ECOREGION The Barents Sea and the Norwegian Sea
SUBJECT NEAFC/JNRFC request to ICES on evaluation of proposed harvest control rules for *Sebastes mentella* in Subareas I and II

Advice summary

ICES has evaluated a wide variety of proposed settings for a management plan for this stock and identified a number of options that are considered precautionary and consistent with the MSY approach. Assumptions on future recruitment and initial yield (in the year of implementation of a management plan) have a large influence on the long-term perspective of yield and risk to the stock, and as usual there are trade-offs for the various options. ICES therefore offers additional considerations for the further development of the plan.

Request

ICES received two requests on the same topic, the evaluation of a harvest control rule for *Sebastes mentella* in Subareas I and II. The first request was submitted by the Joint Norwegian–Russian Fisheries Commission (JNRFC):

> *"The advice on catch levels for* Sebastes mentella *in ICES sub-areas I and II for 2013 was based on the ICES MSY-approach. As an approximation to the reference point* F_{msy}*, ICES used the reference point* $F_{0.1}$*.*
>
> *The parties responsible for managing the stock of* Sebastes mentella *seek to establish a Harvest Control Rule (HCR) for this fish stock. Before such an HCR is adopted the parties would request ICES to assess the consequences of a few alternative rules, in particular the following:*
>
> *A. An HCR based on the ICES MSY-approach with a fishing mortality equal to* $F_{0.1}$*.*
>
> *B. As A, but where the fishing mortality is set to ¾ of* $F_{0.1}$*.*
>
> *C. As A, but where the fishing mortality is set to 4/3 of* $F_{0.1}$*.*
>
> *The fishing mortality indicated in the alternatives above should be the reference point for the annual TAC when the Spawning Stock Biomass is at a level capable of producing maximum sustainable yield. Hopefully, setting the fishing mortality to one of these levels will also sustain the SSB at a productive level. We have, however, seen that due to natural conditions any fish stock may be reduced below such a productive level. An HCR for Sebastes mentella should specify pre-agreed actions if such development is seen in the future. The natural thing to do will be to reduce fishing mortality, and the parties would ask ICES to assess two different ways of doing this.*
>
> *Reduction of F when SSB falls below* $B_{trigger}$
> $B_{trigger}$ *is not known for this stock, but should be the reference point beneath which fishing mortality should be reduced. In lack of a precise figure for* $B_{trigger}$*, the Parties would ask ICES to assess the consequences of various levels of* $B_{trigger}$*. For each of the alternatives A, B or C above,* $B_{trigger}$ *should be set to either* B_{MSY} *or ¾* B_{MSY}*. Should the SSB fall below* $B_{trigger}$*, fishing mortality should be reduced linearly with SSB. F should reach zero before SSB reaches zero, e.g., at* $B_{stop} = ½ B_{MSY}$ *or* $B_{stop} = ¼ B_{MSY}$*. SSB refers to the Spawning Stock Biomass assessed in the year of assessment.*
>
> *Reduction of F when recruitment is reduced*
> *To the extent that recruitment is measured to be low in a series of years, this may call for a reduced fishing mortality when setting the annual TAC. The Parties would therefore ask ICES to assess the consequences of cutting fishing mortality by 25 or 50% if the average strength at age 2 for the year classes which are 3-12 years old in the year for which the TAC advice is given is at or below 33 % of average recruitment at age 2 for the period 1992-1996.*
>
> *ICES is requested to assess the consequences of the various rules with a) no modification of fishing mortality due to low SSB or recruitment, b) reduction of F when SSB falls below trigger points and c) reduction of F when recruitment is at a low level.*
>
> *TAC stability*

Some harvest control rules incorporates expected growth or decline of a fish stock, as well as stability elements, in the decision related to the annual TAC. An example of this is the HCR for Northeast Arctic Cod. The parties responsible for managing the stock of Sebastes Mentella would ask ICES to assess an HCR with some of the same feature as the one for Northeast Arctic Cod, namely;

D. *Estimate the average TAC level for the coming 5 years based on $F_{0.1}$. TAC for the next year will be set to this level as a starting value for the 5-year period. This procedure is to be repeated during the consecutive assessment, but the TAC should not deviate by more than +/-20% compared with the previous year's TAC.*

For all simulations, ICES is asked to assess the consequences through calculating the following performance indicators (expected values):

- *Annual yield during each of the next 5 years*
- *Medium term yield, represented as average yield during the next 5 and 10 years*
- *Long term yield, represented as average yield during the next 50 years*
- *Probability that SSB falls below $B_{trigger}$, in a 5, 10 and 50 year period*

Exploitation patterns
The medium to long-term consequences of various HCRs will also depend upon the exploitation pattern in the fishery. The parties would ask ICES to show which exploitation pattern is used in the simulations as well as to reflect upon how sensitive the results are for possible changes in the exploitation pattern.

