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Evolution and implementation of a management strategy for NAFO Subarea 2 and Divs. 3KLMNO Greenland halibut fishery

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Abstract

A management strategy evaluation for 2+3KLMNO Greenland halibut was initiated in 2007 under the guidance of NAFO Scientific Council. The analysis was completed in 2009 and Scientific Council advised Fisheries Commission on adopting a management strategy for future management of the stock. Subsequently Fisheries Commission initiated a Working Group to "refine" and further advise on implementing a management strategy for Greenland halibut. This WG met three times in 2010 and eventually provided two management strategy options for Fisheries Commission to consider. Fisheries Commission adopted one of these strategies at the annual meeting in September 2010 and this strategy was used to set the TAC for 2011. This working paper provides background information on the process, as well as some thoughts on exceptional circumstances when the harvest control rule should not be used, and lessons that can be learnt from this initial application of management strategy evaluation within NAFO.

Key words: *management strategy evaluation, operating model, fisheries management, harvest control rules, management objectives, performance statistics, satisficing, trade offs, risk.*

Background

Funding provided under the Canadian Government Department of Fisheries and Oceans (DFO) International Governance Strategy component on "Science in support of straddling stocks and highly migratory species" allowed a multi-year (2007-2009) research project to be undertaken to carry out a management strategy evaluation (MSE) for rebuilding and sustainably managing the 2+3KLMNO Greenland halibut fishery. Planning and work on this project was undertaken in close association with, and support from, NAFO Scientific Council throughout. To assist in the process, NAFO SC struck a Study Group on Rebuilding Strategies for Greenland halibut that met in Vigo in February 2008 (NAFO SC 2008). The SG included SC members, independent experts, fisheries managers and fishing industry representatives from Canada, EU and Japan who all provided valuable guidance on the approach to be taken. Methods and results were reported to NAFO Scientific Council for peer review on a regular basis (Miller and Shelton, 2007, Miller et al. 2007, Miller et al. 2008, Shelton and Miller 2009). An internet Wiki site was set up to facilitate communication of ideas between project leaders, other NAFO SC members, and independent scientists.

The SC proposal to endorse the management strategy evaluation (MSE) approach for the management of 2+3KLMNO Greenland halibut met with limited support from NAFO Fisheries Commission (FC) in September 2008 (NAFO/FC Doc. 08/22). The project nevertheless progressed well and a final report was presented to SC in June 2009 (Shelton and Miller 2009). In this report the two best performing management strategies across a range of performance statistics, under eight alternative operating models, were recommended for further consideration by NAFO. The operating models represented alternative plausible permutations of the XSA-based assessment. Performance statistics were divided into "satisficing" statistics and trade-off statistics (Miller and Shelton 2010).

Satisficing statistics require a specified threshold value be achieved within an allowable risk tolerance level across all operating models for the management strategy to be given a "pass" and to be taken forward to an evaluation of trade-off statistics. Seven satisficing performance statistics were considered, related to variation in catch, rebuilding to the FC target of 140kt by 2019, rebuilding the biomass to Bmsy, keeping F below Fmsy and not letting annual catch fall too low. Fourteen trade-off statistics were considered in the analysis to evaluate the tradeoff between conservation objectives and fishery performance (see Shelton and Miller 2009 for more details).

The two recommended management strategies were termed *modFree* and *rbPlan*. *modFree* carries out annual TAC adjustments based on the perceived status of the stock from research surveys

$$TAC_{y+1} = TAC_y \times (1 + \lambda \times slope)$$

where *slope* = unweighted average slope of log-linear regression lines fit to the last five years of each index (mean weight per tow, Canadian fall 2J3K, Canadian spring 3LNO and EU 0-1400m surveys), and λ = an adjustment variable for the relative change in TAC to the perceived change in stock size. Note that in Shelton and Miller (2009) the EU survey index used in the rule was the 0-730m index as being applied in the stock assessment at that time. This was replaced by the EU 0-1400M index in the 2010 assessment (Healey et al. 2010) and used in subsequent MSE updates (see below).

Various λ values were examined and a value of 1.25 was selected in the case of *slope* <1 and a value of 1 in the case of *slope* >1 based on an evaluation of the performance statistics. This process of adjusting harvest control rule parameters to improve performance is called "tuning" the harvest control rule.

rbPlan is a similar strategy to *modFree* but is based on model estimates of the exploitable (5+ biomass) from the XSA assessment. In this case *slope* is the slope of log-linear regression line fit to the last five years of exploitable (5+) biomass estimated in the latest XSA assessment (years y-4 to y-1 from the XSA and year y projected based on the
current TAC, where y is the year in which the assessment is being done). Tuning the rule to improve performance resulted in selecting a value of λ =1.5 for slope<1 (estimated stock decrease) and λ =1 for slope>1 (estimated stock increase). This rule differs from *modFree* in that TAC adjustments were constrained to be ≤15% from y to y+1 going forward, to achieve a performance requirement specified by the fishing industry at the Vigo Study Group meeting in 2008 that TAC should not vary by more than 15% from one year to the next. A second difference is that TACs are only adjusted every second year to give the fishing industry a greater degree of constancy.

