ECOREGION Bay of Biscay and Atlantic Iberian waters
SUBJECT Management plan evaluation for sardine in Divisions VIIIc and IXa

Advice summary

This stock has no agreed biomass reference points and given the data available, ICES was unable to define a B_{lim} to use for this evaluation. ICES therefore concludes that the plan is provisionally precautionary, based on three criteria (see below).

Further exploration of sardine stock dynamics is required; for example it may be possible to draw inferences from studies of other sardine stock dynamics at low biomass. This will provide a better informed basis for determining precautionary criteria which may improve the evaluation of the current proposed plan. Additionally, alternative settings (lower target catch, higher trigger points) and catch stabilizers could be tested to improve the performance of the plan and make it more precautionary.

Request

ICES received the following request from the European Commission:

ICES advice (2012) on the Iberian stock of sardines shows that the biomass has been at a stable historical low since 2009, recruitment has been below the long-term average and the fishing mortality is around the average. To ensure the recovery of this stock, Portugal and Spain developed a multiannual management plan. Given the importance of this fishery for both Portugal and Spain, the European Commission is following closely the implementation of this plan. The introduction of a TAC at EU level is under consideration in light of the results from the implementation of the national plan. In this context, ICES is requested to advise on whether the aforementioned plan is consistent with ICES precautionary approach in the long-term.

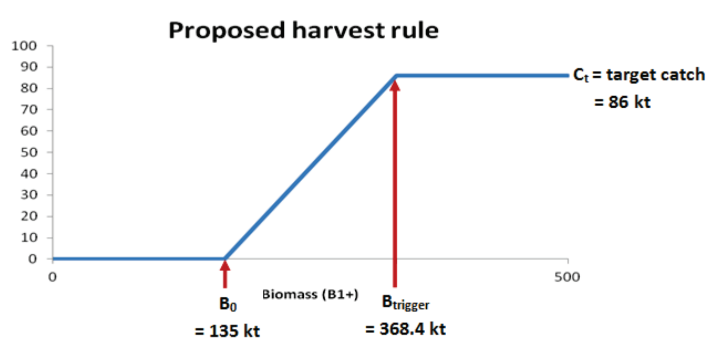
In the document referred to in the request (*Plan de gestion sardina*), the harvest rule is stated as:

$B_{1+} > B_{trigger}$ → $C_{MAX} = C_t$ kt
$B_0 < B_{1+} < B_{trigger}$ → $C_{MAX} = d(B_{1+} - B_0)$ kt
$B_{1+} < B_0$ → $C_{MAX} = 0$

where

B_{1+} = the biomass of the ages 1 and older, in kt [1)]
C_{MAX} = maximum catch in kt
$B_{trigger}$ = 368.4 kt (1.2 B_{lim})
d = 0.36
B_0 = 135 kt
C_t = target catch = 86 kt.

The harvest rule is illustrated in the figure below:



The harvest rule sets a TAC directly according to an estimate of the biomass of fish aged 1 and older (B_{1+}). The TAC is fixed at Ct when B_{1+} is above $B_{trigger}$, and reduced if it is below.

[1] For the purpose of this evaluation the B_{1+} from the beginning of the intermediate year is used.

ICES has not defined a B_{lim} for this stock but for the purposes of the formulation of this plan the value is taken as B_{loss} in 2000 according to the 2012 assessment.

Elaboration on the advice

The basis for the evaluation is a standard ICES approach using recruitment and growth from the last two decades, where productivity is lower than before.

This stock has no agreed biomass reference points and from the data available in 2012 ICES was unable to define a B_{lim} to use for this purpose. Therefore for this stock, ICES concludes that the plan is provisionally precautionary, based on three criteria:

1. A very low probability (zero) of F in the plan exceeding F_{loss}.
2. A low probability (0.13) of $B_{1+} < B_{loss}$ (B_{loss} = 306 kt).
   The evaluations show that the probabilities of B_{1+} being below B_{loss} are higher in the first few years (Table 7.3.5.1.1). These probabilities are shown to reduce to the long-term value (0.13) by 2015.
3. A high probability (0.93) of recovery if B_{1+} declines below B_{loss}.

The main results of the simulations are shown in Tables 7.3.5.1.1 and 7.3.5.1.2, and illustrated in Figure 7.3.5.1.1. As the plan is constructed to give a constant TAC with a relatively rapid reduction if the biomass declines below the $B_{trigger}$ there may be occasions where the TAC will be reduced quite strongly (Figure 7.3.5.1.1, upper right; see also suggestions below).

