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Northwest Atlantic Fisheries Organization

Serial No. N6316 **NAFO SCR Doc.14/021**

SCIENTIFIC COUNCIL MEETING – JUNE 2014

MSY from catch and resilience

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Abstract

A simple Schaefer model was tested on the Greenland halibut stock offshore in NAFO SA 0 and 1. The minimum data required for this model is a catch time series and a measure of the resilience of the species. Other input parameters that had to be guessed were the carrying capacity, the biomass as a fraction of the carrying capacity at both the beginning and end of the time series, and the growth rate. MSY was estimated to be between 19 000 and 23 000 t. Sensitivity tests showed that the estimation of MSY was heavily dependent on the guess of especially the biomass at the end of the time series and the growth rate.

The model assumptions and limitations were discussed.

Introduction

The Schaefer surplus production model requires as a minimum input time series data of abundance and removals in order to estimate the carrying capacity K and the maximum rate of population increase r for a given population in a given ecosystem (ICES, 2012). Martel and Froese (2013) developed a simple Schaefer model, in which the minimum required data is a catch time series from a specific area (a unit stock where the population is closed to immigration and emigration) and the resilience of the species. The model also requires the depletion levels for the population that are described with $\lambda 0$ as the initial depletion level and $\lambda 1$ and $\lambda 2$ as lower and upper bounds for current depletion levels. The depletion levels, if they are not known, need to be “guessed” or approximated based on previous knowledge of the population, and are expressed as a fraction of the carrying capacity K. Again carrying capacity K is “guessed” and assumed to fall within the range of maximum catch (C_{max}), in the available time series, to certain times the C_{max} (e.g. $K=C_{max}-30*C_{max}$). The choice for the K upper limit depends on personal decision and the knowledge of the stock. Additional process error can be added to the model if desired.

The model uses as input data biomass estimates (initial and final in the time series), carrying capacity, growth and commercial catch data. Because only a narrow range of r-K combinations can maintain the population, i.e. that the population does not collapse or exceed the carrying capacity resulting in final stock sizes between λ1 and λ2, a value of 1 is assigned for the eligible pairs. Afterwards, based on the range of the r-K pairs assigned with 1, MSY and other management quantities are calculated from the viable parameter combination. Table 1 shows the details of the model.

Table 1: Production model and management parameters used by Martel and Froese (2013)

Data

Ct observed catch from t=1 to t=n years

Resilience

λ0 depletion level in year 1

λ1, λ2 lower and upper bounds for depletion level

σv process error standard deviation

Parameters

Θ={k,r}

Initial states t=1

Bt=λ0*k*exp(v t)

Dynamic states t>1

Bn+1 = [Bt + r Bt (1 -t/k)-ct] exp(m t)

Likelihood

L(Θ|Ct)=1	λ1≤Bn+1/k≤λ2
=0	λ1>Bn+1/k>λ

Prior densities

p(log(k)) uniform(log(l k),log(u k)

p(log(r)) uniform(log(l r),log(u r)

p(v t) normal (0,σv)

Management quantities

MSY=1/4 r*k

B_{msy}=1/2*k

F_{msy}=1/2*r

Model implementation

The model is programmed in the software R and is readily available in the publication by Martel and Froese (2013). In order to conduct the analysis for Greenland halibut, we used commercial catch data from NAFO areas 0+1 between 1965 and 2013. No estimation for the intrinsic rate r for Greenland halibut is available, but generally Greenland halibut is characterized as a “low resilience” species with r between 0.05-0.5. Musick (1999) constructed a guideline for categorizing productivity of endangered species based on intrinsic rate r, von Bertalanffy K, fecundity, age at maturity and maximum age. Based on this guideline, Greenland halibut falls in the “low” productivity category and this is how we treat it in the model. However, as the model highly depends on the “unknown” input parameters there was also conducted a sensitivity analysis for the range of the carrying capacity K, the initial and final biomass and the resilience.

MSY from catch and resilience

Model results

We run the catch-MSY model with a combination of input parameters that in our opinion, is most in line with what is known for Greenland halibut biology and the stock status. We present six scenarios, a combination of two levels of r and three different ranges in carrying capacity K. The input parameters of the six scenarios are presented in Table 2 and 3.

Table 2: Input parameters and reference points produced with the catch-MSY method. Low r.

Input parameter	Senario 1	Senario 2	Senario 3
Initial B/K	0.5 - 0.9	0.5 - 0.9	0.5 - 0.9
Final B/K	0.5 – 0.7	0.5 – 0.7	0.5 – 0.7
Growth rate r	0.05 – 0.3	0.05 – 0.3	0.05 – 0.3
Carrying capacity K	Cmax-15*C_{max}	Cmax-30*C_{max}	Cmax-50*C_{max}
Reference points			
Mean MSY	20626	18899	19078
MSY +/- 2*SD	13758 - 30922	10857 - 32898	11153 - 32634
Mean F_{msy}	0.123	0.091	0.094
F_{msy} +/- 2*SD	0.073 – 0.207	0.039 - 0.213	0.042 – 0.210
Mean B_{msy}	167951	208059	203778
B_{msy} +/- 2*SD	123025 - 229285	126932 -341038	1275765 - 325496

In scenario 1-3, the model is run with a low input growth rate (r= 0.05-0.3) with three different values of Carrying capacity K (Table 2). The possible combinations of r-K gives a range for r between geometric mean 0.246 and 0.187 for the lowest and highest K value respectively and geometric mean of K between 335902 tons for the lowest input K and 416118 tons for the medium input K (407566 tons for the highest input k). (K=mean BMSY*2, r= mean Fmsy*2, respectively). The MSY is estimated to 20626 tons, 18899 tons and 19078, respectively. The output of the run with low r and medium K (C_{max}-30*$C_{max)}$ is shown in fig 1.

