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Comparison Between Maximum Sustained Yield Proxies and Maximum Sustained Yield

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Abstract: Attaining maximum sustained yield (MSY) is a central goal in U.S. fisheries management. To attain MSY, fishing mortality is maintained at F_{MSY} and biomass at B_{MSY}. Replacing F_{MSY} and B_{MSY} by "proxies" for F_{MSY} and B_{MSY} is commonplace. However, these proxies are not equivalent to F_{MSY} and B_{MSY}. The lack of equivalency is an important issue with regard to whether MSY is attained or whether biomass production is wasted. In this paper we study the magnitude of the equivalency. We compare F_{MSY}/B_{MSY} (calculated using the ASPIC toolbox) with the proxy estimates, $F_{40\%}/B_{40\%}$, published in GARM III. Our calculations confirm that in general the F_{MSY}/B_{MSY} calculations differ from the GARM III proxy estimates. The proxy estimates generally indicate that the stocks are overfished and are at relatively low biomasses, while the ASPIC estimates generally reflect the opposite: the stocks are not overfished and are at relatively high levels of abundance. In comparing the two approaches, the ASPIC estimates appeared favorable over the proxy estimates because 1) the ASPIC estimates involve only a few parameters in contrast to the many parameters estimated in the proxy approach, 2) "real variance" estimates for the proxy are not available so that it is difficult to evaluate the statistical adequacy of the proxy approach relative to the ASPIC approach, and 3) the proxy approach is based on many components (e.g., growth, stock and recruitment, etc.) that are subject to considerable uncertainty.

Keywords: Fisheries management, Biological reference points, Maximum sustained yield, Surplus production model

INTRODUCTION

Fisheries management in the United States is governed by the Magnuson-Stevens Act (MSA). The MSA is focused on obtaining maximum sustained yield (MSY) and preventing overfishing. However, "preventing overfishing" is not well defined. There are several different methods for calculating "overfishing." Implementing these different methods will produce different results using the same data for the same stock. If there are different measures of overfishing, then which measure should be used to determine whether or not a stock is overfished? By one set of measures, a stock might be overfished; by another set of measures, the same stock could by underfished.

Traditionally, MSY is calculated using production-model theory [e.g., 1]. Production model theory enables calculating values of F_{MSY} and B_{MSY}, levels of fishing mortality and biomass, respectively, that will result in attaining MSY. (An important footnote is that other values of F will result in an equilibrium, but this equilibrium is not "maximum.") The ASPIC (A Stock-Production Model Incorporating Covariates) toolbox [2, 3] is a convenient set of computer programs for estimating MSY and other parameters of the production model. It is particularly convenient because it includes calculations that deal with non-equilibrium settings.

Even though with a toolbox such as ASPIC it is "easy" to calculate MSY and consequent values of F_{MSY} and B_{MSY} (given appropriate data), it is commonplace to replace F_{MSY}/B_{MSY} with a "proxy" for F_{MSY}/B_{MSY}. There are many proxies for F_{MSY}/B_{MSY} [see, e.g., 4]. A popular proxy is the "$F_{x\%}$ proxy." This particular proxy controls fishing mortality such that the stock is maintained at x% of its unfished biomass. A commonly used value is x=40 [see 5-11].

But, the $F_{x\%}$ proxy used in GARM III [11] is not in general equal to F_{MSY}. This raises several important questions. Is $F_{x\%}$ the overfishing criterion or is F_{MSY} the overfishing criterion? If $F_{x\%}$ is the overfishing criterion, and if it is always greater than F_{MSY}, then is the stock perpetually overfished? Likewise, if $F_{x\%} < F_{MSY}$, then is the stock perpetually underfished?.

In actuality proxies arose because of perceived difficulties in calculating F_{MSY} and also because optima in the level of fishing mortality were not well defined (see, for example, discussions on $F_{X\%}$). But, in fact, even though it is not customary to calculate F_{MSY} and B_{MSY}, it is "easy" to calculate F_{MSY} and B_{MSY}. Because it is possible to calculate both, it is also possible to compare $F_{40\%}$ and F_{MSY} and $B_{40\%}$ and B_{MSY}. In theory these statistics, F_{MSY}/B_{MSY} and $F_{40\%}/B_{40\%}$, should approximate one another since they purportedly estimate the same thing.