Overall the proposed plan implies a relatively modest exploitation rate with mean F = 0.22, which is 70% of natural mortality and lower than a potential F_{MSY} of 0.27.

Compared to last year's assessment, the estimate of B_{1+} in 2012 was revised downwards by 46% and F_{2011} was revised upwards by around 65%. This revision is particularly sensitive to the missing acoustic survey in 2012 and that it is now two years since the last daily egg production method (DEPM) survey. This overestimation means that the stock has been fished at higher F than intended. The main uncertainties in the assessment relate to the discrepant signals about the stock trends provided by DEPM and acoustic surveys. The basis of the model was changed in 2012 which explains the shift in subsequent assessments. Although the survey data appear to be the primary cause of the problem, ICES is unable to determine whether this problem will continue or not.

In recent years, the assessment has tended to overestimate stock abundance and underestimate mortality. If the present bias persists, it would be advisable to revisit the harvest rule. The same applies if the recruitment regime changes.

Suggestions

The current assessment is sensitive to the DEPM and the acoustic surveys which show discrepant signals in the stock trajectory. The assessment tends to accommodate the signals from the two surveys by providing broadly an average perspective. The triennial modus for the DEPM survey (last survey 2011) can cause large fluctuations in the assessment (eg. between 2012 and 2013). When the biomass is low the plan gives rather large fluctuations in TACs, which could be reduced by aiming for a lower target catch or TAC stabilization.

Alternative target catches (C_t) and trigger points for the harvest control rule were examined briefly to give an indication of other possible options, but no specific alternatives are proposed. Some stability mechanisms were also examined briefly but were not assessed against precautionary criteria. If future amendments are considered, it is recommended to continue to develop them in an inclusive process with involvement of all interested parties.

Basis of the advice

<u>Background</u>

In order to ensure recovery of the sardine stock, Portugal and Spain developed a multiannual management plan. This plan was evaluated by ICES in a workshop in June 2013 (WKSardineMP; ICES, 2013) with scientists and stakeholders. The workshop discussed the definition of reference points in order to evaluate the management plan, and considered alternative approaches to assess if the plan was precautionary, as well as alternative settings of the harvest control rule itself.

The request does not specify which year the biomass shall represent. In this evaluation the biomass at the start of the year before the TAC year was used as biomass B_{1+}. This biomass is directly estimated in the assessment and it does not depend on the unknown magnitude of the incoming year class.

Results and conclusions

Precautionary considerations

ICES considers the proposed management plan to be provisionally precautionary. In lieu of a limit biomass reference point for this stock, ICES has based its precautionary approach on three criteria:

1. A very low probability of F in the plan exceeding F_{loss}.
2. A low probability of $B_{1+} < B_{loss}$ (B_{loss} = 306 kt).
3. A high probability of recovery if B_{1+} declines below B_{loss}.

The reason for this approach is that this stock has no agreed biomass reference points and given the data available, ICES was unable to define a B_{lim} to use for this purpose. Although B_{loss} (B_{1+} = 306 kt) is available from the recent time-series it was not considered a suitable candidate for B_{lim}. This is because information on the recent stock dynamics has been based on a period of relatively low exploitation rates, with mean fishing mortality (F = 0.31) slightly lower than natural mortality (M = 0.33). At this exploitation rate the 2012 assessment showed no decline in recruitment at B_{loss}. Thus, the historical biomass range explored during this period is not considered appropriate to parameterize biomass of the stock in terms of B_{lim}. The criterion of 5% or less probability of $B_{1+} < B_{lim}$ that ICES would normally use as a basis to evaluate whether a management plan is precautionary or not is therefore not appropriate in this case and an alternative approach is required. The following three criteria were selected.

Criterion 1: Very low (negligible) probability of exceeding F_{loss}. F_{loss} is calculated as the F that will provide stock replacement B_{loss} at given recent recruitment (1993–2010) and recent growth (1991–2011) and results in a value of 0.51 (Silva *et al.*, 2013). The evaluation provides the distribution of realised F under the proposed plan. The 10–90% intervals were between F = 0.15 and F = 0.31, and there were no occasions when F exceeded F_{loss} = 0.51 (Figure 7.3.5.1.1 and Table 7.3.5.1.2).