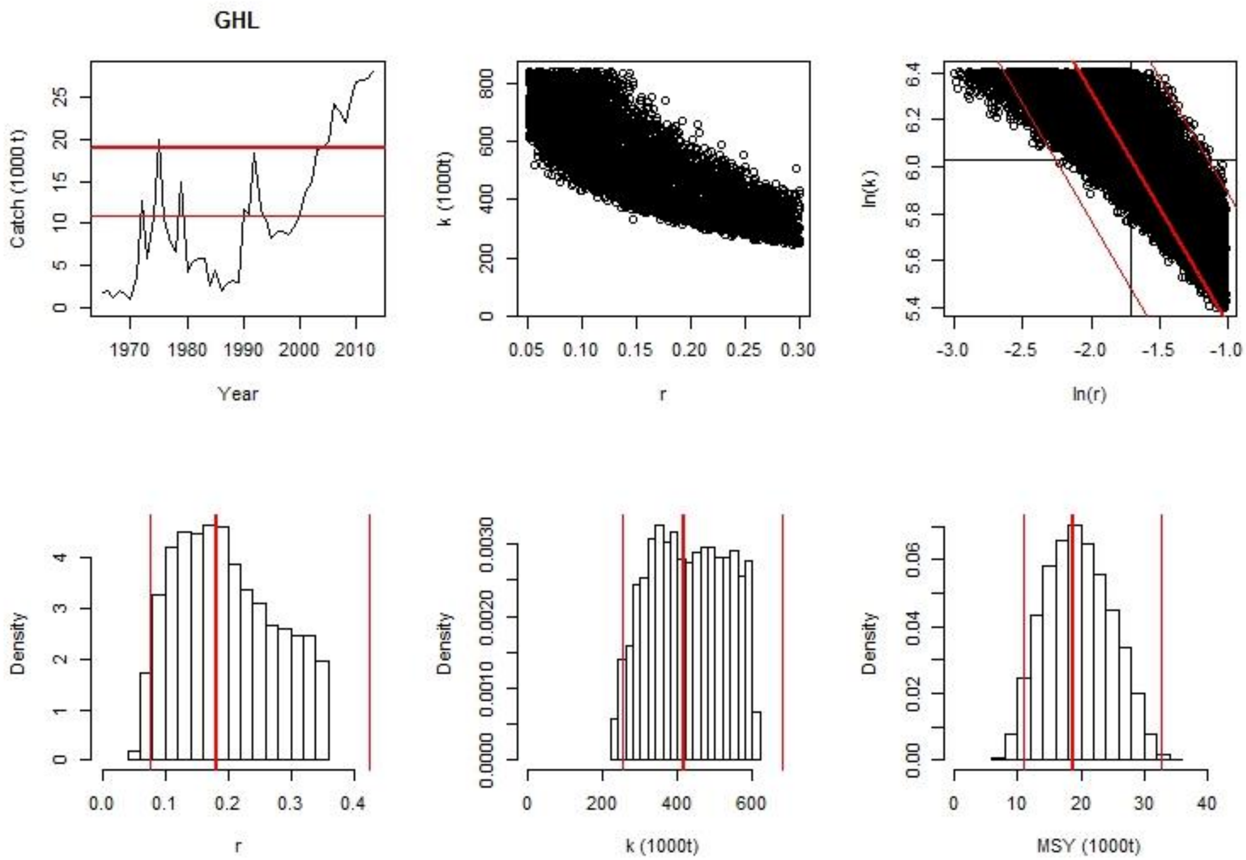

Figure 1: Graphic output from the catch-MSY method for scenario 2. (a) Shows the time series of catches with overlaid estimate of MSY (bold) and the limits that contain about 95% of the estimates. (b) Frames the prior uniform distribution of r and k; the black dots shoe the r-k combinations that are compatible with the time series of catches. (c) Is a magnification of the viable r-k pairs in log space, with the geometric mean MSY estimate (bold) ±2 SD overlaid. (d-f)Show the posterior densities of r,k and MSY, respectively where geometric mean ±2SD are indicated.

In scenario 4-6, the model is run with a high input growth rate (r=0.15-0.45) with the three different values of Carrying capacity K (Table 3). The possible combinations of r-K gives a geometric mean of r on 0.353, 0.366 and 0.351, respectively and geometric mean of K between 262147 tons, 25501 tons and 264060 tons, respectively. MSY is estimated to 23141 tons,23332 tons and 23140 tons, respectively. The output of the run with high r and medium K (Cmax-C30*C_{max}) is shown in fig 2.

Table 3: Input parameters and reference points produced with the catch-MSY method. High r.

Input parameter	Senario 4	Senario 5	Senario 6
Initial B/K	0.5 - 0.9	0.5 - 0.9	0.5 - 0.9
Final B/K	0.5 – 0.7	0.5 – 0.7	0.5 – 0.7
Growth rate r	0.15 – 0.45	0.15 – 0.45	0.15 – 0.45
Carrying capacity K	Cmax-15*C_{max}	Cmax-30*C_{max}	Cmax-50*C_{max}
Reference points			
Mean MSY	23141	23332	23140
MSY +/- 2*SD	16323 - 32807	16698 – 32603	16271 - 32909
Mean F_{msy}	0.177	0.183	0.176
F_{msy} +/- 2*SD	0.104 – 0.301	0.113 – 0.298	0.103 – 0.300
Mean B_{msy}	131074	127501	132030
B_{msy} +/- 2*SD	91303 - 188169	91792 - 177102	91939 - 189604

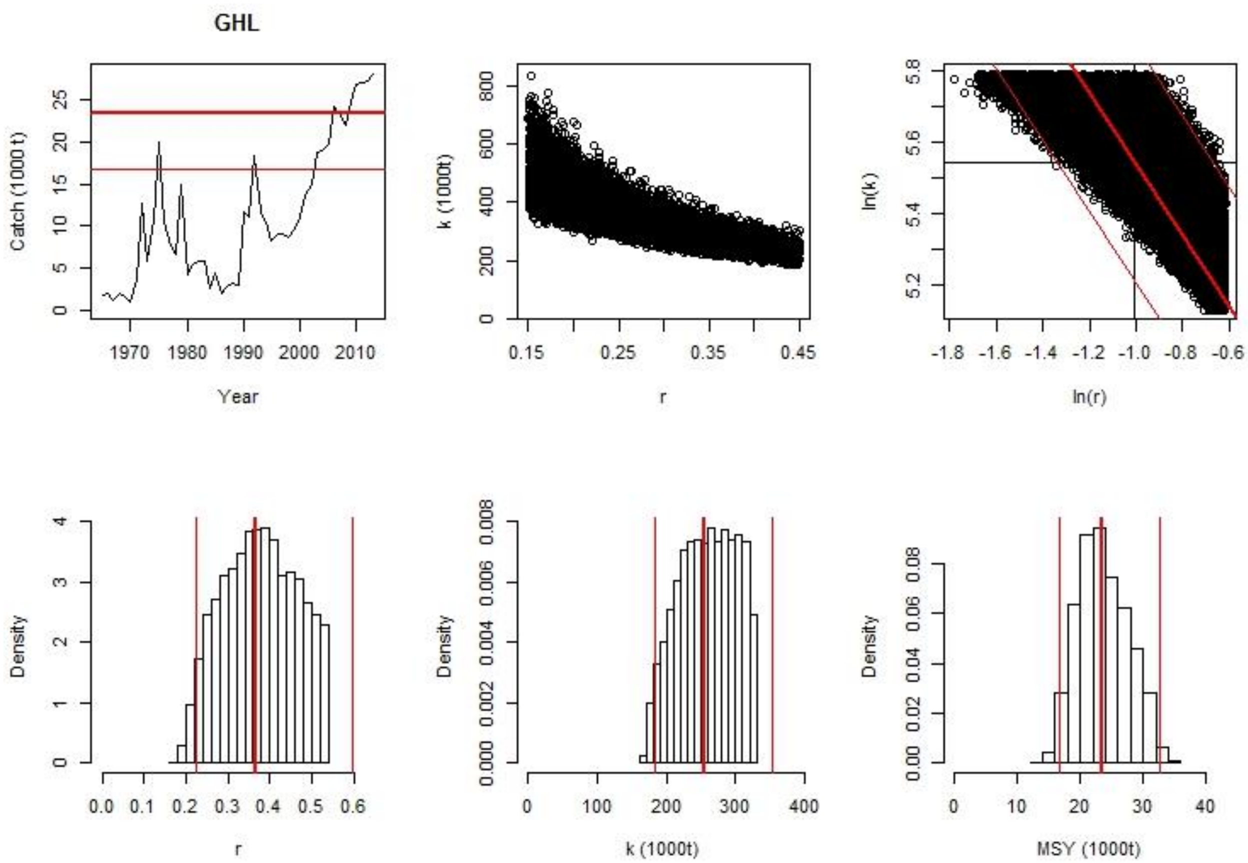

Figure 2: Graphic output from the catch-MSY method for scenario 4. (a) Shows the time series of catches with overlaid estimate of MSY (bold) and the limits that contain about 95% of the estimates. (b) Frames the prior uniform distribution of r and k; the black dots shoe the r-k combinations that are compatible with the time series of catches. (c) Is a magnification of the viable r-k pairs in log space, with the geometric mean MSY estimate (bold) ±2 SD overlaid. (d-f)Show the posterior densities of r, k and MSY, respectively where geometric mean ±2SD are indicated.

Sensitivity analysis of catch-MSY method

The sensitivity runs are made on catch data from 1965-2011. The results of the sensitivity analysis for the catch-MSY method are presented in Appendix A, Table 1. However, the representation in Appendix A is not easy to read and it is difficult to understand, how the input parameters affect the outcome of the method. In order to illustrate graphically the sensitivity of the parameters, a high and a low value was chosen for each of the input parameters and for each of the selected pair (high and low value). Eight different combinations of the other input parameters and compared the obtained values of MSY were tested.

The parameter combinations for the sensitivity analysis for the **initial B/K ratio** are illustrated in Table 4 and the results of each combination in Figure 3. The results illustrate a very low divergence indicating that the value of the initial B/K does not affect the outcome of the model. Table 5 shows the parameter combinations used in the sensitivity analysis for the **final B/K ratio** and Figure 4 illustrates the results. In contrast with the initial B/K ratio, the final B/K ratio shows a very high convergence between the high and the low value. When a high final B/K ratio is chosen the value of MSY is increased by around 5000- 6000 t compared with a low value of final B/K ratio.