In this paper we compute F_{MSY}/B_{MSY} and then compare these statistics to $F_{40\%}/B_{40\%}$, as presented in the GARM III report [11]. We show *inter-alia* that in fact ASPIC and the proxy statistics do not approximate one another. In fact, un-

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der the $F_{40\%}/B_{40\%}$ calculation the stocks generally appear to be overfished; while under the F_{MSY}/B_{MSY} calculation the stocks generally appear to be underfished. In other words, the $F_{40\%}/B_{40\%}$ proxy statistics appear to be biased relative to the F_{MSY}/B_{MSY} or ASPIC-calculated statistics. We begin to address the crucial question: Are the ASPIC statistics better than the proxy statistics?

MATERIALS AND METHODOLOGY

In the GARM III report [11], 14 among 19 groundfish stocks were assessed using $F_{40\%MSP}$ (50% for redfish) as biological reference points (BRPs). For the purpose of comparison with the $F_{40\%MSP}$ proxy, we estimated biomass and F, and directly estimated MSY reference points using Prager non-equilibrium surplus production model [2, 3, 12]. We then compared the estimated relative B and F time series by Prager's ASPIC with GARM III VPA estimated relative B and F time series. The relative B and F time series by Prager's ASPIC were the estimated B and F divided by the estimated B_{MSY}, F_{MSY}. The relative B and F time series by GARM III VPA were the estimated B and F divided by the proxy $B_{40\%}$, $F_{40\%}$.

Data were obtained from the GARM III report [11] and its appendix [13]. The input time series to ASPIC were observations of total catch weight and the Northeast Fisheries Science Center (NEFSC) fall and spring survey indices reported in GARM III. Three sets of ASPIC calculations were made based on: 1) NEFSC fall biomass survey indices; 2) NEFSC spring biomass survey indices; and 3) both NEFSC fall and spring survey indices.

ASPIC is based on the production model where the change of stock biomass over time (dB_t/dt) is:

$$\frac{dB_t}{dt} = rB_t - (r/K)B_t^2 - C_t, \tag{1}$$

where r is the intrinsic rate of population growth, K is the carrying capacity, C_t is the catch, B_t is the stock biomass. Given the parameter estimates of production model, the biological reference points can be calculated as

$$MSY = rK/4,$$
$$B_{MSY} = K/2, \tag{2}$$
$$F_{MSY} = r/2.$$

The parameters were estimated using nonlinear least squares of survey residuals. For alternative A, catch per unit effort (CPUE) from the NEFSC fall survey contributed to the total sum of squares as a series of observed effort. For alternative B, CPUE from the NEFSC spring survey contributed to the total sum of squares as a series of observed effort. For alternative C, CPUE from the NEFSC fall survey contributed to the total sum of squares as a series of observed effort. The NEFSC spring survey worked as independent biomass indices [14].

In the implementation of ASPIC, the biomass in the first year of time series B1 to K, expressed as a ratio of B1/K, were close to or smaller than the carrying capacity. We selected the option of adding penalty term if B1 is greater than K to the objective function in the implementation.

The penalty term was set to 1 unless the estimated B1/K was greater than 2. In that case, we increased the penalty term. Among all 42 (14×3) cases, 36 of them used penalty term 1. The 6 cases with penalty term greater than 1 were white hake in alternative A, Gulf of Maine (GOM) haddock in alternative B, Georges Bank (GB) cod, GB yellowtail flounder, Southern New England/Mid-Atlantic (SNE/MA) winter flounder, and redfish in alternative C.

GARM III reported $F_{40\%}$ proxy BRPs $F_{40\%}$ and the corresponding spawning stock biomass (SSB) $SSB_{40\%}$. The production model, however, gave the MSY BRPs F_{MSY} and the corresponding total stock biomass B_{MSY}. Thus in order to compare with the production model as an additional reference point of $F_{40\%}$ proxy BRPs, we estimated the corresponding $B_{40\%}$ using $SSB_{40\%}$ and the average ratio of B over SSB in most recent five years, i.e.,

$$B_{40\%} = SSB_{40\%} \cdot \frac{1}{5}\sum_{t=2003}^{2007} B_t / SSB_t, \tag{3}$$

where B_t and SSB_t are the total stock biomass and SSB at the year t.

