8.4.3 EU request to ICES on forecast scenarios of the likely consequences of reductions in fishing mortality in the western Baltic cod (*Gadus morhua*) stock

Advice summary

ICES has provided below stochastic medium-term projection results for the western Baltic cod stock for the years 2017 to 2027, based on different scenarios of reduction in fishing mortality in the commercial and recreational fisheries. The results indicate an increase in the spawning-stock biomass (SSB) under all scenarios, but the speed and degree of stock recovery is greater for the scenarios that correspond to a stronger reduction in fishing mortality.

Even under conditions of no fishing it will take several years to reduce the probability of SSB being below B_{lim} to no more than 5%. Scenarios where reductions occur exclusively in the recreational fishery would decrease the probability of the SSB being below B_{lim} in 2027, but this would remain high (to the order of 25% to 50%).

In the simulated scenarios, with annual reductions in the commercial or in both fisheries until the fishing mortality consistent with ICES MSY approach is reached (the d1 and d3 scenarios), the median SSB increases and is higher than MSY $B_{trigger}$ by 2027.

Request

The present advice is in response to the following request from the European Commission:

This request is a follow-up request to the request for additional advice on Western Baltic Cod that had been submitted on 29 August. The Commission is in particular concerned that any biomass at the beginning of 2019 that remains (substantially) below B_{lim} will risk continuing to harm the stock e.g. through impaired recruitment, and this request should clarify the extent to which such a risk exists, even when a small increase in biomass is predicted.

Request:

ICES is requested, by means of stochastic medium-term projections including appropriate stock-recruit modelling, to forecast the likely consequences of reductions in fishing mortality rates according to the following scenarios.

a) *Fishing at levels of mortality as assumed by ICES for 2016 for both the commercial and recreational fisheries, and assuming that catches in both fisheries will alter according to changes in stock size and fishing mortality rate adjustments.*
b) *Cessation of fishing from 2017 by the commercial fishery (b1), by the recreational fishery (b2), or by both (b3). For the fishery which does not cease fishing, the same fishing mortality rates as in part (a) should apply.*
c) *Reduction of fishing mortality to F_{msy} in 2017, by reductions in the commercial fishery (c1), reductions in the recreational fishery (c2) or by equal percentage reductions in both (c3). After 2017 the fishing mortality should be assumed to remain at F_{msy} in all cases.*
d) *Annual reductions of X% in the fishing mortality developed by the commercial fishery (d1), in the fishing mortality developed by the recreational fishery (d2) or by equal percentage reductions in both (d3), until the fishing mortality reaches that corresponding to the ICES MSY approach (for X = 20, 40, 50, 60, 80, 90).*

Consequences should be expressed in terms of spawning stock size, expected levels of future recruitment (corresponding to future spawning stock biomass levels modelled according to an appropriate stock-recruit relationship) and catches in the commercial and recreational fisheries. Values should be provided for the mean and 5th, 25th, 50th, 75th and 95th percentiles of the distribution of these variables in future years. Projections should be calculated for a period from 2017 until 2027, or longer if considered appropriate and informative.

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Elaboration on the advice

In this advice, reference to the 25 requested scenarios is made using the codes in the following table. The ICES MSY approach, used in scenarios labelled d, corresponds to F(y) = F_{MSY} × minimum of (1; SSB(y)/MSY $B_{trigger}$).

Table 8.4.3.1 The 25 projection scenarios: code and description.

Code	Description
a	Fishing at levels of mortality as assumed by ICES for 2016 for both the commercial and recreational fisheries
b1	Cessation of fishing by the commercial fishery
b2	Cessation of fishing by the recreational fishery
b3	Cessation of fishing by both the commercial and the recreational fisheries
c1	Reduction to F_{MSY} in 2017 by a reduction in the commercial fishery; recreational F as in 2016
c2	Reduction to F_{MSY} in 2017 by a reduction in the recreational fishery; commercial F as in 2016
c3	Reduction to F_{MSY} in 2017 by the same percentage reduction in the commercial and recreational fisheries
d1_20	Annual reductions of 20% in the commercial fishery until F corresponds to ICES MSY approach
d1_40	Annual reductions of 40% in the commercial fishery until F corresponds to ICES MSY approach
d1_50	Annual reductions of 50% in the commercial fishery until F corresponds to ICES MSY approach
d1_60	Annual reductions of 60% in the commercial fishery until F corresponds to ICES MSY approach
d1_80	Annual reductions of 80% in the commercial fishery until F corresponds to ICES MSY approach
d1_90	Annual reductions of 90% in the commercial fishery until F corresponds to ICES MSY approach
d2_20	Annual reductions of 20% in the recreational fishery until F corresponds to ICES MSY approach
d2_40	Annual reductions of 40% in the recreational fishery until F corresponds to ICES MSY approach
d2_50	Annual reductions of 50% in the recreational fishery until F corresponds to ICES MSY approach
d2_60	Annual reductions of 60% in the recreational fishery until F corresponds to ICES MSY approach
d2_80	Annual reductions of 80% in the recreational fishery until F corresponds to ICES MSY approach
d2_90	Annual reductions of 90% in the recreational fishery until F corresponds to ICES MSY approach
d3_20	Annual reductions of 20% in both fisheries until F corresponds to ICES MSY approach
d3_40	Annual reductions of 40% in both fisheries until F corresponds to ICES MSY approach
d3_50	Annual reductions of 50% in both fisheries until F corresponds to ICES MSY approach
d3_60	Annual reductions of 60% in both fisheries until F corresponds to ICES MSY approach
d3_80	Annual reductions of 80% in both fisheries until F corresponds to ICES MSY approach
d3_90	Annual reductions of 90% in both fisheries until F corresponds to ICES MSY approach

The spawning-stock biomass (SSB) is expected to increase over the period 2017–2027 under all 25 scenarios (Figures 8.4.3.1–8.4.3.25). However, the speed and degree of stock recovery is greater for the scenarios that correspond to a stronger reduction in fishing mortality (Table 8.4.3.2) and even under conditions of no fishing (scenario b3) it will take several years to reduce the probability of SSB being below B_{lim} to no more than 5%.

For the scenarios where F remains at the 2016 level (scenario a), or where reductions occur exclusively in the recreational fishery (scenarios b2, c2, and d2), F remains above F_{MSY} and the median SSB below MSY $B_{trigger}$ throughout the years 2017–2027, and the probability of the SSB being below B_{lim} in 2027 is above 5% (to the order of 25% to 50% probability). In all other scenarios, F is reduced to F_{MSY} or lower and the median SSB has risen above MSY $B_{trigger}$ by 2027 or earlier.

Table 8.4.3.2 Summary of results for the 25 projection scenarios. Values in the table represent the first year in which the condition noted in each column label is fulfilled; the value −1 indicates that the condition has not been fulfilled by 2027.

Scenarios	$P(SSB < B_{lim}) \leq 0.05$	Median(SSB) > MSY $B_{trigger}$	Median(F) ≤ F_{MSY}	Median(SSB) > MSY $B_{trigger}$ & Median(F) ≤ F_{MSY}
a	−1	−1	−1	−1
b1	2021	2019	2017	2019
b2	−1	−1	−1	−1
b3	2020	2019	2017	2019
c1	2022	2021	2017	2021
c2	−1	−1	−1	−1
c3	2022	2021	2017	2021
d1_20	2025	2022	2021	2022
d1_40	2023	2021	2019	2021
d1_50	2022	2020	2018	2020
d1_60	2022	2020	2018	2020
d1_80	2021	2020	2017	2020
d1_90	2021	2020	2017	2020
d2_20	−1	−1	−1	−1
d2_40	−1	−1	−1	−1
d2_50	−1	−1	−1	−1
d2_60	−1	−1	−1	−1
d2_80	−1	−1	−1	−1
d2_90	−1	−1	−1	−1
d3_20	2023	2021	2020	2021
d3_40	2022	2021	2018	2021
d3_50	2021	2020	2018	2020
d3_60	2021	2020	2017	2020
d3_80	2021	2020	2017	2020
d3_90	2021	2020	2017	2020

Recruitment values for the projection years have been drawn stochastically from the estimates obtained from the stock assessment for the most recent 11 years (age 1 recruitment in 2006–2016), with reduced recruitment when the projected SSB in a given year is below the lowest observed in the stock assessment (B_{loss}). Although higher recruitment values were observed further back in time (in the mid-1990s), the more recent years are considered to provide a more appropriate range for the 2017–2027 simulation period. An explicit aim of the request is to investigate the extent to which there exists a risk to harm the stock through impaired recruitment at low biomass levels; therefore, appropriate recruitment modelling at low SSB values is a key consideration.

Basis of the advice

Methods

Stochastic projections were conducted for the years 2017 to 2027 under the 25 requested scenarios. The starting point for the projections is the population abundance of ages 2 and older at the beginning of 2017, which was obtained from the most recent stock assessment and the assumptions about the fishery in 2016 (corresponding to a total catch of 10 327 tonnes in 2016) used by ICES in the advice provided for this stock earlier this year (ICES, 2016a). The stochastic projections consist of 1000 realizations that take into account uncertainty in the population abundance at the beginning of 2017 and in recruitment in all projection years. The abundances of year classes from 2016 and onwards (age 1 recruitment from 2017 onwards) were drawn stochastically from the recruitment estimates for the most recent 11 years included in the stock assessment, assuming linearly reduced recruitment when SSB is below B_{loss} (additional explanation provided under ”Elaboration on the advice”). Biological parameters (natural mortality, maturity, and weight for each age group) are assumed fixed and equal to the average of the three most recent years included in the stock assessment.

A two-fleet software tool was developed to conduct the requested stochastic projections. The two fleets represent the commercial and the recreational fisheries. Each fleet has its own exploitation pattern (Figure 8.4.3.26) and mean weight-at-age, both of which are assumed to remain constant throughout the projection period. The exploitation pattern for each fleet was calculated from the exploitation pattern for the combined fishery (recreational plus commercial) estimated by the stock assessment (in the three most recent years) and the catch in numbers-at-age by fishery. Considering that the two fisheries can vary independently (a different exploitation pattern for each) differs from the methodology applied by ICES when providing catch options for this stock for 2017 (ICES, 2016a) and in the short-term forecast for 2017 and 2018 provided as a technical service (ICES, 2016b); in both of these the same F-multiplier is applied to both components. It was considered necessary for this request to take into account the different exploitation patterns as the medium-term projections are performed for scenarios that weight the commercial and the recreational fisheries substantially different from the historical observations. There are also some technical differences between the two-fleet software tool and the standard short-term forecast used by ICES for this stock; in particular, the two-fleet tool does not incorporate process error in the projections. The above aspects give rise to some differences in the outputs obtained from the two software products.

The agreed reference points for the stock have been used in all the simulations (ICES, 2016a). Potential modifications to the F_{MSY} value caused by the different overall exploitation pattern resulting from the different scenarios were not considered.

Scenario outputs (SSB, recruitment, catch) are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations (Figures 8.4.3.1–8.4.3.25). Results in tabular form are available in the Baltic Fisheries Assessment Working Group report, annex 11 (ICES, 2016c). It is noted that the results from these simulations display recruitment-at-age 0, whereas the stock assessment results presented by ICES (ICES, 2016a) display recruitment-at-age 1. As there is no fishing on age 0, abundance-at-age 1 results directly from abundance-at-age 0 multiplied by the factor $\exp(-M) = \exp(-0.8) = 0.45$.

Sources and references

ICES. 2016a. Cod (*Gadus morhua*) in subdivisions 22–24, western Baltic stock (western Baltic Sea). *In* Report of the Advisory Committee, 2016. ICES Advice 2016, Book 8, Section 8.3.4.

ICES. 2016b. EU request to ICES on additional catch options for the western Baltic cod (*Gadus morhua*) stock (subdivisions 22–24). *In* Report of the Advisory Committee, 2016. ICES Advice 2016, Book 11, Section 11.2.1.

ICES. 2016c. Report of the Baltic Fisheries Assessment Working Group (WGBFAS), 12–19 April 2016, ICES Headquarters, Copenhagen, Denmark. ICES CM 2016/ACOM:11.

