4.0 Summary and Discussion of the Implications of Re-Calculated Reference Points

4.1 Index-Based Methods Applied to all Stocks and Surveys

Estimates of relative F at replacement, generated for all stocks and surveys, are summarized in Table 4.1.1. In addition the estimates of the relative F necessary for a 10% growth rate of the population are provided in Table 4.1.1. The 10% criterion for population growth should not be construed as a fixed value or scientific recommendation. Rather, it provides a rough measure of the population's capacity for growth that is consistent with the available data. The precision of this estimate as well as the relative F at replacement is provided along with the results of the randomization tests to test for spurious correlations. In general, low precision of the estimates of relF at replacement are associated with uninformative times series. These times series also suggest a weak relationship between the replacement ratio and relative F. In most instances the analyses for the NMFS spring trawl survey mirror the results for the longer time series of autumn (fall) indices. Table 4.1.1 also provides a comparison between the current 3yr average of relative F and the predicted relative F s at replacement and at 10% growth rate. The ratio of the current relative F to these nomimal target levels provides an alternative measure of the relative magnitude of fishing mortality.

The index based method can also be used to generate simple projections of landings over the period 2002-2009. Catch estimates are obtained by multiplying the current population value (in kg/tow) by the target relative F (000 mt/(kg/tow)) in Eq. 10. Thus:

$$\hat{C}_t = relF_{target}\ I_t$$

By definition, application of $\mathbf{relF_{target}}$ to the population results in 10% rate of increase per year. Of course this assumption is appropriate for a limited number of years. A 10% rate of population increase implies a doubling of the population in roughly 8 years. In more formal notation, we can project the population status as:

$$\hat{I}_{t+1} = 1.1 * I_t(F = relF_{target})$$

Recursive application of the above two equations allows for projection of the population status (in units of kg/tow) and catch (in thousands of mt; Table 4.1.2). Comparisons of recent average catches with the average during the rebuilding period suggest that landings would have to be reduced for most species. Note however, that these catch projections are not defined in terms of a target index biomass at the end of 2009.

Due to the developmental nature of these analyses, they should not necessarily be considered reliable for the purposes of management. Initial comparisons however, between these projections and those generated by the age-structured models, suggest reasonable coherence.

Table 4.1.1. Summary of replacement ratio analyses for 19 stocks. Estimates of replacement ratios are based on robust regression

of the model ln(RR)=a + b ln(relF). Replacement F is estimated as the point where the replacement ratio equals 1.0.

Asymptotic standard errors of the estimate are approximate. Significance test is based on randomization test.

Stock	Species	Survey	relF where Replacement ratio =1.0	SE(F_replace)	relF where replacement ratio = 1.1	SE (F grow)	Significance Level based on Randomization test	Current Stock Conditon: Average Relative F	Current Stock Conditon: Ratio of current relF to replacement rel F.	Current Stock Conditon: Ratio of current relF to 10% Increase rel F.
Georges Bank	Cod	Fall	2.04	0.58	1.64	0.56	0.113	3.91	1.92	2.39
		Spring	1.10	0.30	0.93	0.29	0.112	1.29	1.17	1.38
	Haddock	Fall	0.72	0.08	0.65	0.08	0.001	0.44	0.61	0.68
		Spring	0.58	0.08	0.51	0.08	0.001	0.59	1.03	1.16
	N. Windowpane	Fall	0.37	0.48	0.17	0.32	0.197	0.20	0.54	1.17
	Winter Flounder	Fall	1.18	0.11	1.06	0.11	0.001	0.62	0.52	0.58
	Yellowtail Flounder	Fall	2.42	0.36	2.13	0.33	0.001	0.77	0.32	0.36
		Spring	1.96	0.40	1.68	0.36	0.003	0.72	0.37	0.43
Gulf of Maine	American Plaice	Fall	1.40	0.60	0.90	0.62	0.460	1.49	1.06	1.66
		Spring	2.56	0.59	2.06	0.55	0.132	2.43	0.95	1.18
	Cod	Fall	0.67	0.30	0.45	0.27	0.012	1.41	2.10	3.16
		Spring	0.94	0.35	0.70	0.35	0.269	0.99	1.05	1.40
	Haddock	Fall	0.23	0.05	0.20	0.05	0.004	0.15	0.67	0.76
		Spring	0.83	0.35	0.67	0.29	0.010	0.79	0.95	1.18
	Halibut	Fall	0.01	0.01	0.01	0.01	0.284	0.02	1.21	1.45
		Spring	0.02	0.01	0.02	0.01	0.665	0.01	0.29	0.33
	Pollock (all)	Fall	15.48	3.67	12.01	3.36	0.050	12.93	0.84	1.08
	Pollock (USA)	Fall	3.57	0.97	2.70	0.87	0.050	4.33	1.21	1.60
	Pollock (5&6)	Fall	5.88	1.05	4.83	1.00	0.024	5.56	0.94	1.15
	Redfish	Fall	0.83	0.35	0.51	0.23	0.005	0.06	0.08	0.13
		Spring	0.42	0.22	0.31	0.17	0.030	0.06	0.14	0.20
	White Hake	Fall	0.54	0.07	0.42	0.07	0.036	0.80	1.48	1.89
		Spring	0.57	0.15	0.48	0.15	0.040	1.54	2.68	3.19
	Witch flounder	Fall	1.34		0.92		0.346	3.27		
		Spring					0.554	2.26	1.68	2.45
	Yellowtail Flounder	Fall	0.44	0.19	0.34	0.18	0.472	0.25	0.57	0.75
		Spring	0.30	0.36	0.23	0.35	0.686	0.35	1.17	1.54

Southern New England	Mid Atl Yellowtail	Fall	0.33	0.16	0.30	0.15	0.108	1.19	3.60	4.02
		Spring	0.09	0.06	0.07	0.05	0.194	0.55	6.22	7.33
	Ocean pout	Spring	0.01	0.03	0.00	0.01	0.118	0.01	0.60	2.00
	Windowpane	Fall	0.98	0.45	0.73	0.42	0.101	0.70	0.72	0.96
	Winter Flounder	Fall	5.14	1.00	4.40	0.91	0.004	2.15	0.42	0.49
		Spring	6.97	0.53	6.51	0.52	0.001	4.44	0.64	0.68
	Yellowtail Flounder	Fall	0.47	0.61	0.35	0.52	0.461	1.10	2.33	3.12
		Spring	0.37	0.44	0.28	0.39	0.498	0.48	1.31	1.71

Table 4.1.2. Catch projections based on index model. Catches for 2002 represent status quo relative F, rel F at replacement, and rel F at 10% growth rate. Catches for 2003-2009 assume that rel F is set at F_grow and that population grows at 10% per year

			Current Stock Condition		Predicted Catch for 2002			Predicted Catches (mt) with rel F = F_grow and population growth of 10% per year.								
Stock	Species	Survey	Average Relative Biomass (kg/tow)	Average Relative F (mt/(kg/tow))	Predicted Catch in 2002 (mt)	Catch at replacement rel F	Catch at 10% growth F	2003	2004	2005	2006	2007	2008	2009	average catch during rebuild period	Average Catch1998-2000
Georges Bank	Cod	Fall	2.4	3.91	9.4	4.9	3.9	4.3	4.8	5.2	5.8	6.3	7.0	7.7	5.6	9.30
		Spring	8.2	1.29	10.5	9.0	7.6	8.4	9.2	10.1	11.1	12.3	13.5	14.8	10.9	9.30
	Haddock	Fall	14.8	0.44	6.6	10.7	9.6	10.6	11.6	12.8	14.0	15.4	17.0	18.7	13.7	6.80
		Spring	10.6	0.59	6.3	6.1	5.4	5.9	6.5	7.2	7.9	8.7	9.6	10.5	7.7	6.80
	N. Windowpane	Fall	1.2	0.20	0.2	0.4	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.3	0.19
	Winter Flounder	Fall	2.3	0.62	1.4	2.7	2.4	2.7	2.9	3.2	3.6	3.9	4.3	4.7	3.5	1.41
	Yellowtail Flounder	Fall	6.1	0.77	4.7	14.7	12.9	14.2	15.6	17.2	18.9	20.8	22.8	25.1	18.4	4.81
		Spring	6.1	0.72	4.4	12.0	10.2	11.3	12.4	13.6	15.0	16.5	18.1	19.9	14.6	4.81
Gulf of Maine	American Plaice	Fall	2.5	1.49	3.8	3.5	2.3	2.5	2.7	3.0	3.3	3.7	4.0	4.4	3.2	3.69
		Spring	1.5	2.43	3.7	3.9	3.2	3.5	3.8	4.2	4.6	5.1	5.6	6.2	4.5	3.69
	Cod	Fall	3.2	1.41	4.6	2.2	1.4	1.6	1.7	1.9	2.1	2.3	2.6	2.8	2.1	4.34
		Spring	4.2	0.99	4.1	3.9	2.9	3.2	3.6	3.9	4.3	4.7	5.2	5.7	4.2	4.34
	Haddock	Fall	7.3	0.15	1.1	1.7	1.5	1.6	1.8	1.9	2.1	2.4	2.6	2.8	2.1	0.78
		Spring	1.0	0.79	0.8	0.8	0.7	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.0	0.78
	Halibut	Fall	1.5	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02
		Spring	3.5	0.01	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.02
	Pollock (all)	Fall	1.0	12.93	13.4	16.1	12.5	13.7	15.1	16.6	18.2	20.1	22.1	24.3	17.8	14.13
	Pollock (USA)	Fall	1.0	4.33	4.5	3.7	2.8	3.1	3.4	3.7	4.1	4.5	5.0	5.5	4.0	4.74
	Pollock (5 &6)	Fall	1.0	5.56	5.8	6.1	5.0	5.5	6.1	6.7	7.3	8.1	8.9	9.8	7.2	6.09
	Redfish	Fall	5.5	0.06	0.4	4.6	2.8	3.1	3.4	3.7	4.1	4.5	4.9	5.4	4.0	0.33
		Spring	5.7	0.06	0.3	2.4	1.7	1.9	2.1	2.3	2.5	2.8	3.1	3.4	2.5	0.33
	White Hake	Fall	4.8	0.80	3.8	2.6	2.0	2.2	2.5	2.7	3.0	3.3	3.6	4.0	2.9	3.73
		Spring	3.1	1.54	4.8	1.8	1.5	1.7	1.8	2.0	2.2	2.4	2.7	2.9	2.2	3.73
	Witch flounder	Fall	0.6	3.27												
		Spring	0.8	2.26	1.9	1.1	0.8	0.8	0.9	1.0	1.1	1.2	1.3	1.5	1.1	2.52
	Yellowtail Flounder	Fall	6.3	0.25	1.6	2.8	2.1	2.3	2.6	2.8	3.1	3.4	3.8	4.1	3.0	1.71
		Spring	6.6	0.35	2.3	2.0	1.5	1.6	1.8	2.0	2.2	2.4	2.6	2.9	2.1	1.71