Table 6 shows the parameter combinations used in the sensitivity analysis for **the intrinsic growth r** and Figure 5 the results. In six of the scenarios, the value of MSY is around 3000-5000 t higher when a high r value is used, whereas in two of the scenarios (2 and 6) the increase of the MSY value, when the high r is used, is around 1500-2000 t. Table 7 shows the parameter combinations used in the sensitivity analysis for the **carrying capacity K.** The results in Figure 6 show lower convergence and in half of the scenarios, where r has a high value, the effect of K is negligible. The effect of parameter is opposite to that of the other parameters, meaning that a low value of K gives higher estimation of MSY, of around 2000-3000 t, compared with a scenario with a high K value.

Table 4: Input parameters of the sensitivity analysis for the initial B/K ratio. For all 8 scenarios, MSY has been obtained and compared for the two values of the initial B/K ratio (high and low) combined with the given range for the other parameters.

	1	2	3	4	5	6	7	8
Initial B/K	0.7-0.9 0.3-0.7	0.7-0.9 0.3-0.7	0.7-0.9 0.3-0.7	0.7-0.9 0.3-0.7	0.7-0.9 0.3-0.7	0.7-0.9 0.3-0.7	0.7-0.9 0.3-0.7	0.7-0.9 0.3-0.7
Final B/K	0.5-0.7	0.5-0.7	0.5-0.7	0.7-0.5	0.2-0.5	0.2-0.5	0.2-0.5	0.2-0.5
r	0.2-1	0.2-1	0.05-0.5	0.05-0.5	0.2-1	0.2-1	0.05-0.5	0.05-0.5
K	C_{max}-30*C_{max}	C_{max}-10*C_{max}	C_{max}-30*C_{max}	C_{max}-10*C_{max}	C_{max}-30*C_{max}	C_{max}-10*C_{max}	C_{max}-30*C_{max}	C_{max}-10*C_{max}

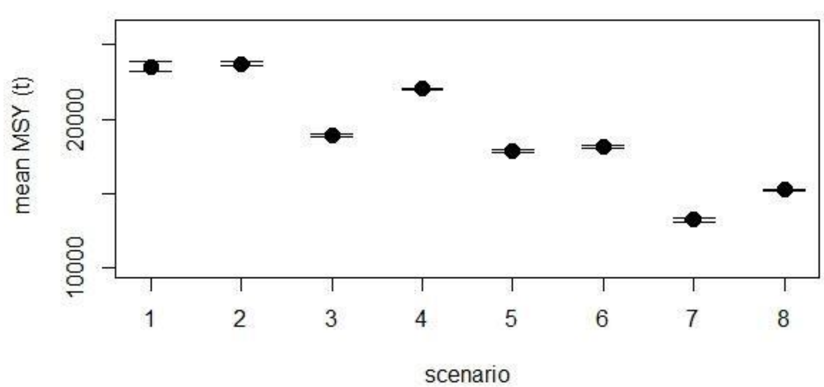

Figure 3: Sensitivity analysis for the initial B/K. For each scenario is presented the estimated MSY with a high and low initial B/K and the mean of the two values. Different scenarios represent different parameters combinations. The bars indicate the value of MSY using the two different B/K ratio values and the black dot the median value.

Table 5: Input parameters of the sensitivity analysis for the final B/K ratio. For all 8 scenarios, MSY has been obtained and compared for the two values of the final B/K ratio (high and low) combined with the given range for the other parameters.

	1	2	3	4	5	6	7	8
Initial B/K	0.7-0.9	0.7-0.9	0.7-0.9	0.7-0.9	0.3-0.7	0.3-0.7	0.3-0.7	0.3-0.7
Final B/K	0.5-0.7 0.2-0.5	0.5-0.7 0.2-0.5	0.5-0.7 0.2-0.5	0.5-0.7 0.2-0.5	0.5-0.7 0.2-0.5	0.5-0.7 0.2-0.5	0.5-0.7 0.2-0.5	0.5-0.7 0.2-0.5
r	0.2-1	0.2-1	0.05-0.5	0.05-0.5	0.2-1	0.2-1	0.05-0.5	0.05-0.5
K	C_{max}-30*C_{max}	C_{max}-10*C_{max}	C_{max}-30*C_{max}	C_{max}-10*C_{max}	C_{max}-30*C_{max}	C_{max}-10*C_{max}	C_{max}-30*C_{max}	C_{max}-10*C_{max}

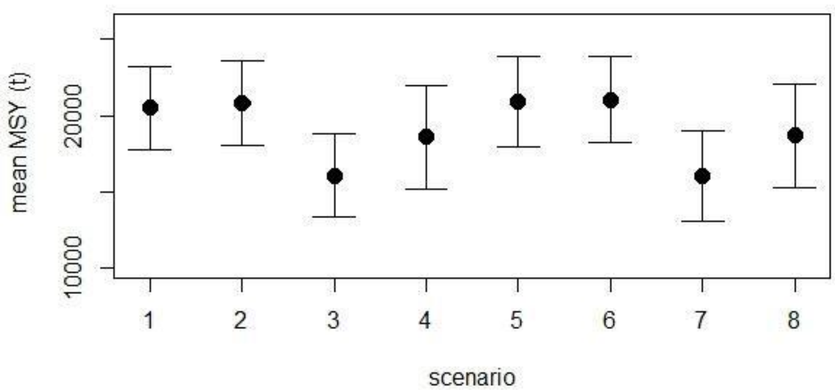

Figure 4: Sensitivity analysis for the final B/K. For each scenario is presented the estimated MSY with a high and low final B/K and the mean of the two values. Different scenarios represent different parameters combinations. The bars indicate the value of MSY using the two different B/K ratio values and the black dot the median value.

Table 6: Input parameters of the sensitivity analysis for the intrinsic growth r. For all 8 scenarios, MSY has been obtained and compared for the two values of r (high and low) combined with the given range for the other parameters.

	1	2	3	4	5	6	7	8
Initial B/K	0.7-0.9	0.7-0.9	0.7-0.9	0.7-0.9	0.3-0.7	0.3-0.7	0.3-0.7	0.3-0.7
Final B/K	0.5-0.7	0.5-0.7	0.2-0.5	0.2-0.5	0.5-0.7	0.5-0.7	0.2-0.5	0.2-0.5
r	0.2-1 0.05-0.5	0.2-1 0.05-0.5	0.2-1 0.05-0.5	0.2-1 0.05-0.5	0.2-1 0.05-0.5	0.2-1 0.05-0.5	0.2-1 0.05-0.5	0.2-1 0.05-0.5
K	C_{max}- 30*C_{max}	C_{max}- 10*C_{max}	C_{max}- 30*C_{max}	C_{max}- 10*C_{max}	C_{max}- 30*C_{max}	C_{max}- 10*C_{max}	C_{max}- 30*C_{max}	C_{max}- 10*C_{max}

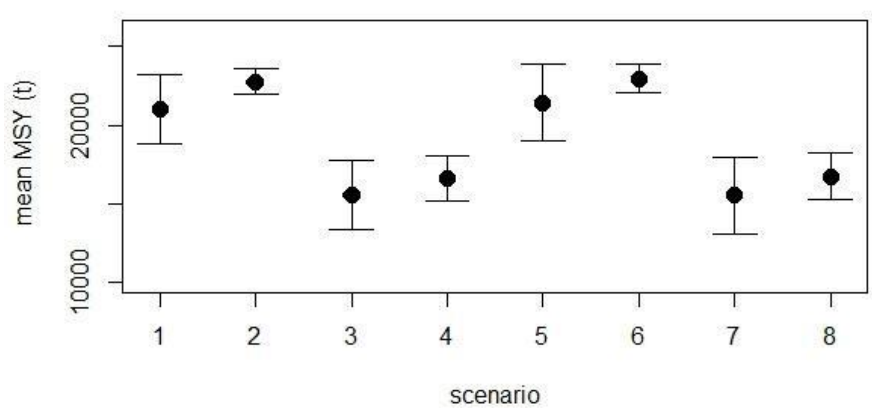

Figure 5: Sensitivity analysis for the intrinsic growth r. For each scenario is presented the estimated MSY with a high and low r and the mean of the two values. Different scenarios represent different parameters combinations. The bars indicate the value of MSY using the two different r values and the black dot the median value

Table 7: Input parameters of the sensitivity analysis for the carrying capacity K. For all 8 scenarios, MSY has been obtained and compared for the two values of K (high and low) combined with the given range for the other parameters.