NAFO SC again expressed support for the MSE approach and a commitment to its use in the provision of advice in future years. The approach and results were presented by the Chair of SC to FC at the September 2009 annual meeting of NAFO. Rather than adopting and implementing one of the two harvest control rules that had been evaluated and found to be robust to uncertainty by SC, FC decided to instead establish a new FC Working Group, the "Working Group on Greenland Halibut Management Strategy Evaluation" (WGMSE), to "refine" the current MSE framework and to "review and revise models if necessary, define acceptable risk level, select appropriate performance indicators and consider alternative management strategies with the view of adopting a strategy for setting the TAC level for 2011 and beyond".

In response to a September 2008 request from FC, an *ad hoc* SC working group met in June 2009, just prior to the SC meeting, to evaluate alternative assessment models for the Greenland halibut stock. Alternative assessment models included a statistical catch at age model (SCAA; Butterworth and Rademeyer 2009). The SC *ad hoc* WG noted that the SCAA estimates were much more optimistic than the XSA assessment (NAFO SCS Doc. 09/25). The base case SCAA model in Butterworth and Rademeyer (2009) estimated current biomass to be at more than 3xBmsy, indicating a very healthy stock rather than one in need of rebuilding, allowing consideration of a considerable increase in TAC. The SC *ad hoc* WG concluded that, while XSA with F-shrinkage as applied in the assessment gave the lowest recent biomass estimates and the steepest declining trend in the recent period among models under consideration, it could not be rejected on robustness grounds. Based on the *ad hoc* WG report, SC noted in its June 2009 report (NAFO Sci. Coun. Rep. 2009, p. 40-43) that "all of the models applied could broadly reproduce the trends when run with similar or the same data sets, and continued use of the XSA model is not considered to be invalidated by this exercise." Consequently the decision was made to continue to base the NAFO assessment and scientific advice on XSA and, similarly, the decision was made to continue to base the Greenland halibut MSE operating models on plausible permutations of the XSA assessment in the final MSE presented to SC in June 2009 (Shelton and Miller 2009).

Nevertheless, WGMSE decided to include SCAA-based operating models in the MSE and asked FC to make a special interim request to SC to review the plausibility of SCAA-based operating models in the Greenland halibut MSE. SC carried out this review by WEBEX in March/April 2010 and concluded that the proposed SCAA conditioned operating models (Butterworth and Rademeyer 2010) were plausible and could be included in the MSE (NAFO SCS Doc. 10/04). SC noted that the estimated SSB for 2008 from SCAA ranged from 10% to 80% of the SSB giving MSY and was 2% to 16% of the SSB at virgin stock levels. Thus SCAA indicated a stock in a depleted state, similar to the XSA assessment, with SSB below SSB at BMSY and well below virgin biomass B0. SC noted that this differed substantially from the more optimistic views of the status and productivity of the stock based on the version of the SCAA presented to the SC *ad hoc* WG in June 2009 by Butterworth and Rademeyer (2009).
The June 2010 SC Greenland halibut assessment was based on a reduced shrinkage XSA model and also included a change in one of the tuning indices (Healey et al. 2010). The reduced amount of shrinkage applied in the 2010 assessment was considered valid on statistical grounds because it resulted in less retrospective error relative to other shrinkage options. The 2010 assessment with reduced shrinkage gave a slightly less pessimistic view of the status of the stock than previous recent assessments (Healey et al. 2010). This further narrowed the gap between the XSA assessment and the revised SCAA estimates, bringing into question the need to include SCAA-based operating models in the MSE.

Summary of work carried out under WGMSE

WGMSE held its first meeting in Brussels 28-29 January 2010. A short summary was presented on the work carried out by SC on the Greenland halibut MSE based on operating models conditioned on XSA (NAFO/FC Doc. 10/2). SCAA was presented as an alternative assessment method with MSE as a way of "bridging the gap" between the two model views of the status and dynamics of the stock. The WG agreed that two sets of operating models – one conditioned by XSA and other conditioned by SCAA using the same input data should be applied in the MSE, pending a review of the plausibility SCAA operating models by SC (see above). The model-free harvest control rule (HCR) from Shelton and Miller (2009) presented above was adopted, although allowance was made that it could be "refined" at the next meeting of the WG in light of intercessional work.

