0.0061	102,635	0.416096047
White hake [1]	4,234	0.0172	92,446	0.374788476
Halibut	300	0.0012	5,400	0.021892324
total	**196,784**	**0.7978**	**1,424,788**	**5.77628153**
Pelagics				
Herring	194,000	0.7865	629,000	2.550050312
Mackerel	148,000	0.6000	644,000	2.610862322
Butterfish	12,175	0.0494	22,978	0.093155892
total	***354,175***	**1.4359**	***1,295,978***	**5.25406853**
Elasmobranchs				
Spiny Dogfish [23]	10,470	0.0424	418,549	1.696853749
Skates [12]	7,323	0.0297	737,182	2.988634641
total	***17,793***	**0.0721**	***1,155,731***	**4.68548839**

1 Bmsy based on area swept biomass and estimated Q for demersal species

2 Msy based on average landings

3 Bmsy based on average of swept area biomass during 1970-2006

Table 6. Calculation of total additional biomass for the three categories of demersal piscivorous (sab=swept area biomass, Q=catchability coefficient, spr=spring, AV=average).

piscivore other			
	sab kg	Q	biomass mt
fall	12829623	0.151	84964.39
spr	12722393	0.1601	79465.29
AV			82214.84
picivore elasmobranch			
	sab kg	Q	biomass mt
fall	25093102	0.3588	69936.18
spr	29393560	0.3588	81921.85
AV			75929.02
piscivore gadid			
	sab kg	Q	biomass mt
fall	111846.1	0.183	611.1807
spr	89837.88	0.2023	444.0825
AV			527.6316
total			158671.5

Table 7. Total biomass (mt) and energy budget density units (t/km^2) for GARM species, 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	1424788.00	5.78
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	**3965956.17**	**16.08**

Table 8. Biomass (mt) and energy budget density units (t/km^2) for groups other than commercial-pelagic (c.f. Link et al. 2006) used for calculating total pelagic density for the US Northeast Shelf LME.

10/25/2004						
strata 24 added to the GOM						
mt/eco-area						
	pel-comm	pel-other	squid	meso	anadromou	total
MA	358752.6	234863.8	85210	137.7	6701.2	685665.3
SNE	889658	73755.4	174760	84.2	10271.2	1148528.8
GB	434330.8	46040.2	42020	1.6	1648.6	524041.2
GOM	359642.2	83892.6	10648.2	5.4	6112.2	460300.6
	0	0	0	0	0	0
total	2042384	438552	312638.2	228.9	24733.2	2818535.9
mt/km**2	or g/m**2/yr		Biomass			
	pel-comm	pel-other	squid	meso	anadromou	total
MA	5.998476	3.92701	1.424743	0.002302	0.112047	11.46457731
SNE	13.88781	1.151342	2.728052	0.001314	0.160336	17.92885055
GB	9.946622	1.054368	0.962301	3.66E-05	0.037755	12.00108276
GOM	4.545072	1.060215	0.134569	6.82E-05	0.077245	5.81716827
total	8.280098	1.777949	1.267477	0.000928	0.100272	11.42672373

Table 9. Total biomass (mt) and energy budget density units (t/km^2) for pelagic components (c.f. Link et al 2006) of the US Northeast Shelf LME.

category	*Biomass (mt)*	*t/km^2*
pelagic commercial	1295978.00	5.25
pelegic other	438552.00	1.78
squid	312638.20	1.27
meso pelagic	228.90	0.00
anadromous	24733.20	0.10
total	**2072130.30**	**8.40**

Table 10. Energy budget density units (total t/km^2) and average (t/km^2) for nine worldwide systems for demersal and pelagic fishes with proposed US Northeast Shelf LME BRP targets and current density.

System	Demersal B (t/km^2)	Pelagic B (t/km^2)	Total t/km^2
Gulf of Alaska	26.478	14.827	41.305
Bering Sea	44.852	7.444	52.296
Barents Sea	4.313	9.323	13.636
North Sea	8.868	10.148	19.015
Baltic Sea	2.130	19.070	21.200
Faroes	10.605	27.907	38.512
Newfoundland-Labrador	10.990	21.820	32.810
Gulf of St Lawrence	21.780	24.080	45.860
Scotian Shelf	6.849	23.386	30.235
Average	**15.207**	**17.556**	**32.763**
Northeast Shelf LME Target	**16.079**	**8.401**	**24.479**
Northeast Shelf LME Current	**11.840**	**16.802**	**28.642**