Combinatorial of HCR explorations
Following the above, the total number of HCR explorations is 3 F's (1, 3/4 and 4/3 of $F_{0.1}$) x 2 $B_{trigger}$ (400 and 800 kt) x 2 B_{stop} (1/2 and ¼ B_{MSY}) x 3 recruitment reductions (0, 25 and 50%) x 2 TAC stability (on, off) = 72 combinations x 4 performance indices = 288 outputs"

The second request was submitted by NEAFC and was less specific:

> *Based on the advice for 2013, ICES is requested to explore possible long-term management plan options for redfish in ICES Sub-areas I and II. The objective of such a management plan shall be to establish levels of catches and fishing effort, which will result in the sustainable exploitation of pelagic redfish in ICES Sub-areas I and II, consistent with the precautionary approach and the principle of Maximum Sustainable Yield.*

Elaboration on the advice

An analytical stock assessment is available for *Sebastes mentella* in Subareas I and II (ICES, 2013). The estimated population time-series is short and is based on a fixed q assumption for one of three bottom surveys included in the assessment (the Norwegian ecosystem survey in the Barents Sea). Landings information is available from 1952, but the assessment starts in 1992 long after the landings peaked. The stock is currently increasing due to good recruitment and low fishing mortality. Some limited medium-term information on recruitment (high or low productivity, cyclic recruitment, influence of maternal biomass) is available back to 1980. Additional fishery-independent information is available from a combined acoustic/bottom trawl survey on mature fish in the Norwegian Sea), conducted in 2008, 2009, and 2013; the next such survey is planned for 2016. This series has not yet been included in the assessment model because of too few data points.

At present the exploitation rate is low and the directed fishery has only restarted after it has been closed within the Norwegian and Russian EEZ since the 1990s. The fishery in the international waters in the Norwegian Sea is managed by NEAFC and regulated by a TAC, while the fishery within the Norwegian and Russian EEZ is a bycatch fishery managed by JNRFC. The NEAFC TAC for 2013 was set at 19 500 t, but available records show that only about 5200 t had been taken by the end of September. In addition the bycatch fishery in 2013 is assumed to be close to the recent level of about 4000 t. The management situation is expected to change as it is planned to open a directed fishery inside the Norwegian and Russian EEZ in 2014. The average catch since 1952 is 40 kt; ten-year averages for 1952–1961, 1962–1971, 1972–1981, 1982–1991, 1992–2001, and 2002–2011 are: 30, 17, 121, 50, 12, and 13 kt.

ICES considers that with any management action for a long-lived, slow-growing, late-maturing stock it will take longer than five years before changes in the biomass are likely to be detected. Therefore, ten years seems to be a more sensible time span to assess the impact of a harvest control rule. The life history characteristics of this stock also make it vulnerable to overfishing, and once overfished, the recovery might take decades. ICES therefore recommends to apply a rather conservative management approach.

ICES evaluated 32 of the 72 potential combinations of settings provided by the requesting body, indicating which of the results are considered precautionary. The rationale for the evaluation of results was as follows: The biomass long-term equilibrium of the stock if harvested at $F_{0.1}$ (a proxy for F_{MSY}) is around 900 kt. If this is seen as a proxy for B_{MSY}, then a limit reference point B_{lim} could be half of it, around 450 kt. The request asked for the exploration of a $B_{trigger}$ or B_{stop} at 400 kt, so this value was used in the evaluation. ICES considers only those options precautionary which result in a low (< 5%) probability of the biomass falling below 400 kt in the next 50 years (time frame as requested).

From the results of the simulations ICES concludes that:

- A trigger of 800 kt increases variability of TAC between years. A trigger of 400 kt was tested, but was rarely encountered in the simulations. Triggers between 400 and 800 kt have not been evaluated, but should result in less variability than 800 kt at the same F. A biomass trigger of 600 kt seems to be a good starting point for future evaluations;

- The proposed F_{target} of 0.039 appears to be at the lower and 0.052 at the higher end of the range of F candidates that will result in a high long-term yield. There is, however, little long-term gain in yield if F_{target} is increased much above 0.039;

- A cyclic recruitment scenario requires the most conservative management approach. The stock and recruitment might benefit from a delayed or gradual implementation of a management plan, or a gradual increase of F (fishing at F_{target} only after the incoming stronger year classes have fully recruited to the fishery in 2017/2018); a low fixed TAC in the initial period or a stabilizing element in the management plan might have a similar effect if implemented on the basis of recent catch ;

- A pronounced decrease in F is considered sensible if weaker year classes are detected;

- Selectivity differs for pelagic and demersal fleets, with the share of immature fish being higher in demersal fisheries. Management might want to consider a strategy that gives a higher share of the catch to pelagic fisheries as this would reduce F and increase SSB (if yield is fixed) or give a higher overall yield (if F is fixed). Other potential differences in environmental impact, e.g. on habitats, were not considered in the evaluation.

