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A PA-compliant Rebuilding Plan for Subarea 2 + Divisions 3KLMNO Greenland Halibut
Based on the 2005 NAFO Assessment
By

Peter A. Shelton

Northwest Atlantic Fisheries Center, Department of Fisheries and Oceans
PO Box 5667, St John's, NL, CANADA A1C 5X1

Abstract

In September 2003 NAFO Fisheries Commission put in place a 15 year rebuilding plan for NAFO Subarea 2 + Divisions 3KLMNO Greenland halibut involving a step-wise reduction in TAC commencing in 2004. Previous analysis has shown that the FC rebuilding plan is not robust to uncertainty in the strength of recent year classes or to the assessment approach that is taken, and is unlikely to be successful. NAFO has yet to implement the Precautionary Approach on any fish stock. The FC rebuilding plan is considerably less cautious than one which would be specified under a Precautionary Approach and is thus inconsistent with The United Nations Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of December 10, 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks. Current fishing mortality on this stock is estimated to be more than 3xF_{max}. To be compliant with the Precautionary Approach fishing mortality should be immediately reduced to below $F_{0.1}$. A PA-compliant variable F rebuilding plan is described in which fishing mortality is initially set at 0.5x$F_{0.1}$, but increases as the stock rebuilds.

Introduction

Although a so-called "rebuilding plan" was developed for Subarea 2 + Div. 3KLMNO Greenland halibut by NAFO Fisheries Commission in September 2003 for implementation starting in 2004, this plan did not have a peer-reviewed scientific basis and subsequent analysis has shown that it is not robust to the assessment method or to uncertainty in future recruitment, and is unlikely to be successful (Shelton, 2005). The 2004 TAC overrun has exacerbated the overfishing of this stock, but should not be considered as the primary cause for the failure of the rebuilding plan. The plan was fundamentally flawed from the start because the step-wise TAC reductions that are specified cause F to increase and the biomass of older fish in to decrease over the period for which population estimates are available. Subsequent projected rebuilding based on optimistic recruitment generated from very low biomass should not be considered a good basis for a rebuilding strategy.

Under the FC rebuilding plan, projections carried out it in September 2003 indicated that average F on ages 5-10 would rise as high as 0.7 in the medium term. This has in fact occurred (average F on ages 5-10 is 0.71 for 2004 in the 2005 assessment). $F_{0.1}$ for this stock has been estimated at 0.14 and F_{max} at 0.24 (Healey and Mahé, 2005). Current F is thus more than 3xF_{max}. Before the collapse of a number of groundfish stocks in the Northwest Atlantic, both Canada and NAFO subscribed to $F_{0.1}$ as a useful target fishing mortality for a stock which would now be considered to be in the "Safe Zone" under the NAFO PA Framework. Further, there is precedent within NAFO for setting TACs consistent with an $F< F_{0.1}$ to promote stock rebuilding when the stock is in what would now be called the "Cautionary F Zone" (e.g. F=0.8x $F_{0.1}$ on Div. 2J+3KL cod between 1978 and 1983; Shelton, 1998). It is suggested here that the F on Subarea 2 + Div. 3KLMNO Greenland halibut should be reduced 0.5x $F_{0.1}$ or less for the 2006 fishing season in accordance with general principles of the Precautionary Approach and the United Nations

Fisheries Agreement on Straddling Stocks. This would be consistent with the current extremely low stock size and high F, a situation which undoubtedly places the stock in or near the "Collapse Zone" of the recently adopted (but not yet implemented) NAFO PA Framework. Unless immediate conservation steps are taken it would seem highly likely that this fishery would, in only a few years, join a number of other NAFO managed Grand Banks groundfish stocks in being relegated to by-catch fishery status.

Even by-catch status does not ensure recovery once a stock is depleted to very low levels because of the "by-catch trap" into which commercially valuable species fall (Shelton and Morgan, 2005). As examples, two collapsed stocks for which there are no directed fisheries, Div. 3LNO American plaice and 3NO cod, currently have average (2002-2004) $F > F_{0.1}$ and $F > F_{max}$, respectively. Simulation studies indicate that unless by-catch mortality is substantially reduced, neither of these two stocks will reach their respective B_{lim} levels by 2020 (Shelton and Morgan, 2005).