	1	2	3	4	5	6	7	8
Initial B/K	0.7-0.9	0.7-0.9	0.7-0.9	0.7-0.9	0.3-0.7	0.3-0.7	0.3-0.7	0.3-0.7
Final B/K	0.5-0.7	0.5-0.7	0.2-0.5	0.2-0.5	0.5-0.7	0.5-0.7	0.2-0.5	0.2-0.5
r	0.2-1	0.05-0.5	0.2-1	0.05-0.5	0.2-1	0.05-0.5	0.2-1	0.05-0.5
K	C_{max}-30*C_{max} C_{max}-10*C_{max}	C_{max}-30*C_{max} C_{max}-10*C_{max}	C_{max}-30*C_{max} C_{max}-10*C_{max}	C_{max}-30*C_{max} C_{max}-10*C_{max}	C_{max}-30*C_{max} C_{max}-10*C_{max}	C_{max}-30*C_{max} C_{max}-10*C_{max}	C_{max}-30*C_{max} C_{max}-10*C_{max}	C_{max}-30*C_{max} C_{max}-10*C_{max}

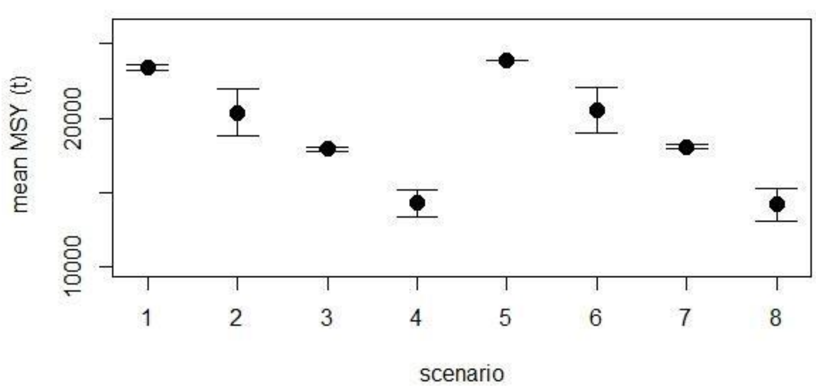

Figure 6: Sensitivity analysis for the carrying capacity K. For each scenario is presented the estimated MSY with a high and low K and the mean of the two values. Different scenarios represent different parameters combinations. The bars indicate the value of MSY using the two different K values and the black dot the median value.

Discussion

MSY from catch and resilience

Input parameters

The model developed by Martel and Froese (2013) is built on a simple surplus production model that uses removal data and estimates of the carrying capacity K and intrinsic growth r of the stock as input parameters. As the carrying capacity K and the intrinsic growth rate r are not exactly known, r-K pairs from the given distribution of these two parameters, are randomly selected and the model accepts the ones that do not result in a stock collapse or exceed the carrying capacity, resulting in a final biomass within the depletion level limits.

In the implementation of the model, the upper limit of the carrying capacity K, was chosen to be 15, 30 and 50 times the maximum catch in the time series , meaning a carrying capacity of around 420000 t, 840000 t and 1400000 t, respectively. The choice of these three different upper limits is based on rough estimates of Greenland halibut biomass in areas 0+1 and runs with K <15* max catch.

In the sensitivity runs of the model data from 1965-2011 were used, and the upper limit of the carrying capacity K, was chosen to be 10, 20 and 30 times the maximum catch in the time series (27000 t), meaning a carrying capacity of around 270000 t, 540000 t and 810000 t respectively.

For the intrinsic growth rate of Greenland halibut no estimations are available, but based on what is known of the species biology, it is believed to be a low resilience species. The analysis was also conducted with very low and medium resilience in order to assess, how the choice of growth rate impacts the model outcome. Another important input parameter to the model is the depletion level in the beginning and in the end of the time series, expressed as a B/K ratio. For the two scenarios presented, the range of the initial and final depletion was set be 0.5-0.9 K and 0.5-0.7 K respectively. The reason for choosing these depletion levels is that in the beginning of the available time series, the total catches of Greenland halibut were around 1700 t, which is very low compared to the maximum catch, being around 27000 t in 2010. Therefore, a very low depletion level could be assumed and a stock close to the virgin biomass. For the last year of the time series, where the catches are close to 27000 t, a higher degree of depletion is assumed compared to the first year of the time series. The CPUE are rather stable with a slight increase and the rough biomass estimation for areas 0+1 is also rather stable (however CPUE is not always proportional to stock biomass, as new more effective gears could be the reason for CPUE increase) and therefore the final depletion level can be assumed to be as previously stated. However, as the stock size of Greenland halibut is not known, it is hard to accurately define the depletion level. There were also Therefore conducted analysis for different depletion levels in order to see how this affects the model output.

Model assumptions and limitations

The model is based on the classic Schaefer surplus production, in which the overall effects of recruitment, growth and mortality are pooled into a single production function. That type of biomass dynamics model ignores the age structure of the stock and does not consider individual growth, recruitment or the vulnerability of the fish to the fishing gear (Hilborn and Walters 1992; Haddon 2011). The population is defined through the intrinsic growth rate r and the carrying capacity K. Both factors are assumed to be constant for all the years in the time series, and therefore environmental changes that could affect the growth rate and the carrying capacity of the population are not considered. However, as Greenland halibut is a deep water species living in temperatures between 0-6 ^{o}C and their larvae being bathypelagic (Bowering and Nedreas, 2000; Jørgensen, 2012), one can assume that its environment is relatively stable and buffered from environmental changes. Therefore a constant growth rate and carrying capacity can be assumed for the purpose of this work. Another aspect of the model is that it ignores the spatial structure of the stock, which is assumed to be closed to emigration and immigration. Greenland halibut in West Greenland is assessed at a separate stock, but it probably closely connected to the stock in NAFO SA 2 and 3 and may be also to the stock at East Greenland (Boje, 2002). In these runs it is assumed to be a separate stock.

The surplus production of the stock represents the biomass increase in the absence of fishing, or the amount of catch that can be taken, assuming that the stock is in equilibrium. Martel and Froese (2013) in their model do not assume equilibrium status for the stock but they assume constant r and K values. Furthermore, in the production equation, a symmetric relationship between surplus production and biomass is assumed, meaning that the surplus production is zero when the population is zero or when the population is equal to K due to density dependence, and maximum at a biomass of K/2, where K/2 is the B_{msy}. However, it is known that the relationship of the surplus production and carrying capacity can be asymmetric and therefore a parameter could be added, in order to skew the relationship, but the estimation of the skeweness is hard to conduct (Hilborn and Walters, 1992).

Another limitation of the model is that it only includes a process error, meaning that the catch is assumed to be measured without an error and all errors are attributed to the functional relationship between population growth rate and population size. Polacheck et al. (1993) compared three different application methods of biomass dynamic models: the equilibrium, process error and observation error method and applied from the methods for researching different fisheries. The results revealed that the observation method performed the best, wherea s the process error method, even though operated better than the equilibrium method, proved to be very imprecise. Therefore, it seems that the addition of observation error could make the model more robust. Finally, the most critical limitation of the model is that all the input parameters: the intrinsic growth rate, carrying capacity K and depletion levels for the first and for the final year of the time series are not known, but are approximated based on the available knowledge and therefore the estimation procedures are highly model dependent.