Production model estimates total stock biomass B instead of SSB. For most stocks, GARM III reported time series of estimated SSB, estimated unweighted average of fishing mortality of fully recruited ages and estimated population abundance in terms of Jan-1 population in number and biomass. However, GARM III [11, 13] did not report estimated biomass time series for such stocks as GOM winter flounder, SNE/MA winter flounder, GOM haddock, GB winter flounder, witch flounder, and white hake. Therefore, for these 6 stocks we estimated B by a simple calculation. The biomass at year t, B_t, was calculated by

$$B_t = \sum_{a=1}^{A} N_{t,a} \cdot w_{t,a}, \tag{4}$$

where $B_{t,a}$ is the Jan-1 population number at age, $w_{t,a}$ is the mean biomass weight at age, and A is the oldest age. The mean biomass weight at age was derived from mean catch weight at age using Rivard toolbox [15].

RESULTS

ASPIC diagnostics for the 14 stocks are summarized in Table **1**. Table **1** contains diagnostics for all three relative abundance indices. Results were not convergent for the 1) SNE/MA yellowtail flounder for all alternatives, 2) GOM haddock for the spring survey, 3) white hake for the fall survey, and 4) GB haddock in the fall and spring surveys combined.

The values of r^2 were generally rather low. Fig. (**1**) shows the relative magnitude of r^2 values associated with each of the three survey data sets. The r^2 values for the fall survey are greater than those for either the spring or the combined spring and fall survey. The correlation between the spring and fall survey indices is given in (Table **2**). Most correlations between spring and fall surveys are relatively low in terms of explanatory power. For example, only about 16% of the variability in the GOM cod spring survey is accounted for by the fall survey. In terms of B1/K, the fall surveys had the largest values.

Table 1. Diagnosis Summary of ASPIC Implementation. The Asterisk "*" Refers to the Stock that at Least One Parameter Estimate is at or Near a Constraint in the Implementation of ASPIC; therefore, the Solution may be Trivial. In GARM III, Among these 14 Stocks Analyzed (Which Applied $F_{40\%}$ Proxy), 12 Stocks were Estimated by VPA Model

Stock	Alternative A Fall Survey Only		Alternative B Spring Survey Only		Alternative C Fall and Spring Survey		
	r^2	B1/K	r^2	B1/K	r^2 for Fall sv.	r^2 for Spring sv.	B1/K
GB cod	0.471	1.284	0.302	0.824	0.487	0.294	1.056
GOM cod	0.237	1.614	0.071	1.355	0.175	0.085	1.549
GB yellowtail flounder	0.459	0.482	0.507	0.757	0.592	0.390	1.079
SNE/MA yellowtail flounder	0.368*	0.052*	0.295*	0.805*	0.383*	0.413*	0.057*
CC/GOM yellowtail flounder	0.028	0.410	0.115	0.237	0.064	0.098	0.305
GB haddock	0.781	0.266	0.372	0.313	-0.161*	-0.118*	1.386*
GOM haddock	0.300	1.678	-1.075*	1.449*	0.336	0.048	1.151
GB winter flounder	0.345	0.459	0.093	0.050	0.161	0.084	0.186
GOM winter flounder	0.154	1.159	0.184	1.152	0.074	0.141	1.391
SNE/MA winter flounder	0.425	1.421	0.784	0.580	0.177	0.374	1.150
GB/GOM white hake	0.410	0.055*	0.362	0.230	0.314	0.282	0.311
Witch flounder	0.456	0.491	0.528	0.339	0.207	0.555	1.035
GB/GOM American plaice	0.405	1.063	0.654	0.373	0.432	0.681	0.216
Acadian redfish	0.784	0.311	0.325	0.320	0.778	0.358	0.343