Figures

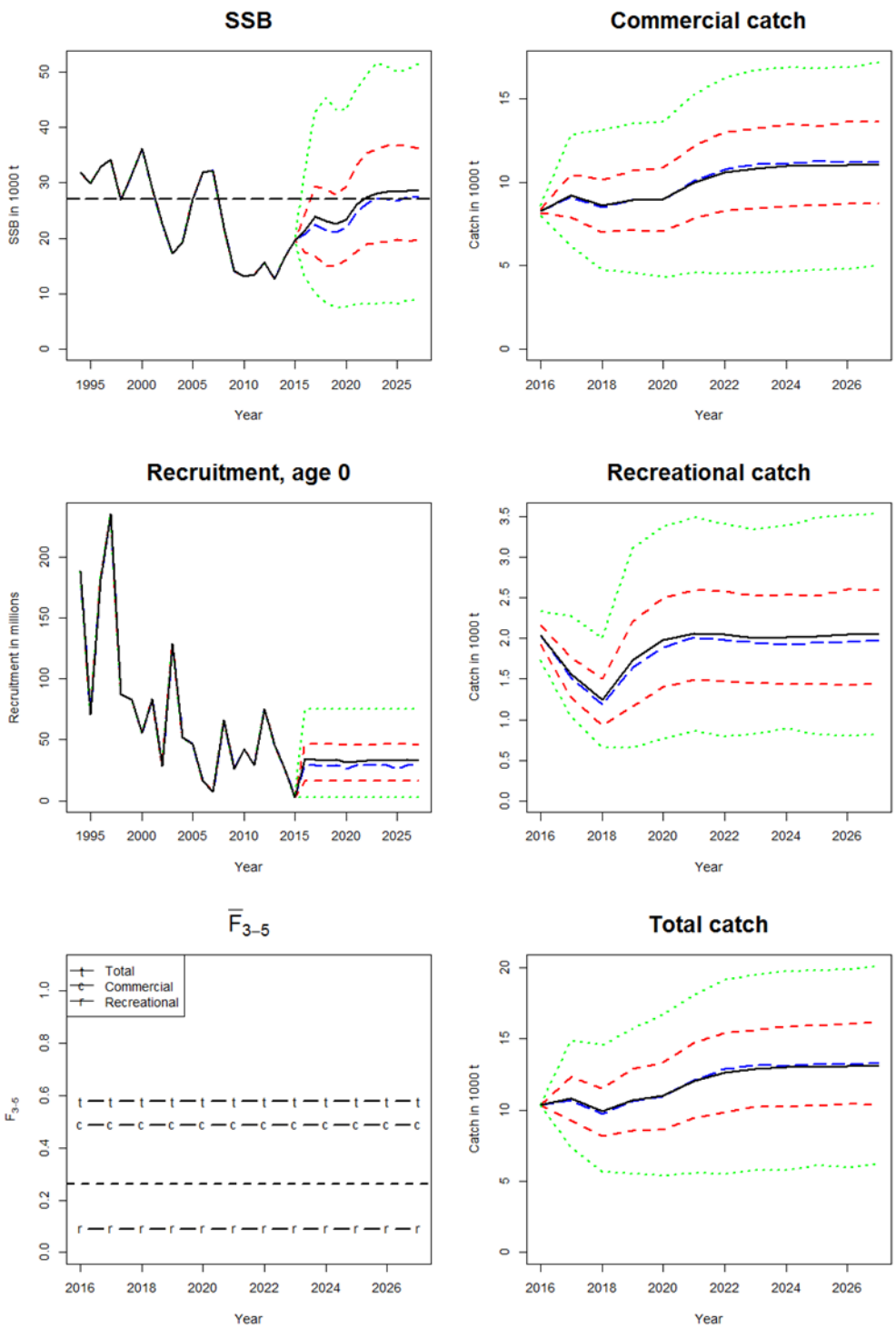

Figure 8.4.3.1 *Scenario a*. Fishing at levels of mortality as assumed by ICES for 2016 for both the commercial and the recreational fisheries. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

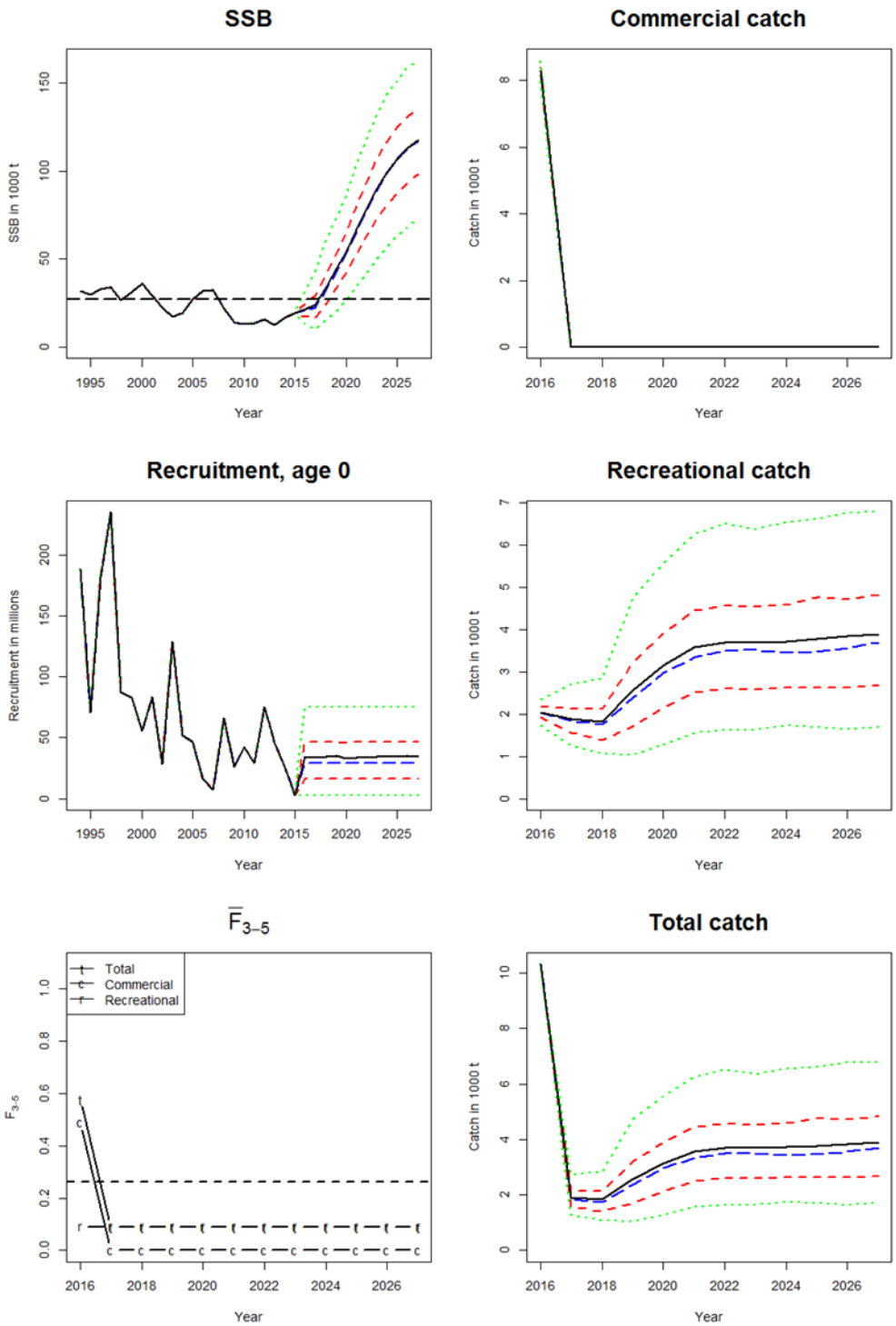

Figure 8.4.3.2 *Scenario b1.* Cessation of fishing by commercial fishery. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

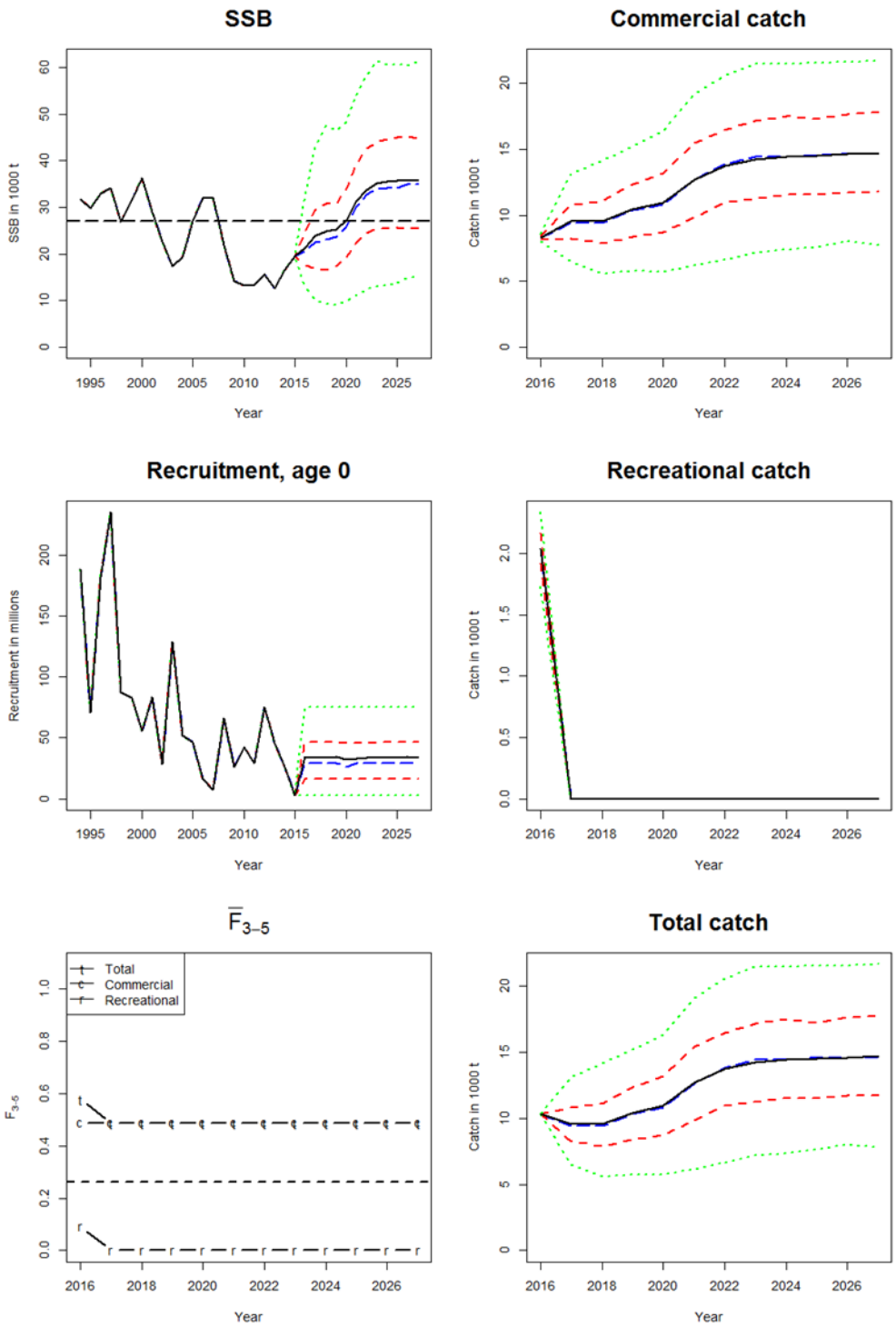

Figure 8.4.3.3 *Scenario b2.* Cessation of fishing by recreational fishery. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