Model results

The six senarios are cominations of two levels of r and three levels of carrying capacity ranging from 420000 to 1400000 tons. In the runs with the low input r range (r=0.05-0.3) all output parameters are relatively stable (MSY : 19000 – 20600 tons, K: 336000 - 416000 t and r: 0.182- 0.246). In the runs with high input r range (r= 0.15-0.45) all output parameters were also relatively stable (MSY: 23332-23140 t, K: 262000-336000 t and r: 0.351 - 0.366). Indicated that model is rather insensitive to the input carrying capacity. However, a run with (C_{max}-10*C_{max}) showed that the possible combinations of r-K produced are distributed in the upper corner of the panel, indicating a too low upper limit given for K.

In both r scenarios the r-K plot follows the expected typical pattern, in which, while the value of r is increasing, the number of viable r-K pairs is declining. This is most pronounced with the high r values (fig 1 and 2 panel b). This is due to the fact that a high value of r can cause strong fluctuations in stock size, which is associated with risks of overshooting the carrying capacity or collapsing the stock (Martel and Froese, 2013). The low r also gives a wider distribution of K an MSY (Fig. 1 and 2 panel e and f). The low r input value also produces a wider range of K (Fig. 1 and 2 panel d) and a K value close to what is the maximum swept area biomass i.e a large population with a low growth rate a relatively low MSY.

As previously mentioned, the model depends on the “unknown” input parameters and therefore it was important to investigate, how sensitive the model is when the value of the parameters vary. The depletion level of the stock for the first year in the time series seems to have no effect on the estimation of MSY, but all the other parameters are affecting the model outcome. That seems logical, as it does not really matter what the stock size was 50 years ago. The two parameters that seem to affect the model outcome the most are the depletion level for the last year in the time series i.e. the present stock status, and the intrinsic growth rate. In order to a combination of r-K to be accepted by the model, the stock size in the last year of the time series needs to fall within the depletion level limits. In the case, where the depletion is high (low B/K ratio), the model gives a lower range for the carrying capacity K and a similar growth rate as for a low depletion. That means that during the iterations the production model, in order to explain the catch time series in combination with the high final depletion, gives estimates for the stock to be of a smaller size but with a relatively high growth rate. MSY is the product of 1/4r*K, the estimated MSY is lower in cases of assumed high current exploitation.

When the model is run with a high growth rate (medium resilience), even though the prior distribution of the carrying capacity -is the same with the model run with low growth rate, the posterior range for K is much lower. This stock with assumed higher growth rate, in order to be compatible with the catch time series and not collapse or exceed the carrying capacity, must be of a smaller size. Therefore even though the stock is smaller, as it grows faster and can recover faster from the fishing pressure, a higher MSY is estimated compared to a stock with low growth rate. The effect of carrying capacity combined with high growth rate is negligible. This is due to the fact that in the case of a higher growth rate, independently of the given value of the carrying capacity, the possible r-K combinations consist of lower values of K and therefore small difference in the MSY value is produced. On the opposite side, when the growth rate is low, the carrying capacity affects the model outcome, but in the opposite way than the other parameters.

The conducted analysis indicates that the choice of the appropriate range for the current depletion level, growth rate and carrying capacity is very crucial, as they highly affect the estimated reference points and consequently any decisions based on the results. However, the way the model estimates are affected by the input parameters seem to follow the common sense of population dynamics and therefore are as would be expected.

Application of the model

Biomass dynamics models have traditionally been the major assessment tool for many fisheries, particularly for the tuna agencies (ICCAT and IATTC). Even though they have been widely used in the past, more recently they have been looked down upon as poor cousins of the age-based models. The reason is that biomass dynamic models tend to fail to produce reasonable estimates for effort and MSY. However that cannot be due to model failure, but due to poor contrast between fishing effort and stock abundance (usually expressed as CPUE). The same type of data failure could cause an age-based model to fail (Hilborn and Walters, 1992).

The new catch-MSY method developed by Martel and Froese (2013), instead of using CPUE and fishing effort data that used to cause problems, is based on catch data. As the method is new, it is not yet widely used for stock assessments and its accuracy is not verified. The IOTC (Indian Ocean Tuna Commission) has recently used this method in order to assess the status of two neretic tuna species (Zhou and Sharma, 2013). Martel and Froese (2012) compared the MSY estimates produced with the catch-MSY method to MSY estimates from full stock assessments for 48 stocks from the Northeast Atlantic and 98 stocks from all over the world. A log-log linear comparison of the MSY estimates revealed that the catch–MSY estimates fell within the range of 0.5-1.5 of the independent estimates. Only in six cases the Catch-MSY estimate was significantly different from the full assessment estimate, and that was because the stocks were very lightly exploited and therefore the catch data in these cases did not contain sufficient information on the stock productivity (Figure 8 and Figure 9). Therefore, it is very important when the Catch-MSY tool is used that the catches reflect the stock productivity. When the estimated carrying capacity K was compared with the unexploited total biomass for all stocks, the catch-MSY method overestimated the carrying capacity and related biomass reference points by about 10%. Moreover, the comparison of r with F_{msy} fall below the 1:2 line of the relationship between r and F_{msy}. However, a better match was obtained when r was compared with the conservative $F_{0.1}$ from Y/R analysis. The authors concluded that the method's estimation of MSY is fairly robust and in agreement with the MSY estimates derived from full stock assessment methods and the bias of r and K is precautionary, as it suggests higher thresholds for biomass and lower thresholds for fishing mortality.

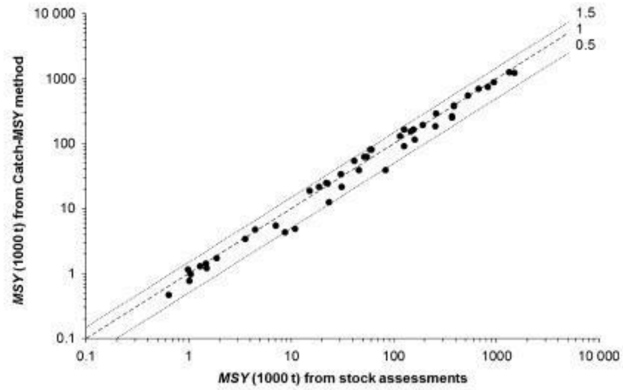

Figure 8: Plot of MSY estimated by the Catch-MSY method vs. full stock assessments for 48 stocks from the Northeast Atlantic. The broken line indicates the 1:1 relation, while the dotted lines indicate ratios of 0.5 and 1.5 respectively.

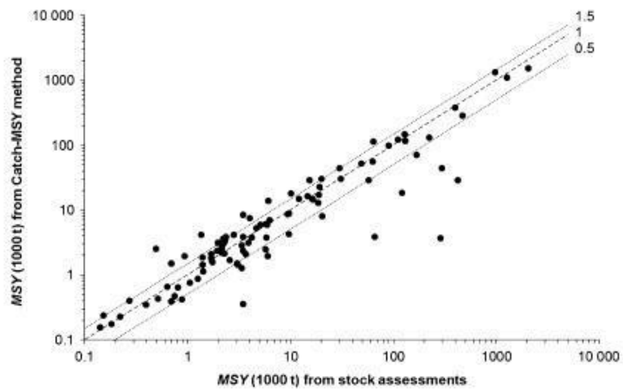

Figure 9: Plot of MSY estimated by the Catch-MSY method vs. full stock assessments for 98 global stocks. The broken line indicates the 1:1 relation, while the dotted lines indicate ratios of 0.5 and 1.5 respectively. The six outliers in the lower-right section of the graph are very lightly exploited stocks

However, the authors did not discuss the fact that the estimates of MSY using the catch-MSY tool fell within the range of 0.5-1.5 of the independent estimates, due to the fact that they were plotted on a log scale. Therefore, the relationship produced is simply a feature of the fact that the stocks examined differ by several orders of magnitude (Cook, 2013). In order to observe this model's weakness, it was implemented, using the default values for the input parameters Martel and Froese (2013) used in their paper, for seven different fully assessed stocks managed by ICES. The model output for the estimation of MSY in some cases was close to the ICES estimation of MSY, whereas in other cases the difference was significant. However, once these values were transformed into a log scale the difference between the estimated values became small and the plot of the two MSY estimates resulted in a fit within the range of 0.5-1.5. Indeed the transformation of the MSY estimate into log scale hid the model's inability of producing relatively accurate MSY estimates. However, it was also noticed that in the cases, where the difference of the MSY values was large, the current stock status was different than the one computed by the model using the default settings, which probably was the reason behind the failure. As Martel and Froese (2013) mentioned in their paper, the default values are not recommended for serious stock assessment and the best available knowledge about the respective stock should be used. Therefore, for the stocks with the greatest divergence in the MSY estimates, the current depletion level was changed to be according to the current stock status, and consequently the model outcome improved yielding results closer to the ICES MSY estimates. It should also be noted that the estimations of natural mortality and r were taken from Fishbase and the model was run only twice for each stock using only the available information on stock status available in the ICES assessment reports without any further information on the stocks. Therefore it is believe that if more information and time was used for testing the model, as conducted in the case of Greenland halibut, the model outcome would also be better.