The FC rebuilding plan specified arbitrary TAC reduction steps to promote rebuilding. This plan is not working and projections that it will work in the future are optimistic. What is needed is an immediate reduction in fishing mortality to below $F_{0.1}$, at least for the medium term. In this analysis *I* use the projection framework from the 2005 NAFO assessment (Healey and Mahé, 2005) to explore a number of F reduction scenarios through stochastic simulation to 2020. An "F_{vary}" strategy is presented for consideration which, although possibly not as precautionary as that which would properly be implemented under the PA and the United Nations Fisheries Agreement on Straddling Stocks, it is at least a move towards the approach outlined in the PA Framework that has been adopted by NAFO, and much more conservation-minded and risk-averse than the current FC rebuilding plan. This implementation requires the use of some reference points which are defined below.

Proposed PA reference points for Greenland halibut

Subarea 2 + Div. 3KLMNO Greenland halibut was considered as a case study in the 2004 Lorient WS on LRPs (Anon., 2004). It is an unusual stock in that there is a reasonably good analytical assessment, but considerable uncertainty about production functions which, at this stage, is considered to preclude the use of S-R or production model based reference point determination. It should be noted that the notion that most of the recruitment comes from outside the stock area, possibly from stocks in areas 0 and 1 in the north, is inconsistent with is generally known biologically about the establishment and maintenance of populations. Other methods of deriving reference points such as SPR (spawner per recruit) are also considered problematical given the current difficulty in defining spawner biomass for this stock. This is somewhat incongruous since an age 14+ estimate is available within which the mature age-classes presumably fall. The trajectory of 5+ biomass, average fishing mortality on ages 5-10 and yield-per-recruit analysis probably provide the best basis for deriving limit and buffer reference points at the present time, given the inability to form an opinion on recruitment and spawner stock size in the assessments. It is proposed here to define B_{lim} as $B_{recovery}$ = 5+ biomass in 1997 (about 80 000 tons). This is the biomass from which the stock has previously sustained a rapid recovery. Further, it is proposed to define $F_{lim} = F_{max}$ which is computed to be 0.24 based on average weights and partial recruitment for the past 3 years. This can be considered a proxy for F_{msy}. Lastly, it is proposed that F_{buf} or F_{target} bet set at $F_{0.1}$ which is estimate to be 0.14. The PA-compliant rebuilding plan put forward here, termed "F_{vary}" comprises the following harvest control rules: $F = 0.5\text{x}\ F_{0.1}$ when $B \leq B_{lim}$, $F = 0.8\text{x}\ F_{0.1}$ when $B_{lim} < B \leq B_{msy}$ and $F = F_{0.1}$ when $B > B_{msy}$. A proxy for B_{msy} is considered to be the FC rebuilding target: 5+ biomass corresponding to a relatively stable period of reasonably high catches (about 140 000 tons).