Criterion 2: Low probability of $B_{1+} < B_{loss}$ (with B_{loss} greater than B_{lim} and a probability of $B_{1+} < B_{loss}$ much less than 0.5). The evaluation provides the distribution of realised biomass under the assumptions of the simulations (see methods below). The probability of $B_{1+} < B_{loss}$ under the proposed management plan was 0.13. This probability is considered acceptable.

Criterion 3: High probability of stock recovery from below B_{loss} in a short time period. The likelihood of recovery was evaluated and showed that should the stock fall below B_{loss}, the probability of recovering above B_{loss} in five years or less was 93%. In the longer term all simulated stocks recover above B_{loss}. This result is based on the assumptions in the simulations (see methods below), which is regarded as a relatively conservative model for recruitment below B_{loss}. Moreover, the simulations also tested the sensitivity of recovery to bias in the assessment and even with a positive bias of up to 30%, the probability of recovery in five years once the stock falls below B_{loss} is still as high as around 80%.

None of these criteria alone would be sufficient to consider the proposed plan as precautionary; however, taken together these criteria are considered sufficient to class the proposed plan as precautionary. Additionally it should be noted that the proposed plan includes the possibility of closing the fishery should the biomass reduce substantially below B_{loss}.

MSY considerations

In addition to the management plan evaluations ICES also evaluated potential values for F_{MSY}. Highest yield was obtained with F = 0.34, but this implied a 0.44 probability of $B_{1+} < B_{loss}$ which was considered not precautionary. At the other extreme was F = 0.22, similar to the average F under the management plan, which gave a probability of 0.05 of $B_{1+} < B_{loss}$. Using similar precautionary criteria to those described above, F_{MSY} would be 0.27. This corresponds to an F around 80% of the natural mortality (M) which would conform to the general considerations for choosing F based on M (Deriso, 1982). By comparison the proposed plan implies a relatively modest exploitation rate with mean F = 0.22, which is 70% of the natural mortality.

Short-term considerations

The evaluations were carried out using population numbers from the 2012 assessment as the starting point. This starting point is well below the median for the simulations and the probabilities of B_{1+} being below B_{loss} are therefore higher in the first few years (Table 7.3.5.1.1) These probability values are shown to reduce to the long-term values by 2015. After the evaluation took place, the 2013 assessment was done which gives even lower population numbers than in 2012. This implies that the time needed to reduce probabilities of B_{1+} being below B_{loss} to the long-term values will be extended.

Main performance results

The main results of the simulations are shown in Tables 7.3.5.1.1 and 7.3.5.1.2, and illustrated in Figure 7.3.5.1.1. As the plan is constructed to give a constant TAC with a relatively rapid reduction in the TAC if the biomass declines below the $B_{trigger}$, there may be occasions when the TAC reduction is quite large (Figure 7.3.5.1.1, upper right).

In recent years, the assessment has tended to overestimate stock abundance and underestimate mortality. Such bias has implicitly been taken into account in the simulations, based on the assumption that this is a temporary situation. If the present bias persists, it would be advisable to revisit the harvest rule. The plan has been evaluated assuming recruitment and growth comparable to the period from 1993 to 2010. During an earlier period (1978 to 1992) mean recruitment was higher, at nearly twice the current level. If the recruitment changes, it would be advisable to revisit the harvest rule.

The rule has been evaluated under the assumption that the actual catches are equal to the TACs.

Suggestions

Alternative rules were not explored in depth, but some examples of variants of the rule are shown in Figures 7.3.5.1.2 and 7.3.5.1.3 The probability of $B_{1+} < B_{loss}$ increases with increasing C_t, B_0, and or lower $B_{trigger}$. Conversely, the probability of $B_{1+} < B_{loss}$ can be reduced by applying a lower C_t, a higher B_0, and/or a higher $B_{trigger}$. For this type of plan, based on a target catch and not target fishing mortality, the resulting mean catch is closely related to the probability of being below $B_{trigger}$. For example, a probability of 5% is typically associated with a mean catch between 60 and 70 thousand tonnes. In contrast, harvest rate plans that take a more variable catch in proportion to the stock size give higher yields for the same probabilities. Introducing a minimum TAC to the HCR can help to avoid closing the fisheries. A minimum TAC may have little effect on the overall results when set at moderate values (Figure 7.3.5.1.2), but further analysis is needed to explore recovery under such conditions.