While a lot of effort has been spent evaluating the full range of options provided, an assumption in the evaluation appears to be unrealistic, namely assuming a five-fold increase in yield in the first year (2014) even though the sum of the TACs set for that year is not yet known. Implementing a harvest control rule from 2015 onwards may therefore result in slightly higher stock sizes and catches for the years 2015 and onwards than indicated by the evaluation.

Implementing a harvest control rule with a catch stabilizer based on a high initial catch may have unwanted effects; this needs to be explored before implementing a HCR.

Suggestions

ICES recommends including a revision clause in the management plan, as a major revision of stock assessment results might be expected when data from the next survey in 2016 become available. This should provide more information on the absolute stock size and confirm whether the good year classes after 2003 have started recruiting to the mature stock.

ICES suggests that any stabilizer on TAC coming from a harvest control rule should be suspended when the SSB falls below $B_{trigger}$, as seen in the HCR for Northeast Arctic cod.

Basis of the advice

Methods

The PROST software (Åsnes and Bogstad, 2014) was chosen to perform the long-term stochastic simulations. PROST has previously been used in the evaluation of harvest control rules for Northeast Arctic cod, haddock, and saithe (see e.g. Kovalev and Bogstad, 2005). The software was modified for WKREDMP to accommodate for the features in the HCRs to be tested. In total, 10 000 simulations were run for each operating model/HCR combination.

The operating models

Simulations started from the beginning of 2013. The initial stock size was taken from the most recent assessment of the stock (ICES, 2013). Three alternative stock size scenarios were considered, calculated by assuming different values for the fixed catchability (q) for the Barents Sea ecosystem survey in the assessment model. In the simulations natural mortality (M), weight-at-age, and maturity-at-age were all assumed to be constant (M = 0.05, weights and maturity from modelled values).

The simulations were not full feedback (i.e. an assessment was not run for each year in the projection). Uncertainty in deriving the perceived view of the true stock (i.e. accounting for observation error in future catches and indices and model error) is included in a single ‘assessment error’ term. The assessment error was set to CV = 0.2 on a log scale for all age groups in all years, uncorrelated.

There is no clear stock–recruiment relationship for this stock (Figure 3.2.3.1.1). In the simulations two recruitment scenarios were considered: a hockey-stick and a cyclic recruitment function. The hockey-stick function assumes average recruitment, with variations in historically observed residuals. The cyclic recruitment function assumes that recruitment goes through phases of high and low recruitment.

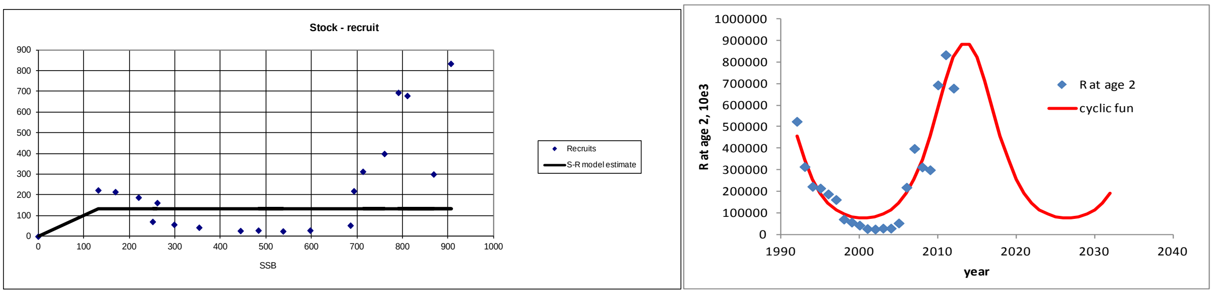

Figure 3.2.3.1.1 The two stock–recruitment functions used in the simulations.

Three alternative selection curves are considered – the average of the last five years for the total fleet, and the selection calculated at the 2013 assessment for the demersal and the pelagic fleet separately (Figure 3.2.3.1.2). Applying the same mean F for ages 12–18 to the different selectivities results in different yields. To further examine the impact of selectivity, runs were conducted fixing the mean F for each selectivity such that the long-term yields match those of the base case.

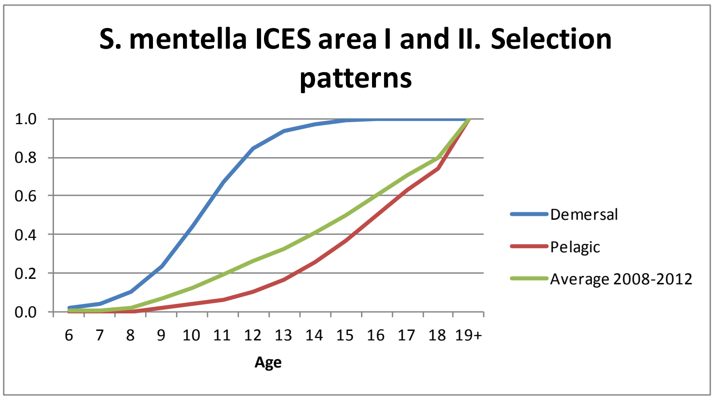

Figure 3.2.3.1.2 The three selectivity curves examined in the simulations.