Southern New England	Mid Atl Yellowtail	Fall	0.2	1.19	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.30
		Spring	0.5	0.55	0.3	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.30
	Ocean pout	Spring	2.1	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02
	Windowpane	Fall	0.2	0.70	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.12
	Winter Flounder	Fall	2.0	2.15	4.2	10.2	8.7	9.6	10.5	11.6	12.7	14.0	15.4	16.9	12.4	4.23
		Spring	0.9	4.44	4.2	6.6	6.2	6.8	7.5	8.2	9.0	9.9	10.9	12.0	8.8	4.23
	Yellowtail Flounder	Fall	0.7	1.10	0.7	0.3	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.3	0.68
		Spring	1.4	0.48	0.7	0.5	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.5	0.68

4.2 Summary of Revised Reference Points

The Working Group recommendations for revised biomass and fishing mortality rate reference points are summarized in Table 4.2.1. For most stocks, revised F reference points are similar to those previously recommended (in many cases the comparisons between current and proposed reference points are confounded by differences in the measurement scale - biomass weighted or fully-recruited ages). Similarly, the biomasses associated with MSY are comparable for most stocks - the exceptions being Georges Bank cod and haddock, Gulf of Maine haddock, and Acadian redfish - where recommended Bmsy values represent substantial increases over current values. In the case of Georges Bank cod and the two haddock stocks, historical growth overfishing substantially diminished the biomass potential of year classes. Thus, the observed pattern of spawning biomasses was not consistent with basic yield and spawning biomass per recruit calculations and the observed patterns of recruitment. For redfish, the revised analysis considered historical recruitment patterns that must have occurred to support biomasses that accumulated prior to the initiation of intensive fishing in the 1930s.

Calculations of maximum fishing mortality rates associated with stock rebuilding by 2009 are given in Table 4.2.2 and Figure 4.2.1. In several cases (witch flounder, Georges Bank winter flounder) fishing at the proposed Fmsy will allow the stock to rebuild - no further reductions are required. For most others, the F-rebuild is only slightly below the Fmsy level (Gulf of Maine cod, Georges Bank haddock, plaice, Georges Bank yellowtail, SNE winter flounder). For two of the stocks the proposed biomass targets cannot be achieved in 2009 with >50% probability, even if F=0.0 beginning in 2003 - Georges Bank cod and Acadian redfish. In the case of redfish, basic life history constraints limit the rapidity with which rebuilding can occur (Table 2.5). For Georges Bank cod, the recent run of below-average year classes means that it is unlikely that the stock can rapidly rebuild.

For most index-based stocks, current fishing mortality rates are below the threshold levels, the exception being Mid-Atlantic yellowtail flounder (Figure 4.2.2).

Current (year 2000) biomass levels as a ratio of proposed Bmsy values are presented in Figure 4.2.3. The comparison of Bmsy to biomass in 2000 represents, in most cases, the most recent year that analytical assessments actually estimate spawning stock biomasses. Projections give estimated biomasses in subsequent years (2001, 2002) that could be compared with Bmsy, although the latter comparisons are less reliable than with the results of assessment updates. Estimated catches in 2001 (Table 4.2.3) are compared to proposed MSY values in Figure 4.2.4. The summed catches of all 19 stocks in 2001 was 69,200 mt - 36% of the MSY potential of the complex when the stocks are rebuilt (192,900 mt).

Interestingly, there were no cases where a Ricker curve was used to calculate parametric MSY-based reference points. In practice, it is often impossible to discern between Beverton-Holt and Ricker curves based solely on statistical goodness-of-fit criteria (Brodziak 2002). Nonetheless, least squares estimation procedures combined with AIC criteria, similar to those used in this report, have been found to have an inherent bias towards selection of Ricker curves when the actual curve was Beverton-Holt in recent simulation studies (de Valpine and Hastings 2002). Thus, strict adherence to goodness-of-fit criterion to choose a parametric model could be misleading and it is very important to apply common sense when judging the adequacy of fisheries models (Schnute and Richards 2001).

In this report, most Ricker models implied a calculated value of F_{MSY} that substantially exceeded F_{MAX}. For this to be true, it must be the case that growth overfishing is relatively unimportant in contrast to the counterintuitive concept of “recruitment underfishing”, which is simply the notion that high numbers of spawners reduce intraspecific juvenile survival through some overcompensatory density-dependent mechanism. One possible mechanism for strong density-dependent intraspecific interactions is cannibalism. Cannibalism in the primary New England groundfish stocks examined in this report appears to be relatively minor. Food habits data collected during spring and autumn NEFSC surveys during 1973-1997 (Dr. J. Link, Northeast Fisheries Science Center, Pers. comm.) show that the observed incidence of cannibalism in cod and haddock is very low. Out of 12,305 Atlantic cod stomachs examined, only 16 contained cannibalized cod (<0.2%) and the average percent composition by weight of the cannibalized cod was less than 0.1%. Similarly, out of 3,537 haddock stomachs examined only 1 contained cannibalized haddock (<0.1%) and the average percent composition by weight of cannibalized haddock was less than 0.1%. For benthic feeding flatfishes, such as yellowtail and winter flounder, the incidence of cannibalism was virtually nil. Thus, the observed data on groundfish food habits do not support the hypothesis that cannibalism is a viable mechanism for overcompensatory stock-recruitment dynamics in primary New England groundfish stocks.

It is unknown whether application of $F_{40\%}$ as a F_{MSY} proxy for Georges Bank haddock, Georges Bank and Southern New England yellowtail flounder, American plaice, witch flounder, and Cape Cod yellowtail flounder would result in B_{MSY} values that are substantially different from 40% of unfished biomass. If stock-recruitment dynamics for these resources are more closely approximated by a Beverton-Holt curve, then it may be expected that the resulting B_{MSY} values would be lower than 40% of unfished biomass (Goodyear 1993). In contrast, if stock-recruitment dynamics for these stocks are more closely approximated by a Ricker curve, then the resulting B_{MSY} values could be greater than or less than 40% of unfished biomass depending upon the curve’s slope at the origin. The same is true of the proxy B_{MSY} value for redfish based on $F_{50\%}$. This uncertainty is likely to persist until more information on the stock-recruitment dynamics of these stocks, especially at higher spawning stock biomasses, is available.

Table 4.2.1. Summary of current and recommended biomass and fishing mortality rate reference points for New England groundfish stocks. The units for biomass (total or spawning stock) and fishing mortality reference points are provided as footnotes.

Stock	**Biomass target (Bmsy)**		**MSY (metric tons)**		**Fishing Mortality Threshold (Fmsy)**		**Basis for Reference Points**
	Current	**Recommended**	**Current**	**Recommended**	**Current**	**Recommended**	
Gulf of Maine Cod	78,000[1]	82,800[1]	16,100	16,600	0.23[3]	0.23[3]	Parametric S-R
Georges Bank Cod	108,000[2]	216,800[1]	35,000	35,200	0.32[4]	0.18[3]	Parametric S-R
Georges Bank Haddock	105,000[1]	250,300[1]	N/A	52,900	0.26[3]	0.26[3] (F40%)	Empirical Non-parametric
Gulf of Maine Haddock	8.25 kg/tow	22.17 kg/tow	2,400	5,100	0.29 (C/I)	0.23 (C/I)	Catch-Survey Proxy
Georges Bank Yellowtail Flounder	43,500[2]	58,800[1]	14,100	12,900	0.33[4]	0.25[3] (F40%)	Empirical Non-parametric
Southern New England Yellowtail Flounder	51,000[2]	45,200[1]	11,700	9,000	0.23[4]	0.27[3] (F40%)	Empirical Non-parametric
Cape Cod Yellowtail Flounder	6,100[2]	8,400[1]	2,400	1,700	0.40[4]	0.21[3] (F40%)	Empirical Non-Parametric (mean)
Mid-Atlantic Yellowtail Flounder	11.69 kg/tow	12.91 kg/tow	3,300	4,300	0.36 (C/I)	0.33 (C/I)	Catch-Survey Proxy
American Plaice	24,200[1]	28,600[1]	4,400	4,900	0.19[3]	0.17[3] (F40%)	Empirical Non-parametric (mean)
Witch Flounder	25,000[2]	19,900[1]	2,684	3,000	0.106[4]	0.16[3] (F40%)	Empirical Non-Parametric (mean)

