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Working Paper 4.1
April 26, 2008

Overview of Current Biological Reference Point Methods and Estimates for Multispecies Groundfish in the Northeast US

by

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A Working Paper in Support of GARM Reference Points Meeting Term of Reference 4a

> "For each stock, list what the current BRPs and/or BRP Proxies are (e.g., B_{MSY}, B_{MAX}, F_{MSY}, $F_{40\%MSP}$, historical catch per tow, etc.) and give their values (i.e., typically from GARM II)."

GARM 2008 Reference Points Meeting
Woods Hole, MA
28 April – 2 May

Introduction

The definition of Biological Reference Points (BRP) for fish stock is an essential component of stock assessment. Measures of abundance and harvest rates derived from assessment models are compared to standards that constitute desirable states for each stock. These states are based on the concept of maximum sustainable yield. When sufficient information is available, BRPs can be based on fishing mortality and biomass values that produce maximum sustainable yield. In other instances, the BRPs are based on a proxy value that should approximate the fishing morality rates and biomass levels associated with maximum sustainable yield. Biological reference points are also important for the derivation of rebuilding strategies. In general, rebuilding strategies are designed to achieve target biomass values within a finite rebuilding period.

Background

This Working Paper provides a summary of the current BRPs for the 19 GARM stocks and some background on their basis. Biological Reference Points for the GARM stocks were first treated as a group in the report of the Overfishing Definition Review Panel (Applegate et al. 1998). Their report relied heavily on the application of surplus production models to derive B_{MSY} and F_{MSY} levels for 42 stocks. MSY was estimable for 20 stocks; proxy values were assigned to 19 of the 22 remaining stocks. No BRP recommendations were made for Gulf of Maine winter flounder, southern red hake, and offshore hake. The Applegate et al. (1998) report was a valuable synthesis of available information and the use of a common modeling approach allowed for commensurate comparisons of BRPs across stocks. However, the BRPs did not necessarily comport with the estimates of spawning stock biomass or full F derived from the stock assessment models. For example, surplus production models estimate BRPs in terms of total biomass and biomass-weighted F. VPA models use information on age composition and maturity to estimate spawning stock biomass and age-specific fishing mortality rates. The exploitation history of the GARM stocks imposes another constraint on the generality of BRPs derived from surplus production models. Since many of these stocks have been fished for centuries, inferences based on catches in the last 30-40 years could be unnecessarily restrictive. Specifically, biomass targets may underestimate the true biological potential of the stock when much higher historical landings are excluded from the analysis.

The need to develop BRPs that were consistent with the estimates derived from more complicated models led to the convening of the Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish. (2002). The 19 stocks fell broadly into three groups. In the first group had sufficient information to allow development of a parametric stock-recruitment relationship. AIC criterion favored a Beverton Holt model for these stocks. When a parametric model was not estimable a non-parametric method was applied to the other age-based stocks. The non-parametric method relies on the distribution of empirical estimates of recruits and static estimates biomass per recruit under different fishing mortality rates (eg. F_{MAX} or $F_{\%MSP}$).

A third group of stocks proved resistant to application of surplus production models and an empirical index method was developed. This approach used catch and survey data to derive measures of relative F and measures of population growth rate. The essential feature of this approach is to estimate a relative F associated with a static estimate of population growth rate, or F at population replacement. Relative Fs greater than the replacement Fs led to decreases in population size and increases for Fs below the replacement F. The approach assumes linear population growth and is applicable only for stocks well below carrying capacity. This latter criterion was thought to be applicable to many of GARM stocks.

The biological reference points derived from the Working Group were first used in GARM I (NEFSC 2002) and subsequently at GARM II (Mayo and Terceiro, 2005).

Taxonomy of BRP Estimators

Biological reference points can be derived as part of the model identification and estimation process. For lack of a better term, these can be called internal estimates of BRPs as they rely on specification of stock recruitment relationship or a production function within the assessment model. BRP estimates derived from surplus production models are a simple example; internal estimation of a stock-recruitment relationship within an age- or size-structured model is a more complex example. The derived parameters can either be used to directly define reference points or, where analytical solutions are more complicated, to parameterize simulation or forecasting models to derive BRPs and measures of uncertainty. Internal estimates are advantageous since they incorporate the full uncertainty of the model estimation and potentially, covariances among parameters as part of the uncertainty in reference points. This can also be a disadvantage when the model does not fit particularly well. In these cases, the BRPs can be unstable, varying with minor changes in model configuration.