The Brussels WGMSE meeting was held prior to the March/April WEBEX SC review of SCAA in terms of providing plausible operating models, hence the perception held by some was still that of a much more optimistic view of the status and dynamics of the Greenland halibut stock compared to that obtained from XSA. Consequently it seemed necessary to reduce the performance statistics list to those that could be compatible with these two very disparate views. In the process, many of the conservation orientated performance statistics provided in Shelton and Miller (2009) were lost. Four properties were considered to still be relevant: (i) the risk of steep decline be kept moderately low; (ii) the risk of annual average catch variation of greater than 15% be kept moderately low, (iii) the magnitude of the average catch in the short, medium term and long term be maximized; (iv) the risk of failure to meet an interim target within a prescribed period of time should be kept moderately low.

The second meeting of WGMSE took place in Halifax 2-4 May 2010 (NAFO/FC Doc. 10/5). The WG specified threshold values and risk tolerances for the reduced list of performance statistics adopted in the previous meeting: (1) The probability of the decline of 25% or more in terms of exploitable biomass from 2011 to 2016 is kept at 10% or lower (with the caveat that should the risk tolerance level of 10% unduly constrain the tuning of the Harvest Control Rule such that a rule cannot be developed to satisfy this or other constraints, then flexibility is provided to consider a risk tolerance level of up to 25%); (2) a) The probability of annual TAC variation of greater than 15% be kept at 25% or lower and b) The probability of variation of TAC more than 25% over any period of 3 years should be kept at 25% or lower. If the conditions a) and b) are not met, then an alternate performance target should be considered as follows: c) The TAC should not be below 10 000 t for the period 2011-2015 in any one year with a probability of 25% on a year by year basis; (3) The magnitude of the average TAC in the short, medium and long term should be maximized; (4) The probability of failure to meet or exceed a milestone within a prescribed period of time should be kept at 25% or lower. "Milestone" means the average exploitable biomass for the period 1985-1999 compared with the exploitable biomass in 2031.

Compared with the performance statistics provided in Shelton and Miller (2009), the list produced by WGMSE places more emphasis on short term catch related performance and less on longer term conservation concerns. Important PA related performance statistics such as F relative to Fmsy and B relative to Bmsy no longer appear. Rebuilding rate statistics are also diminished with the dropping of the time to rebuild to Bmsy and the need to rebuild to 140kt by 2019 as originally specified in the FC rebuilding plan, extending this time to 2031. The performance statistics adopted by WGMSE allow for a high risk (up to 25%) of a significant decline (25%) in the 5+ biomass in the initial period (2011-2016).

The May WGMSE meeting also agreed to a set of operating models conditioned on XSA and a different set conditioned on SCAA. The XSA-based operating models were reduced to six from the eight applied in Shelton and Miller (2009) and previously reviewed by SC. SC did not review the SCAA-based operating models.

At third meeting of WGMSE, held in Halifax 16-17 September 2010, just prior to the NAFO Annual meeting. Both the XSA and SCAA operating models were updated to be conditioned on the 2010 assessment data from Healey et al. (2010). For XSA this meant using the new tuning which gave a more optimistic view of the stock compared to the 2009 assessment. The SCAA-based runs introduced two new aspects to the harvest control rule not considered in the model free rule by Shelton and Miller (2009). Firstly, base TACs other than the actual 2010 TAC of 16kt were considered. Secondly, constraints were inserted in the rule to limit the amount of TAC variation allowed from year to year. In the study reported in Shelton and Miller (2009) the model free rule is unconstrained and the two λ parameters (up and down) are tuned to result in a TAC that infrequently exceeds the 15% annual TAC variation threshold specified by the fishing industry at the Study Group meeting in Vigo in 2008.

WGMSE in its report (NAFO/FC Doc. 10/30) provided two management strategy options for further consideration by FC (MS1 and MS2; Table 1). The results from the application of these two rules are given in Table 2. For MS1, which has a lower TACy, a lower value for λ-down and less constraint on TAC change, the average TAC over the period 2011 to 2015 drops to 13.4kt for SCAA compared to 14.8kt for XSA based runs. This indicates a steeper negative average slope in the log indices being applied in the rule in the SCAA-based runs. This is caused by a difference in approaches applied in the XSA-based and SCAA-based MSE runs. In the XSA-based analysis, each run of the MSE generates a bootstrap realization of the survey from the modeled population that is extended from the beginning of the historic survey period into the future (one for each iteration of the simulation, sometimes referred to as a “worm” in the plot of results). In the SCAA-based analyses there is a transition from the actual observed survey index series that ends in 2009 to the modeled survey index from 2010 onwards. This transition from observed to modeled indices creates steep negative slopes in the Canadian Fall and EU index series in the SCAA analyses. Table 2 shows that the XSA-based MSE is more optimistic regarding the catches that will be generated under the rule and the biomass levels that will result (except for short-term 2011-2015 biomass). MS2 generates higher short-term catch at the expense of slightly lower biomass levels for both XSA and SCAA conditioned operating models.