Stock	Biomass target (Bmsy)		MSY (metric tons)		Fishing Mortality Threshold (Fmsy)		Basis for Reference Points
	Current	Recommended	Current	Recommended	Current	Recommended	
Southern New England Winter Flounder	27,810[2]	30,100[1]	10,220	10,600	0.37[4]	0.32[3]	Parametric S-R
Georges Bank Winter Flounder	2.49 kg/tow	9,400[2]	3,000	3,000	1.21 (C/I)	0.32[4]	Surplus Production
Acadian Redfish	121,000[2]	236,700[1]	14,000	8,200	0.116[4]	0.04[3] (F50%)	Empirical Non-Parametric (mean upper Q)
White Hake	14,700[5]	14,700 [5]	4,200[5]	4,200[5]	0.29[4]	0.29[4]	Surplus Production
Pollock	102,000[1,6]	3.0 kg/tow	40,000[6]	17,600[7]	0.65[1]	5.88 (C/I)	Catch-Survey proxy
N. Windowpane	0.94 kg/tow	0.94 kg/tow	1,000	1,000	1.11 (C/I)	1.11 (C/I)	Catch-Survey proxy
S. Windowpane	0.41 kg/tow	0.92 kg/tow	900	900	2.24 (C/I)	0.98 (C/I)	Catch-Survey Proxy
Ocean Pout	4.9 kg/tow	4.9 kg/tow	1,500	1,500	0.31 (C/I)	0.31 (C/I)	Catch-Survey Proxy
Atlantic Halibut	5,400[2]	5,400[2]	300	300	0.06[3]	0.06[3]	Catch-YPR prox

1/ unit is spawning stock biomass, metric tons
2/ unit is total biomass, metric tons
3/ unit is fully-recruited F
4/ unit is biomass-weighted F
5/ unit is total stock biomass >/= 60 cm
6/ applies to NAFO Divisions 4VWX and Subareas 5&6
7/ applies to NAFO Subareas 5&6

Table 4.2.2. Summary of estimated fishing mortality rates required to rebuild stocks to Bmsy by 2009 with probability >/= 50%. Estimated fishing mortality rates in 2000 are also given.

Species/Stock	F-rebuild	Fishing Mortality Rate in 2000
Gulf of Maine Cod	0.17	0.73
Georges Bank Cod	0.0[1]	0.22
Georges Bank Haddock	0.21	0.19
Georges Bank Yellowtail Flounder	0.22	0.14
Southern New England Yellowtail Flounder	N/A	0.22
Cape Cod Yellowtail Flounder	0.14	1.39
American Plaice	0.13	0.31
Southern New England Winter Flounder	0.30	0.31
Acadian Redfish	0.0[2]	0.003
White Hake	N/A	0.85

1/ based on projections the probability of Georges Bank cod biomass reaching the target in 2009 is <50% even if F=0.0

2/ redfish will not rebuild by 2009 even if F=0.0, owing to its life history

Table 4.2.3 Total catch (mt) and catch components estimated for 2001. The estimated total catch was used to determine fishing mortality in 2001for those stocks for which rebuilding projections were performed.

Stock	U. S. Commercial Landings	CDN Commercial Landings	U.S. Commercial Discard	U.S. Recreational Landings	U.S. Recreational Discard	Total Catch
Gulf of Maine Cod	4,016	—	1,362	2,616	—	7,994
Georges Bank Cod	10,631	2,134	—	—	—	12,765
Georges Bank Haddock	4,842	6,712	—	—	—	11,554
Gulf of Maine Haddock	946	—	—	—	—	946
Georges Bank Yellowtail fl.	4,172	2,890	678	—	—	7,740
So. New Engl. Yellowtail fl.	830	—	203	—	—	1,033
Cape Cod Yellowtail fl.	2,224	—	347	—	—	2,571
Mid-Atl Yellowtail fl.	206	—	206	—	—	206
Georges Bank Am. plaice	4,369	45	956	—	—	5,370
Witch flounder	2,931	—	528	—	—	3,459
So. New Engl. Winter fl.	3,917	—	274	531	24	4,746
Georges Bank Winter fl.	2,070	590	—	—	—	2,670
Acadian redfish	325	—	—	—	—	325
White hake	3,360	200	—	—	—	3,560
Pollock	3,901	—	—	—	—	3,901
No. Windowpane fl.	44	—	—	—	—	44
So. Windowpane fl.	112	—	—	—	—	112
Ocean pout	18	—	—	—	—	18
Atlantic halibut	10	—	—	—	—	10

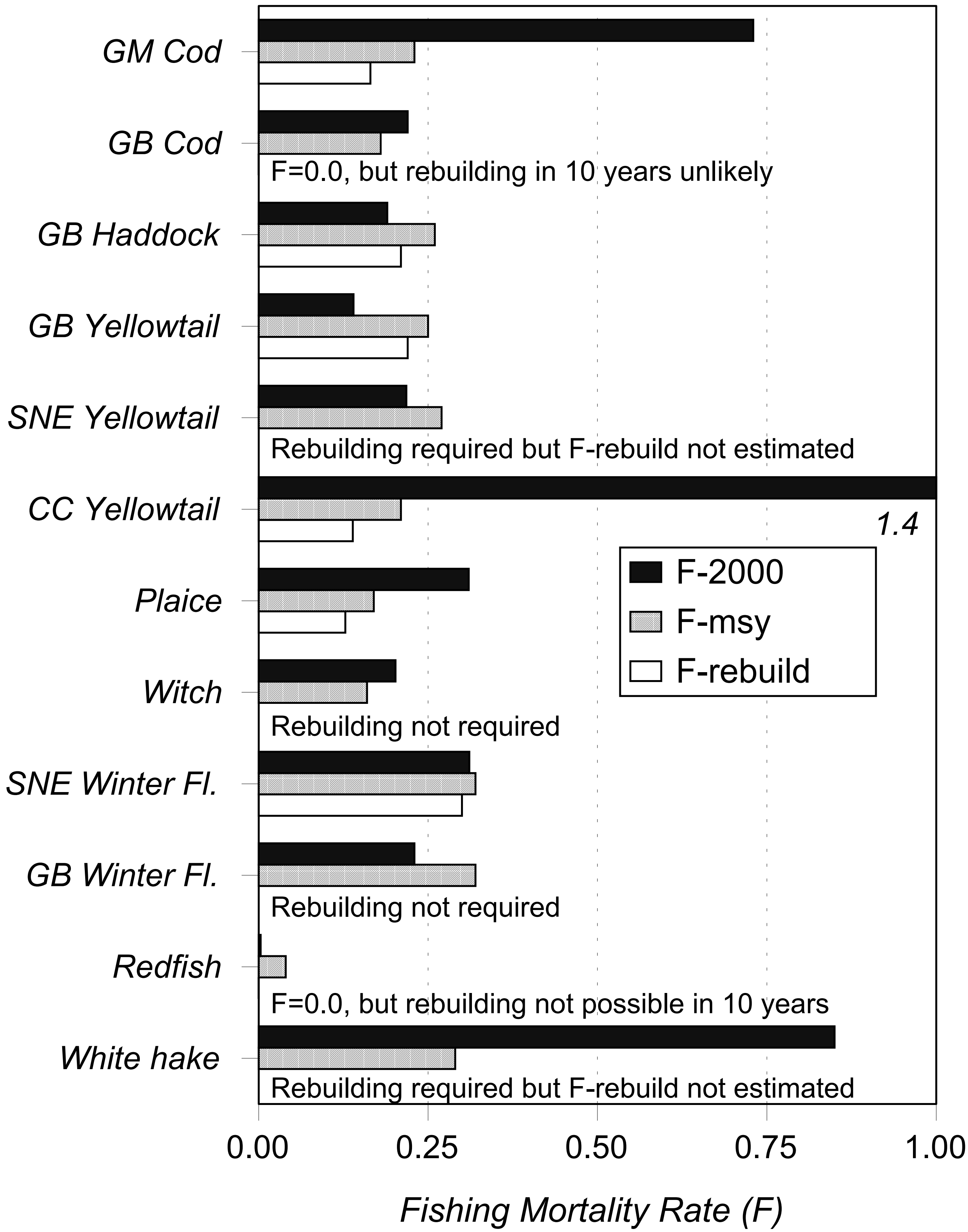

Figure 4.2.1. Estimates of F in 2000, Fmsy (or proxy) and corresponding fishing mortality rates needed to reach Bmsy by 2009 with >50% probability (F-rebuild). Data are only for stocks with analytical assessments (e.g., non index-based).