Methods

The evaluation was done by simulating possible developments of the stock when practising the rule. Simulations were done over 30 years with 1000 realisations of stochastic elements. The distribution of initial numbers and of selection in the fishery were taken as estimated in the 2012 assessment. The high risk to B_{loss} in 2012 reflects the low starting numbers and the assessment uncertainty. Uncertainties in future assessments were modelled to reproduce some consistency in deviation from the true values over years (retrospective bias), and calibrated to give the same overall uncertainty as in the 2012 assessment.

Recruitments were representative of the low productivity period (1993–2010), with no regular appearance of strong year classes. This corresponds to a mean recruitment that is 50% of the mean of the earlier period (1978–1992). Weights-at-age were as observed in recent years, which is higher than those from the earlier period. The stock–recruitment model was based on a fixed mean above B_{loss} with a linear decline to zero below B_{loss}. This approach is considered to give a conservative perception of probability of reduced recruitment. The model was run using HCS software.

Sources

Deriso, R. B. 1982. Relationship of fishing mortality to natural mortality and growth at the level of maximum sustainable yield. Canadian Journal of Fisheries and Aquatic Sciences, 39: 1054–1058.

ICES. 2013. Report of the Workshop to Evaluate the Management Plan for Iberian Sardine (WKSardineMP), 4–7 June 2013, Lisbon, Portugal. ICES CM 2013/ACOM:62.

Silva, A., Uriarte, A., Riveiro, I.. Santos, B., Azevedo, M.. Murta, A., Carrera, P., Ibaibarriaga, L., and Skagen, D. 2013. Reference points for the Iberian sardine stock (ICES areas VIIIc and IXa). Working Document to ICES-ACOM (5 June 2013) and to WGHANSA. *In* Report of the Working Group on Southern Horse Mackerel, Anchovy, and Sardine (WGHANSA), 21–26 June 2013, Bilbao, Spain. ICES CM 2013/ACOM:16.