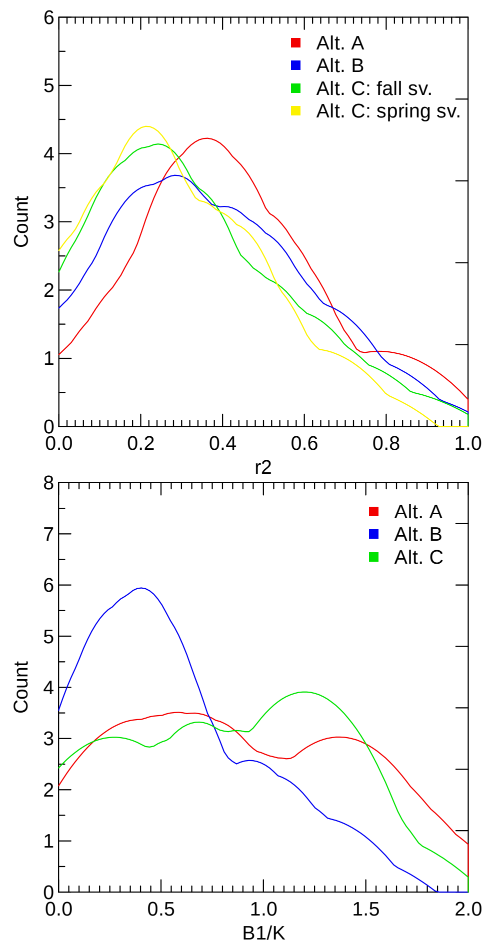

Fig. (1). Kernel curve of r^2 in top panel and B1/K in bottom panel from ASPIC. SNE/MA yellowtail flounder of all three alternatives, GB haddock of alternative C, GOM haddock of alternative B, and white hake of alternative A are not included due to ASPIC warning message. Refer to Table **1**.

Table 2. Correlation Coefficient between Fall Survey Indices and Spring Survey Indices for the 14 Groundfish Stocks. The time Period of the Survey Time Series are the Same as the Catch Data of the Stock

Stock	Correlation Coefficient
GB cod	0.29
GOM cod	0.41
GB yellowtail flounder	0.66
SNE/MA yellowtail flounder	0.83
CC/GOM yellowtail flounder	0.31
GB haddock	0.56
GOM haddock	0.54
GB winter flounder	0.17
GOM winter flounder	0.44
SNE/MA winter flounder	0.40
GB/GOM white hake	0.54
Witch flounder	0.67
GB/GOM American plaice	0.84
Acadian redfish	0.52

Table 3. Comparison of 2007 Relative Fishing Mortality from GARM III and ASPIC Results. The Asterisk "*" Refers to the Stock that at Least One Parameter Estimate is at or Near a Constraint in the Implementation of ASPIC; therefore, the Solution may be Trivial. Also see Fig. (3) for the Comparison

Stock	GARM III $F_{2007}/F_{40\%}$	ASPIC F/F_{MSY}		
		Alternative A Fall Survey Only	Alternative B Spring Survey Only	Alternative C Fall and Spring Survey
GB cod	1.20	0.982	0.789	0.874
GOM cod	1.90	0.313	0.261	0.334
GB yellowtail flounder	1.16	0.070	0.085	0.092
SNE/MA yellowtail flounder	1.65	0.250*	3.888*	0.349*
CC/GOM yellowtail flounder	1.73	0.143	0.147	0.159
GB haddock	0.66	0.615	1.438	0.048*
GOM haddock	0.81	0.208	0.018*	0.189
GB winter flounder	1.08	0.169	2.144	0.756
GOM winter flounder	1.49	0.083	0.261	0.114
SNE/MA winter flounder	2.60	0.111	0.861	0.225
GB/GOM white hake	1.15	1.276*	0.379	0.633
Witch flounder	1.45	0.845	0.591	0.583
GB/GOM American plaice	0.47	0.272	0.341	0.373
Acadian redfish	0.18	0.076	0.094	0.080

Comparisons of fishing mortalities estimated in GARM III and ASPIC are displayed in (Table **3**). Proxy ratios for GARM III are generally greater than 1, whereas ratios for the ASPIC calculations are generally less than 1. Put another way, according to the GARM III proxy calculations, the stocks were generally subject to overfishing, whereas according to the ASPIC calculations, the stocks are subject to underfishing.

Comparisons of biomass reflect another major contrast (Table **4**). Under the proxy the biomass of the stocks is much less than 0.5, whereas under ASPIC calculations biomasses are generally greater than 0.5. Thus according to the GARM III proxy calculations the stocks are overfished, whereas according to the ASPIC calculations the stocks are underfished.

As an illustrative example, Fig. (**2**) compares the relative fishing mortality and relative total stock biomass time series by ASPIC and from GARM III for stocks of GB cod, and GB yellowtail flounder.

Fig. (**3**) summarizes these observations, which show that the calculations that the GARM III and the ASPIC calculations that purport to estimate the same parameter values produce substantially different views of the status of the stocks.