When ageing of the fish is not possible or highly biased, as is the case with Greenland halibut, an age-based analysis is often not practical and the use of a biomass dynamics model is a better choice. In many cases a biomass dynamics model can provide answers that are as useful as or sometimes even better than, answers from age based methods and with the fraction of the cost (Jennings et al. 2001; Haddon, 2011). It is better to think of the two methods as simply different. If a biomass dynamic method provides a different answer than an age-based model, one should try to understand why the answers are different and analyze the management implications of the different predictions, rather than concentrate on deciding which method is correct.

Conclusion

The estimated MSY by the catch-MSY tool, 19000 t – 23000 t, is relatively low compared with the TAC, 30 000t, set for the stock. The conducted sensitivity analysis revealed, the results of the catch-MSY tool are highly dependent on the current depletion level assumed for the stock. Assuming a precautionary current depletion level in combination with the modeled value for the carrying capacity K, a relatively conservative MSY estimation was obtained. If more thorough biomass estimates become available in the future, the values for the carrying capacity K and for the depletion level could be more precisely set and a more accurate estimate of MSY could therefore be produced.

It should be noted, that all the input parameters used in the different models, i.e. the life history traits, carrying capacity K, growth rate r, stock biomass and depletion level are associated with uncertainty and their use and the outcome of the models are therefore considered precautionary. Moreover, the model applied is newly developed and one needs to be precautionary when utilizing the models, as they are not yet validated. Nevertheless, the results of the different models converged, seemingly confirming each other and providing an insight on the stock status, indicating that Greenland halibut is sustainably exploited.

The use of the newly developed catch-MSY method seems to be robust and provide valuable information when used with caution. In the case of Greenland halibut, where age-based models fail to produce reference points, the precautionary use of the catch-MSY model combined with further understanding on the stock dynamics and biology, could lead in a sustainably managed stock.

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Appendix A. Sensitivity analysis of catch-MSY method

Table 1: Results from the sensitivity analysis

Parameter/Scenariocen	1	2	3	4	5
Natural mortality M	0.2	0.2	0.2	0.2	0.2
Initial B/K	0.5-0.9	0.5-0.9	0.5-0.9	0.5-0.9	0.5-0.9
Final B/K	0.5-0.8	0.5-0.8	0.5-0.8	0.5-0.8	0.5-0.8
Initial r	0.05-0.2	0.05-0.5	0.015-0.1	0.2-1	0.05-0.5
Initial K	26934-808020	26934-808020	26934-808020	26934-808020	26934-269340
First MSY	15741	19858	9388	26956	21563
First r	0.113	0.18	0.0576	0.404	0.382
New upper bound for r	0.24	0.6	0.12	1.2	0.6
New range for K	250920-518163	141408-518163	353485-711283	82596-272607	142236-269255
Number of iterations	30000	30000	30000	30000	30000
Possible combinations	12023	8622	8622	9467	6120
Geom.mean r	0.155	0.265	0.0743	0.585	0.429
r±SD	0.0823-0.29	0.0953-0.736	0.0359-0.154	0.27-1.27	0.267-0.688
Geom.mean K	420553	328040	578669	178085	215959
K±SD	293969-573372	176593-609366	428240-781939	98761-321120	158476-294292
Geom.mean MSY	15869	21724	10753	26066	23151
MSY±SD	9209-27345	10678-44198	5687-20332	16486-41214	15386-34835
Fmsy	0.0775	0.1325	0.03715	0.2925	0.2145
Fmsy±SD	0.04115-0.145	0.04765-0.368	0.01795-0.077	0.135-0.635	0.1335-0.344
Bmsy	210276	164020	289334	89042	107979
Bmsy±SD	146984-286686	88296-304683	214120-390969	49380-160560	79238-147146

6	**7**	**8**	**9**	**10**	**11**	**12**
0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.5-0.9	0.5-0.9	0.5-0.9	0.5-0.9	0.5-0.9	0.5-0.9	0.5-0.9
0.5-0.8	0.5-0.7	0.5-0.7	0.5-0.7	0.5-0.7	0.5-0.7	0.5-0.7
0.05-0.5	0.05-0.5	0.05-0.2	0.015-0.1	0.2-1	0.05-0.5	0.05-0.5
26934-538680	26934-808020	26934-808020	26934-808020	26934-808020	26934-269340	26934-538680
20680	16787	14386	9397	22847	21267	18044
0.235	0.157	0.107	0.0577	0.404	0.378	0.21
0.6	0.6	0.24	0.12	1.2	0.6	0.6
142637-521937	145237-5144481	250920-492400	353485-636541	83549-263562	142236-269255	142637-532540
30000	30000	30000	30000	30000	30000	30000
10978	8223	10749	6758	7004	5237	8362
0.264	0.239	0.158	0.0822	0.564	0.417	0.231
0.0939-0.745	0.0837-0.68	0.0882-0.284	0.0458-0.148	0.26-1.22	0.261-0.688	0.0788-0.676
326323	31072	394603	536505	168500	212050	322443
174167-611406	164106-608762	288783-539198	417135-690034	92424-307193	155217-289694	165350-628787
21579	18847	15605	11027	23769	22118	18603
10579-44005	10662-33315	9573-25438	6580-18480	17235-32781	15877-30812	10418-33217
0.132	0.1195	0.079	0.0411	0.282	0.2085	0.1155
0.04695-0.3725	0.04185-0.34	0.0441-0.142	0.0229-0.074	0.13-0.61	0.1305-0.344	0.0394-0.338
163161	158036	197301	268252	84250	106025	161221
87083-305703	82053-304381	144391-269599	208567-345017	46212-153596	77608-144847	82675-314393

13	**14**	**15**	**16**	**17**	**18**	**19**
0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.5-0.9	0.5-0.9	0.5-0.9	0.5-0.9	0.5-0.9	0.5-0.9	0.5-0.9
0.3-0.7	0.3-0.7	0.3-0.7	0.3-0.7	0.3-0.7	0.3-0.7	0.2-0.5
0.05-0.5	0.05-0.2	0.015-0.1	0.2-1	0.05-0.5	0.05-0.5	0.05-0.5
26934-808020	26934-808020	26934-808020	26934-808020	26934-269340	26934-538680	26934-808020
15003	12677	7049	21032	17866	15189	11224
0.155	0.104	0.047	0.409	0.337	0.187	0.132
0.6	0.24	0.12	1.2	0.6	0.6	0.6
121470-416128	203478-420628	294541-558250	74050-221434	120303-269268	122110-407190	117684-367361
30000	30000	30000	30000	30000	30000	30000
10266	12101	9559	9184	7490	10104	6836
0.254	0.153	0.0722	0.586	0.372	0.26	0.229
0.0897-0.722	0.0796-0.296	0.0329-0.158	0.267-1.28	0.198-0.699	0.0933-0.727	0.0805-0.652
264828	334748	460915	146955	202930	260253	234314
145214-482970	241006-464954	346491-613127	84171-256572	138494-297345	143831-470914	128549-427100
16848	12835	8317	21520	18856	16944	13420
8568-33131	7261-22686	4193-16495	14162-32701	11651-30517	85-33133	7787-23125
0.127	0.0765	0.0361	0.293	0.186	0.13	0.1145
0.04485-0.361	0.0398-0.148	0.01645-0.079	0.1335-0.64	0.099-0.3495	0.04665-0.3635	0.04025-0.326
132414	167374	230457	73477	101465	130126	117157
72607-241485	120503-232477	173245-306563	42085-128286	69247-148672	71915-235457	64274-213550