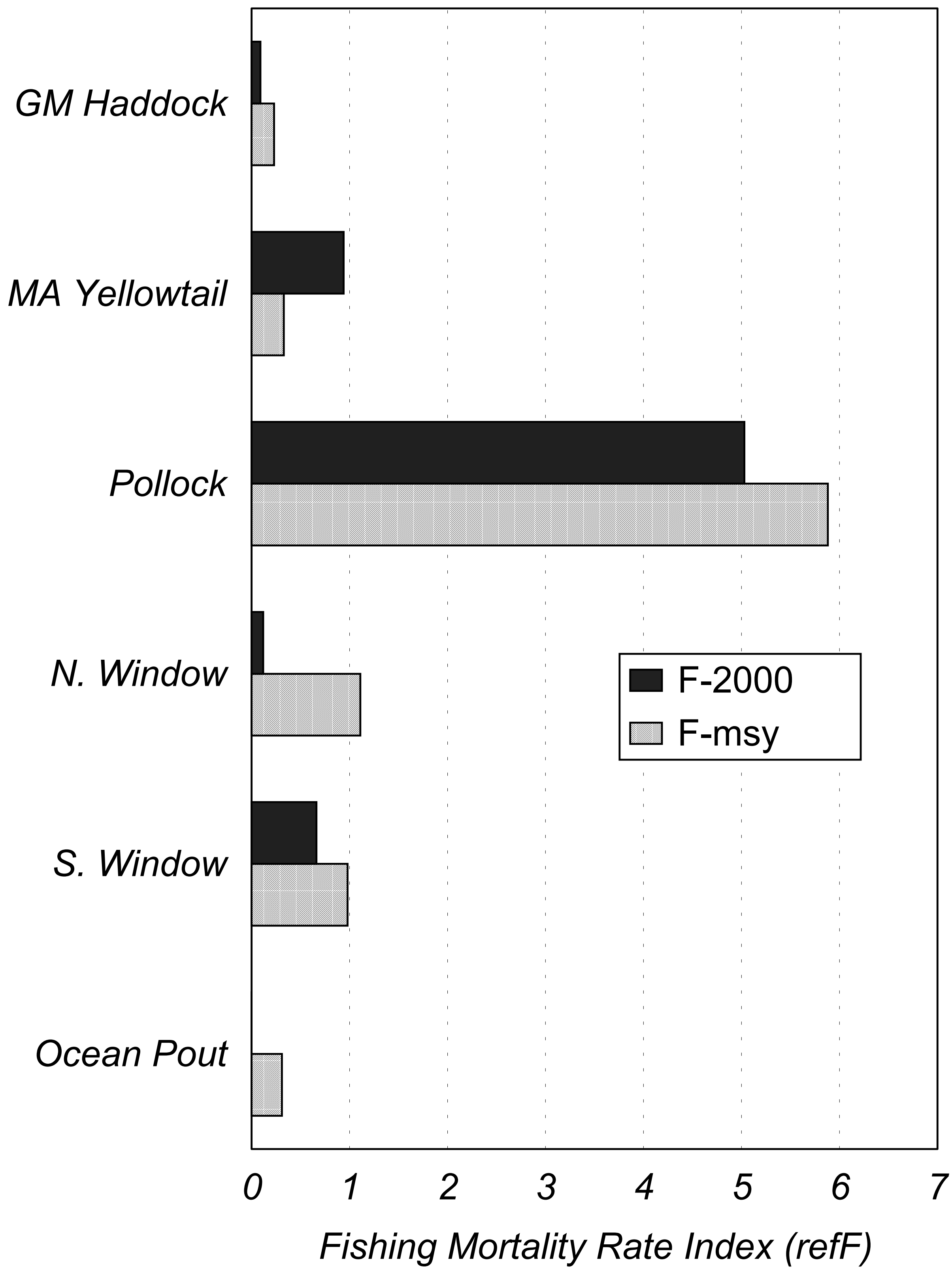

Figure 4.2.2. Estimates of fishing mortality rate indices (relF) in 2000 and the Fmsy proxy for six New England groundfish stocks Data are only for stocks with index-based assessments.

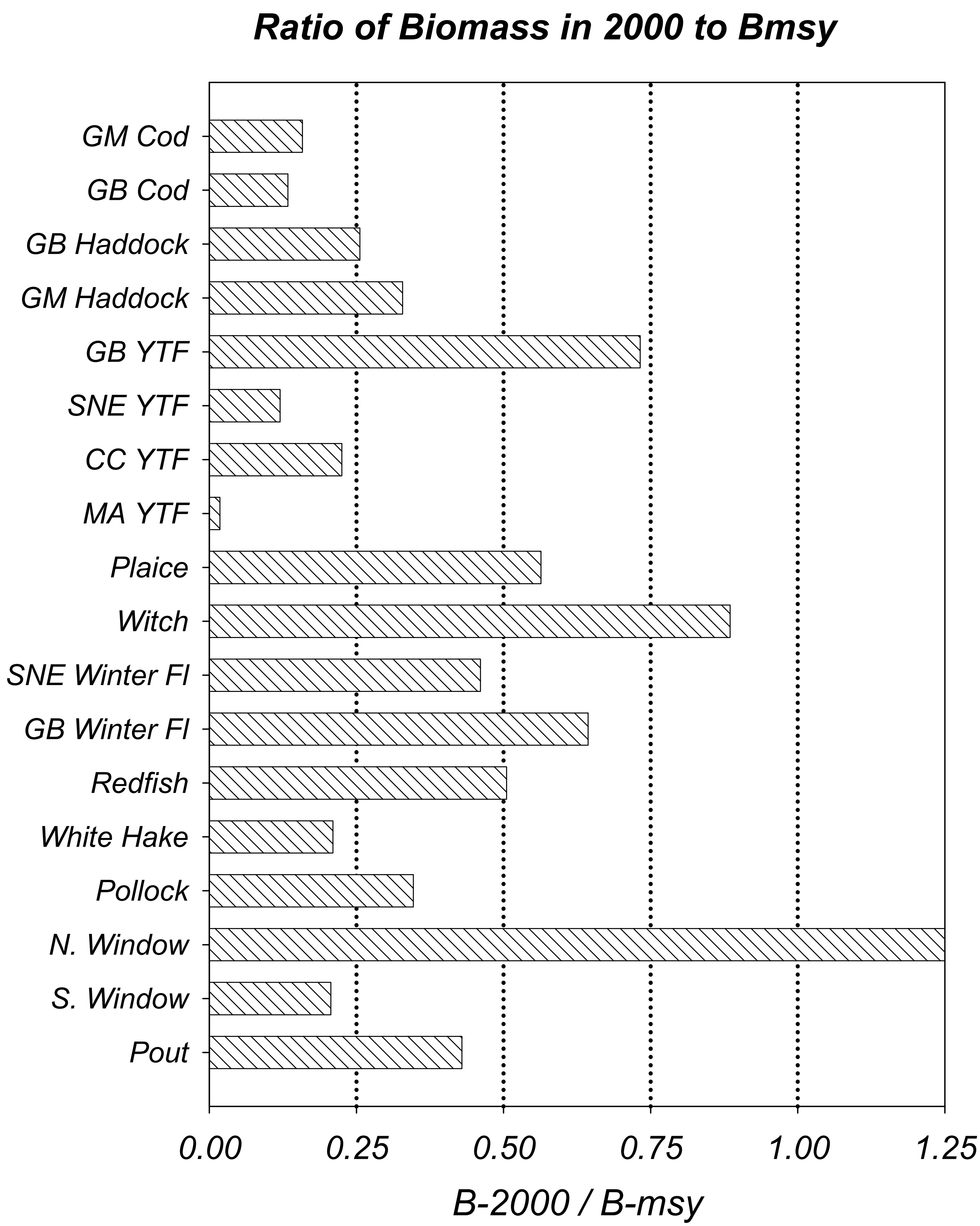

Figure 4.2.3. Ratios of the biomasses in 2000 to Bmsy for 18 groundfish stocks.

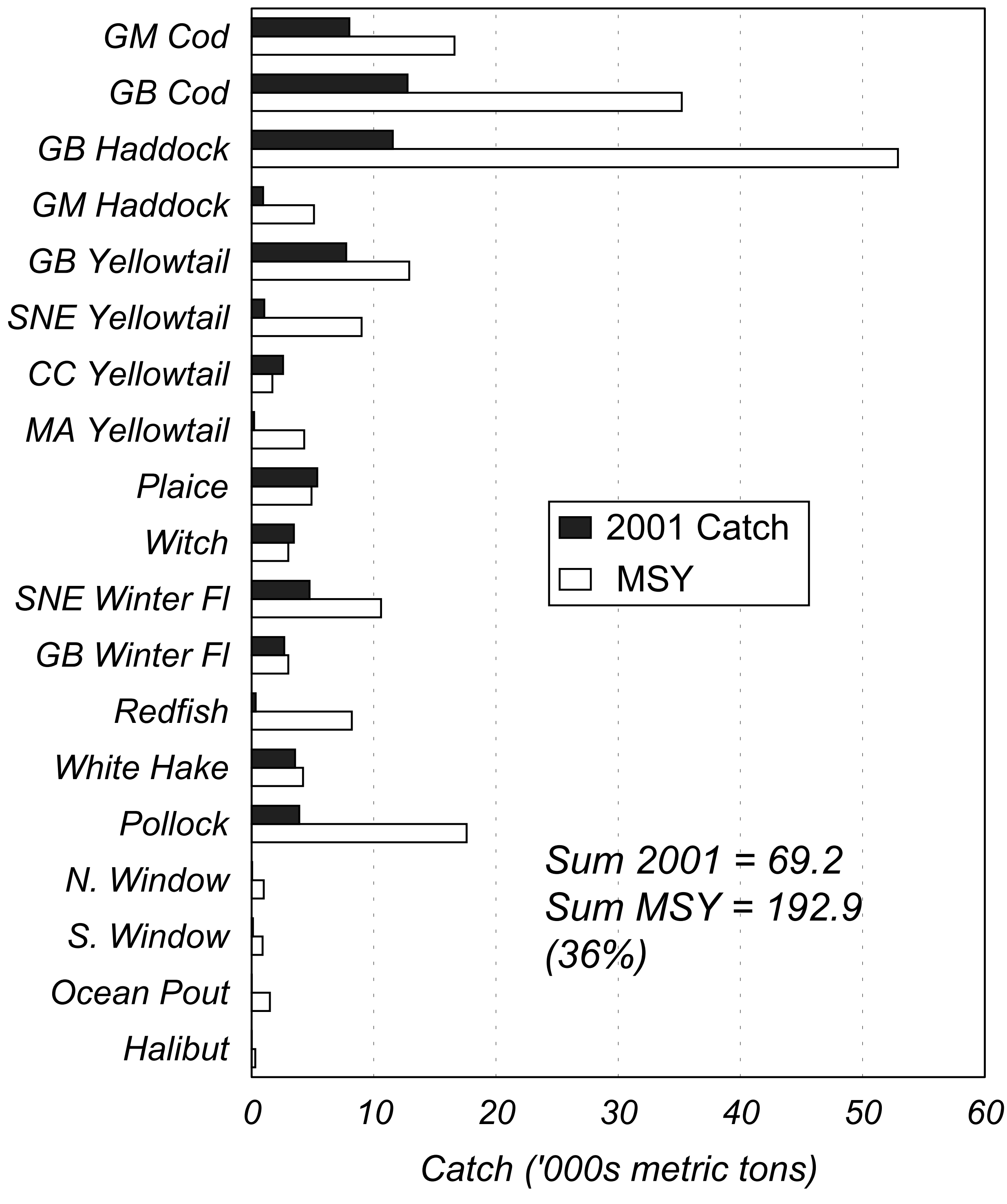

Figure 4.2.4. Estimated catches in 2001 and MSY values for 19 New England groundfish stocks.