The HCRs examined

Reference and trigger points

For this stock $F_{0.1}$ = 0.039 (ages 12–18; ICES, 2013) is currently not accepted as the F_{MSY} reference point and is used here only as proxy. Following the request, this leads to alternative F targets of F = 4/3 × $F_{0.1}$ = 0.052 and F = 3/4 × $F_{0.1}$ = 0.029. Stock development with no fishing (F = 0) was also examined.

No biomass reference points are defined for this stock at the moment, and it is unclear what the basis for the proposed trigger points (800 and 400 kt) is. Simulations show that long-term equilibrium for this stock at $F_{0.1}$ (proxy for F_{MSY}) is around 900 kt. If this is seen as a proxy for B_{MSY}, then B_{lim} could be around 450 kt. The request asked for the exploration of a $B_{trigger}$ or B_{stop} at 400 kt; therefore ICES only considers options precautionary when they result in a low (< 5%) probability of the biomass falling below 400 kt in the next 50 years (time frame as requested).

Reduction of F when recruitment is impaired

The request specifies under *Reduction of F when recruitment is reduced*: "…assess the consequences of cutting fishing mortality with 25 or 50% if the average strength at age 2 for year classes which are 3–12 years old in the year for which the TAC advice is given is at or below 33% of average recruitment at age 2 for the period 1992–1996." The 1992–1996 average is 293 million recruits at age 2, so ICES used 100 million as the threshold since that is very close to 33% of the average. If $SSB < B_{trigger}$, the reduction in F due to weak incoming year classes is applied to the F after it has been adjusted for $SSB < B_{trigger}$ (this issue was not dealt with in the request). For simplification, only the effect of a 50% reduction was considered.

TAC stabilizers

Concerning TAC stability, we suggest that limits on annual variability of TAC should be suspended when the SSB is below $B_{trigger}$, in the same way as in the HCR for Northeast Arctic cod. It was decided to have no stability clause as default, and then check the consequences of having a five-year rule, a 20% limit in annual TAC variation, as well as having a combination of those measures.

Since the simulations began in 2013, the first TAC set by the HCR in the simulations is for 2014. This leads to a higher initial TAC as a starting point for the HCRs (47 kt as advised for 2013 vs. 27 kt as advised for 2014). Hence in the simulations this led to very high catches in 2014 relative to what would be expected from the realised TAC for 2014 and the observed catches over the last decade. TACs in most simulations then show a gradual decline over the first five years. A more appropriate approach would likely start with a lower TAC and could gradually increase the catches if the stock responds (i.e. grows). There are several ways to formulate a rule for this purpose, but nothing specific has been proposed or tested.

Performance measures

The following performance indicators were used:

- Yield for the years 2014, 2015, 2016, 2017, and 2018.
- Mean yield for the periods 2014–2018, 2014–2023, and 2014–2063.
- Mean interannual variation in yield for the period 2014–2063 *(not in the request).*
- Mean F and SSB for the period 2014–2063 *(not in the request).*
- Probability of SSB falling below 800 kt for the periods 2014–2018, 2014–202,3 and 2024–2063.
- Probability of SSB falling below 400 kt for the periods 2014–2018, 2014–2023, and 2024–2063.

Base cases

A base case operating model and harvest control rule were defined. It was decided to explore the effect of the various operating models and HCRs by varying one or two factors at a time compared to the base case, rather than run all combinations. In total 32 runs were conducted. The full list of simulations conducted are listed in Annex 1.

Table 3.2.3.1.1 Base case operating model and harvest control rule.

	OM				HCR			
	1/q	Recruitment	Assess. Error	Selectivity	Fmp	Btrigger	Bstop	Stabiliser
Base case	3.5	H-st	0.2	Recent avg.	0.039	0	0	No

Results and conclusions

Simulation results for the selected performance indicators for each of simulations conducted are given in Annex 2.

Operating model sensitivity runs

Table 3.2.3.1.2 shows the performance of a constant F = 0.039 strategy for the different operating model settings. Long-term yield is lower in the case of a smaller stock and higher in the case of a large stock, with little difference in interannual variation in TAC. Cyclic recruitment leads to similar yields as for the hockey-stick recruitment, but due to larger fluctuations in stock size this leads to an increased probability of the stock falling below 400 kt. Performance in the absence of assessment error (i.e. perfect knowledge) is very similar in terms of yield, F, and SSB, but with a lower interannual variation in TAC.

Table 3.2.3.1.2 Operating model sensitivity tests. All results are for a constant F of 0.039.