Implementation of MSE by Fisheries Commission

At the annual meeting in September 2010, FC adopted MS2 for the management of 2+3KLMNO Greenland halibut stock for the next four years (NAFO/FC Doc.10/29). Application of the rule by FC generated a 2011 TAC of 17.185kt. Appendix 1 contains R-code and input files for the 2010 and 2011 application of the rule (application in R actually generates a TAC of 17.182kt for 2011 suggesting slight rounding error in the FC calculation). The TAC generated from the harvest control rule for 2012 based on the updated Greenland halibut assessment (Healey 2011) is 16.326kt. Note that in this instance the -5% change in TAC constraint is triggered. The fitted slopes to the surveys from the 2010 and 2011 assessments are shown in Appendix Fig. 1a and b. In allocating the 2011 TAC, FC made no allowance for the considerable amount of implementation error that is estimated by SC to occur in this fishery (Healey et al. 2010), generating catches that exceed the TAC by an average factor of 1.33x between 2004 and 2009. It should be noted that the 2010 catch estimated by SC exceeded the TAC by a factor of 1.64 (Healey 2011).

The initial decline in exploitable (age 5-9) biomass that is expected to occur under MS2 assuming no implementation error is illustrated in Fig. 2 for the CAV (current assessment view operating model) as an example. The 2011 estimate of biomass from Healey (2011) is shown with an X. Although below the median estimate it is above the lower 5^{th} percentile. Exploitable biomass is expected to decline to the lowest observed level and not begin rebuilding until after 2013 under MS2. Further, the exploitable biomass is not expected to reach the FC rebuilding target (140kt expressed in equivalent age 5-9 biomass averaged over the period 1985-1999) within the time period examined (2031). Not that the FC timeline for reaching the target was set at 2019.

Exceptional circumstances

In its request for advice in 2010, FC asked SC to provide guidance on what might constitute "exceptional circumstances" and to provide advice on whether or not the "exceptional circumstances" provision should be applied in setting the TAC for the following year (2012).

The "exceptional circumstances" refer to conditions under which FC might want to take over control of the TAC-setting process from the "autopilot" that constitutes MS2. Ideally this should only rarely be necessary if the robustness of the management strategy has been properly evaluated. Technically, these concerns would arise when key performance statistics fall in the tails or completely outside the range of distribution of values generated in the MSE.

Direct comparison of observed performance statistics with the "true" modeled performance statistics can only be made for catch and survey values. All other values are only "perceived" though the XSA assessment and are therefore not "true". Thus the survey values for the three indices for 2010 should be compared with the OM percentiles for the same year. Similarly, observed catch (the SC estimate for 2010) and the MS2 generated TAC for 2011 and 2012 (with and without expected TAC overruns) can be compared with the OM percentiles for those three years.

Further, the 2011 and 2012 TACs, generated by MS2 can be applied in short-term stochastic projections assuming no TAC overrun and assuming TAC overruns randomly sampled from the 2004-2010 period. "Perceived" exploitable (5-9) biomass and "perceived" F can then be compared with the "true" simulated percentiles from the OMs. However, care needs to be exercised in the interpretation of a comparison of "perceived" values from the assessment against "true" values from the MSE simulations.

Lessons to be learnt

There are many lessons that could be learnt from this initial foray into management strategy evaluation as a tool for the management of NAFO stocks. Only some are touched on here.

Firstly, the analyses required under MSE are complex and there is only limited expertise within NAFO in this area. Relying on consultants to carry out analyses and advise delegations marginalizes NAFO SC and creates difficulty in evaluating methods and results.

Secondly, while contested stock assessments and competing views regarding stock status are not necessarily bad in and of themselves (see for example the perspective by Starr et al. 1998), rules of procedure need to be followed and there should be a level playing field. NAFO obtains its scientific advice from Scientific Council, not from industry consultants or advisors to delegations operating outside the NAFO SC process or from informal and non-transparent government-industry working groups. While joint NAFO working groups comprising scientists, fisheries managers, industry and representatives from environmental groups may be required to have input in order to make progress on some complex issues within NAFO, such as MSE, the scientific inputs and results from any analysis based on scientific data need to be peer reviewed by SC before they are used to make decisions by NAFO.

Lastly, it needs to be recognized that, while management strategy evaluation is a potentially very valuable tool, and the negative aspects of the Greenland halibut application could be overcome in future applications by NAFO, it is not a panacea. It cannot take the place of a sound understanding of the biology and dynamics of the stock built up through dedicated research programs based on regular research vessel surveys of the whole stock area together with accurate catch reporting and sampling.