4.3 Ecosystem Implications of Revised Biomass targets

The question of whether or not species interaction strengths are sufficiently strong to preclude the simultaneous attainment of B_{MSY} across the suite of primary groundfish stocks is important. Data presented in Figures 4.3.1-4.3.6 summarize the biomass histories of each of the regulated stocks as a function of the biomasses of all the other stocks inhabiting similar stock areas. In most cases it is clear that the stocks themselves have coexisted at much higher biomasses in the past.

While Brown et al.'s (1976) surplus production analyses suggested the possibility that MSY may not be obtainable across a suite of species in the northeast U.S. continental shelf community, this analysis does not include recent data and was based on relatively short data series. Analyses based on the entire time series of fishery independent data do not clearly support the notion that strong species interactions may preclude stock rebuilding or simultaneous attainment of MSYs. In particular, the single species versus multispecies survey abundance plots show that there is strong coherency by region. For the Gulf of Maine, the spring and autumn survey indices show that abundances of cod, haddock, redfish, plaice, and witch flounder stocks have positive coherence. This indicates that these stocks have simultaneously existed at higher abundances in the past, relative to their current levels. Similar patterns of coherence are evident for Georges Bank cod, haddock, and yellowtail, as well as for Southern New England yellowtail and winter flounder and Mid-Atlantic yellowtail flounder. The implication of these fishery-independent data is that these stocks coexisted at higher abundances in the 1960s-1970s which suggests that B_{MSY} values that lie within the range of implied survey abundances could be realized. Similarly, in a recent study of structure of food web of the northeast U.S. continental shelf community, Link (1999) found a higher degree of complexity and connectivity than other food webs where community structure has been documented. The relatively high connectance and species richness suggests that this marine ecosystem may be highly persistent and resistant to perturbations, in comparison to other studied systems. Link (1999) also found that the interactions implied by the community interaction matrix of the food web of the northeast U.S. continental shelf ecosystem were relatively weak in comparison to other less complex systems. Taken together with the observed increases in the relative abundances of depleted sea scallop, haddock, and yellowtail flounder stocks on Georges Bank under large-scale closed area management (Murawski et al. 2000), the available data suggest that trophic interactions are moderate in strength and are probably not strong enough to limit the rebuilding of primary New England groundfish stocks.

A broader question to pose relative to the recovery of flatfish and groundfish stocks is can all the components of the ecosystem (flatfish, groundfish, pelagics, and spiny dogfish) coexist simultaneously at high biomass? Much of the recent literature has chronicled the large changes in biomass in the Northeast ecosystem that have occurred during 1961-2000 (Clark and Brown 1977; Overholtz et al 1995; Link et al 2001). Most studies have concluded that the cause for these changes in the ecosystem are related directly to serial depletion of individual resources resulting from high fishing rates during the ICNAF fishery years (Brown et al. 1976; Clark and Brown 1977; Anthony and Waring 1980; Anthony1993) and subsequently through intense fishing by vessels from the United States (Anthony 1990: NEFSC 1991; Anthony 1993; Overholtz et al 1995; Link et al 2001). Serial depletion as such has nothing to do with the coexistence question, but it is important since some researchers have concluded that changes in the ecosystem are related to community interactions. There is little evidence for this, however, with a few exceptions (Fogarty and Cohen 1991).

Information from several lines of evidence suggests that all the major groups of fishes (flatfish, gadids, pelagics, and spiny dogfish) can exist simultaneously at high biomass in the Northeast shelf ecosystem. Results from the multi year food habits data base at the NEFSC suggest that in the 1960's groundfish were present in the diets of piscivorus fish in low percentages (Langton and Bowman 1980), while recently the proportion of groundfish in diets is even lower than in the past (Overholtz et al. 2000). This indicates that large numbers of groundfish were likely present during the earlier time period because the diet composition of piscivores in the region generally reflects the more abundant prey fishes that are available (Overholtz et al 2000) Herring and mackerel were also present in the diets of predatory fish in the 1960s in higher percentages than groundfish (Langton and Bowman 1980) back before these pelagic stocks collapsed (NEFSC 2001).

Another general conclusion from the NEFSC food habits data is that flatfish, groundfish, pelagics, and spiny dogfish have weakly connected diets (Link 1999). This may be related to spatial, temporal, and size related segregation that tends to prevent direct competition for food resources. Coupled with the fact that this ecosystem is rather open in terms of nutrients, prey fishes, and other food resources, the evidence suggests that the system can support a large biomass of different species (Link et al 2001).

Cumulative landings during the ICNAF era (1963-1977) for cod, haddock, silver hake, mackerel, herring, and other species indicate that the individual biomass of each of these species was large and that these species occurred simultaneously in the region (Clark and Brown 1977; Anthony and Waring 1980). Cumulative landings of mackerel and herring alone were about 3 million mt each during this period (Anthony and Waring 1980; NEFSC 2000).

Finally, trends in relative abundance indices from NEFSC groundfish surveys indicate that a large biomass of cod, haddock, flatfish, mackerel, silver hake , and herring were present simultaneously during the 1960's (Brown et al. 1976; Clark and Brown 1977). Recent trends in survey indices suggest that large biomasses of herring, mackerel, and dogfish were present during the late 1980s and early 1990s, before the fishery began on dogfish in 1994 (NEFSC 2001b).

Based on the above considerations, there do not appear to be trophic limitations to the recovery of groundfish biomasses to the targets recommended herein.

4.4 Adaptive Approaches for Determining Long-Term Biomass and Mortality Targets

For several important stocks, revised biomass reference points are higher than the current estimates of Bmsy – in some cases substantially so. The new estimates rely on recruitment distributions near the long term mean or recruitments correlated with increases in projected spawning stock biomasses. For many of the stocks the proposed biomass reference points are in *terra incognita* - chronic growth overfishing has limited stock biomasses to well below their estimated potential. Given the lack of experience in observing these populations at high biomass, we can only model the expected behavior of the system under varying assumptions. The NEFMC is advised that an adaptive approach to biomass management is a prudent tactic to explore the

Gulf of Maine -Fall Survey Indices (kg/tow)

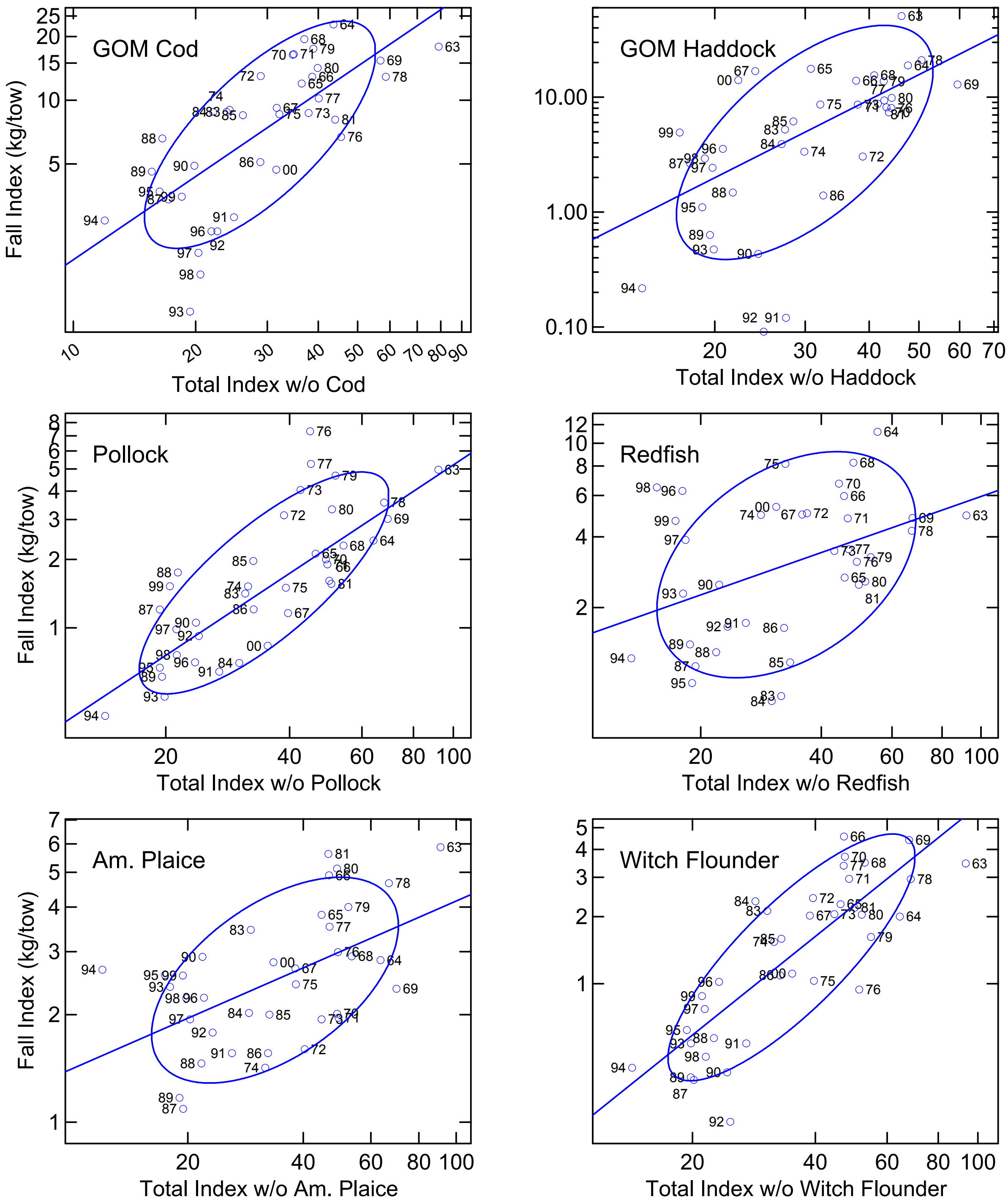

Figure 4.3.1. Relationship between fall survey indices for individual stocks and the sum of all other regulated groundfish stocks in the Gulf of Maine region, 1963-2000.