				Yield								IAV yield%
	1/q	Recr	Assess. Error	2014	2015	2016	2017	2018	2014-2018	2014-2023	2014-2063	2014-2063
Base case	3.5	H-st	0.2	54	49	46	44	42	47	46	54	15
Smaller stock	**3**	H-st	0.2	44	41	38	36	35	39	39	50	15
Larger stock	**6**	H-st	0.2	99	91	84	79	77	86	83	71	16
Cyclic recruitment	3.5	**Cyclic**	0.2	53	49	46	44	42	47	46	56	16
No Assessment uncertainty	3.5	H-st	**0**	53	49	46	44	42	47	46	54	4

				Mean F	Mean SSB	prob2 < 800			prob2 < 400		
	1/q	Recr	Assess. Error	2014-2063	2014-2063	2014-2018	2014-2023	2024-2063	2014-2018	2014-2023	2024-2063
Base case	3.5	H-st	0.2	0.039	918	0.84	0.84	0.81	0	0	0.01
Smaller stock	**3**	H-st	0.2	0.039	862	1.00	1.00	0.86	0	0	0.01
Larger stock	**6**	H-st	0.2	0.039	1192	0.00	0.00	0.71	0	0	0.01
Cyclic recruitment	3.5	**Cyclic**	0.2	0.039	964	0.84	0.84	0.96	0	0	0.09
No Assessment uncertainty	3.5	H-st	**0**	0.039	916	0.84	0.84	0.81	0	0	0.01

Effect of varying F (Runs 7–9)

In the absence of fishing (F = 0), the long-term average of SSB in the base case operating model is 1640 kt in the case of no fishing. In the short term, even with no fishing, there is a >50% chance of the stock being below 800 kt, but a < 0.01% chance of the stock being below 400 kt. Table 3.2.3.1.3 shows the results for the base case HCR with alternative F target values. The long-term gain in yield by increasing F from 0.039 to 0.052 is low, but the probability of the stock falling below 400 kt increases to greater than 5%. If appropriate trigger points or starting TAC and stabilizers were applied, this probability could be reduced.

Table 3.2.3.1.3 The performance in the base case operating model of HCRs with alternative F target values.

		Yield								IAV yield%
	Fmp	2014	2015	2016	2017	2018	2014-2018	2014-2023	2014-2063	2014-2063
Base case	0.039	54	49	46	44	42	47	46	54	15
High F	0.052	71	64	58	54	51	59	57	60	14.8
Low F	0.029	41	38	36	35	34	39	37	47	15.9

		Mean F	Mean SSB	prob2 < 800			prob2 < 400		
	Fmp	2014-2063	2014-2063	2014-2018	2014-2023	2024-2063	2014-2018	2014-2023	2024-2063
Base case	0.039	0.039	918	0.84	0.84	0.81	< 0.01	< 0.01	0.01
High F	0.052	0.052	798	0.94	0.95	0.96	< 0.01	< 0.01	0.09
Low F	0.029	0.029	1028	0.74	0.74	0.52	< 0.01	< 0.01	< 0.01

Effect of varying trigger points (Run 10–23)

Table 3.2.3.1.4 shows the results for alternative $B_{trigger}$ and B_{stop} values used in the HCR. Under the assumption of a hockey-stick recruitment the difference between a $B_{trigger}$ of 400 kt and no $B_{trigger}$ (base case) is insignificant. When $B_{trigger}$ is set to 800 kt, the average F during the period 2014–2063 is slightly reduced compared to the target F since the stock biomass is often below $B_{trigger}$. A high $B_{trigger}$ (i.e. 800 kt) also increases interannual variation in yield. Lower B_{stop} values imply a less steep reduction in F below $B_{trigger}$ and hence, lower interannual variation in TAC. The very high probabilities of the stock being below 800 kt in the short and long term suggest that a $B_{trigger}$ lower than 800 kt would be more appropriate (e.g. between 600 and 700 kt).

Table 3.2.3.1.4 The performance in the base case operating model and in the operating model with cyclic recruitment of HCRs with alternative $B_{trigger}$ and B_{stop} values.

				Yield								IAV yield%
	Btrigger	Bstop	Recr	2014	2015	2016	2017	2018	2014-2018	2014-2023	2014-2063	2014-2063
Base case	0	0	H-st	54	49	46	44	42	47	46	54	15
800-400	800	400	H-st	46	41	38	37	38	40	43	52	29
800-200	800	200	H-st	48	43	40	38	39	42	44	52	24
800-0	800	0	H-st	49	45	42	40	39	43	45	53	21
800-0, cyclic	800	0	Cyclic	50	45	42	40	40	43	45	55	23
400-200	400	200	H-st	53	49	46	44	42	47	46	54	16
400-100	400	100	H-st	53	49	46	43	42	47	46	54	16
400-0	400	0	H-st	53	49	46	43	42	47	46	54	16
400-0, cyclic	400	0	Cyclic	54	49	46	44	42	47	46	56	16