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Table 1. Two candidate management strategies evaluated at the September 2010 meeting of WGMSE.

	Management Strategy 1	Management Strategy 2
Starting TAC Control Parameter	16, 000 t	17, 500 t
λ if slope is negative	1.25	2.00
λ if slope is positive	1.00	1.00
Constraint on the rule-generated TAC change	± 10%	± 5%

Table 2. Some results from the application of the two management strategies from the September WGMSE meeting. Biomass is exploitable age 5-9.

	SCAA average		XSA average	
	MS 1 (mp01)	MS 2 (mp14 (+-5%))	MS 1 (mp01)	MS 2 (mp14 (+-5%))
$C_{2011-2015}$	13374	15766	14800	16400
$C_{2016-2020}$	13566	15827	19600	19100
$C_{2011-2030}$	14335	16195	23100	21400
$B_{2011-2015}$	91530	89361	69446	66588
$B_{2016-2020}$	107715	103211	131854	128102
$B_{2011-2030}$	117766	113381	127975	127612
$B_{2011-2015}/B_{2011}$	1.05	1.03	1.04	1.02
$B_{2016-2020}/B_{2011}$	1.26	1.20	1.98	1.98
$B_{2011-2030}/B_{2011}$	1.36	1.31	1.93	1.97

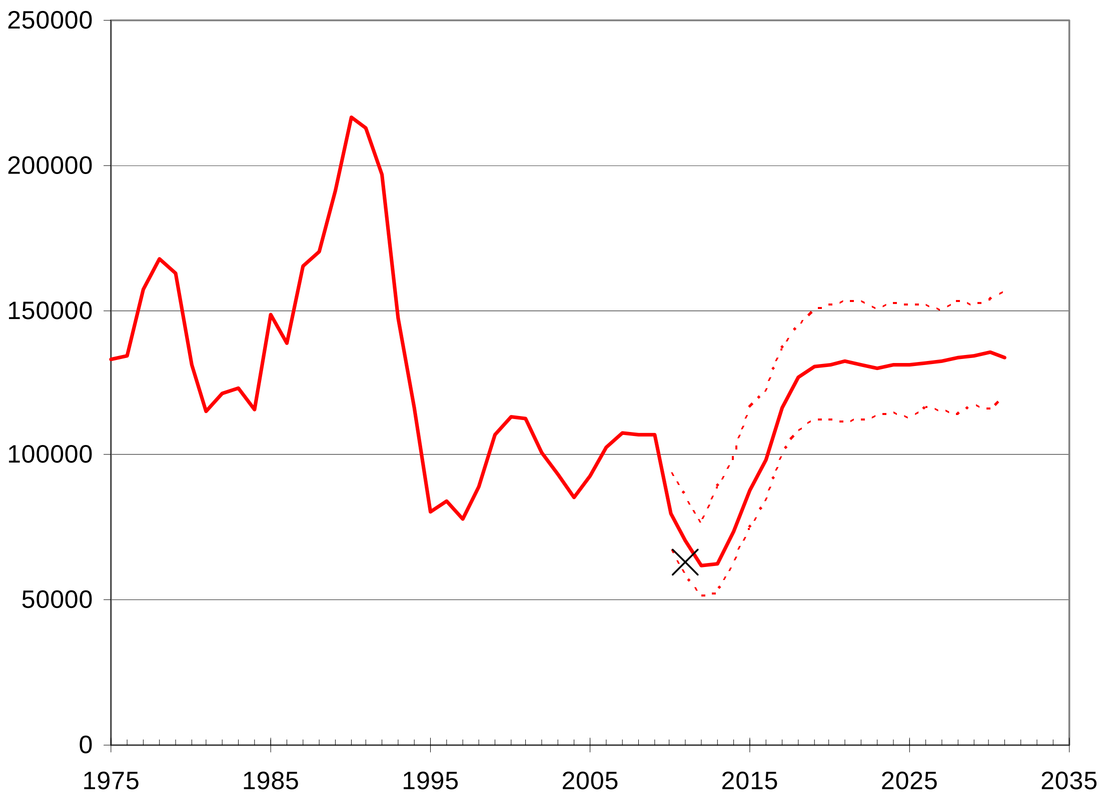


Fig. 1. Median values of exploitable (5-9) biomass under MS2 applied to the "Current assessment view" (CAV) operating model. The broken lines represent the 5th and 95th percentiles. X marks the biomass estimate for 2011 from the 2011 assessment – it is below the median but falls above the lower 5th percentile.