Table 4. Comparison of 2007 Relative Total Stock Biomass from GARM III and ASPIC Results. The Asterisk "*" Refers to the Stock that at Least one Parameter Estimate is at or Near a Constraint in the Implementation of ASPIC; therefore, the Solution may be Trivial. The Red Fish from GARM III is not Listed as its Biomass Time Series was not Available

Stock	GARM III $B_{2007}/B_{40\%}$	ASPIC B/B_{MSY}		
		Alternative A Fall Survey Only	Alternative B Spring Survey Only	Alternative C Fall and Spring Survey
GB cod	0.11	0.546	0.347	0.451
GOM cod	0.53	1.642	1.716	1.610
GB yellowtail flounder	0.18	1.821	1.800	1.788
SNE/MA yellowtail flounder	0.09	0.030*	0.189*	0.025*
CC/GOM yellowtail flounder	0.19	1.699	1.689	1.680
GB haddock	1.65	1.255	0.626	1.965*
GOM haddock	1.02	1.766	1.983*	1.807
GB winter flounder	0.33	1.684	0.029	0.236
GOM winter flounder	0.26	1.869	1.119	1.755
SNE/MA winter flounder	0.07	1.873	0.188	1.380
GB/GOM white hake	0.36	0.078*	0.661	0.471
Witch flounder	0.33	0.243	0.269	0.407
GB/GOM American plaice	0.72	1.077	0.250	0.156
Acadian redfish	-	1.106	0.906	1.121

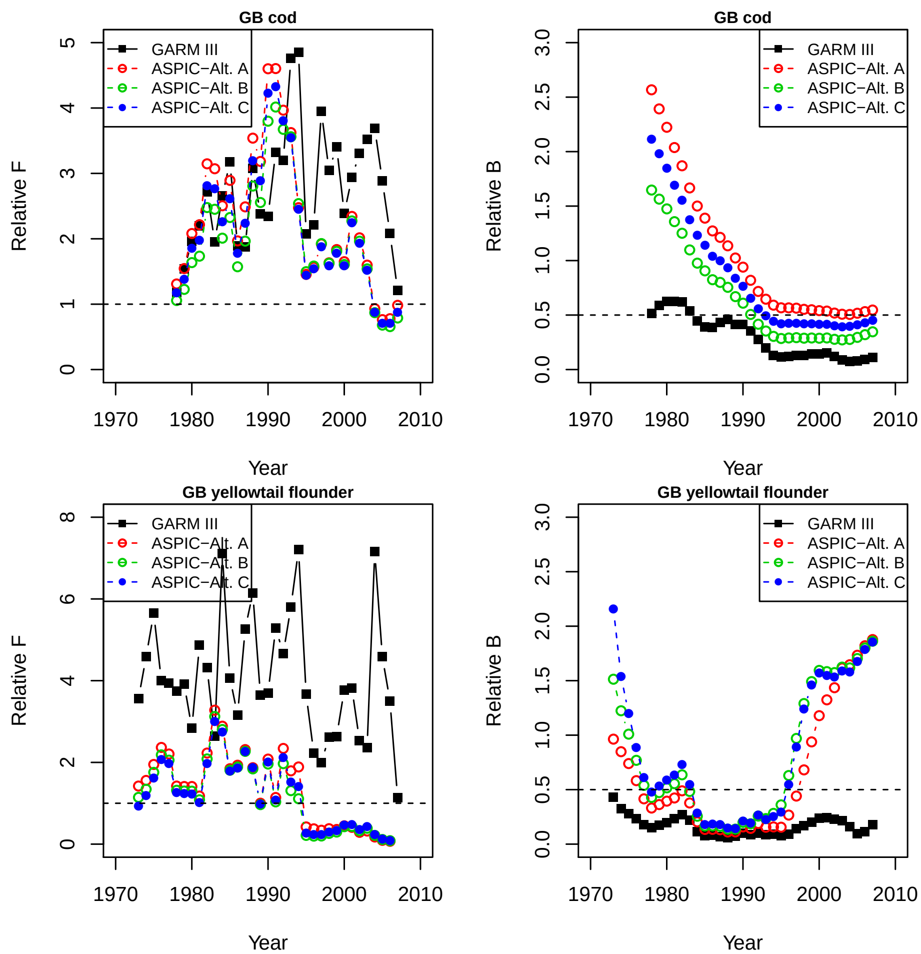

Fig. (2). Comparison of relative fishing mortality and relative total stock biomass time series by ASPIC and from GARM III. If the relative F is greater than 1 (dashed horizontal line), the stocks are subject to overfishing. If the relative B is less than 0.5 (dashed horizontal line), the stocks are overfished.