				Mean F	Mean SSB	prob2 < 800			prob2 < 400		
	Btrigger	Bstop	Recr	2014-2063	2014-2063	2014-2018	2014-2023	2024-2063	2014-2018	2014-2023	2024-2063
Base case	0	0	H-st	0.039	918	0.84	0.84	0.81	< 0.01	< 0.01	0.01
800-400	800	400	H-st	0.036	944	0.82	0.82	0.78	< 0.01	< 0.01	< 0.01
800-200	800	200	H-st	0.037	936	0.83	0.83	0.79	< 0.01	< 0.01	< 0.01
800-0	800	0	H-st	0.037	935	0.84	0.84	0.79	< 0.01	< 0.01	< 0.01
800-0, cyclic	800	0	Cyclic	0.036	984	0.84	0.84	0.95	< 0.01	< 0.01	0.01
400-200	400	200	H-st	0.039	919	0.84	0.84	0.81	< 0.01	< 0.01	0.01
400-100	400	100	H-st	0.039	920	0.85	0.85	0.81	< 0.01	< 0.01	0.01
400-0	400	0	H-st	0.039	919	0.85	0.85	0.81	< 0.01	< 0.01	0.01
400-0, cyclic	400	0	Cyclic	0.039	966	0.84	0.84	0.96	<0.01	< 0.01	0.08

Effect of stabilizers (Runs 24–29)

The observed effect of introducing stabilizers is small (Table 3.2.3.1.5). WKREDMP (ICES, 2014) only considered runs applying the stabilizers that did not include $B_{trigger}$ or B_{stop} values in the HCRs. Although some reduction in interannual variation in TAC can be observed, it is unclear how effective these measures would be in reducing the higher interannual variation observed when biomass trigger points are included in the HCR. Under base case assumptions, the five-year rule will decrease the catches in the years 2014–2016 compared to a HCR without a stabilizer. However, this conclusion is specific to the choice of initial TAC for the HCR which was based on the 2014 TAC. Alternative starting conditions such as the 2013 TAC or catches in 2013 might give a different response for the first years.

Table 3.2.3.1.5 The performance in the base case operating model of HCRs with alternative stabilizers.

			Yield								IAV yield%
	Stabiliser	Recr	2014	2015	2016	2017	2018	2014-2018	2014-2023	2014-2063	2014-2063
Base case	No	H-st	54	49	46	44	42	47	46	54	15
20%, H-st	20%	H-st	54	50	47	44	42	47	46	54	16
20%, cyclic	20%	Cyclic	53	50	47	44	42	47	46	56	12
5yr, H-st	5-year av.	H-st	47	45	44	44	45	44	48	54	16
5yr, cyclic	5-year av.	Cyclic	53	50	47	44	42	47	46	56	12
both, H-st	20% +5-year av.	H-st	47	45	44	44	44	45	48	54	11
both, cyclic	20% +5-year av.	Cyclic	47	45	44	44	44	45	48	56	11

			Mean F	Mean SSB	prob2 < 800			prob2 < 400		
	Stabiliser	Recr	2014-2063	2014-2063	2014-2018	2014-2023	2024-2063	2014-2018	2014-2023	2024-2063
Base case	No	H-st	0.039	918	0.84	0.84	0.81	< 0.01	< 0.01	0.01
20%, H-st	20%	H-st	0.039	919	0.85	0.85	0.81	< 0.01	< 0.01	0.01
20%, cyclic	20%	Cyclic	0.039	968	0.85	0.85	0.96	< 0.01	< 0.01	0.10
5yr, H-st	5-year av.	H-st	0.039	915	0.80	0.80	0.78	< 0.01	< 0.01	0.01
5yr, cyclic	5-year av.	Cyclic	0.039	968	0.85	0.85	0.96	< 0.01	< 0.01	0.10
both, H-st	20% +5-year av.	H-st	0.039	916	0.80	0.80	0.79	< 0.01	< 0.01	0.01
both, cyclic	20% +5-year av.	Cyclic	0.040	955	0.80	0.80	0.95	< 0.01	< 0.01	0.05

Effect of reducing F for low incoming recruitment (Run 30)

In the scenario of cyclic recruitment, applying the recruitment-based reduction in F rule leads to notably lower probabilities of the stock falling below 400 kt (Table 3.2.3.1.6). This comes at a cost of higher interannual variation in TAC.

Table 3.2.3.1.6 The performance in the cyclic recruitment operating model of HCRs with alternative F target values.