Appendix 1

R-code and input file for generating the TAC under MS2.

```
#Greenland halibut harvest control rule based on survey mean wt per tow
#Each survey has equal weight
#Ver May 26 2011

rm(list=ls(all=T))          #will remove all objects from R-Workspace
setwd("C:/Documents and Settings/sheltonp/My Documents/Work/NAFO/NAFO 2011/Greenland halibut rule")

#INPUT TAC to be updated
OldTAC<-17.5 #this is the TAC set in the year in which the assessment is done - will be used in the HCR to
generate tac for next year

#DATA
#Edit file name an nrows
index<-read.table("surv_2009.txt", header=T, nrows = 33, colClasses = "numeric", comment.char = "")

#COMPUTE SLOPES
nyrs<-length(index$Year)

#Use last 5 years of index data for computing the slopes
Year<-index$Year[(nyrs-4):nyrs]
log_fall<-log(index$Cdn_Fall[(nyrs-4):nyrs])
log_spring<-log(index$Cdn_Spring[(nyrs-4):nyrs])
log_eu<-log(index$EU_0_1400[(nyrs-4):nyrs])

log_index<-data.frame(Year, log_fall, log_spring, log_eu)

z_fall <- lm(log_fall ~ Year, data=log_index, na.action=na.exclude)
z_spring <- lm(log_spring ~ Year, data=log_index, na.action=na.exclude)
z_eu <- lm(log_eu ~ Year, data=log_index, na.action=na.exclude)

z_fall_int<-coef(z_fall)[[1]]
z_fall_slp<-coef(z_fall)[[2]]
z_spring_int<-coef(z_spring)[[1]]
z_spring_slp<-coef(z_spring)[[2]]
z_eu_int<-coef(z_eu)[[1]]
z_eu_slp<-coef(z_eu)[[2]]

pred_fall<-z_fall_int+z_fall_slp*Year
pred_spring<-z_spring_int+z_spring_slp*Year
pred_eu<-z_eu_int+z_eu_slp*Year

par(mfrow=c(3,1))
plot(Year,log_fall, ylim=c(min(log_fall, pred_fall, na.rm = TRUE),max(log_fall, pred_fall, na.rm = TRUE)))
lines(Year, pred_fall)

plot(Year,log_spring, ylim=c(min(log_spring, pred_spring, na.rm = TRUE),max(log_spring, pred_spring, na.rm =
TRUE)))
lines(Year, pred_spring)

plot(Year,log_eu, ylim=c(min(log_eu, pred_eu, na.rm = TRUE),max(log_eu, pred_eu, na.rm = TRUE)))
lines(Year, pred_eu)
```

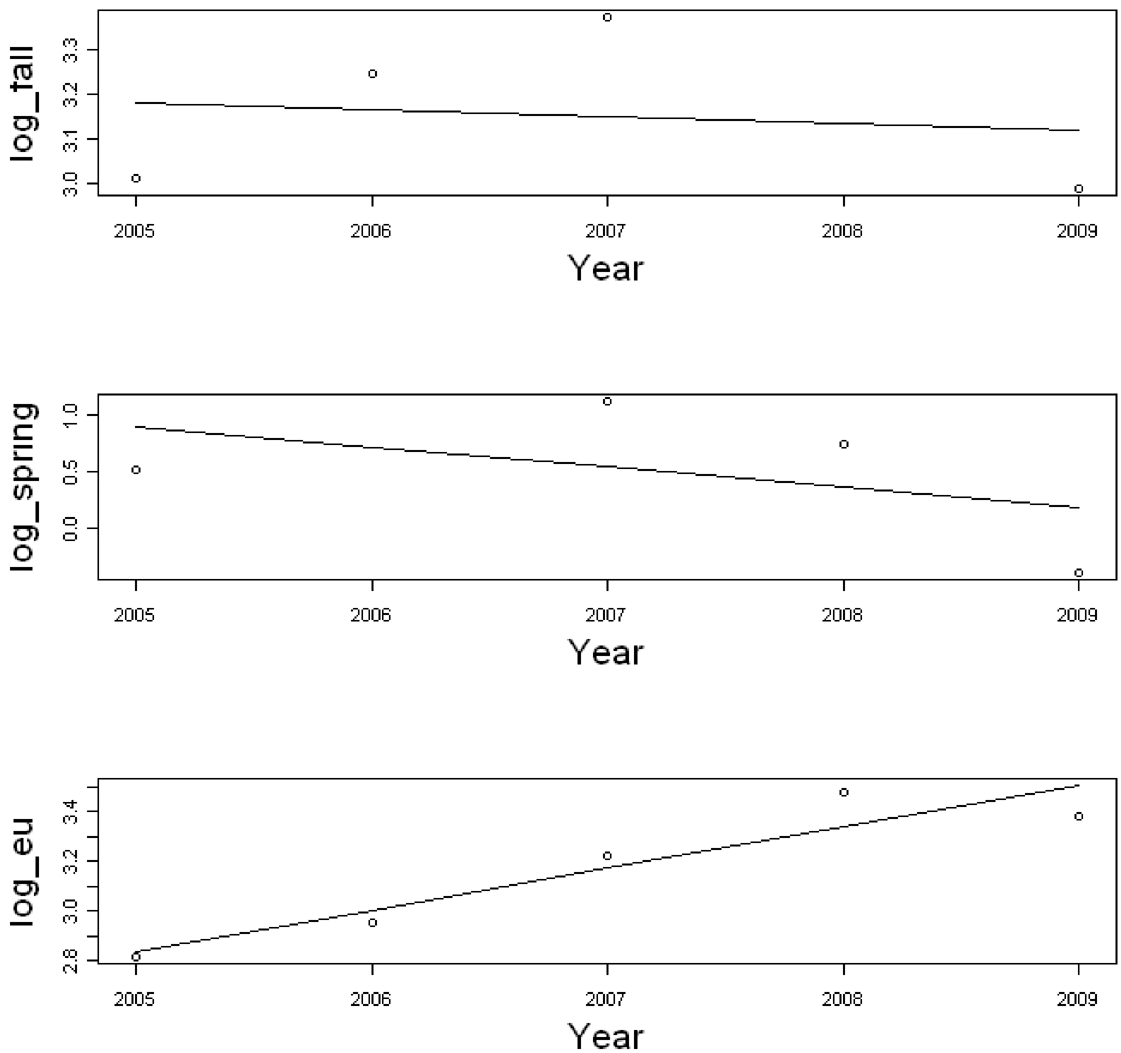
```
mean_slp<-(z_fall_slp+z_spring_slp+z_eu_slp)/3

#APPLY HCR TO GENERATE TAC

if (mean_slp<0) {
mult<-2
updown<- -1
} else {
mult<-1
updown<- 1
}

NewTAC<-OldTAC*(1+mult*mean_slp)

#APPLY 5% CONTRAINT ON TAC CHANGE
TACchange<-(NewTAC-OldTAC)/OldTAC
abs_change<-abs(TACchange)

ifelse(abs_change<0.05, TAC<-NewTAC, TAC<-OldTAC*(1+updown*0.05))
```