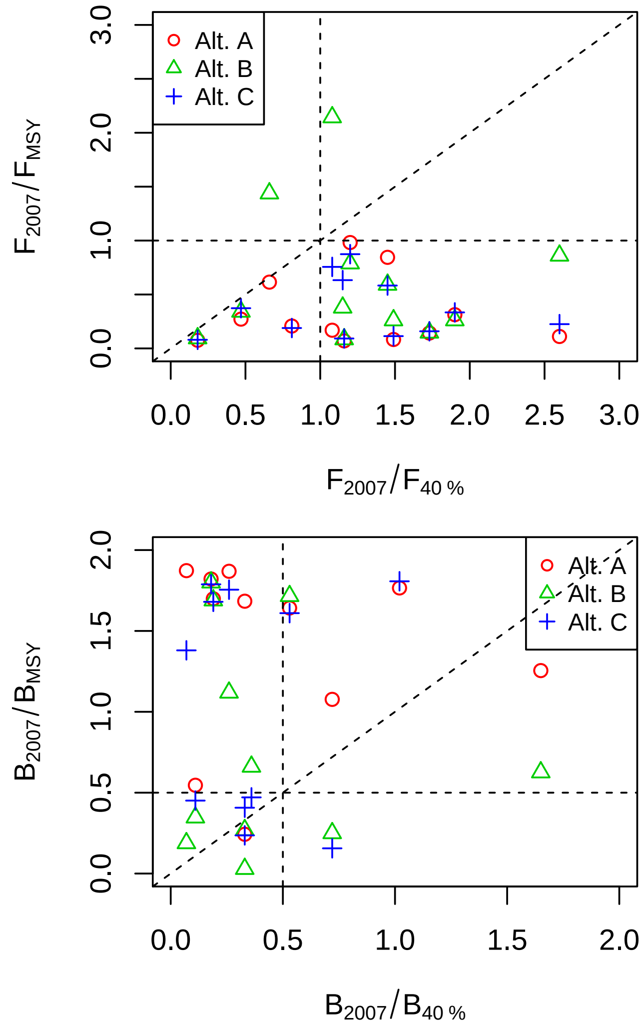

Fig. (3). Comparison of 2007 relative fishing mortality in top panel and total stock biomass in bottom panel derived from ASPIC and from GARM III. The relative value of F_{2007}/F_{MSY} and B_{2007}/B_{MSY} are from ASPIC by three alternatives, $F_{2007}/F_{40\%}$ and $B_{2007}/B_{40\%}$ are from GARM III. SNE/MA yellowtail flounder of all three alternatives, white hake of alternative A, GOM haddock of alternative B, and GB haddock of alternative C are not included due to ASPIC warning message.

DISCUSSION

If we follow the mandate of the MSA and choose F_{MSY} and B_{MSY} as the biological reference points rather than a proxy for F_{MSY} and B_{MSY}, then contrary to GARM III results, most stocks are underfished and not subject to overfishing. On the other hand, if the GARM III proxies for F_{MSY} and B_{MSY} continue to be used, then most stocks will continue to be considered as overfished and subject to overfishing (Table **5**).

Clearly, the proxy and the ASPIC approaches do not yield the same results. The key question is: which approach is better, the ASPIC calculation or the proxy calculation?

An answer to this question will ultimately involve in-depth studies that are beyond the scope of this paper. However, it is important to take account of the fact that the task of comparing alternative scientific approaches or alternative models has a well-known and straightforward structure. Given two alternative models, the model that estimates the least number of parameters and has the smallest variance, *inter alia*, has more explanatory power than a model with more parameters and greater variance.

The ASPIC approach, in fact, involves many fewer parameters than the proxy approach. Accordingly, on this basis, all other things being equal, the ASPIC approach, with many fewer parameters, would be chosen, consistent with best scientific practices (e.g., Ockham's razor) and modern statistical theory (e.g., Akaike's information criterion), over the proxy approach.