Methods

I use the projection inputs as summarized in Table 7a of the 2005 assessment (Healey and Mahé, 2005; my Table 1). The variability in the projection parameters are described by the coefficients of variation (column CV in the table). Numbers at age 2 and older at 1st of January 2005 and corresponding CVs are computed from the XSA output. These distributions are assumed to be lognormal. Recruitment is bootstrapped with replacement from the 1975-2001 age 1 numbers from the XSA. Note that this may be optimistic since year-classes have been relatively small since 1997 and by 2005 the biomass of older fish had reached a very low level. Scaled selection pattern and corresponding CVs are derived from the 2002 to 2004 average from the XSA. Weights at age in the stock and in the catch and corresponding CVs are computed from the 2002-2004 average input data. Natural mortality was assumed to be 0.2 with a CV of 0.15. Note that all distributions are assumed to be normal, in accordance with the 2005 assessment stochastic projections, except for the lognormal distribution applied to survivors. Co-variance is not taken into account. Unlike the 2005 assessment projections, no uncertainty is included in the implementation of the fishing mortality rule. It is assumed that the uncertainty in natural mortality, weights and selectivity represent uncertainty regarding the true value rather than estimation or process error. Thus these inputs are drawn randomly from the described distributions once for each replicate and then held fixed at this random value for a 15 year projection period (i.e. to 2020). The only input varying from year to year within a replicate is the recruitment. It is not clear whether this is the same approach adopted in the stochastic simulation results presented in the 2005 assessment by Healey and Mahé (2005). 1000 replicates are drawn randomly from these distributions and data on 5+ biomass and catch are collected for the period 2005 to 2020 under the following F levels or harvests control rules: $F = 0.5\text{x } F_{0.1}$, $F = 0.8\text{x } F_{0.1}$, $F = 0.1$, $F = F_{max}$, $F{=}F_{current}$ and F_{vary} which is defined as: $F = 0.5\text{x } F_{0.1}$ when $B \leq B_{lim}$, $F = 0.8\text{x } F_{0.1}$ when $B_{lim} < B \leq B_{msy}$ and $F = F_{0.1}$ when $B > B_{msy}$. Summary performance statistics in terms of biomass and catch are provided at 5, 10 and 15 year intervals.

TABLE 1. Stochastic projection inputs to evaluate PA-compliant rebuilding options for the Div. 2+3KLMNO Greenland halibut stock (from Table 7a in Healey and Mahé, 2005).

Name	Value	Uncertainty (CV)	Name	Value	Incertainty (CV)
Population at age in 2005			Selection pattern		(2002-2004)
N1	Bootstrap (1975-2001)		sH1	0.000	0.00
N2	68365	0.30	sH2	0.000	0.00
N3	70529	0.23	sH3	0.000	0.00
N4	55719	0.19	sH4	0.033	0.27
N5	41621	0.15	sH5	0.175	0.48
N6	29650	0.14	sH6	0.655	0.31
N7	10289	0.13	sH7	1.862	0.10
N8	2896	0.17	sH8	1.643	0.08
N9	1764	0.20	sH9	0.925	0.13
N10	1558	0.20	sH10	0.740	0.24
N11	927	0.20	sH11	0.777	0.26
N12	415	0.20	sH12	0.856	0.38
N13	253	0.20	sH13	0.807	0.26
N14	245	0.22	sH14	0.807	0.260
Weight in the catch (2002-2004)			Weight in the stock		(2002-2004)
WH1	0.000	0.00	WS1	0.000	0.00
WH2	0.000	0.00	WS2	0.000	0.00
WH3	0.195	0.10	WS3	0.000	0.00
WH4	0.249	0.01	WS4	0.000	0.00
WH5	0.378	0.03	WS5	0.378	0.03
WH6	0.552	0.03	WS6	0.552	0.03
WH7	0.823	0.02	WS7	0.823	0.02
WH8	1.196	0.00	WS8	1.196	0.00
WH9	1.680	0.04	WS9	1.680	0.04
WH10	2.196	0.03	WS10	2.196	0.03
WH11	2.776	0.04	WS11	2.776	0.04
WH12	3.508	0.03	WS12	3.508	0.03
WH13	4.388	0.00	WS13	4.388	0.00
WH14	6	0.03	WS14	5.528	0.027

Results

TABLE 2. Summary performance statistics from 1 000 replicates for biomass and catch after 5, 10 and 15 years for 6 fixed *F* approaches and for a variable *F* harvest control rule "F_{vary}" (see text for description).