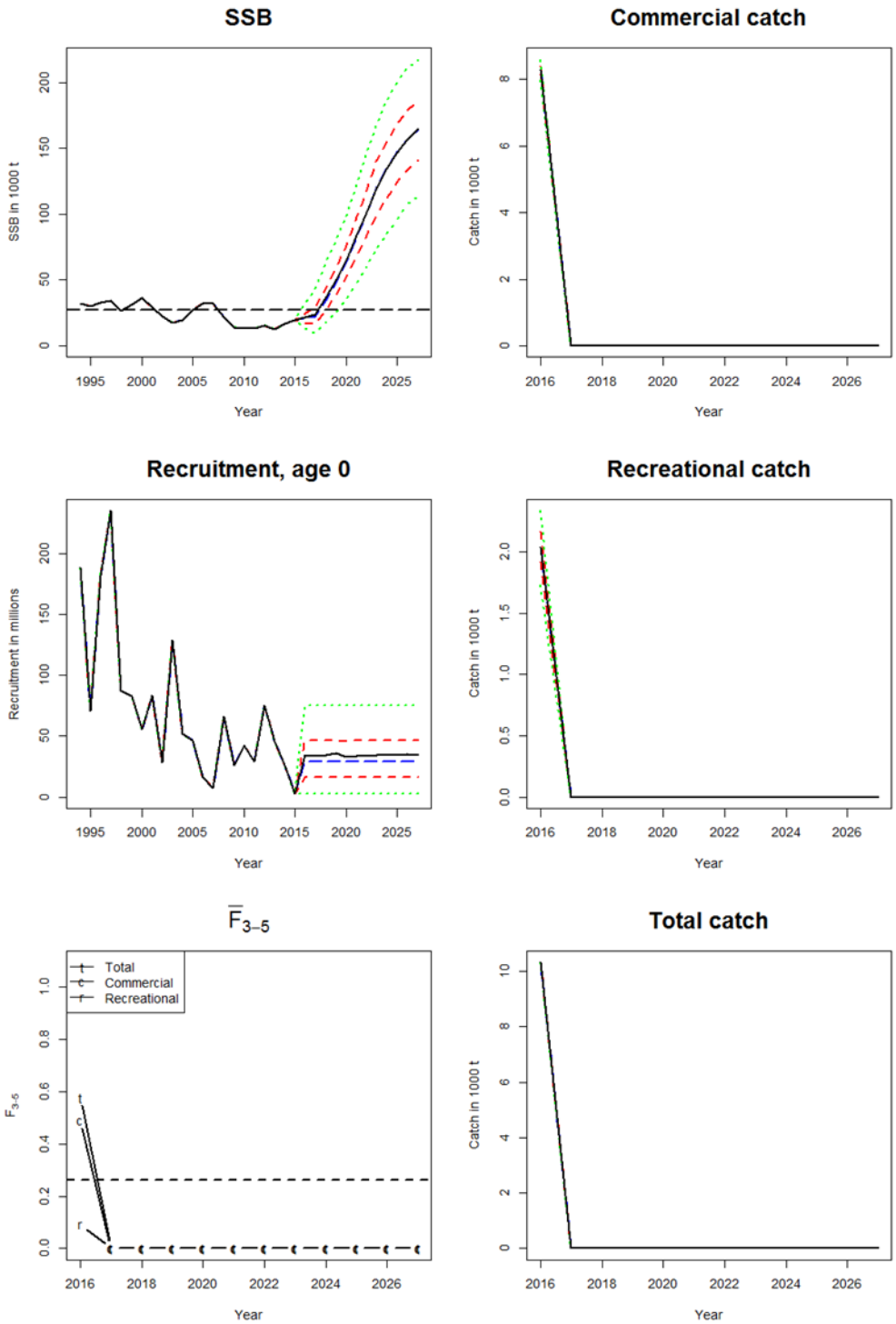

Figure 8.4.3.4 *Scenario b3.* Cessation of fishing by both commercial and recreational fishery. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

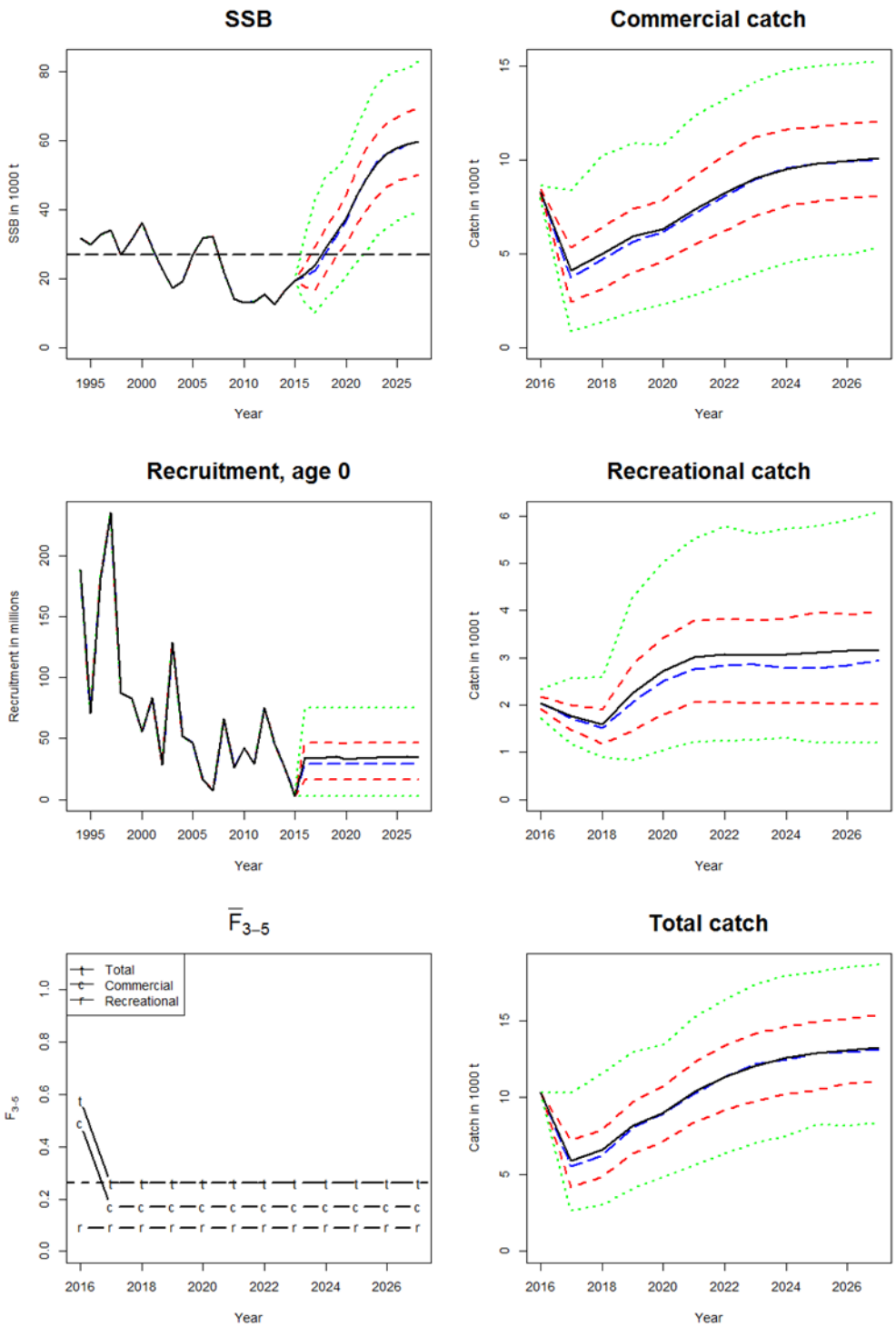

Figure 8.4.3.5 *Scenario c1.* Reduction to F_{MSY} in 2017 by reductions in the commercial fishery. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

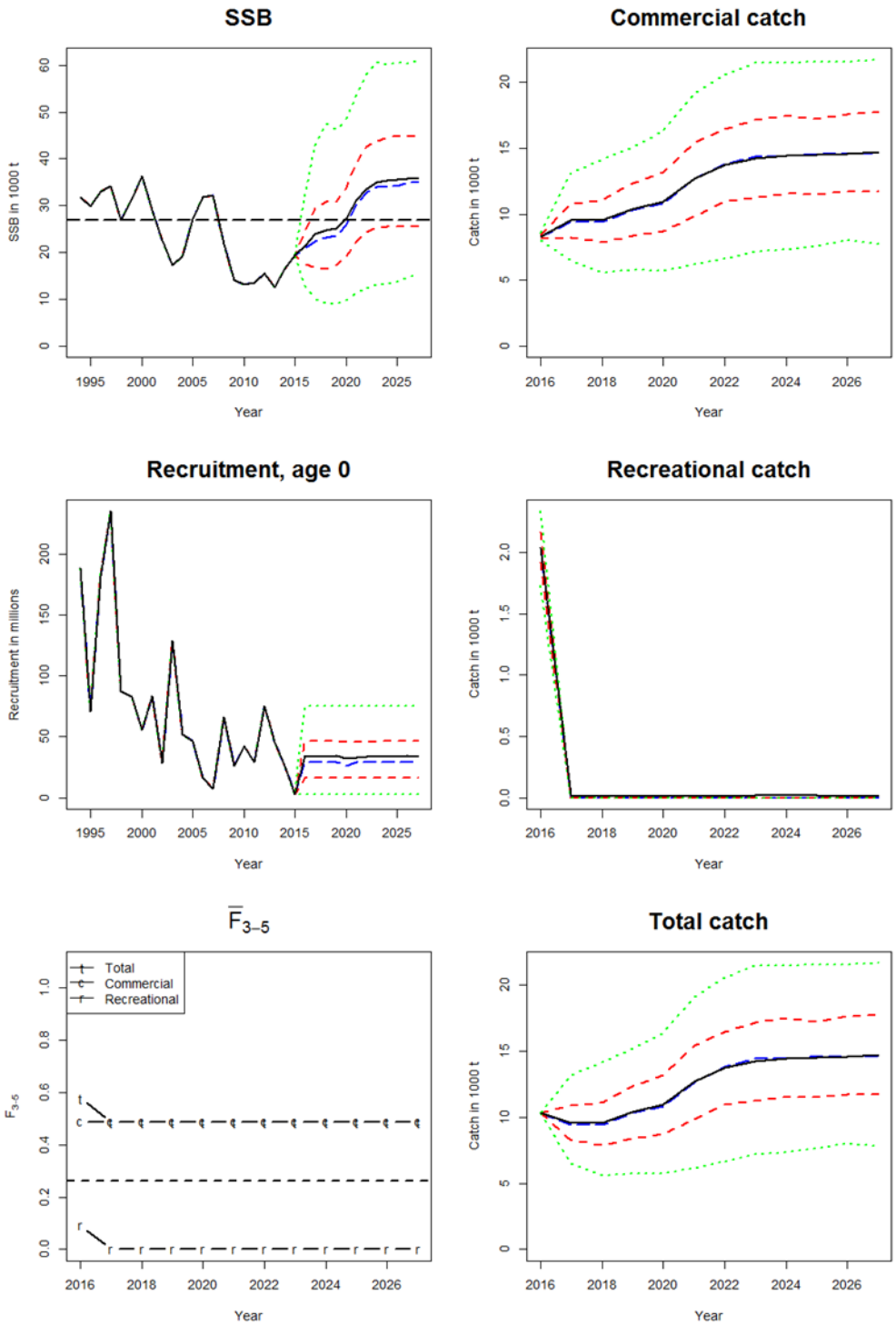

Figure 8.4.3.6 *Scenario c2*. Reduction to F_{MSY} in 2017 by reductions in the recreational fishery. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