"External" estimators of BRPs use model outputs of abundance, SSB, recruits and fishing mortality as inputs to stand alone models. In the Northeast these include stock recruitment models (SRFIT), yield per recruit models (YPR), and stochastic population projection models (AGEPRO). The SRFIT program, based on the publication of Brodziak and Legault (2005), uses AIC methods to identify appropriate models from either Beverton-Holt or Ricker stock-recruitment models with and without correlated error terms. When an acceptable model can be defined, standard approaches can be used to estimate Fmsy and Bmsy values.

If none of the parametric models are acceptable, a nonparametric method is used to estimate proxy values for Fmsy and Bmsy. These proxies are derived by combining standard yield per recruit (YPR) and SSB per recruit (SSB/R) methods with model-based estimates of absolute recruitment. Model parameters can be used to define appropriate partial recruitment vectors for YPR analyses leading to estimates of Fmax. Fmax serves as a proxy for Fmsy. SSB/R estimates for F=Fmax can be multiplied by some function of the recruitment time series to obtain an estimate of SSBmsy or Bmsy. The term "some function" can imply a simple mean of the recruitment series or other measure of central tendency. Under some circumstances, there may be justification to restrict the function of recruitment to a more recent stanza associated with something like changing environmental conditions. Another important consideration in the estimation of reference points is the selection of average weights at age. These have important consequences for the F associated with maximum yield and for biomass targets. Often the choice of the appropriate stanzas are influenced but not determined by the estimation model outputs. Consideration of ecosystem conditions, trends in other populations or evidence of environmental trends can be relevant.

Index methods constitute another general approach to estimation of reference points. For the GARM stocks this approach is formalized as the AIM model in the NOAA Fisheries Toolbox. As noted above, this empirical approach finds a reference point for relative F where the population replaces itself. The model provides estimates of the finite rate of population increase and the survey q, but in this context these are nuisance parameters useful only in the context of deriving an estimate of relative F at replacement. A major limitation of the AIM model is that the relative biomass target must be externally supplied. Often this is done by considering the time series of relative abundance and deriving a "reasonable" target value based on a high percentile of the historical index values. The indeterminancy of the target biomass is often the reflection of an uninformative exploitation history (e.g. the one-way trip). This is of course precisely the reason why results of surplus production models can be unreliable.

For a number of stocks even the index methods fail to provide precise quantitative guidance. For these stocks proxy reference points were deduced by examining historical landings, relevant aspects of the fisheries, and behavior of surveys.

Summary

The conceptual bases of the biological reference points for each stock are summarized in Table 1. The range of approaches reflects the range of available data types and quantity, and historical exploitation patterns. Additional details on the estimation methods may be found in the references. The derived numeric values of the reference points are presented in Table 2.

Information necessary to update these tables may be found in Working Papers 4A to 4S.

Table 1. Summary of estimation methods for current Biological Reference Points for 19 GARM stocks.

SPECIES	STOCK	Modeling				
		Assessment Model	**Data Used**	**Stock-Recruitment Model**	**Basis for Biomass target**	**Basis for Fishing Mortality Threshold**
COD	GB	VPA	1978-2000	Parametric	Bev-Holt SSB_{MSY}	Bev-Holt F_{MSY}
	GOM	VPA	1982-2000	Parametric	Bev-Holt SSB_{MSY}	Bev-Holt F_{MSY}
HADDOCK	GB	VPA	1931-2000 w/o 1963 YC	Nonparametric	SSB/R ($F_{40\%MSP}$) * Ave (R)	F 40%MSP
	GOM	Index	1963-2000	Equilibrium Point	External: Fall Survey MSY(5100mt)/ $relF_{replace}$(0.23)	Relative F at Replacement
YELLOWTAIL FLOUNDER	GB	VPA	1973-2000, 1963-1972 Hindcast	Nonparametric	SSB/R ($F_{40\%MSP}$) * Ave (R| SSB>5000mt)	F 40%MSP
	SNE/MA	VPA	1973-2000, 1963-1972 Hindcast	Nonparametric	SSB/R ($F_{40\%MSP}$) * Ave (R| all years)	F 40%MSP
	CC/GOM,	VPA	1985-2002	Nonparametric	SSB/R ($F_{40\%MSP}$) * Ave (R| all years)	F 40%MSP
AMERICAN PLAICE		VPA	1980-2000	Nonparametric	SSB/R ($F_{40\%MSP}$) * Ave (R| all years)	F 40%MSP
WITCH FLOUNDER (SARC 37, 2003)		VPA	1982-2002	Nonparametric	SSB/R ($F_{40\%MSP}$) * Ave (R| all years)	F 40%MSP
WINTER FLOUNDER	GB	ASPIC	1963-2000	NA	Surplus Production B_{MSY}	Surplus Production F_{MSY}
	GOM	VPA	1982-2002	Parametric	Bev-Holt SSB_{MSY}	Bev-Holt F_{MSY}
	SNE/MA	VPA	1982-1998	Parametric	Bev-Holt SSB_{MSY}	Bev-Holt F_{MSY}
REDFISH		SCAA	1952-1999	Nonparametric (mean, upper Q)	SSB/R ($F_{50\%MSP}$) * Ave (R| SSB>75%ile of SSB)	F50%MSP