Data file (surv_2009.txt)

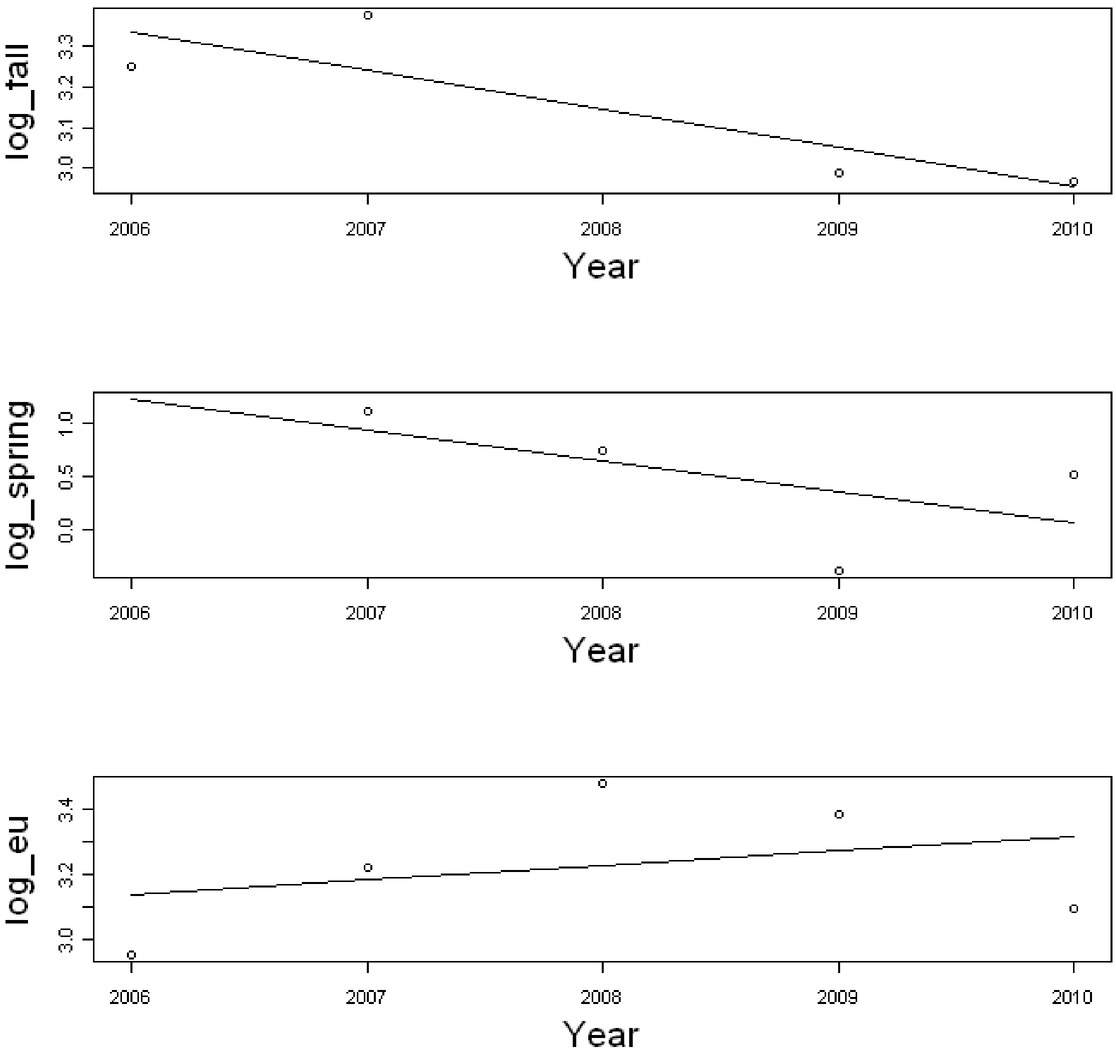
Year	Cdn_Fall	Cdn_Spring	EU_0_730	EU_0_1400
1978	38.37	NA	NA	NA
1979	28.10	NA	NA	NA
1980	29.99	NA	NA	NA
1981	32.13	NA	NA	NA
1982	35.60	NA	NA	NA
1983	36.92	NA	NA	NA
1984	37.24	NA	NA	NA
1985	27.46	NA	NA	NA
1986	35.44	NA	NA	NA
1987	25.48	NA	NA	NA
1988	23.61	NA	8.62	NA
1989	25.43	NA	5.56	NA
1990	21.20	NA	7.21	NA
1991	11.50	NA	10.16	NA
1992	8.25	NA	10.85	NA
1993	15.29	NA	8.93	NA
1994	10.78	NA	10.00	NA
1995	14.15	NA	13.52	NA
1996	21.58	1.53	14.42	NA
1997	24.80	2.46	20.01	NA
1998	23.83	4.56	30.13	NA
1999	32.48	2.81	26.37	NA
2000	23.89	3.04	21.08	NA
2001	22.69	1.46	17.25	NA
2002	14.07	0.72	15.05	NA
2003	15.31	1.45	7.73	NA
2004	17.45	1.12	15.28	23.33
2005	20.34	1.67	14.55	16.71
2006	25.73	NA	14.56	19.17
2007	29.12	3.03	16.22	25.10
2008	NA	2.10	14.92	32.35
2009	19.88	0.68	9.67	29.44

Data file (surv_2010.txt)

Year	Cdn_Fall	Cdn_Spring	EU_0_730	EU_0_1400
1978	38.37	NA	NA	NA
1979	28.10	NA	NA	NA
1980	29.99	NA	NA	NA
1981	32.13	NA	NA	NA
1982	35.60	NA	NA	NA
1983	36.92	NA	NA	NA