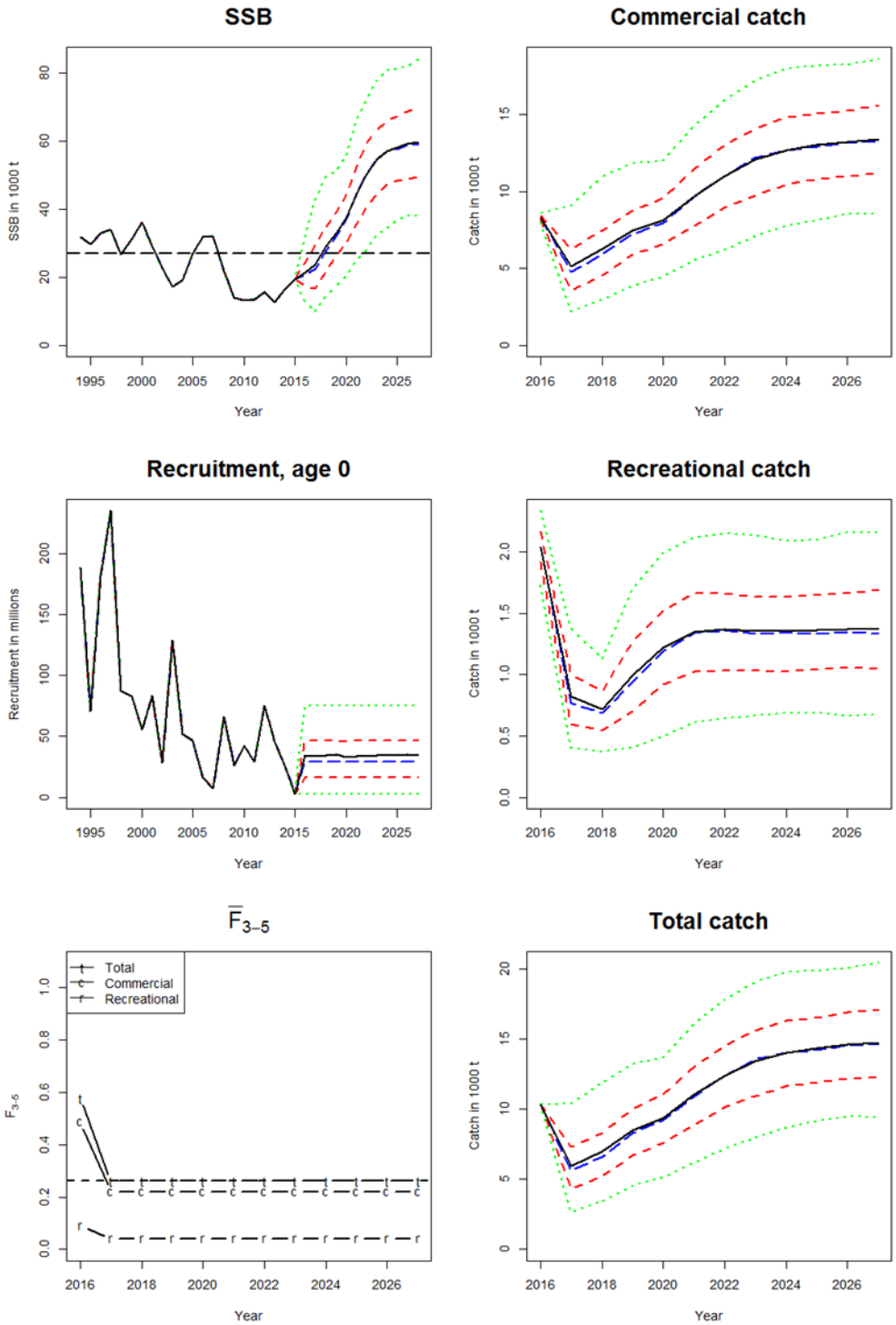

Figure 8.4.3.7 *Scenario c3.* Reduction to F_{MSY} in 2017 by reductions in the commercial and recreational fisheries by equal percentage. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

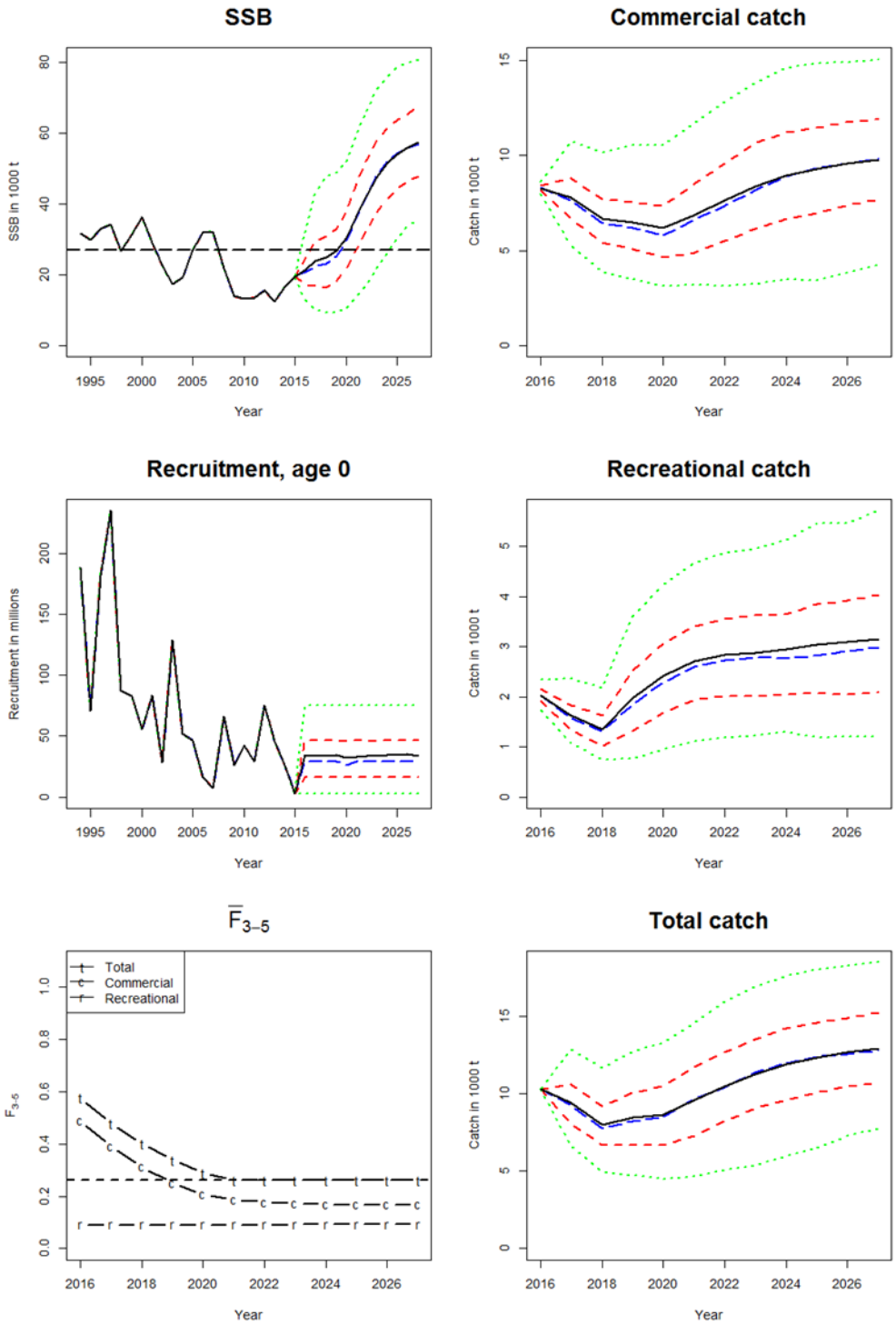

Figure 8.4.3.8 *Scenario d1_20.* Annual reductions of 20% in the commercial fishery until F corresponds to the ICES MSY approach. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

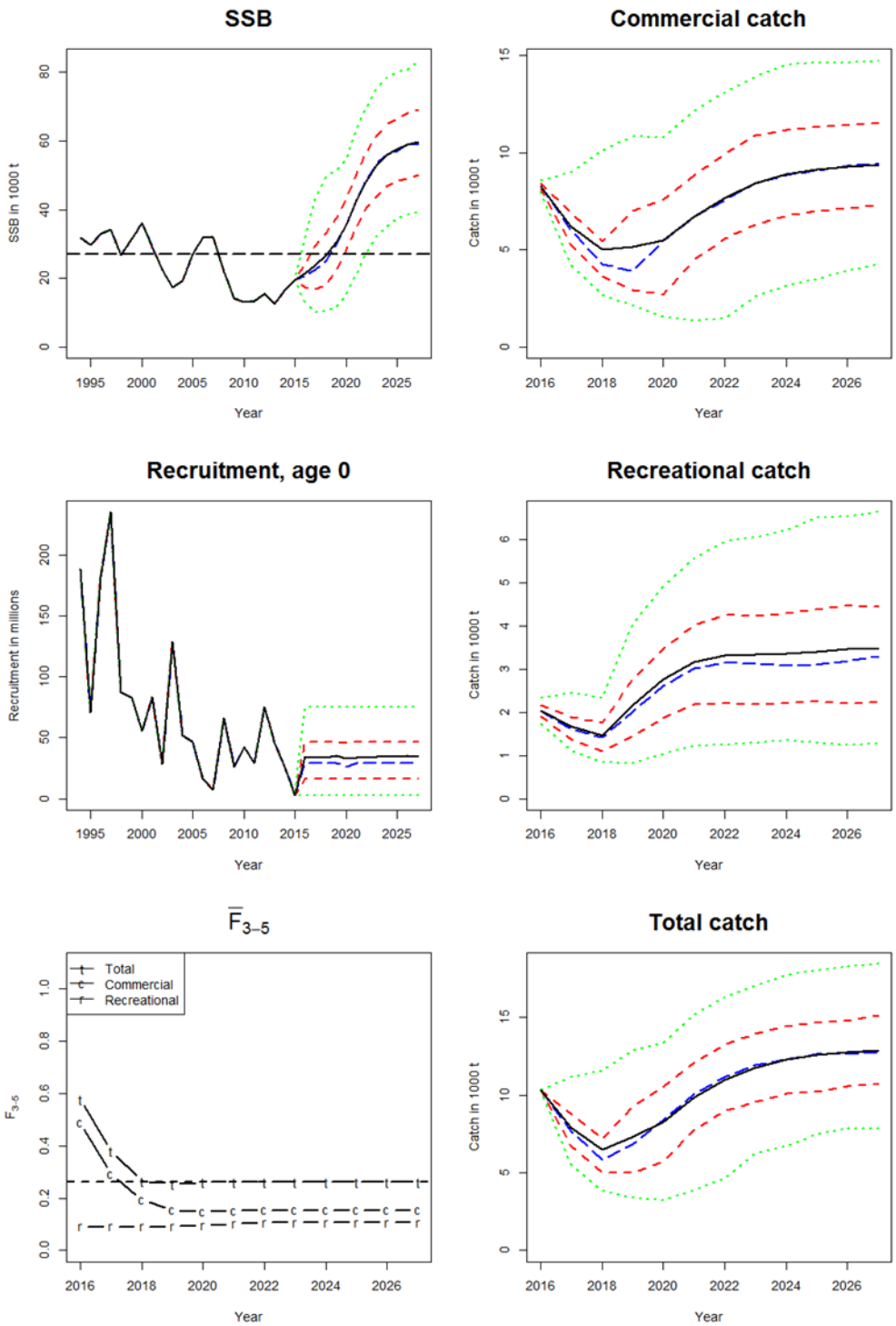

Figure 8.4.3.9 *Scenario d1_40.* Annual reductions of 40% in the commercial fishery until F corresponds to the ICES MSY approach. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