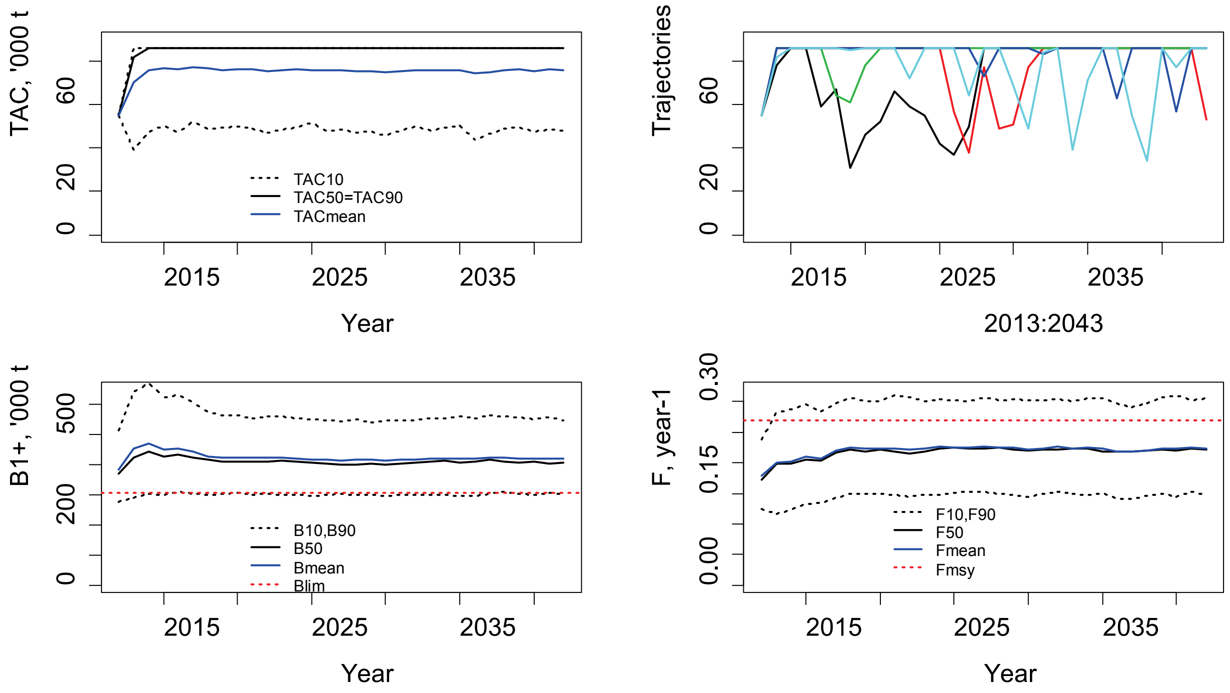


Figure 7.3.5.1.1 Performance of the proposed management plan. Mean values and 10, 50, and 90% quantiles of the TAC, biomass, and fishing mortality. Five individual randomly chosen TAC trajectories are shown in the top right plot.

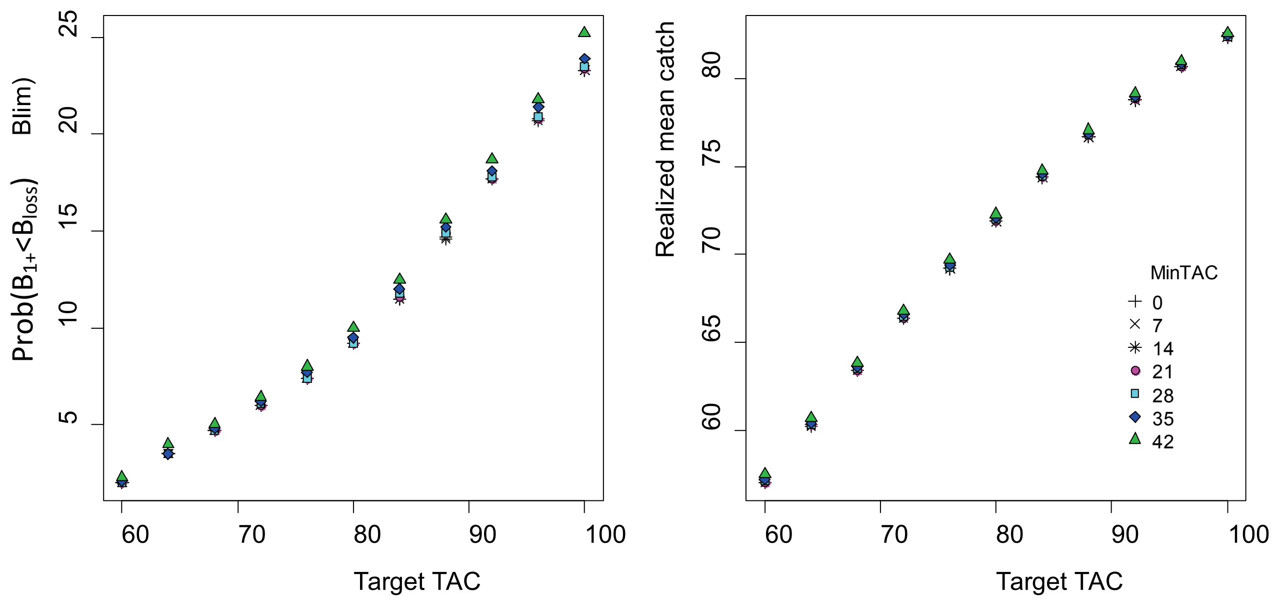


Figure 7.3.5.1.2 Sensitivity of the probability of $B_{1+} < B_{loss}$ (left) and realized catch (right) to changes in the target catch (C_t, x-axis) for a range of values for minimum TAC (catch allowed below B_0, between 0 and 42 t, see colour of symbols).