1984	37.24	NA	NA	NA
1985	27.46	NA	NA	NA
1986	35.44	NA	NA	NA
1987	25.48	NA	NA	NA
1988	23.61	NA	8.62	NA
1989	25.43	NA	5.56	NA
1990	21.20	NA	7.21	NA
1991	11.50	NA	10.16	NA
1992	8.25	NA	10.85	NA
1993	15.29	NA	8.93	NA
1994	10.78	NA	10.00	NA
1995	14.15	NA	13.52	NA
1996	21.58	1.53	14.42	NA
1997	24.80	2.46	20.01	NA
1998	23.83	4.56	30.13	NA
1999	32.48	2.81	26.37	NA
2000	23.89	3.04	21.08	NA
2001	22.69	1.46	17.25	NA
2002	14.07	0.72	15.05	NA
2003	15.31	1.45	7.73	NA
2004	17.45	1.12	15.28	23.33
2005	20.34	1.67	14.55	16.71
2006	25.73	NA	14.56	19.17
2007	29.12	3.03	16.22	25.10
2008	NA	2.10	14.92	32.35
2009	19.88	0.68	9.67	29.44
2010	19.47	1.68	8.28	22.13



Appendix Fig. 1a. Survey slopes for log index values over the 5 years previous to the 2010 assessment. These slopes are averaged and then applied in the harvest control rule to adjust the TAC.



Appendix Fig. 1b. Survey slopes for log index values over the 5 years previous to the 2011 assessment. These slopes are averaged and then applied in the harvest control rule to adjust the TAC.