Gulf of Maine-Fall Survey Indices (kg/tow) [cont.]

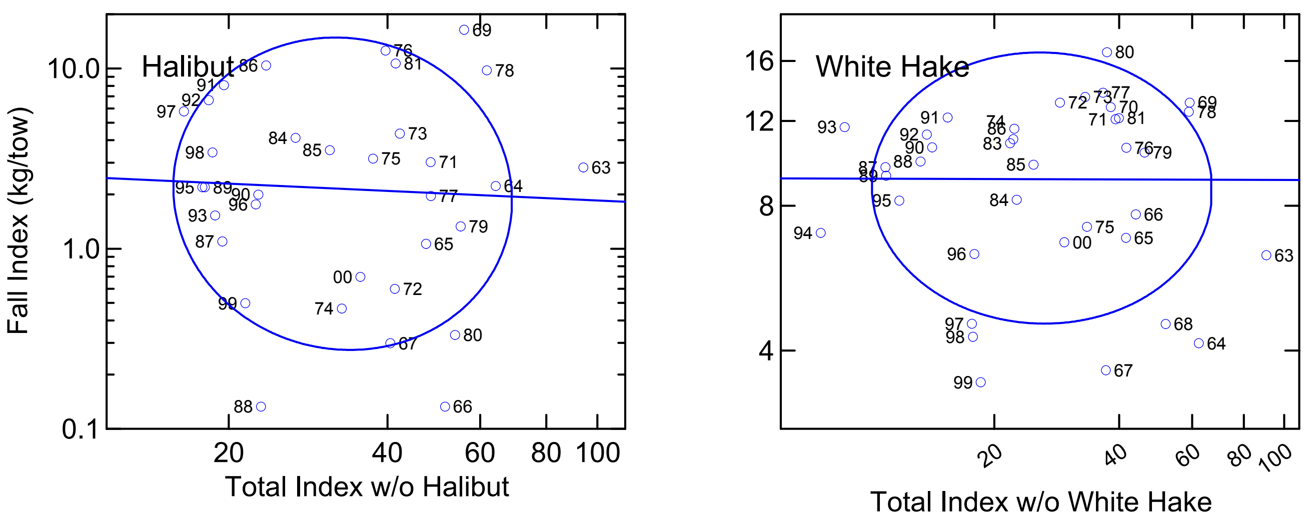

Figure 4.3.1 (continued). Relationship between fall survey indices for individual stocks and the sum of all other regulated groundfish stocks in the Gulf of Maine region, 1963-2000.

Gulf of Maine -Spring Survey Indices (kg/tow)

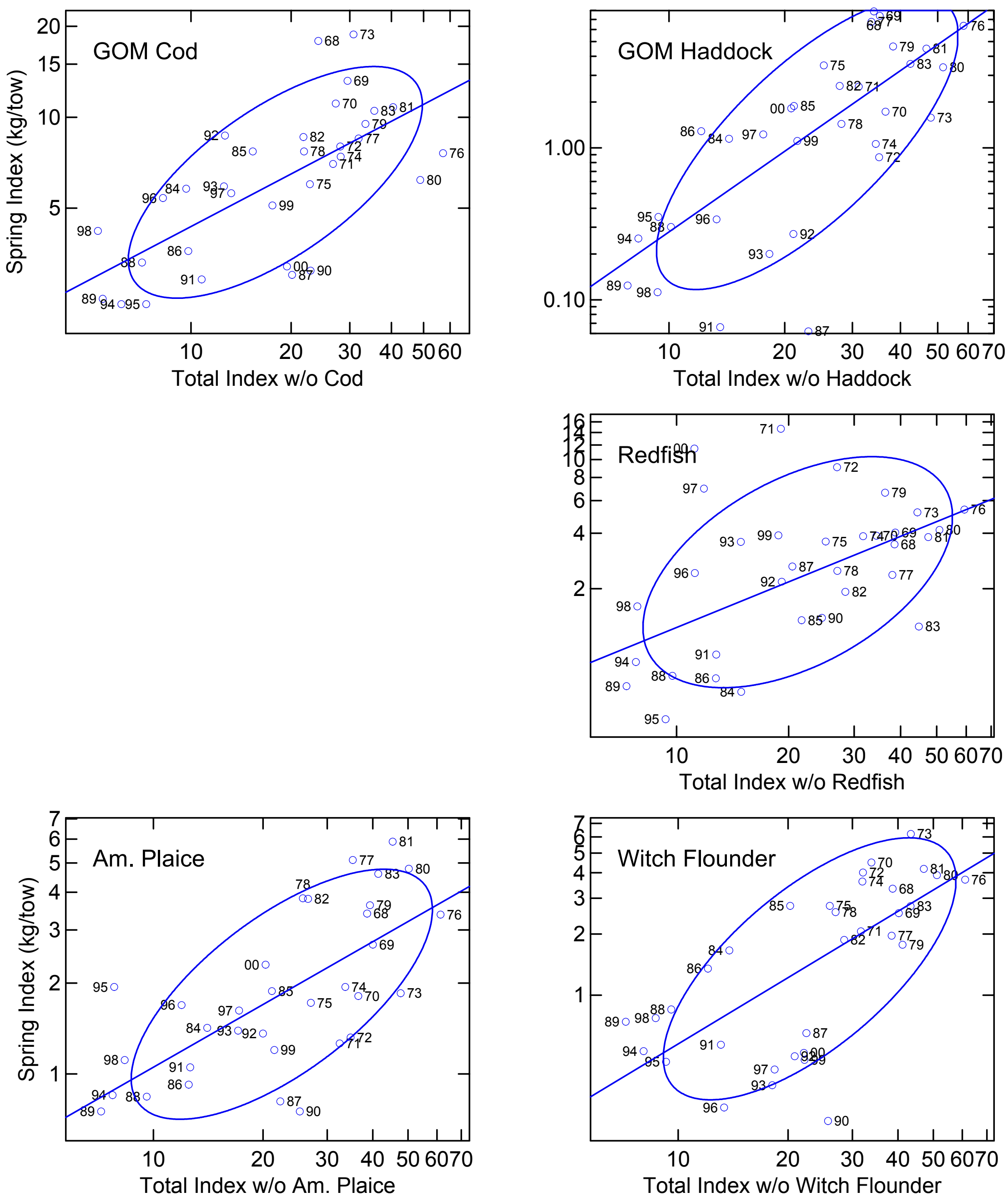

Figure 4.3.2. Relationship between spring survey indices for individual stocks and the sum of all other regulated groundfish stocks in the Gulf of Maine region, 1968-2000.

Gulf of Maine-Spring Survey Indices (kg/tow) [cont.]

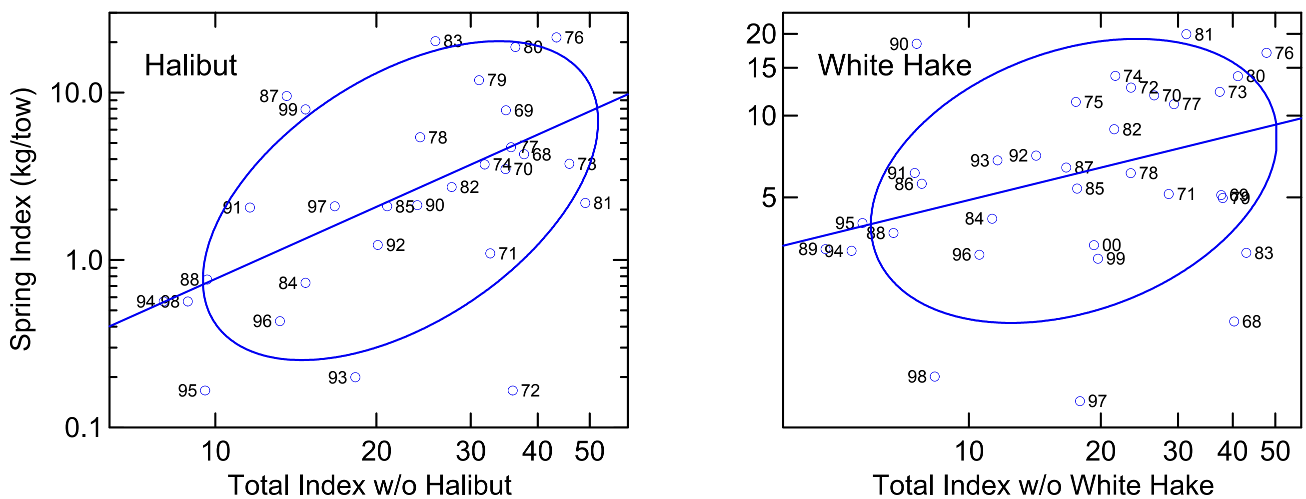

Figure 4.3.2 (continued). Relationship between spring survey indices for individual stocks and the sum of all other regulated groundfish stocks in the Gulf of Maine region, 1968-2000.