20	**21**	**22**	**23**	**24**	**25**	**26**
0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.5-0.9	0.5-0.9	0.5-0.9	0.5-0.9	0.5-0.9	0.7-0.9	0.7-0.9
0.2-0.5	0.2-0.5	0.2-0.5	0.2-0.5	0.2-0.5	0.5-0.8	0.5-0.8
0.05-0.2	0.015-0.1	0.2--1	0.05-0.5	0.05-0.5	0.05-0.5	0.05-0.2
26934-808020	26934-808020	26934-808020	26934-269340	26934-538680	26934-808020	26934-808020
9832	5950	16901	14741	11447	19400	15723
0.0942	0.0421	0.402	0.292	0.151	0.175	0.112
0.24	0.12	1.2	0.6	0.	0.6	0.24
193208-385608	269213-460583	69582-208837	116879-269317	113427-373959	139772-514481	250111-494731
30000	30000	30000	30000	30000	30000	30000
11029	7628	5602	5593	6845	9999	10727
0.145	0.0792	0.521	0.316	0.226	0.262	0.161
0.0757-0.279	0.0421-0.149	0.224-1.21	0.153-0.652	0.0777-0.656	0.0934-0.732	0.0905-0.288
301938	393134	137417	192709	236354	326184	399371
217999-418197	311031-496909	76619-246458	125265-296466	127768-437225	174746-608863	293934-542628
10963	7785	17912	15207	13338	21326	16124
6807-17656	4476-13542	12817-25033	10328-22588	7678-2319	10692-42537	9703-26796
0.0725	0.0396	0.2605	0.158	0.113	0.131	0.0805
0.03785-0.1395	0.02105-0.0745	0.112-0.605	0.0765-0.326	0.03885-0.328	0.0467-0.366	0.04525-0.144
150969	196567	68708	96354	118177	163092	199685
108999-209098	155515-248454	38309-123229	62632-148233	63884-218612	87373-304431	146967-271314

27	**28**	**29**	**30**	**31**	**32**	**33**
0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.7-0.9	0.7-0.9	0.7-0.9	0.7-0.9	0.7-0.9	0.7-0.9	0.7-0.9
0.5-0.8	0.5-0.8	0.5-0.8	0.5-0.8	0.3-0.7	0.3-0.7	0.3-0.7
0.015-0.1	0.2-1	0.05-0.5	0.05-0.5	0.05-0.5	0.05-0.2	0.015-0.1
26934-808020	26934-808020	26934-269340	26934-538680	26934-808020	26934-808020	26934-808020
9373	26092	21724	20404	14776	12531	7040
0.0574	0.39	0.384	0.231	0.153	0.103	0.0469
0.12	1.2	0.6	0.6	0.6	0.24	0.12
358046-657701	81453-275350	146165-269255	141734-522007	120481-416125	201314-408721	295426-529319
30000	30000	30000	30000	30000	30000	30000
7246	21986	5857	10226	9734	11313	8517
0.0803	0.571	0.429	0.26	0.25	0.155	0.0767
0.0426-0.151	0.271-1.2	0.273-0.676	0.0939-0.722	0.0879-0.71	0.0834-0.29	0.0385-0.153
547398	179192	216858	328272	266443	329266	443596
420451-712675	100755-318692	160338-293303	175340-614593	145887-486623	241864-448251	342361-574767
10991	25564	23265	21371	16649	12799	8511
6283-19224	16755-39005	15804-34248	10849-42094	8560-32385	7471-21925	4636-15624
0.04015	0.2855	0.2145	0.13	0.125	0.0775	0.04258
0.0213-0.0755	0.1355-0.6	0.1365-0.338	0.04695-0.361	0.04395-0.355	0.0417-0.145	0.03835-0.0765
273699	89596	108429	164136	133221	164633	221798
210225-356337	50377-159346	80169-146651	87670-307296	72943-243311	120932-224125	171180-287383

34	35	36	37	38	39	40
0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.7-0.9	0.7-0.9	0.7-0.9	0.7-0.9	0.7-0.9	0.7-0.9	0.7-0.9
0.3-0.7	0.3-0.7	0.3-0.7	0.5-0.7	0.5-0.7	0.5-0.7	0.5-0.7
0.2-1	0.05-0.5	0.05-0.5	0.05-0.5	0.05-0.2	0.015-0.1	0.2-1
26934-808020	26934-269340	26934-538680	26934-808020	26934-808020	26934-808020	26934-808020
20694	17989	15044	16496	14165	9374	22468
0.4	0.339	0.185	0.155	0.105	0.0576	0.391
1.2	0.6	0.6	0.6	0.24	0.12	1.2
74050-215202	123701-269268	122199-538680	145523-513827	247571-462476	344461-677357	83319-271290
30000	30000	30000	30000	30000	30000	30000
7810	7332	9806	7714	9208	7204	5957
0.584	0.369	0.254	0.236	0.166	0.0776	0.524
0.278-1.23	0.197-0.691	0.0901-0.717	0.0836-0.667	0.0944-0.279	0.0392-0.154	0.24-1.14
146356	203861	262914	317776	380468	560491	177102
86189-248523	139741-297403	144819-477313	166277-607311	289183-500569	425768-737844	97256-322499
21357	18793	16707	18760	15827	10871	23206
14376-31728	11746-30067	8653-32254	10812-32550	10236-24472	5958-19834	16893-31877
0.292	0.1845	0.127	0.118	0.083	0.0388	0.262
0.139-0.615	0.0985-0.3455	0.04505-0.3585	0.0418-0.3335	0.0497-0.1395	0.0196-0.077	0.12-0.57
73178	131457	131457	158888	190234	280245	88551
43094-121261	72409-238656	72409-238656	83138-303655	144591-250284	212884-368922	48628-161249

42	**43**	**44**	**45**	**46**	**47**	**48**
0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.7-0.9	0.7-0.9	0.7-0.9	0.7-0.9	0.7-0.9	0.7-0.9	0.7-0.9
0.5-0.7	0.5-0.7	0.2-0.5	0.2-0.5	0.2-0.5	0.2-0.5	0.2-0.5
0.05-0.5	0.05-0.5	0.05-0.5	0.05-0.2	0.015-0.1	0.2-1	0.05-0.5
26934-269340	26934-538680	26934-808020	26934-808020	26934-808020	26934-808020	26934-269340
21316	17879	11086	9595	5734	16806	14812
0.38	0.208	0.135	0.0953	0.041	0.398	0.293
0.6	0.6	0.6	0.24	0.12	1.2	0.6
141982-269216	141264-520726	117684-368801	189133-342263	282879-499376	70782-207694	117689-269317
30000	30000	30000	30000	30000	30000	30000
4713	7480	6536	8861	9799	5118	5315
0.414	0.235	0.228	0.162	0.0716	0.512	0.316
0.262-0.654	0.0822-0.673	0.0795-0.656	0.0962-0.274	0.0329-0.156	0.226-1.16	0.152-0.653
212478	317120	233984	281924	415349	138936	192578
155991-289420	164072-612935	127740-428592	217508-365417	318437-541756	78966-244450	125193-296231
21993	18648	13363	11444	7436	17794	15196
16176-29900	10725-32424	7795-22908	7605-17221	3818-14481	12894-24557	10320-22377
0.207	0.1175	0.114	0.081	0.0358	0.256	0.158
0.131-0.327	0.0411-0.3365	0.03975-0.328	0.0481-0.137	0.01645-0.078	0.113-0.58	0.076-0.3265
106239	116992	116992	140962	207674	69468	96289
77995-144710	63870-214296	63870-214296	108754-182708	159218-270878	39483-122225	62596-148115