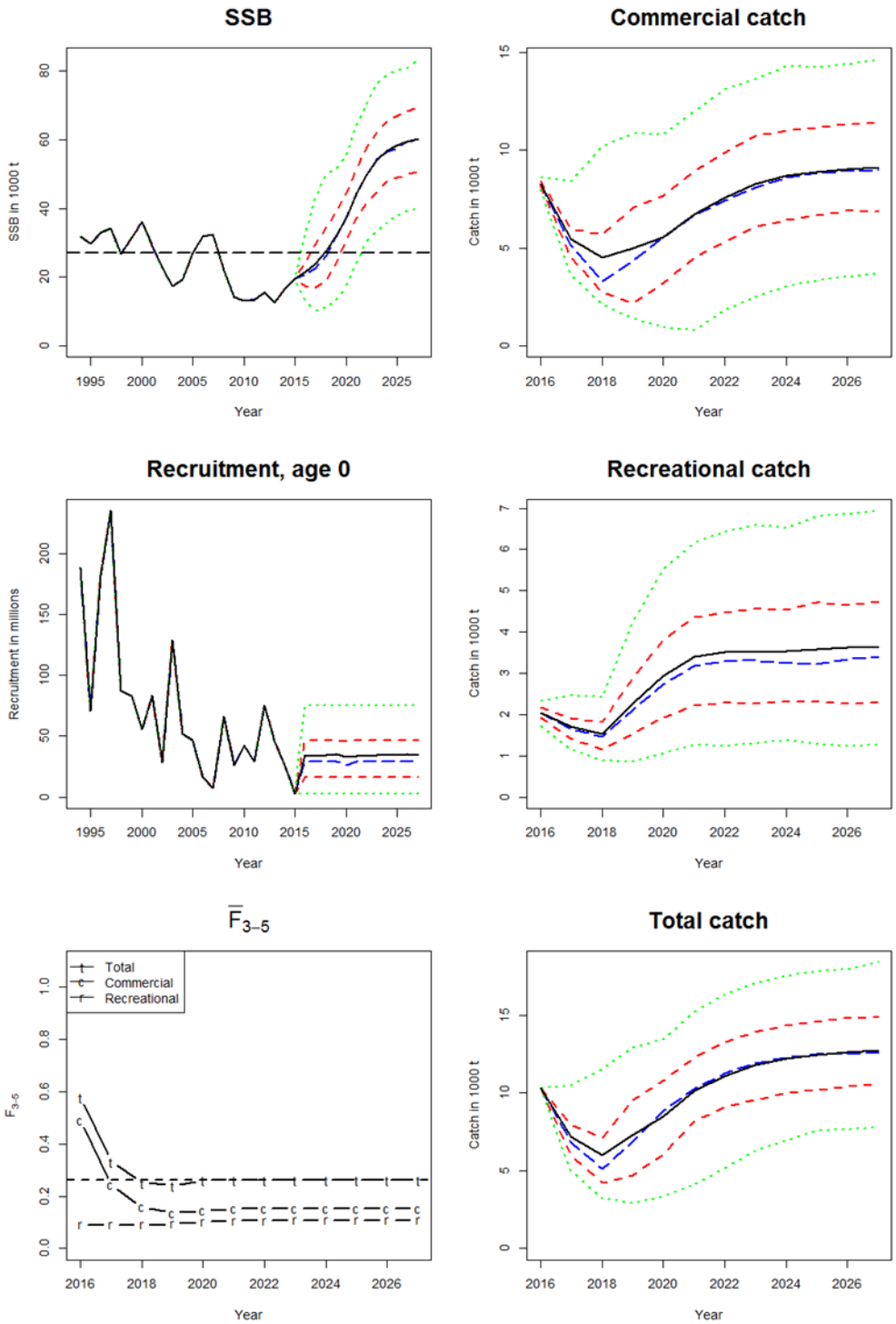

Figure 8.4.3.10 *Scenario d1_50.* Annual reductions of 50% in the commercial fishery until F corresponds to the ICES MSY approach. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

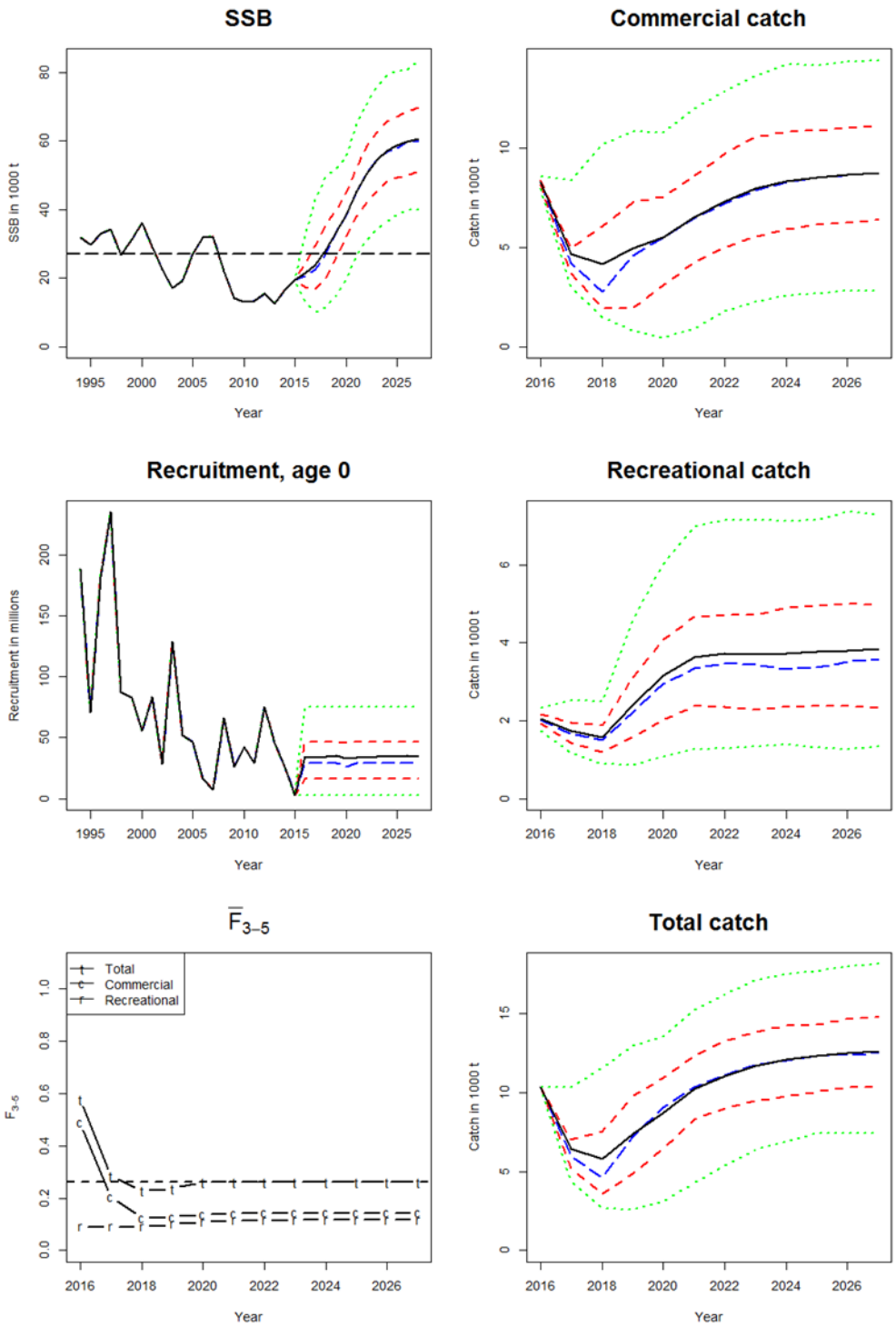

Figure 8.4.3.11 *Scenario d1_60.* Annual reductions of 60% in the commercial fishery until F corresponds to the ICES MSY approach. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

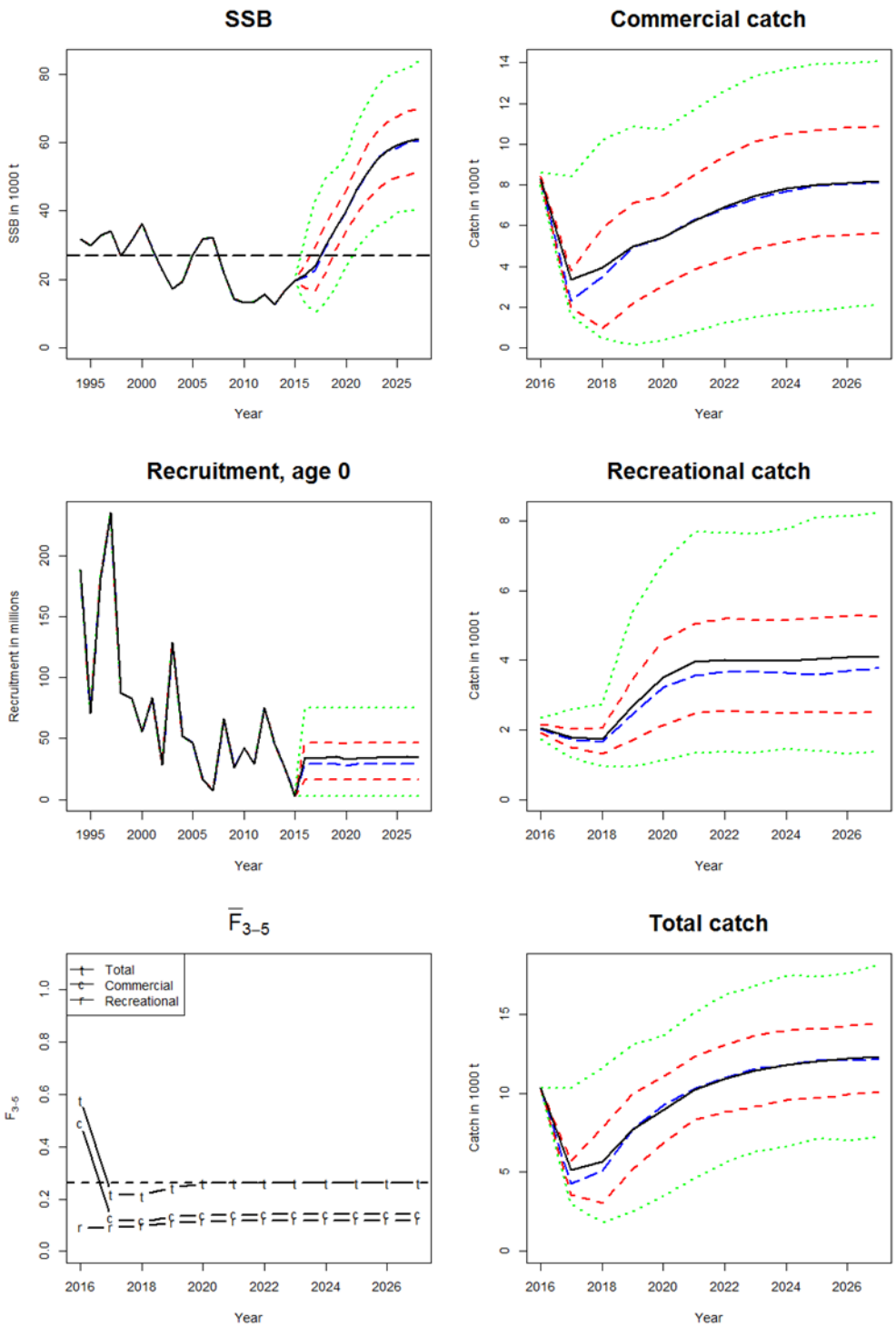

Figure 8.4.3.12 *Scenario d1_80.* Annual reductions of 80% in the commercial fishery until F corresponds to the ICES MSY approach. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

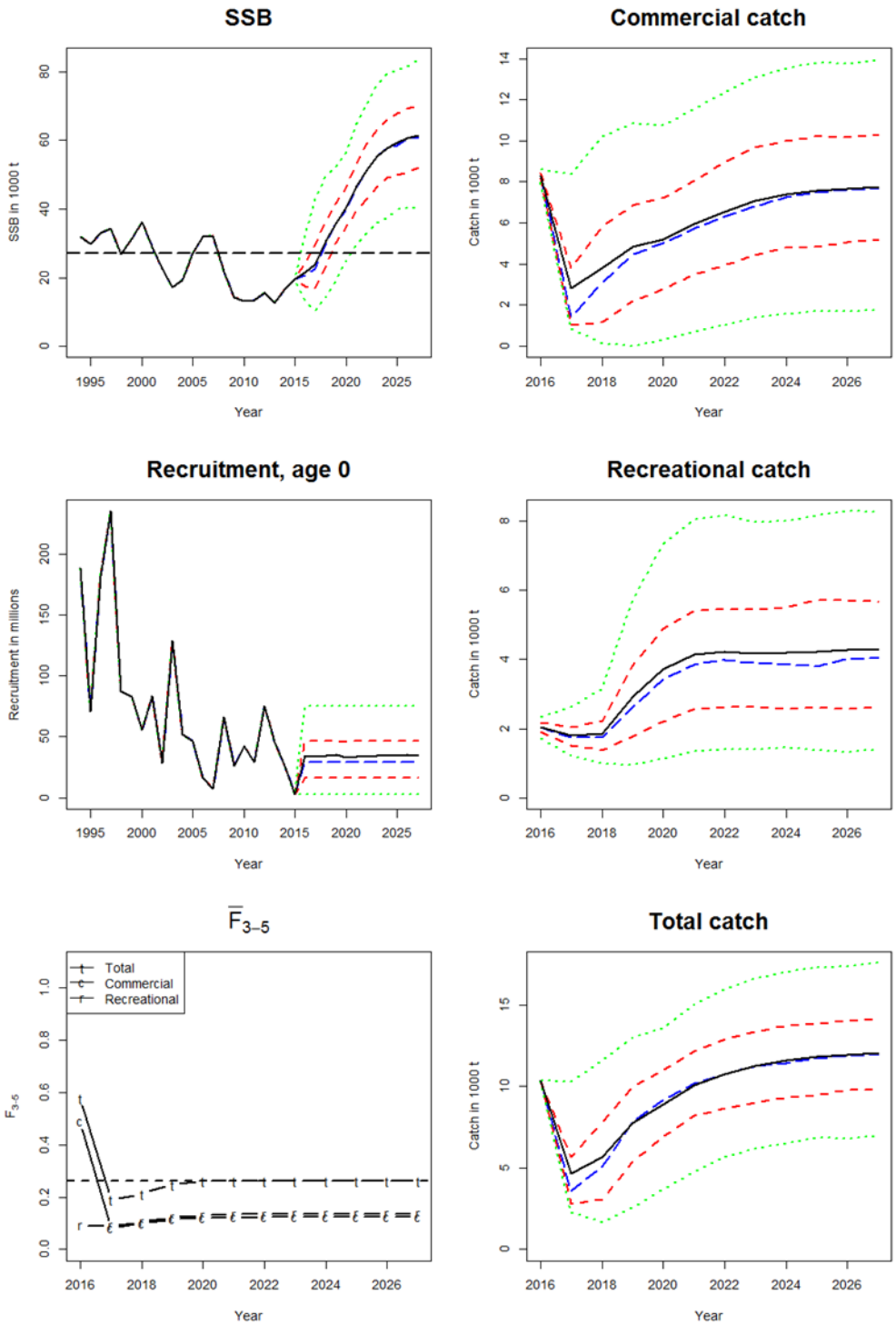

Figure 8.4.3.13 *Scenario d1_90.* Annual reductions of 90% in the commercial fishery until F corresponds to the ICES MSY approach. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