5+Biomass

F Rule	Year	Mean	CV	Max	P95	Median	P5	Min	P(B>140kt)
0	2010	230457	16.408	392966	296827	228620	173004	136251	0.999
0.5*F0.1	2010	181663	16.840	307836	232411	180158	134446	110479	0.920
0.8*F0.1	2010	161901	16.995	270231	209728	161161	119837	78955	0.777
F0.1	2010	149550	17.278	261885	196471	147394	112014	90551	0.625
Fmax	2010	117632	17.550	192617	153937	116961	85569	67652	0.134
Fcurrent	2010	62509	20.340	103734	84524	61940	42580	30943	0.000
Fvary	2010	163339	14.929	276543	207612	160831	126890	103313	0.843
0	2015	445410	27.296	1109913	673742	429865	278913	184579	1.000
0.5*F0.1	2015	304223	26.205	699922	443882	296860	190134	142355	1.000
0.8*F0.1	2015	250664	25.912	509097	373281	242426	156760	85479	0.983
F0.1	2015	223501	25.177	484502	330538	215706	145901	115190	0.969
Fmax	2015	154203	24.126	336491	220900	151335	100364	68636	0.615
Fcurrent	2015	67810	22.584	132412	93525	66295	44129	30855	0.000
Fvary	2015	232932	24.360	526997	337171	226072	154560	112470	0.995
0	2020	575638	34.686	1832968	954627	539170	321608	203866	1.000
0.5*F0.1	2020	363070	31.891	999119	567620	345243	204701	150999	1.000
0.8*F0.1	2020	289620	30.880	656204	462063	274751	166791	89248	0.988
F0.1	2020	252356	29.003	627574	389850	241439	155172	109915	0.976
Fmax	2020	164969	26.628	398689	243998	160185	103632	71948	0.696
Fcurrent	2020	68583	22.753	140926	96714	67299	45760	25668	0.001
Fvary	2020	258253	29.179	656989	395940	245991	158803	124293	0.985

Catch

F Rule	Year	Mean	CV	Max	P95	Median	P5	Min
0	2010	0	0.000	0	0	0	0	0
0.5*F0.1	2010	10697	20.009	18353	14373	10488	7430	5740
0.8*F0.1	2010	14809	19.024	25956	19614	14598	10465	7162
F0.1	2010	16787	19.709	34734	22724	16500	11878	10059
Fmax	2010	21191	20.281	39944	28702	20994	14510	11008
Fcurrent	2010	22447	21.460	43468	30967	22179	15270	10185
Fvary	2010	17888	21.164	33921	23671	17990	11160	8640
0	2015	0	0.000	0	0	0	0	0
0.5*F0.1	2015	17586	28.421	40570	26348	16962	10755	7028
0.8*F0.1	2015	22745	27.819	50849	34363	21978	13934	8686
F0.1	2015	25181	26.980	61555	37862	24143	16036	12157
Fmax	2015	28552	26.369	62105	42457	27823	17545	12263
Fcurrent	2015	26087	24.189	54805	37821	25513	16762	11335
Fvary	2015	26076	26.047	63098	38967	25403	16826	10013
0	2020	0	0.000	0	0	0	0	0
0.5*F0.1	2020	20493	33.962	58020	32883	19223	11591	7132
0.8*F0.1	2020	25898	32.286	65696	41090	24754	14701	8629
F0.1	2020	27967	30.249	72577	44083	26450	16966	10326
Fmax	2020	30244	27.786	68642	45614	29526	18453	11990
Fcurrent	2020	26428	24.498	51454	38735	25910	16946	9816
Fvary	2020	28491	30.132	74477	44484	27310	16662	10620