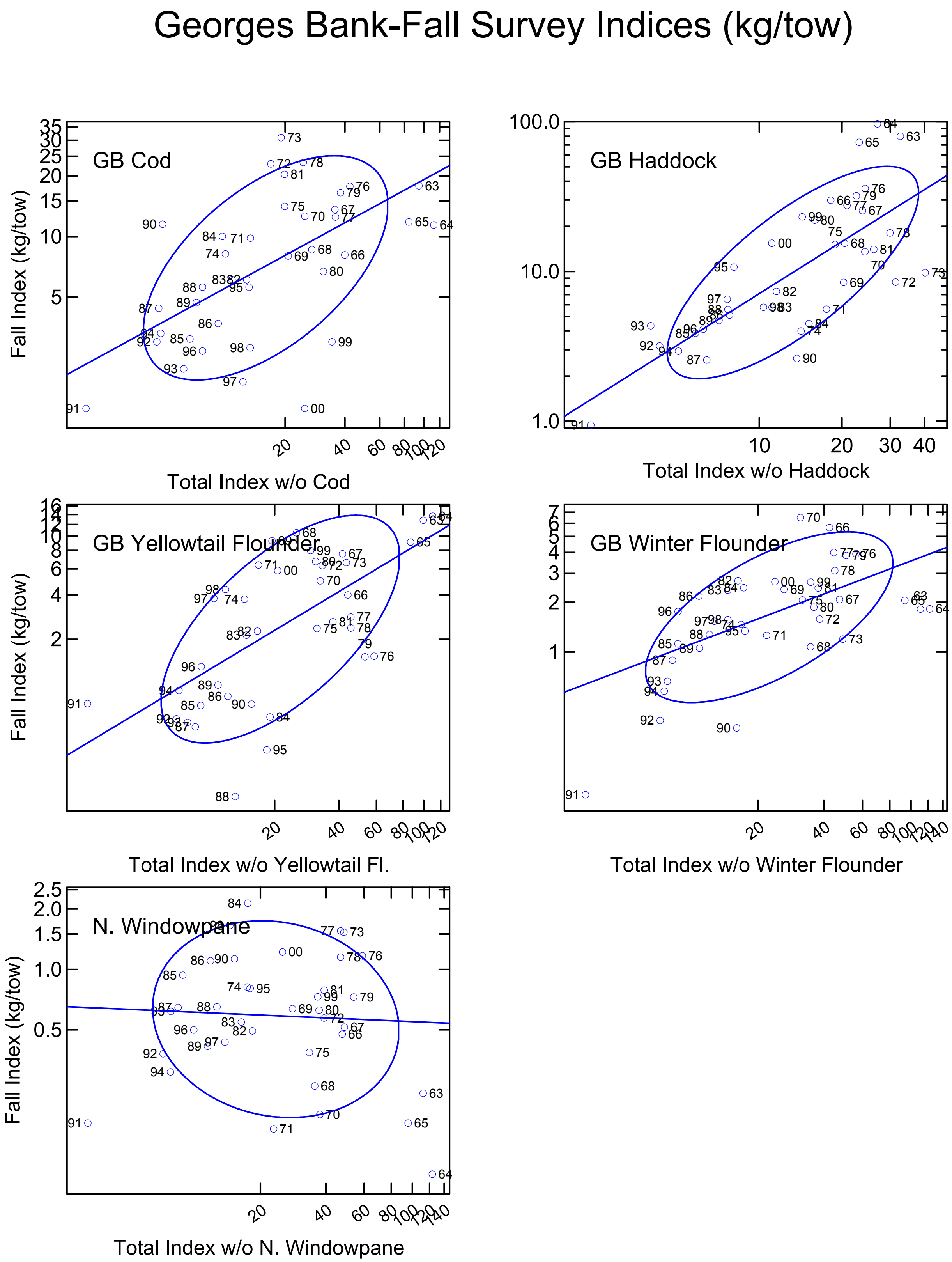

Figure 4.3.3. Relationship between fall survey indices for individual stocks and the sum of all other regulated groundfish stocks in the Georges Bank region, 1963-2000.

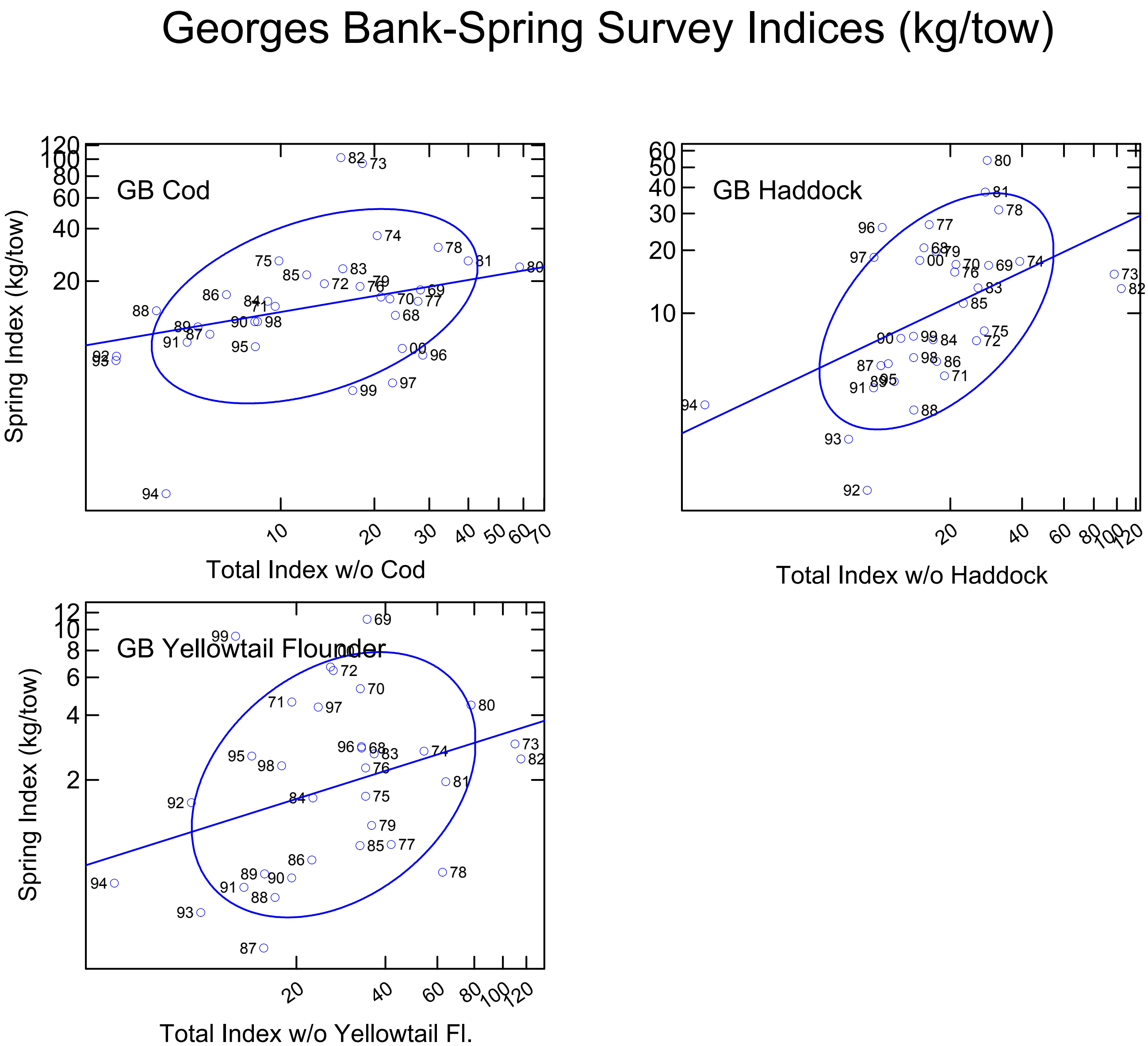

Figure 4.3.4. Relationship between spring survey indices for individual stocks and the sum of all other regulated groundfish stocks in the Georges Bank region, 1968-2000.