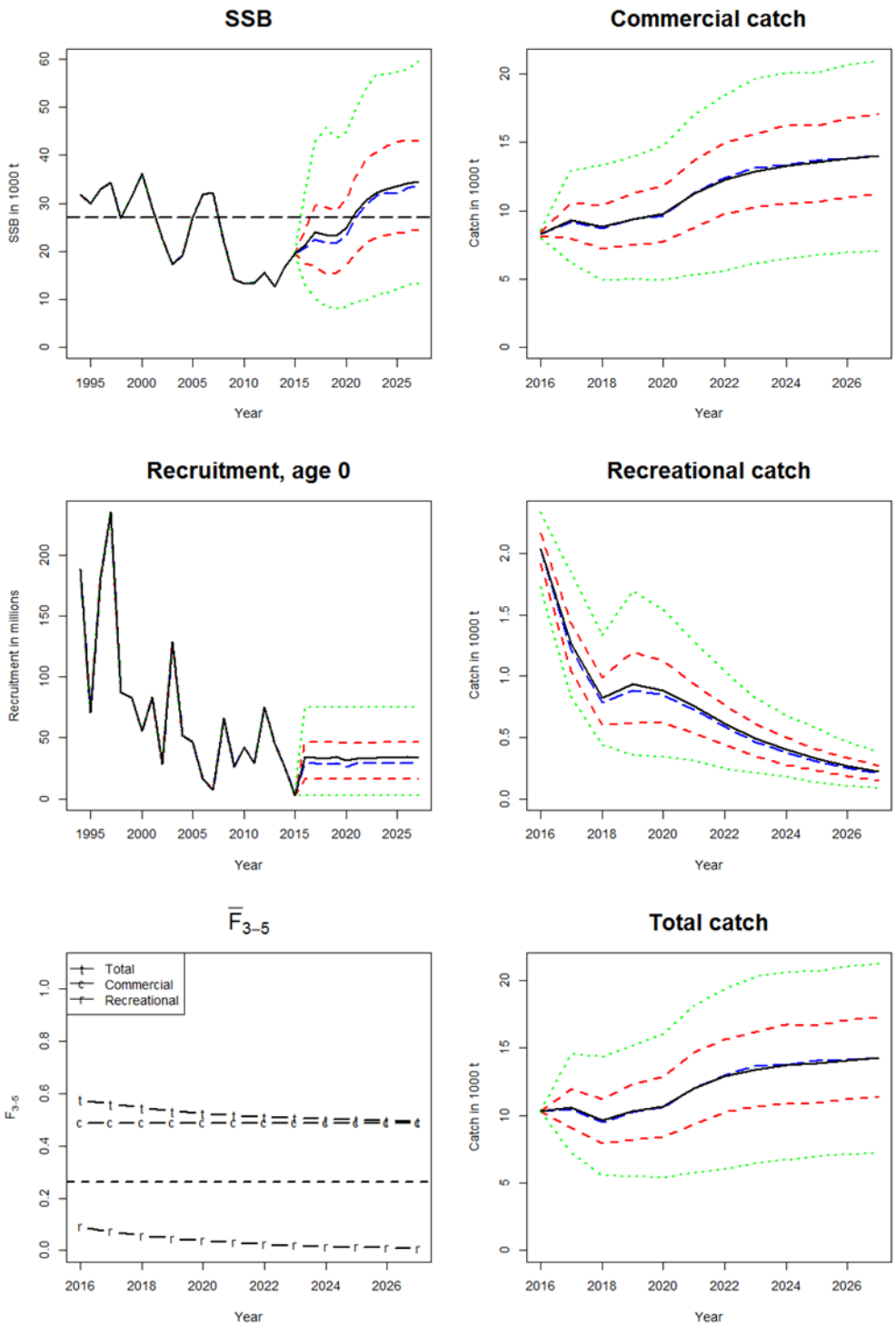

Figure 8.4.3.14 *Scenario d2_20.* Annual reductions of 20% in the recreational fishery until F corresponds to the ICES MSY approach. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

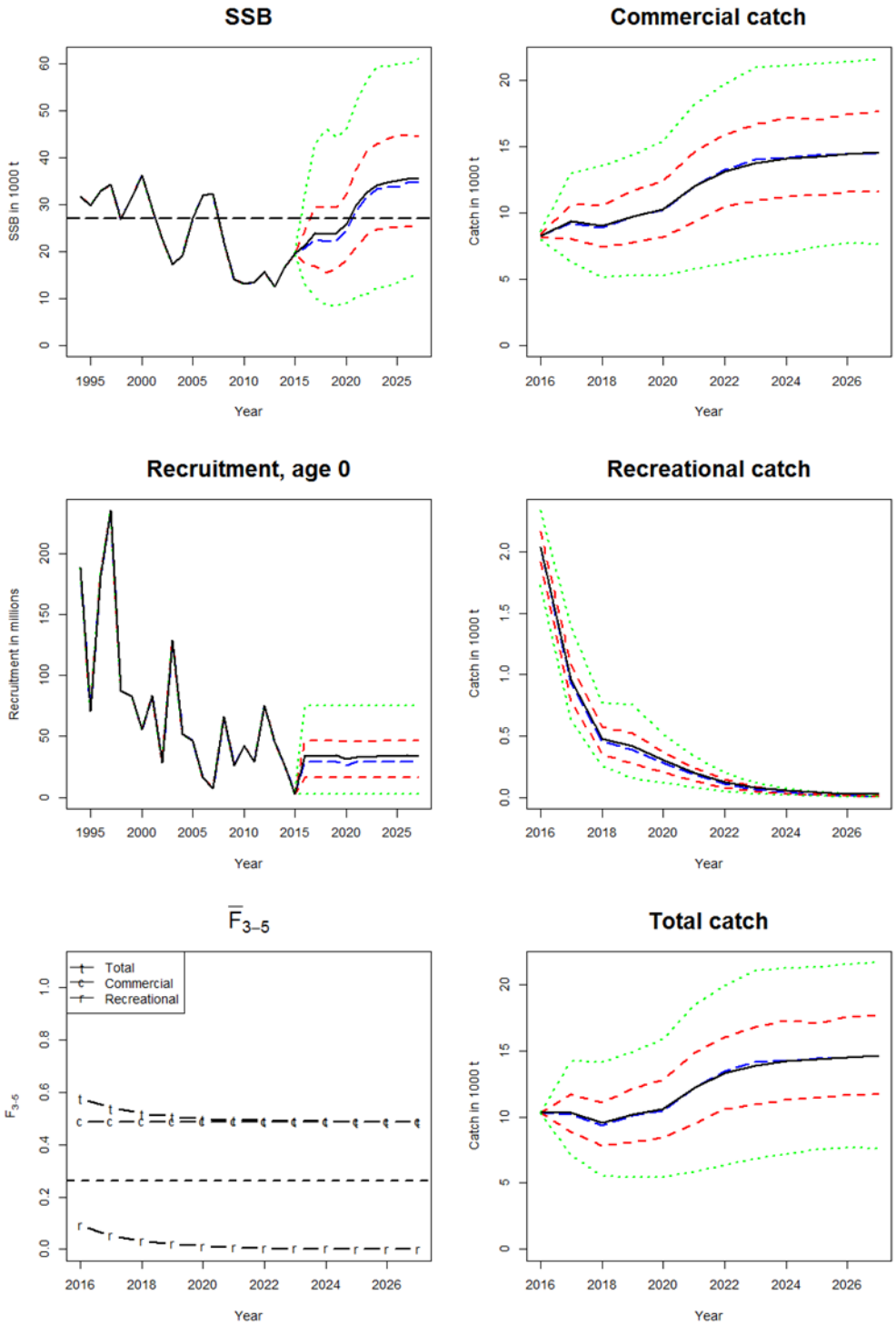

Figure 8.4.3.15 *Scenario d2_40.* Annual reductions of 40% in the recreational fishery until F corresponds to the ICES MSY approach. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

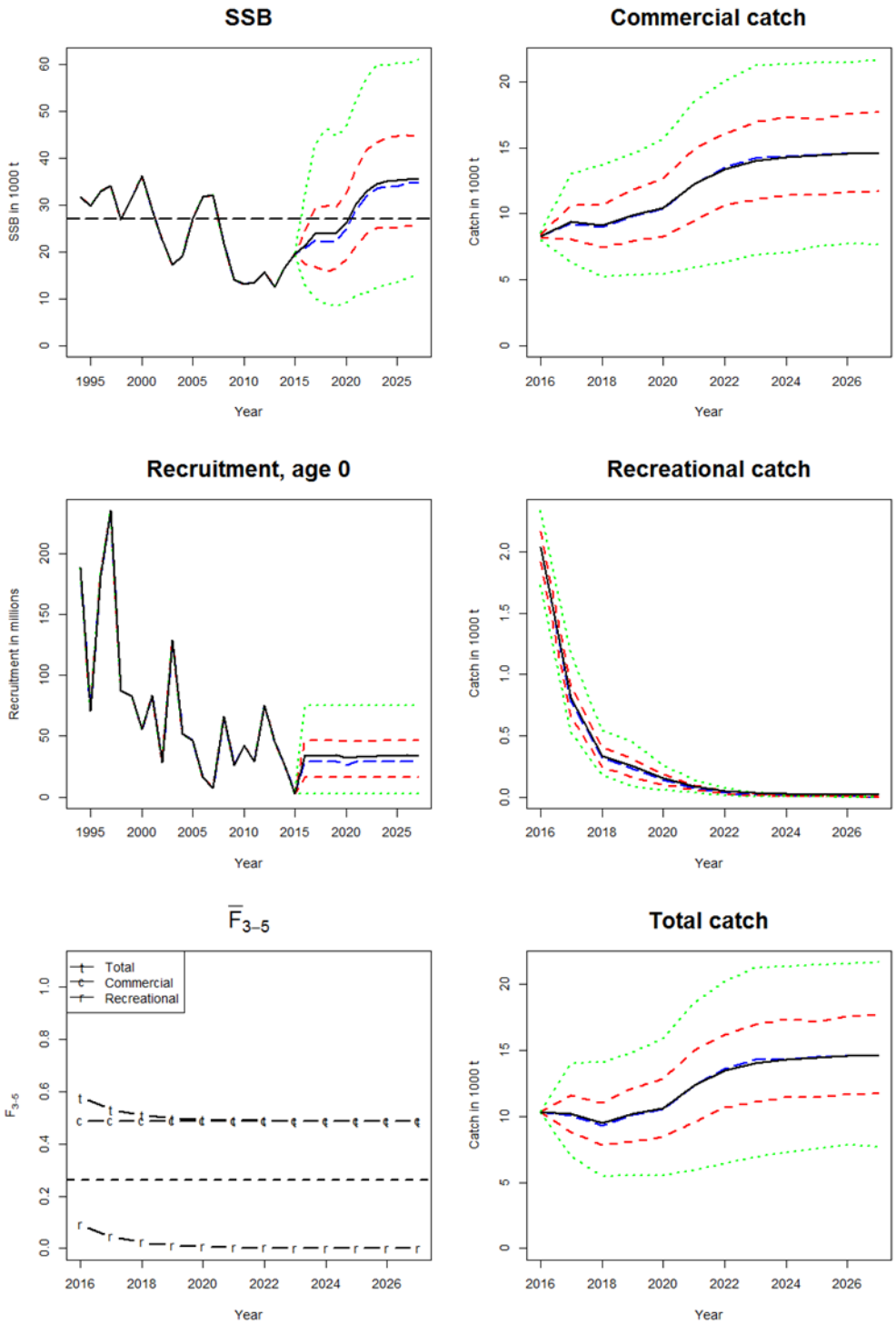

Figure 8.4.3.16 *Scenario d2_50.* Annual reductions of 50% in the recreational fishery until F corresponds to the ICES MSY approach. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