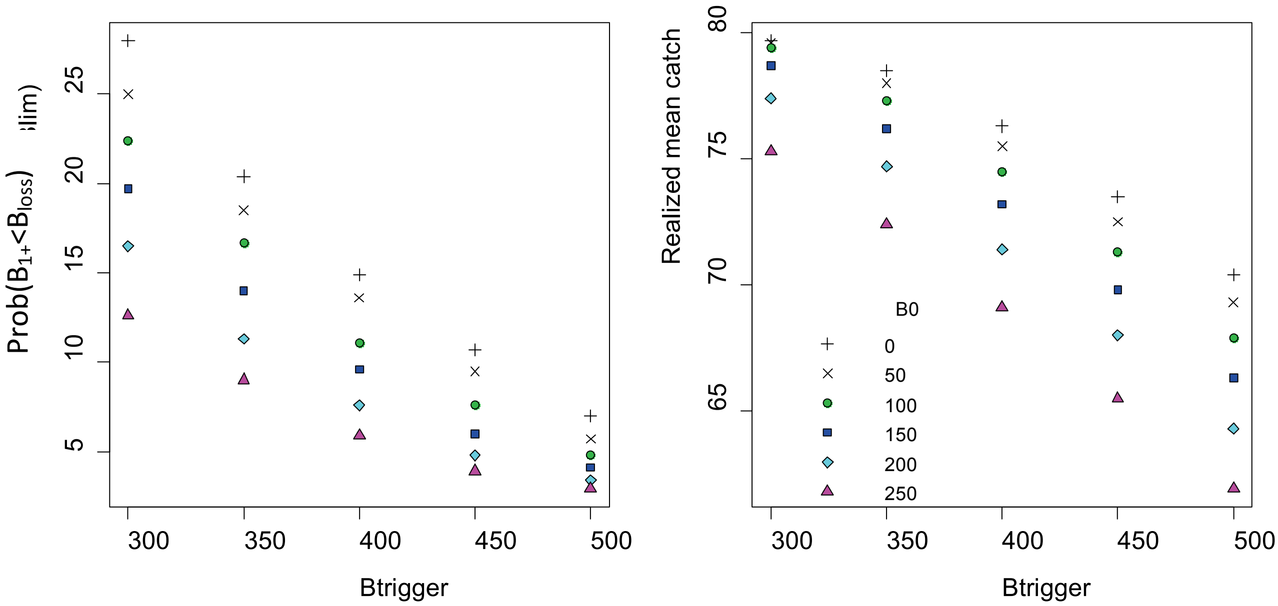


Figure 7.3.5.1.3 Sensitivity to changes in the biomass trigger points $B_{trigger}$ and B_0.

Table 7.3.5.1.1 Mean annual values of F, biomass, and TAC, and probabilities of the biomass being below $B_{trigger}$ and B_{loss} for the proposed management plan. Abs IAV = Interannual TAC variation observed in the evaluation. Ptrig and Plim = probability of ending below the trigger or the limit (B_0).

Year	F	B1+	TAC	AbsIAV	Ptrig	Plim
2012	0.18	384	55	0	0	20.3
2013	0.20	453	70	36.3	55.1	12.5
2014	0.20	469	76	19.8	36.4	10.2
2015	0.21	450	77	14.6	35.0	11.3
2016	0.21	455	76	13.5	36.2	9.5
2017	0.22	443	77	13.3	34.1	10.8
2018	0.23	428	77	13.3	35.3	12.4
2019	0.22	425	76	14.6	39.9	11.3
2020	0.22	425	76	15.4	38.2	10.1
2021	0.22	422	76	14.5	39.0	11.9
2022	0.22	422	75	16.3	40.8	11.7
2023	0.22	425	76	16.0	40.9	11.7
2024	0.23	421	76	14.6	37.7	12.0
2025	0.23	417	76	15.7	39.7	12.3
2026	0.23	418	76	15.0	39.5	11.5
2027	0.23	414	76	15.4	40.0	11.3
2028	0.23	415	75	16.3	40.9	11.2
2029	0.23	415	75	16.1	42.1	11.3
2030	0.22	415	75	16.5	41.6	12.4
2031	0.22	416	75	16.2	42.1	11.3
2032	0.23	416	76	15.7	41.2	12.4
2033	0.22	420	76	15.6	39.4	12.0
2034	0.23	421	76	15.1	38.8	11.2
2035	0.22	420	76	15.4	41.1	13.2
2036	0.22	421	75	16.1	40.5	11.4
2037	0.22	425	75	16.6	38.5	10.9
2038	0.22	424	76	15.1	38.5	9.2
2039	0.22	421	76	14.4	39.4	11.3
2040	0.22	419	75	15.4	40.4	12.0
2041	0.23	421	76	16.7	39.6	9.8
2042	0.22	419	76	15.0	39.3	11.0

Table 7.3.5.1.2 Annual values of 10%, 50%, and 90% quantiles of TAC, F, biomass, recruitment, and IAV (interannual variation of the TAC) for the proposed management plan.