WHITE HAKE[2] (>60 cm)		ASPIC and AIM	1964-2000	Equilibrium Point	Surplus Production, B_{MSY}	Relative F at Replacement
POLLOCK		Index: AIM	1963-2000	Equilibrium Point	External: Fall Survey	Relative F at Replacement
WINDOWPANE FLOUNDER	North	Index	1963-2000	Equilibrium Point	External: Fall Survey	Relative F when I>0.94 kg/tow; MSY from ASPIC
	South	Index	1963-2000	Equilibrium Point	External: Fall Survey, MSY/relF at replacement	Relative F at Replacement; MSY by inspection 900 mt
OCEAN POUT		Index	1968-2000	Equilibrium Point	External: Spring Survey median 1980-1991	Relative F at Replacement; MSY by inspection 1500 mt; proxy Fmsy=MSY/median Index
ATLANTIC HALIBUT		Landings	1893-1997	NA	Externally defined: MSY/F0.1	Proxy F 0.1 MSY (300mt) by inspection

Table 2 – Amendment 13 numerical estimates of status determination criteria. (from Amendment 16 draft management measures)

SPECIES	STOCK	NUMERICAL ESTIMATE OF STATUS DETERMINATION CRITERIA				
		B_{TARGET} (metric tons or NEFSC survey index)	$B_{THRESHOLD}$ (metric tons or NEFSC survey index)	F_{MSY} **(Maximum fishing mortality) (5)**	**Ftarget (at biomass target) (5)**	**MSY** (metric tons)
COD	GB	216,800	108,400	0.18	0.14	35,200
	GOM	82,800	41,400	0.23	0.17	16,600
HADDOCK	GB	250,300	125,150	0.26	.20	52,900
	GOM	22.17 kg/tow	11.09 kg/tow	0.23C/I	0.17 C/I	5,100
YELLOWTAIL FLOUNDER	GB	58,800	29,400	0.25	0.19	12,900
	SNE/MA	69,500	34,750	0.26	0.20	14,200
	CC/GOM	12,600	6,300	0.17	0.13	2,300
AMERICAN PLAICE		28,600	14,300	0.17	0.13	4,900
WITCH FLOUNDER		25,240	12,620	0.23	0.17	4,375
WINTER FLOUNDER	GB	9,400(1)	4,700	0.32	0.24	3,000
	GOM	4,100	2,050	0.43	0.32	1,500
	SNE/MA	30,100	15,050	0.32	0.24	10,600
REDFISH		236,700	118,350	0.04	0.03	8,200
WHITE HAKE[2] ***top row ASPIC bottom row index method***		14,700(2) 7.70 kg/tow	7,350 3.35 kg/tow	0.29 0.55 C/I	0.22 0.41 C/I	4,200
POLLOCK		3.0 kg/tow	1.5 kg/tow	5.88 C/I	4.41 C/I	17,600
WINDOWPANE FLOUNDER	North	0.94 kg/tow	0.47 kg/tow	1.11 C/I	0.83	1,000
	South	0.92 kg/tow	0.46 kg/tow	0.31 C/I	0.23 C/I	900
OCEAN POUT		4.9 kg/tow	2.95 kg/tow	0.31 C/I	0.23 C/I	1,500
ATLANTIC HALIBUT		5,400(1)	2,700	0.06	0.4	300

1. Total biomass, metric tons
2. Unit is total stock biomass for fish >= 60 cm., mt
3. Unit is biomass weighted F
4. Survey based equivalents developed by GARM 2002
5. C/I refers to Index-based method (Catch/Index)

References:

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Amendment 16 to the Northeast Multispecies Fishery Management Plan (FMP)
Draft Management Measures
April 2, 2008

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Software and documentation associated with all of the methods used in this report may be found in the NOAA Fisheries Toolbox Version 3.0. http://nft.nefsc.noaa.gov/