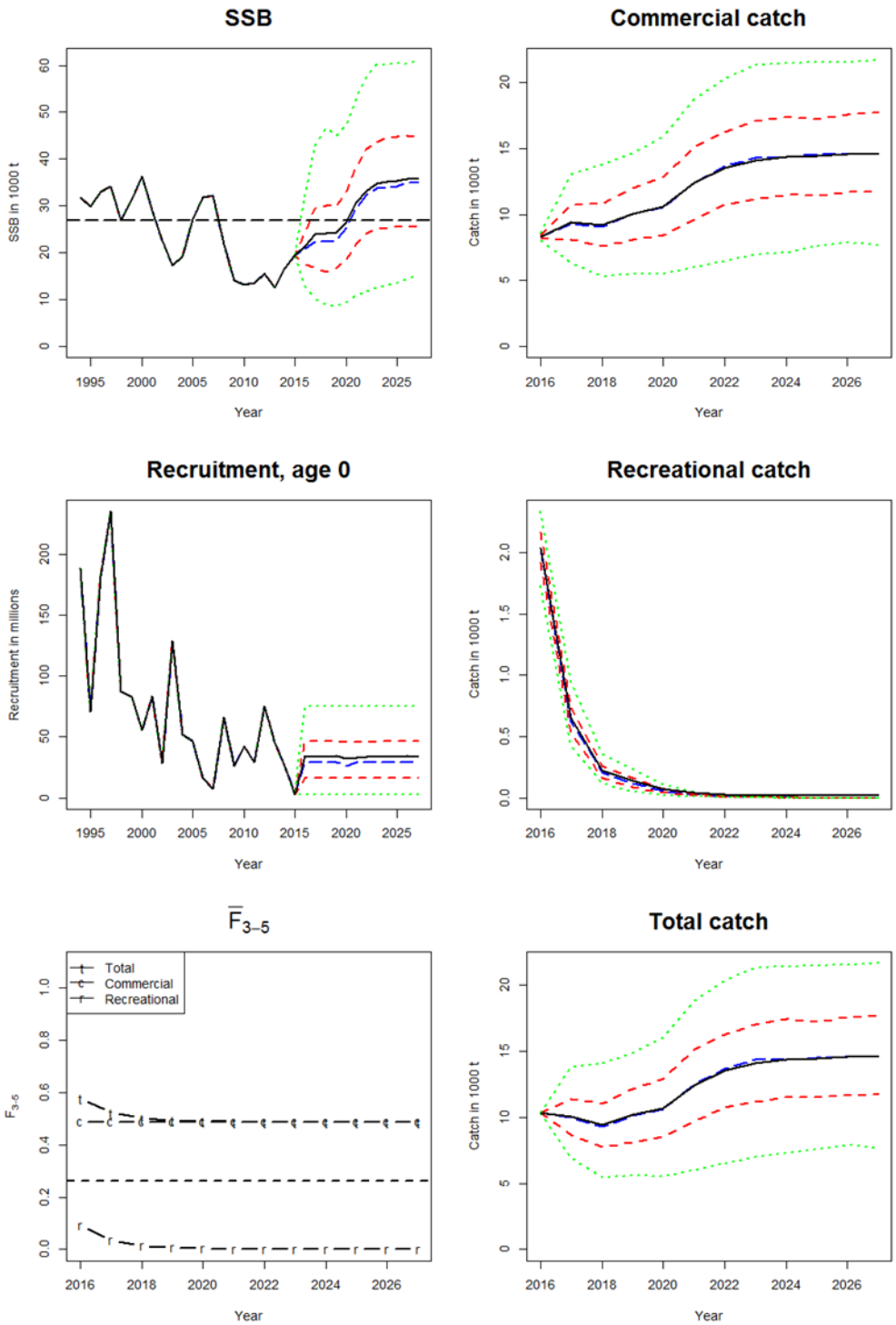

Figure 8.4.3.17 *Scenario d2_60.* Annual reductions of 60% in the recreational fishery until F corresponds to the ICES MSY approach. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

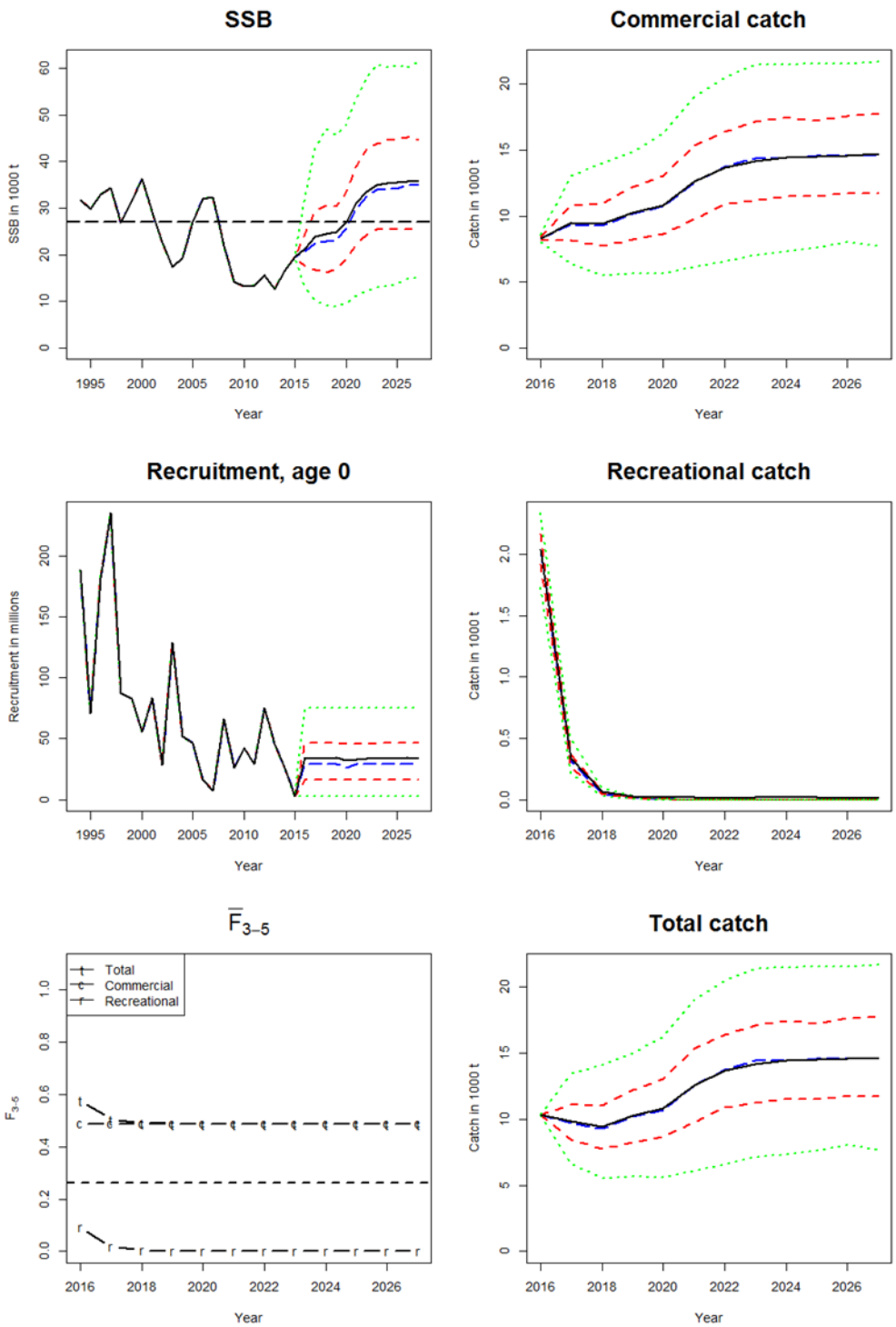

Figure 8.4.3.18 *Scenario d2_80.* Annual reductions of 80% in the recreational fishery until F corresponds to the ICES MSY approach. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

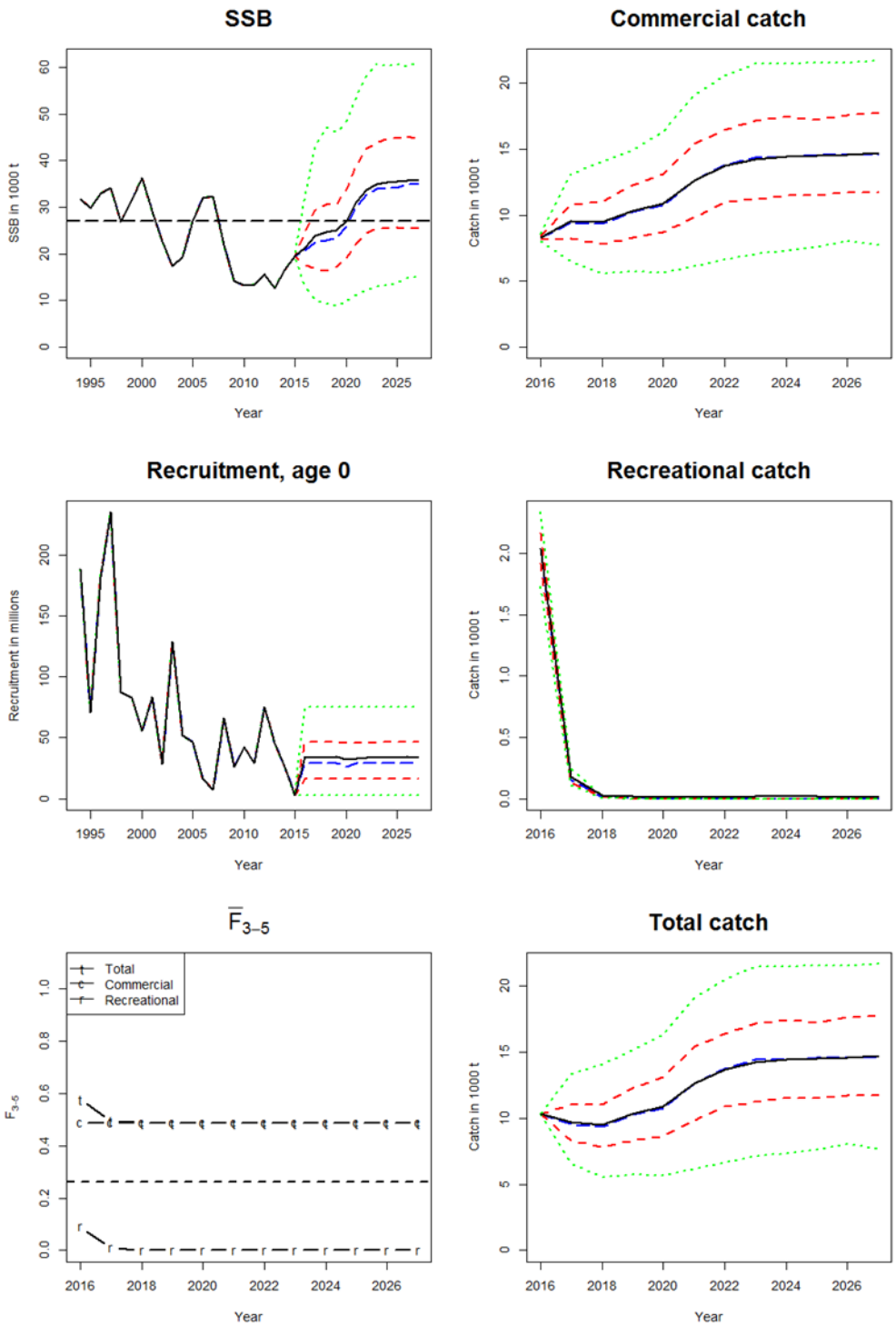

Figure 8.4.3.19 *Scenario d2_90.* Annual reductions of 90% in the recreational fishery until F corresponds to the ICES MSY approach. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