But variance also needs to be considered. One might argue, "the ASPIC approach might be favored because it estimates fewer parameters, but the proxy approach is better than the ASPIC approach because the variance associated with the proxy approach is much smaller than the variance associated with the ASPIC approach." There is no evidence for such an assertion. It is true that the r^2 are seemingly small in the ASPIC approach, but it is not clear that r^2 (or some other figure of merit) associated with the proxy approach are larger than the ASPIC r^2. Speaking intuitively, the many complex estimation schemes that comprise the proxy approach imply a much larger variance (how does one assess the variance of stock and recruitment, age-length keys, or VPA calculations, just to cite a few examples) and smaller r^2.

Table 5. Summary of 2007 Stock Status from GARM III and ASPIC results. In GARM III, the Stock is Overfished if SSB <½ SSB_{MSY}, and Overfishing if F > F_{MSY}. Accordingly, for the ASPIC Approach, we Define that the Stock is Overfished if B < ½B_{MSY}, and Overfishing if F > F_{MSY}. The Symbol "—" Indicates not Overfished, or not Overfishing; the Symbol "X" Indicates Overfished, or Overfishing. The Asterisk "*" Refers to the Stock that at Least one Parameter Estimate is at or Near a Constraint in the Implementation of ASPIC; therefore, the Stock Status is not Assessed. In GARM III, Among the 14 Stocks Analyzed (Which Applied $F_{40\%}$ Proxy), 12 Stocks Were Estimate by VPA Model

Stock	GARM III Stock Status		Alternative A Fall Survey Only		Alternative B Spring Survey Only		Alternative C Fall and Spring Survey	
	Overfished	Overfishing	Overfished	Overfishing	Overfished	Overfishing	Overfished	Overfishing
GB cod	X	X	—	—	X	—	X	—
GOM cod	—	X	—	—	—	—	—	—
GB yellowtail flounder	X	X	—	—	—	—	—	—
SNE/MA yellowtail flounder	X	X	*	*	*	*	*	*
CC/GOM yellowtail flounder	X	X	—	—	—	—	—	—
GB haddock	—	—	—	—	—	X	*	*
GOM haddock	—	—	—	—	*	*	—	—
GB winter flounder	X	X	—	—	X	X	X	—
GOM winter flounder	X	X	—	—	—	—	—	—
SNE/MA winter flounder	X	X	—	—	X	—	—	—
GB/GOM white hake	X	X	*	*	—	—	X	—
Witch flounder	X	X	X	—	X	—	X	—
GB/GOM American plaice	—	—	—	—	X	—	X	—
Acadian redfish	—	—	—	—	—	—	—	—

Criticism of the ASPIC analysis is of course warranted, but because the ASPIC approach and its underlying production model are well defined in the literature, these criticisms are well-known. Referring specifically to the analysis presented here, the relatively low r^2 are particularly striking (Table **1**). The most important point is not the low values of r^2, but how the ASPIC r^2 compares to the proxy r^2; and, as mentioned, the statistical error associated with the proxy approach taken in its totality has not been evaluated.

To put this into clearer perspective, while it may be possible to measure the uncertainty in *some* of the many "blocks" (e.g., growth, mortality) of the proxy calculation, it is difficult to combine all of them, particularly taking into account many covariances into a single measure of merit. For example, it is important to recognize that the fall survey and spring survey measure different aspects of the fish population. This is because kg per tow is used as a measure of relative abundance while numbers per tow is ignored. Yet number per tow can be more relevant from a population dynamics point of view than kg per tow.

Examining the general aspects of model choice involving the tradeoff between the number of estimated parameters and variance leads to focus on the many assumptions, assertions, and choices (AACs) [8] made in the proxy approach that are not made in the simpler ASPIC approach. These are exemplified by 1) stock and recruitment, 2) setting X in the MSP approach used in the proxy approach, 3) the equilibrium setting required by the proxy approach, 4) retrospective patterns, 5) and method of averaging fishing mortality.

Stock and Recruitment

As implied above, there are many parameter estimates required in the proxy approach that are not required in the ASPIC approach. A particularly important set of parameters required by the proxy, but not by ASPIC, is the parameters associated with stock and recruitment. In fact, Clark [5, 6] noted in his discussion of the $F_{x\%}$ reference point that these reference points are the most sensitive to stock-and-recruitment estimates. Yet stock and recruitment is perhaps the least known, least understood aspect of fishery science.