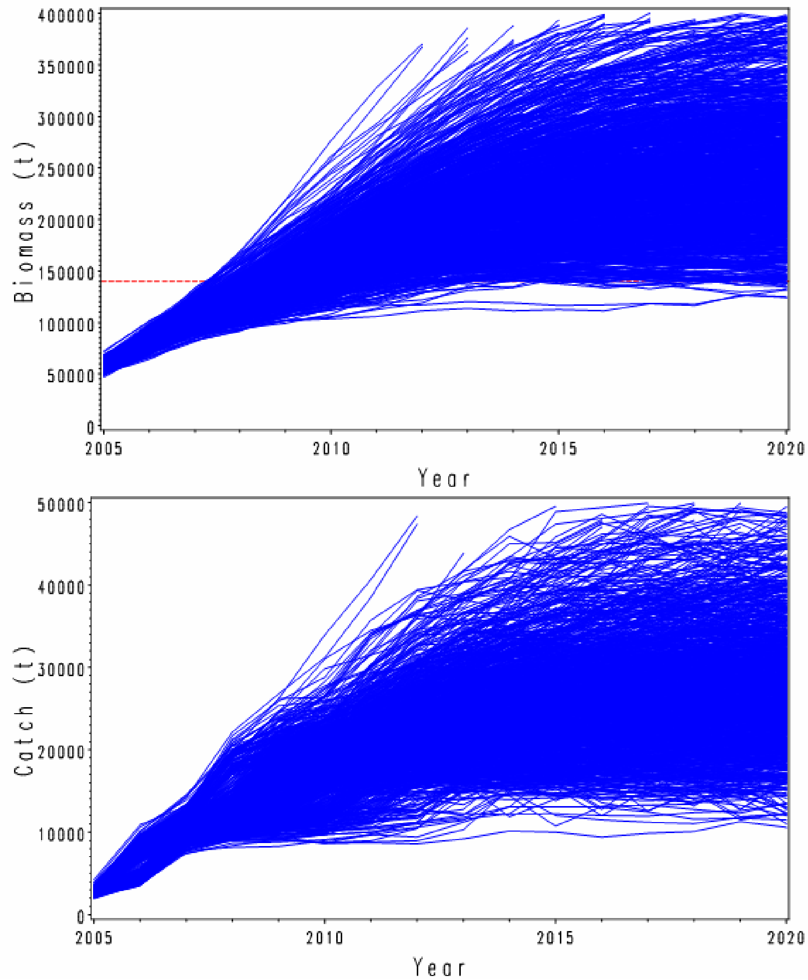

Fig. 1. 1 000 replicate 5+biomass and catch trajectories for the F_{vary} strategy proposed as a PA-compliant rebuilding plan for Subarea 2 + Div. 3KLMNO Greenland halibut. The broken line in the top panel indicates the FC rebuilding target.

Discussion

Under the assumptions of the simulation, the Subarea 2 + Div. 3KLMNO Greenland halibut stock is expected to rebuild to above the target of 140 000 tons with a very high probability by 2010 in the absence of any fishery. It should be noted, as pointed out in Healey and Mahé (2005), this quantification of risk is incomplete and should only be used in relative terms to compare rebuilding strategies. Also, resampling recruitment from the long-term series would seem to be optimistic for a stock with an estimated extremely low 10+ biomass. It should be noted that an *F*-based strategy will be much more risk averse than predetermined TAC levels (which allow the *F* to float, e.g. current $F = 0.71$) in the face of recruitment uncertainty.

Under a fixed $F = 0.5$x $F_{0.1}$ strategy, probability of reaching the target is only slightly lower than under $F = 0$. The catch in 2010 would average about 10 kt under this strategy, increasing to 18 kt in 2015 and 20 kt in 2020. The 0.8x $F_{0.1}$ and $F_{0.1}$ strategies have a moderate probability of reaching the rebuilding target by 2010 but a relatively high probability of doing so by 2015. The gain in average catch in year 2010 over the more conservative 0.5x $F_{0.1}$ strategy is 4-6 kt. The F_{max} strategy has a relatively low probability of reaching the rebuilding target by 2010 and a moderate probability of doing so by 2020. There is only about a 3-4kt increase in catch with this strategy compared to $F_{0.1}$. $F_{current}$ is clearly inconsistent with any stock rebuilding and in addition results in growth overfishing as demonstrated by reduced catches.

F_{vary} provides good balance between initial rapid rebuilding and catch. The stock has a higher probability of reaching the rebuilding target (i.e. is likely to rebuild more quickly) and the average catch is higher at 5, 10 and 15 years compared to a constant $F_{0.1}$ strategy. The F_{vary} strategy is to some degree compliant with the NAFO PA Framework (i.e. low *F* at low stock size) and is shown to generally outperform the fixed *F* strategies.

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