			Yield								IAV yield%
	Adjust F	Recr	2014	2015	2016	2017	2018	2014-2018	2014-2023	2014-2063	2014-2063
Base case	No	Cyclic	53	49	46	44	42	47	46	56	16
Recruit based	Recruit based	Cyclic	53	49	46	43	42	47	46	52	20

			Mean F	Mean SSB	prob2 < 800			prob2 < 400		
	Adjust F	Recr	2014-2063	2014-2063	2014-2018	2014-2023	2024-2063	2014-2018	2014-2023	2024-2063
Base case	No	Cyclic	0.039	964	0.84	0.84	0.96	< 0.01	< 0.01	0.09
Recruit based	Recruit based	Cyclic	0.035	1013	0.84	0.84	0.93	< 0.01	< 0.01	< 0.01

Effect of varying selection pattern (Run 31–32)

If the F applied under each selectivity scenario is scaled to give the same average yield for the period 2014–2063 as the base case, the mean F for ages 12–18 is higher for the demersal selectivity compared to the pelagic selectivity (Table 3.2.3.1.7). In this case fishing with the pelagic selectivity leads to a higher stock size and a lower probability of the stock falling below 400 kt than the demersal selection pattern, with a slightly higher interannual variation in TAC. If the same mean F for ages 12–18 (F = 0.039) is fished using the demersal selectivity, a lower catch would be taken compared to using the pelagic selectivity. This would also result in a higher average biomass of the stock in the long term.

Table 3.2.3.1.7 The performance in the base case operating model of HCRs with alternative selectivity functions.

		Mean F	Yield								IAV yield%
	Selectivity	2014-2063	2014	2015	2016	2017	2018	2014-2018	2014-2023	2014-2063	2014-2063
Base case	Recent avg.	0.039	54	49	46	44	42	47	46	54	15
Demersal, same LT yield	Demersal	0.060	48	47	46	47	49	47	53	54	13
Demersal, same F	Demersal	0.039	31	31	32	32	34	32	37	43	8
Pelagic, same LT yield	Pelagic	0.032	56	50	46	42	39	48	47	54	17
Pelagic, same F	Pelagic	0.039	68	60	53	49	45	55	50	59	20

		Mean F	Mean SSB	prob2 < 800			prob2 < 400		
	Selectivity	2014-2063	2014-2063	2014-2018	2014-2023	2024-2063	2014-2018	2014-2023	2024-2063
Base case	Recent avg.	0.039	918	0.84	0.84	0.81	< 0.01	< 0.01	0.01
Demersal, same LT yield	Demersal	0.060	837	0.81	0.81	0.91	< 0.01	< 0.01	0.03
Demersal, same F	Demersal	0.039	1031	0.67	0.67	0.46	< 0.01	< 0.01	0.00
Pelagic, same LT yield	Pelagic	0.032	948	0.86	0.86	0.76	< 0.01	< 0.01	0.01
Pelagic, same F	Pelagic	0.039	874	0.92	0.92	0.90	< 0.01	< 0.01	0.04

Sources

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3.2.3.1 Annex 1

Overview of runs made to explore sensitivity to changes in the operating model and the HCR.

Run no	1/q	Recr	Assess. Error	F	Selectivity	Btrigger	Bstop	Stabiliser	F dep incom recr
1	3.5	H-st	0.2	0.039	Recent average	0	0	No	No
2	3	H-st	0.2	0.039	Recent average	0	0	No	No
3	6	H-st	0.2	0.039	Recent average	0	0	No	No
4	3.5	Cyclic	0.2	0.039	Recent average	0	0	No	No
5	3	Cyclic	0.2	0.039	Recent average	0	0	No	No
6	3.5	H-st	0	0.039	Recent average	0	0	No	No
7	3.5	H-st	0.2	0.052	Recent average	0	0	No	No
8	3.5	H-st	0.2	0.02925	Recent average	0	0	No	No
9	3.5	H-st	0.2	0	Recent average	0	0	No	No
10	3.5	H-st	0.2	0.039	Recent average	800	400	No	No
11	3.5	H-st	0.2	0.039	Recent average	800	200	No	No
12	3.5	H-st	0.2	0.039	Recent average	800	0	No	No
13	3.5	Cyclic	0.2	0.039	Recent average	800	0	No	No
14	3.5	H-st	0.2	0.039	Recent average	400	200	No	No
15	3.5	H-st	0.2	0.039	Recent average	400	100	No	No
16	3.5	H-st	0.2	0.039	Recent average	400	0	No	No
17	3.5	Cyclic	0.2	0.039	Recent average	400	0	No	No
18	3	H-st	0.2	0.039	Recent average	800	400	No	No
19	3	H-st	0.2	0.039	Recent average	800	200	No	No
20	3	H-st	0.2	0.039	Recent average	800	0	No	No
21	3	H-st	0.2	0.039	Recent average	400	200	No	No
22	3	H-st	0.2	0.039	Recent average	400	100	No	No
23	3	H-st	0.2	0.039	Recent average	400	0	No	No
24	3.5	H-st	0.2	0.039	Recent average	0	0	20%	No
25	3.5	Cyclic	0.2	0.039	Recent average	0	0	20%	No
26	3.5	H-st	0.2	0.039	Recent average	0	0	5-year av.	No
27	3.5	Cyclic	0.2	0.039	Recent average	0	0	5-year av.	No
28	3.5	H-st	0.2	0.039	Recent average	0	0	20% +5-year	No
29	3.5	Cyclic	0.2	0.039	Recent average	0	0	20% +5-year	No
30	3.5	Cyclic	0.2	0.039	Recent average	0	0	No	Yes
31	3.5	H-st	0.2	0.060	Demersal	0	0	No	No
32	3.5	H-st	0.2	0.032	Pelagic	0	0	No	No

3.2.3.1 Annex 2

Results of runs for various operating models and HCRs. Mean biomasses and catches in thousand tonnes.