Setting x

As implied in this paper, x is often set at 35-40%. We have pointed out that arbitrarily setting the value of x and choosing M creates an arbitrary choice of overfishing [7]. Our more recent analysis [10] sheds more light on this subject. As is well known, the choice of x strongly influences the overfishing reference point. At the same time, the shape of the stock-recruitment function influences x. We used Shepherd's [16] parameterization that defines β as the curvature of the stock-recruitment curve. In a case study of GOM cod, we found β=2.25, implying on the basis of these data alone that there is substantial underfishing of GOM cod (Fig. **4**).

Equilibrium

An important contrast between the two approaches is that the proxy approach is based on the populations being in equilibrium. In a detailed analysis, Rothschild and Jiao [7] have shown that a mathematical solution using the proxy

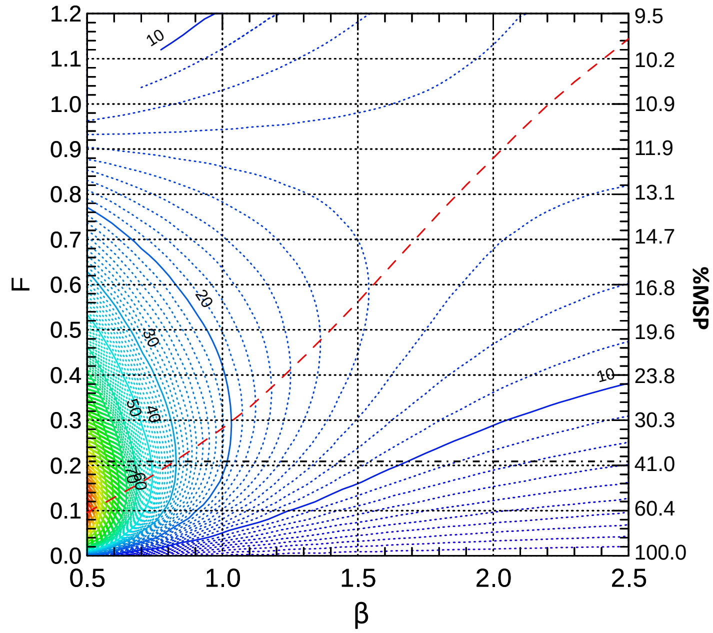

Fig. (4). Yield versus β and F (%MSP) contour plot for the parameters of $\alpha = 0.90$, $K = 17.72$ for GOM cod-like fish stock. The horizontal dotted-dashed line indicates 40%MSP. The dashed line represents the locus of maximum yield. In the simulation, the step of β is 0.1, the step of F is 0.02. The point estimates of Shepherd stock-recruitment [16] parameters on GOM cod stock-recruit data [11] are $\alpha = 0.90$, $K = 17.72$, and $\beta = 2.26$.

approach for populations not in equilibrium does not exist. In contrast, the use of Prager's method in ASPIC explicitly allows for populations to not be in equilibrium. In other words, based on this observation alone and the fact that real populations do not even seem to be at equilibrium, the proxy approach seems biased.

Fogarty *et al.* [17] developed surplus production models for 12 demersal species in GOM at the single species and aggregate species levels. They claimed that their results are similar to those from GARM III. However, it is difficult to compare their results with ours. A major point in this regard is that they actually estimated MSY, F_{MSY}, and B_{MSY}, while we estimated the ratios of B/B_{MSY} and F/F_{MSY} so that we can directly compare the stock status of ours with that of GARM III. The input data is different. We used catch and research vessel survey (kg/tow) data. Fogarty *et al.* [17] used landing and only fall survey data adjusted with an estimate of catchability. Our results related to SSB in order to be comparable with the GARM III, but Fogarty *et al.* [17] presented results in terms of total stock biomass.

Retrospective Patterns

Retrospective patterns appear to be commonplace in the groundfish stock assessments. As far as we know, they only occur in the proxy calculations, not the MSY calculations [see, e.g., 18].

Averaging Fishing Mortality

The ASPIC approach does not require estimates of fishing mortality. In the proxy approach fishing mortality is required. However, calculations of fishing mortality yield a value of fishing mortality for each age and year. In order to summarize the fishing mortalities, fully recruited fishing mortality is used. However, this way of computing fishing mortality ignores the often substantial fishing mortality on pre-recruits. This is source of potential error in the proxy approach.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

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