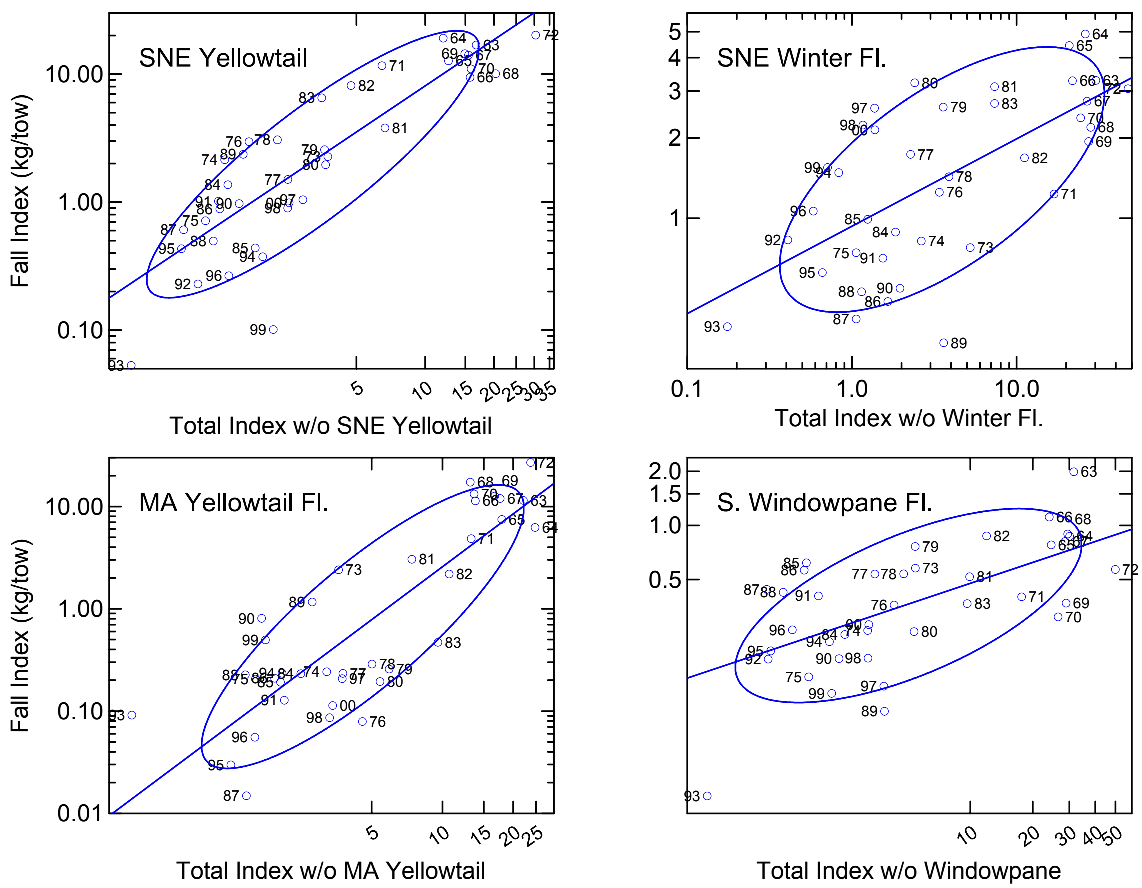

Figure 4.3.5. Relationship between fall survey indices for individual stocks and the sum of all other regulated groundfish stocks in the Southern New England region, 1963-2000.

S. New England-Spring Survey Indices (kg/tow)

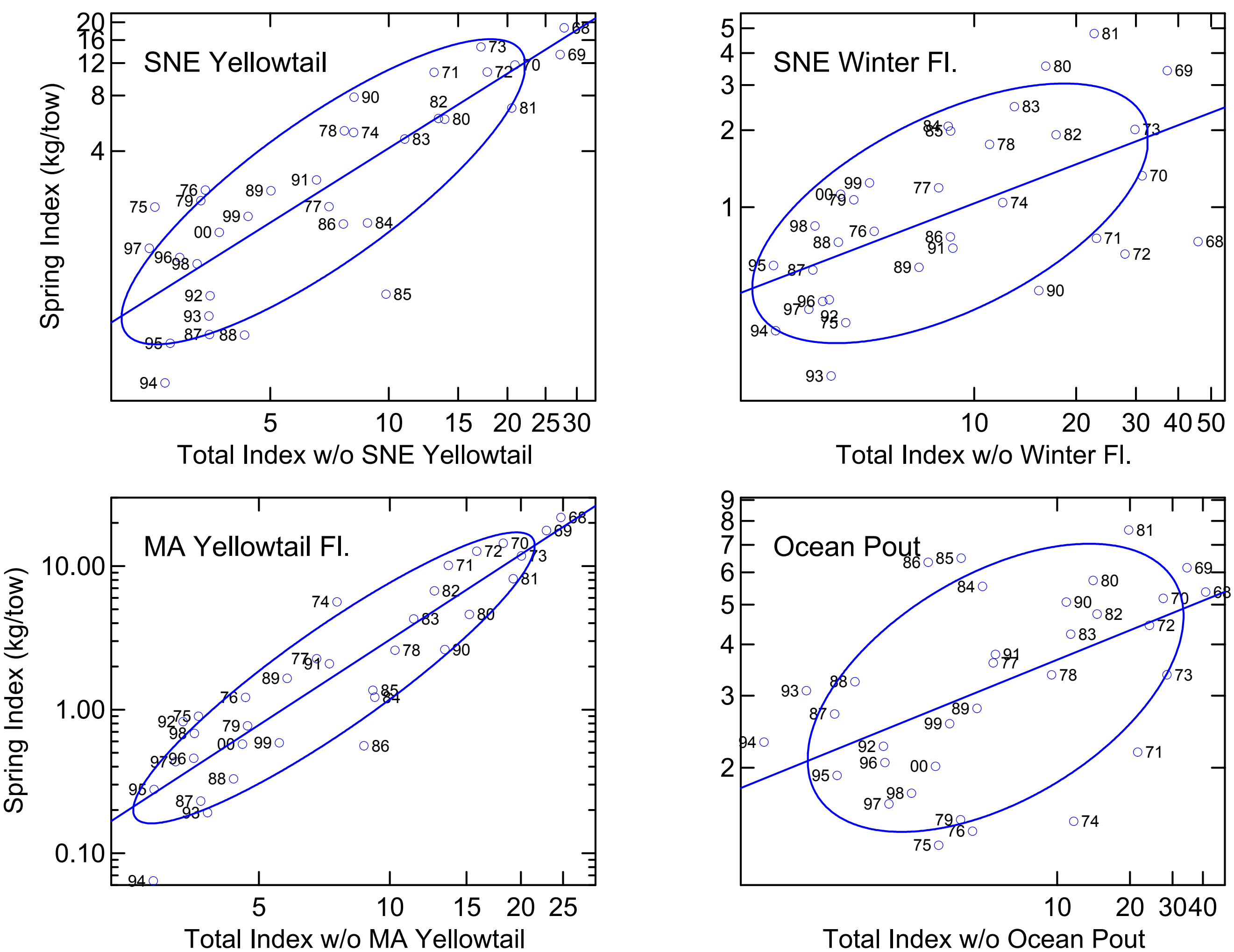

Figure 4.3.6. Relationship between spring survey indices for individual stocks and the sum of all other regulated groundfish stocks in the Southern New England region, 1968-2000.

implications of higher biomasses and to find the point of diminishing returns to yields as a function of increased stock density. The adaptive approach recommended is to build the spawning stock biomasses by reducing fishing mortality (or in some cases maintaining current rates) such that the realized recruitments at high spawning stock biomasses are observed. This will allow direct examination of recruitment associated with maximum sustainable yield and thus the appropriateness of recruitment levels used to set biomass reference points.

Given the histories of most of these stocks, there is likely substantial biomass growth, and commensurate increases in catch, before these points are reached. Continued monitoring of vital population rates - including growth, sexual maturity at age, feeding habits to reveal predation and competition among populations, and distribution patterns in relation to abundance - will indicate when biomass production becomes limited by density-dependent factors. This will allow direct estimation of realized spawning biomass per recruit used to set the reference points. Under these conditions the form of the stock-recruitment relationships will become more apparent, as will be the MSY potential for each of the stocks and the system as a whole. Thus, the panel recommends that the NEFSC adopt the revised biological reference points recommended herein, and evaluate the rebuilding process at periodic intervals. Changes in vital rates in relation to stock density, or lack thereof, will dictate necessary refinements in Bmsy and Fmsy, either up or down.

5.0 Conclusions

The Working Group developed a systematic approach to the re-estimation of biomass and fishing mortality reference points using a hierarchy of methods dictated by available population and fishery data. Proposed biomass and fishing mortality reference points have been updated for 15 of the 19 stocks considered. For the remaining four, there was no basis for recommending changes.

For only two stocks, the surplus production estimates of Bmsy and Fmsy are retained (GB Winter Flounder, white hake), while assessment types were changed for several others (e.g. pollock was changed from age-based to index-level, based on the lack of recent VPA updates).

For all stocks, reference points were re-estimated within analytical frameworks that are compatible with the monitoring tools used to determine stock status (e.g., we eliminated surplus production estimates of Bmsy and Fmsy for stocks monitored using age-based methods). This should allow more consistent and interpretable advice to managers and the public.

Based on analyses undertaken by the Working Group, and relevant literature on the subject, it is unlikely that multispecies interactions between various components of the fish community are strong enough to inhibit continued rebuilding to the groundfish complex, at least to levels seen last in the early 1960s.

Projections of medium-term stock status in relation to biomass targets are critically dependent on the realized recruitments to the various stocks. Making one set of most likely projections is difficult for stocks that exhibit infrequent high recruitment followed by long periods of recruitment failure (e.g., Southern New England yellowtail flounder). For Southern New England yellowtail flounder and white hake, the Working Group did not feel sufficiently confident in the basis for such projections and they have not been given.

Last, the Working Group recognizes that setting biomass targets to levels not seen in decades, or in fact outside of the maximum levels estimated in modern fishery monitoring systems, is a difficult proposition for managers, fishermen and the public. In cases where the Working Group recommends such targets, they are based on observed recruitment histories and biomass per recruit that should be realized if fisheries are managed to their F targets. Yield and biomass per recruit models are simple and robust and relatively high confidence can be placed in their results. Improving biomasses should result in higher and more stable recruitments and larger fishery catches, in the long-term. In several examples where reference biomasses have been set at high levels relative to recent history, fishery yields and catch rates have increased steadily and significantly (e.g. sea scallop, and summer flounder). An adaptive approach to understanding the limits of groundfish stock productivity at higher biomasses is recommended as a prudent step forward.