	Y	Y	Y	Y	Y	Y 14-18	Y 14-23	Y 14-63	IA var yield%	Mean F	Mean SSB	prob2 < 800	prob2 < 800	prob2 < 800	prob2 < 400	prob2 <400	prob2 < 400
Run	2014	2015	2016	2017	2018	2014-2018	2014-2023	2014-2063	2014-2063	2014-2063	2014-2063	2014-2018	2014-2023	2024-2063	2014-2018	2014-2023	2024-2063
1	54	49	46	44	42	47	46	54	15	0.039	918	0.839	0.839	0.807	0.000	0.000	0.010
2	44	41	38	36	35	39	39	50	15	0.039	862	0.999	0.999	0.858	0.010	0.010	0.013
3	99	91	84	79	77	86	83	71	16	0.039	1192	0.001	0.001	0.713	0.000	0.000	0.007
4	53	49	46	44	42	47	46	56	16	0.039	964	0.837	0.837	0.962	0.000	0.000	0.090
5	44	41	38	36	35	39	39	53	16	0.039	909	1.000	1.000	0.964	0.009	0.009	0.130
6	53	49	46	44	42	47	46	54	4	0.039	916	0.841	0.841	0.806	0.000	0.000	0.011
7	71	64	58	54	51	59	57	60	15	0.052	798	0.945	0.945	0.964	0.000	0.000	0.091
8	41	38	36	35	34	39	37	47	16	0.029	1028	0.743	0.743	0.520	0.000	0.000	0.000
9	0	0	0	0	0	0	0	0	0	0.000	1640	0.543	0.543	0.000	0.000	0.000	0.000
10	46	41	38	37	38	40	43	52	29	0.036	944	0.824	0.824	0.783	0.000	0.000	0.000
11	48	43	40	38	39	42	44	52	24	0.037	936	0.829	0.830	0.795	0.000	0.000	0.000
12	49	45	42	40	39	43	45	53	21	0.037	935	0.840	0.840	0.791	0.000	0.000	0.000
13	50	45	42	40	40	43	45	55	23	0.036	984	0.837	0.837	0.955	0.000	0.000	0.007
14	53	49	46	44	42	47	46	54	16	0.039	919	0.841	0.842	0.806	0.000	0.000	0.009
15	53	49	46	43	42	47	46	54	16	0.039	920	0.846	0.846	0.805	0.000	0.000	0.010
16	53	49	46	43	42	47	46	54	16	0.039	919	0.850	0.850	0.813	0.000	0.000	0.012
17	54	49	46	44	42	47	46	56	16	0.039	966	0.841	0.842	0.959	0.000	0.000	0.085
18	29	26	24	24	26	26	46	48	18	0.034	896	0.998	0.998	0.821	0.007	0.007	0.000
19	34	30	28	28	29	30	34	49	26	0.035	888	0.998	0.998	0.826	0.005	0.005	0.000
20	37	33	31	30	30	32	35	49	22	0.036	884	0.999	0.999	0.834	0.007	0.007	0.000
21	44	40	38	36	35	39	39	50	16	0.039	861	1.000	1.000	0.862	0.009	0.009	0.012
22	44	40	38	36	35	39	39	50	15	0.039	862	1.000	1.000	0.860	0.010	0.010	0.014
23	44	40	38	36	35	39	39	50	15	0.039	861	0.999	0.999	0.858	0.009	0.009	0.011
24	54	50	47	44	42	47	46	54	16	0.039	919	0.845	0.846	0.806	0.000	0.000	0.013
25	53	50	47	44	42	47	46	56	12	0.039	968	0.852	0.852	0.961	0.000	0.000	0.097
26	47	45	44	44	45	44	48	54	16	0.039	915	0.803	0.803	0.780	0.000	0.000	0.005
27	53	50	47	44	42	47	46	56	12	0.039	968	0.849	0.849	0.959	0.000	0.000	0.101
28	47	45	44	44	44	45	48	54	11	0.039	916	0.797	0.797	0.786	0.000	0.000	0.005
29	47	45	44	44	44	45	48	56	11	0.040	955	0.804	0.804	0.947	0.000	0.000	0.052
30	53	49	46	43	42	47	46	52	20	0.035	1013	0.840	0.840	0.926	0.000	0.000	0.003
31	48	47	46	47	49	47	53	54	13	0.060	837	0.805	0.806	0.911	0.000	0.000	0.028
32	56	50	46	42	39	48	47	54	17	0.032	948	0.862	0.862	0.763	0.000	0.000	0.008