	TAC			F			B1+			Recruitment			IAV		
Year	10%	50%	90%	10%	50%	90%	10%	50%	90%	10%	50%	90%	10%	50%	90%
2012	54.9	54.9	54.9	0.12	0.17	0.24	275.4	368.4	512.9	3486	9350	22616	-33.2	39.2	44.1
2013	39.1	81.7	86	0.12	0.20	0.28	289.6	423.1	642.2	5158	8341	14692	-20.9	0	50.8
2014	47.5	86	86	0.12	0.20	0.29	304.3	444.7	672.0	5309	8502	15169	-25.7	0	29.4
2015	50.1	86	86	0.13	0.21	0.30	301.4	425.8	625.9	5376	8352	15119	-27.1	0	25.4
2016	47.1	86	86	0.13	0.20	0.28	309.0	432.9	632.7	5164	8277	14577	-20.3	0	28.6
2017	52.3	86	86	0.14	0.22	0.30	302.4	423.1	606.4	5161	8585	15737	-31.2	0	21.1
2018	49.0	86	86	0.15	0.22	0.31	298.5	417.2	575.6	5295	8396	15164	-31.3	0	23.7
2019	49.4	86	86	0.15	0.22	0.30	301.8	411.7	564.1	5327	8557	15102	-29	0	31
2020	49.7	86	86	0.15	0.22	0.30	305.5	408.6	564.2	5256	8612	15281	-30.3	0	26.5
2021	49.1	86	86	0.15	0.22	0.31	299.6	408.6	555.5	5303	8504	15369	-36.8	0	28.7
2022	47.2	86	86	0.14	0.22	0.31	302.2	409.6	559.5	5172	8598	15473	-27.2	0	32.9
2023	48.6	86	86	0.15	0.22	0.30	300.3	414.7	561.5	5243	8519	14940	-29.1	0	30.2
2024	49.4	86	86	0.15	0.22	0.30	299.4	410.5	554.3	5330	8379	15357	-32.9	0	29.8
2025	51.8	86	86	0.15	0.23	0.30	295.1	406.1	552.3	5298	8359	14699	-32.8	0	28.8
2026	47.6	86	86	0.15	0.22	0.30	298.8	404.2	547.2	5208	8478	14657	-31.2	0	30.2
2027	48.5	86	86	0.15	0.22	0.31	301.6	399.7	542.6	5367	8717	15542	-34.3	0	30.4
2028	47.0	86	86	0.15	0.23	0.30	300.8	401.1	552.4	5334	8289	14976	-28.8	0	31.8
2029	47.5	86	86	0.15	0.22	0.30	301.0	404.7	542.2	5361	8546	15260	-34.4	0	29.4
2030	45.9	86	86	0.15	0.22	0.30	295.2	401.6	547.6	5169	8277	15319	-32.9	0	33.6
2031	47.9	86	86	0.15	0.22	0.30	300.8	403.1	547.3	5279	8662	15607	-26.9	0	33.2
2032	49.7	86	86	0.15	0.22	0.30	299.1	405.3	548.3	5199	8353	16260	-32.8	0	27.9
2033	47.8	86	86	0.15	0.22	0.30	298.6	410.4	553.9	5248	8769	15914	-29.5	0	29.7
2034	49.5	86	86	0.15	0.22	0.31	298.7	413.2	554.5	5388	8415	15058	-31.3	0	29.3
2035	50.5	86	86	0.15	0.22	0.31	295.4	405.3	561.9	5246	8749	15691	-37.9	0	27.5
2036	43.9	86	86	0.14	0.22	0.30	296.9	409.8	555.7	5267	8582	15958	-33.2	0	34.1
2037	46.7	86	86	0.14	0.22	0.29	302.0	416.7	563.2	5314	8626	15206	-27.1	0	30.9
2038	49.0	86	86	0.15	0.22	0.30	308.4	411.7	561.3	5237	8365	15238	-26.2	0	28.5
2039	49.6	86	86	0.15	0.22	0.31	302.0	405.8	555.8	5363	8452	15126	-32.7	0	27.9
2040	47.3	86	86	0.15	0.22	0.31	298.9	409.6	549.5	5333	8589	15067	-28.8	0	34.6
2041	48.3	86	86	0.15	0.22	0.30	307.0	404.7	558.7	5369	8583	15052	-29.7	0	27.8
2042	48.2	86	86	0.15	0.22	0.31	302.8	407.2	548.3	5220	8747	15778			