49	**50**	**51**	**52**	**53**	**54**	**55**	**56**
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.7-0.9	0.3-0.7	0.3-0.7	0.3-0.7	0.3-0.7	0.3-0.7	0.3-0.7	0.3-0.7
0.2-0.5	0.5-0.8	0.5-0.8	0.5-0.8	0.5-0.8	0.5-0.8	0.5-0.8	0.5-0.7
0.05-0.5	0.05-0.5	0.05-0.2	0.015-0.1	0.2-1	0.05-0.5	0.05-0.5	0.05-0.5
26934-538680	26934-808020	26934-808020	26934-808020	26934-808020	26934-269340	26934-538680	26934-808020
11293	20558	16314	11389	24458	21549	21372	17330
0.149	0.187	0.116	0.0698	0.293	0.382	0.244	0.164
0.6	0.6	0.24	0.12	1.2	0.6	0.6	0.6
117059-538680	140576-583387	250111-579870	356600-727715	84598-377879	142236-269255	138561-538619	144253-535473
30000	30000	30000	30000	30000	30000	30000	30000
6483	11330	12905	6680	8865	6162	10711	8132
0.218	0.251	0.152	0.0839	0.466	0.429	0.268	0.237
0.0739-0.643	0.0857-0.736	0.0795-0.291	0.0493-0.143	0.166-1.31	0.267-0.69	0.0975-0.736	0.085-0.664
240701	347887	439530	587636	217146	215988	330169	319916
130451-444129	176050-687449	297498-649371	432509-798403	102099-461830	158306-294686	173058-629916	163950-624255
13114	21844	16724	12325	25278	23167	22105	18991
7484-22979	10592-45050	9396-29767	7684-19769	14298-44691	15346-34974	11035-44280	11077-32561
0.109	0.1255	0.076	0.04195	0.233	0.2145	0.134	0.1185
0.03695-0.3215	0.04285-0.368	0.03975-0.1455	0.02465-0.0715	0.083-0.655	0.1335-0.345	0.04875-0.368	0.0425-0.332
120350	173943	219765	293818	108573	107994	165084	159958
65225-222064	88025-343724	148749-324685	216254-399201	51049-230915	79153-147343	86529-314958	81975-312127

57	**58**	**59**	**60**	**61**	**62**	**63**	**64**
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.3-0.7	0.3-0.7	0.3-0.7	0.3-0.7	0.3-0.7	0.3-0.7	0.3-0.7	0.3-0.7
0.5-0.7	0.5-0.7	0.5-0.7	0.5-0.7	0.5-0.7	0.3-0.7	0.3-0.7	0.3-0.7
0.05-0.2	0.015-0.1	0.2-1	0.05-0.5	0.05-0.5	0.05-0.5	0.05-0.2	0.015-0.1
26934-808020	26934-808020	26934-808020	26934-269340	26934-538680	26934-808020	26934-808020	26934-808020
14999	11376	22889	21280	18635	15371	13155	8467
0.11	0.0697	0.405	0.379	0.221	0.158	0.106	0.0553
0.24	0.12	1.2	0.6	0.6	0.6	0.24	0.12
250920-587893	356600-727715	82596-263562	139583-269255	137368-538619	121470-445976	207978-440696	309290-690031
30000	30000	30000	30000	30000	30000	30000	30000
12166	11376	7006	5247	8012	10441	12475	10481
0.145	0.0838	0.573	0.415	0.238	0.249	0.154	0.0713
0.0755-0.28	0.0492-0.143	0.263-1.25	0.258-0.667	0.0844-0.669	0.0873-0.708	0.0827-0.288	0.0326-0.156
437743	588568	166763	212717	321296	273423	344297	532654
295297-648902	434630-797029	91111-305231	155471-291040	164812-626355	144795-516316	241998-489839	366846-773404
15903	12326	23872	22067	19088	16992	13282	9500
9530-26538	7682-19781	17264-33009	15722-30972	11052-32965	8780-32885	7710-22881	4822-18718
0.0725	0.0419	0.2865	0.2075	0.119	0.1245	0.077	0.03565
0.03775-0.14	0.0246-0.0715	0.1315-0.625	0.129-0.3335	0.0422-0.3345	0.04365-0.354	0.04135-0.144	0.0163-0.078
218871	294284	83381	106358	160648	136711	172148	266327
147648-324451	217315-398514	45555-152615	77735-145520	82406-313177	72397-258158	120999-244919	183423-386702

65	**66**	**67**	**68**	**69**	**70**	**71**	**72**
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.3-0.7	0.3-0.7	0.3-0.7	0.3-0.7	0.3-0.7	0.3-0.7	0.3-0.7	0.3-0.7
0.3-0.7	0.3-0.7	0.3-0.7	0.2-0.5	0.2-0.5	0.2-0.5	0.2-0.5	0.2-0.5
0.2-1	0.05-0.5	0.05-0.5	0.05-0.5	0.05-0.2	0.015-0.1	0.2-1	0.05-0.5
26934-808020	26934-269340	26934-538680	26934-808020	26934-808020	26934-808020	26934-808020	26934-269340
21151	18006	15702	11670	10397	7131	16970	14855
0.41	0.339	0.195	0.132	0.0942	0.0484	0.405	0.295
1.2	0.6	0.6	0.6	0.24	0.12	1.2	0.6
74050-219359	121279-269268	122110-439408	115312-420628	189632-416128	281718-610228	70757-208668	115680-269317
30000	30000	30000	30000	30000	30000	30000	30000
9289	7596	10265	6884	10282	9778	5849	5612
0.6	0.373	0.249	0.208	0.142	0.0699	0.527	0.316
0.276-1.3	0.199-0.701	0.088-0.7	0.0684-0.633	0.0738-0.272	0.0324-0.151	0.227-1.22	0.155-0.646
144930	203056	273071	251706	314831	471933	136378	193154
83746-250815	137904-298987	145800-511436	129145-490580	219370-451831	330606-673675	75851-245203	125558-297140
21729	18947	17013	13098	11156	8248	17963	15268
14255-33121	11674-30750	8873-32619	7601-22569	7133-17446	4447-15298	12919-24977	10362-22496
0.3	0.1865	0.1245	0.104	0.071	0.03495	0.2635	0.158
0.138-0.65	0.0995-0.3505	0.0444-0.35	0.0342-0.3165	0.0369-0.136	0.0162-0.0755	0.1135-0.61	0.0775-0.323
72465	101528	136535	125853	157415	235966	68189	96577
41873-125407	68952-146493	72900-255718	64572-245290	109685-225915	165303-336837	37925-122601	62577-148570

73	**74**	**75**	**76**	**77**
0.2	0.2	0.2	0.2	0.2
0.3-0.7	0.7-0.9	0.7-0.9	0.3-0.7	0.3-0.7
0.2-0.5	0.5-0.7	0.2-0.5	0.5-0.7	0.2-0.5
0.05-0.5	0.2-1	0.2-1	0.2-1	0.2-1
26934-538680	26934-269340	26934-269340	26934-269340	26934-269340
11915	23060	16772	23468	16906
0.157	0.503	0.406	0.522	0.414
0.6	1.2	1.2	1.2	1.2
117323-414658	84046-256760	70645-200899	81996-261539	70645-269340
30000	30000	30000	30000	30000
6945	5674	5000	7128	5720
0.212	0.533	0.536	0.572	0.545
0.0709-0.633	0.265-1.15	0.243-1.18	0.264-1.24	0.247-1.2
249349	170370	134642	166858	133567
129332-480738	96373-301185	77420-234160	91548-304120	76806-232276
13203	23559	18048	23864	18193
7690-22667	17451-31805	13313-24467	17284-32948	13312-24862
0.106	0.2665	0.268	0.286	0.2725
0.03545-0.3165	0.1325-0.575	0.1215-0.59	0.132-0.62	0.1235-0.6
124674	85185	97321	83429	66783
64666-240369	48186-150592	38710-117080	45774-152060	38403-116138