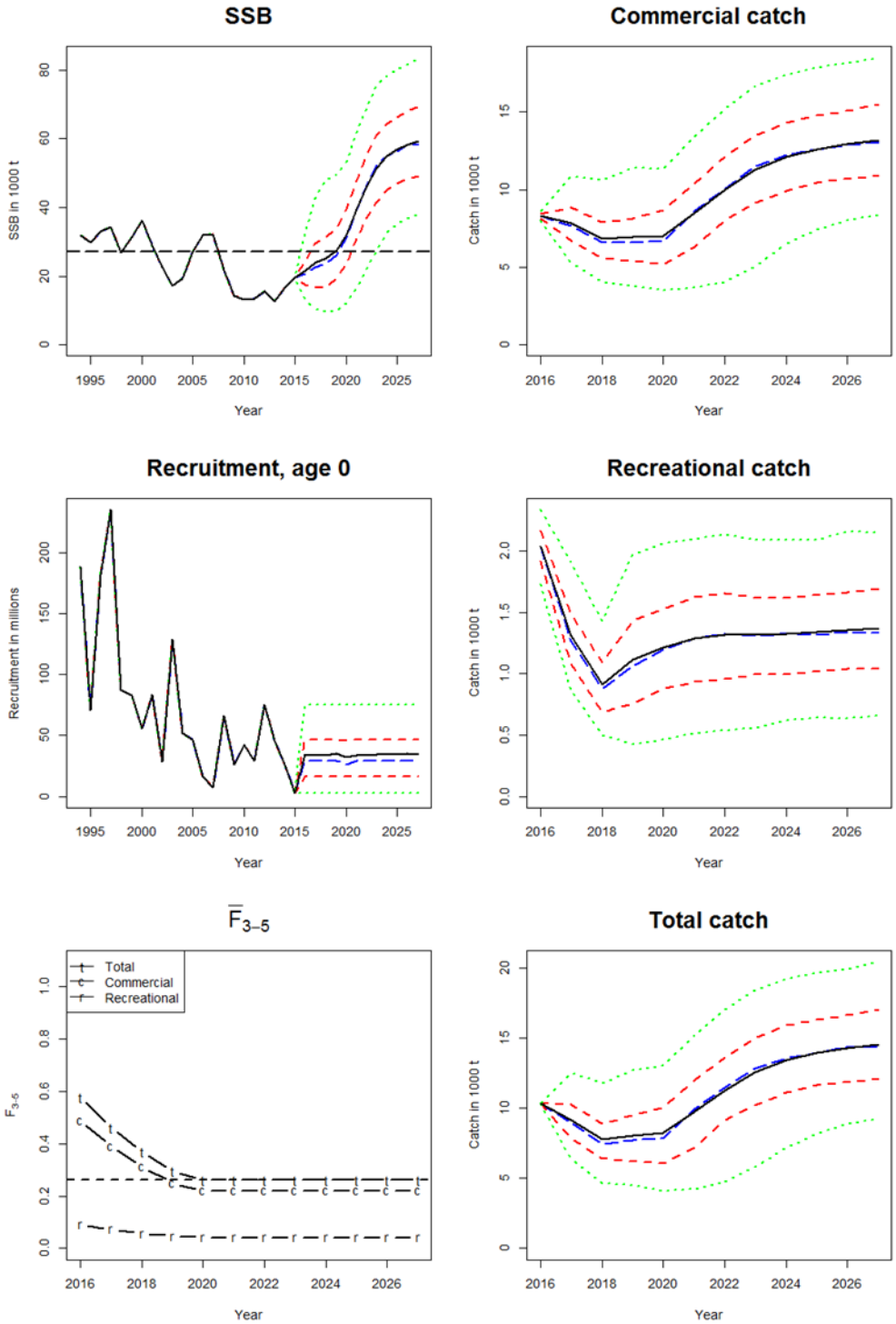

Figure 8.4.3.20 *Scenario d3_20.* Annual reductions of 20% in both the commercial and recreational fisheries until F corresponds to the ICES MSY approach. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

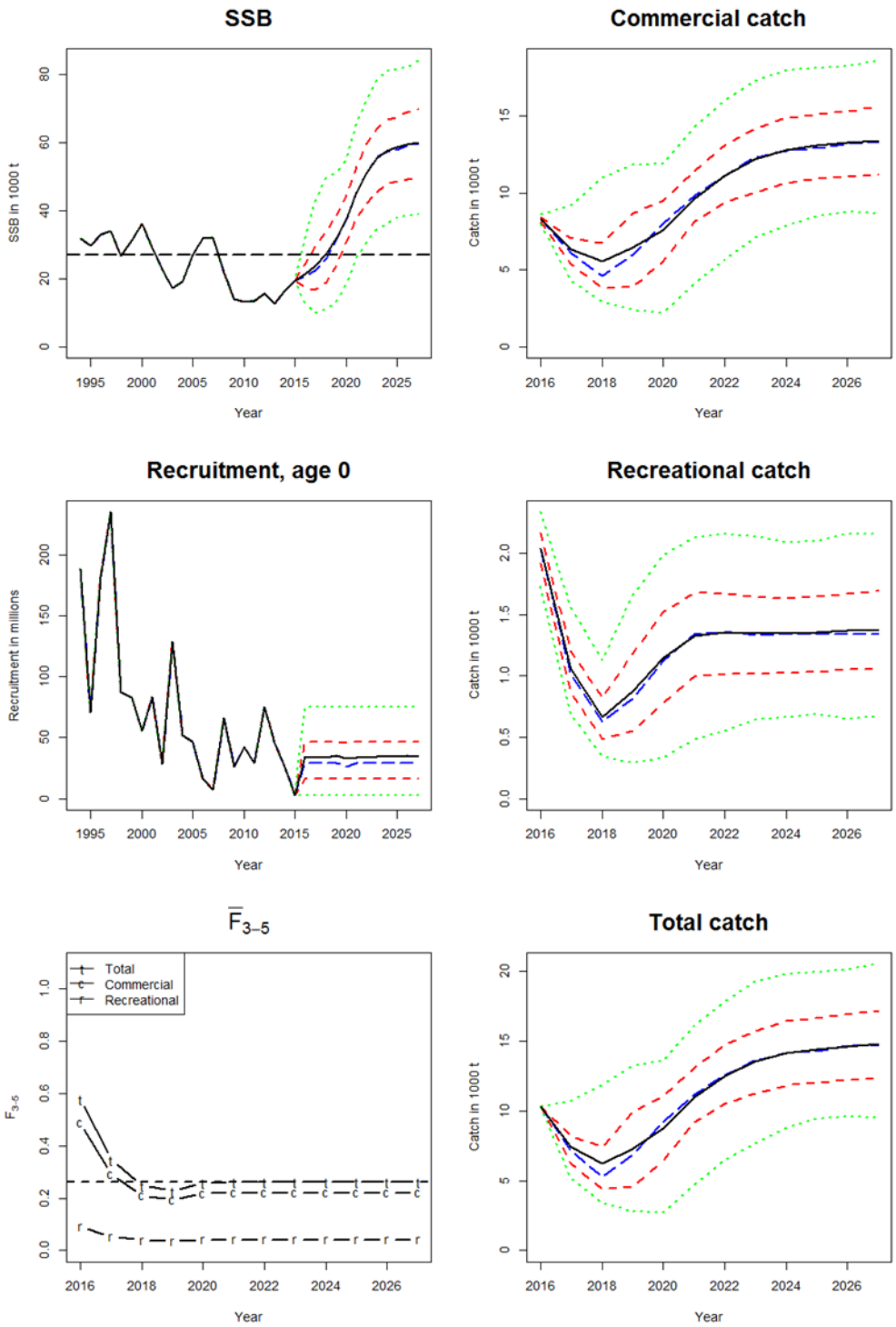

Figure 8.4.3.21 *Scenario d3_40.* Annual reductions of 40% in both the commercial and recreational fisheries until F corresponds to the ICES MSY approach. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

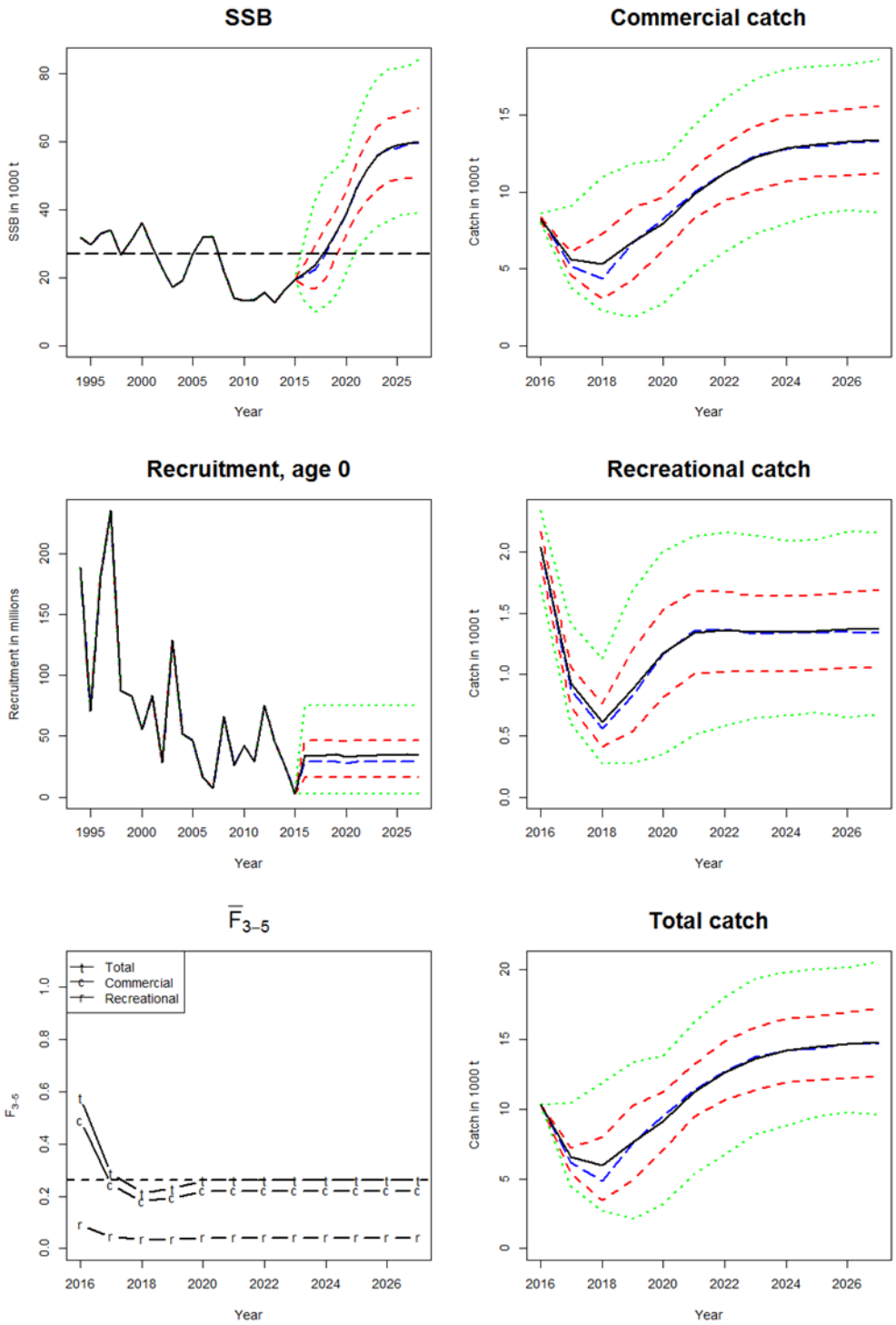

Figure 8.4.3.22 *Scenario d3_50.* Annual reductions of 50% in both the commercial and recreational fisheries until F corresponds to the ICES MSY approach. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

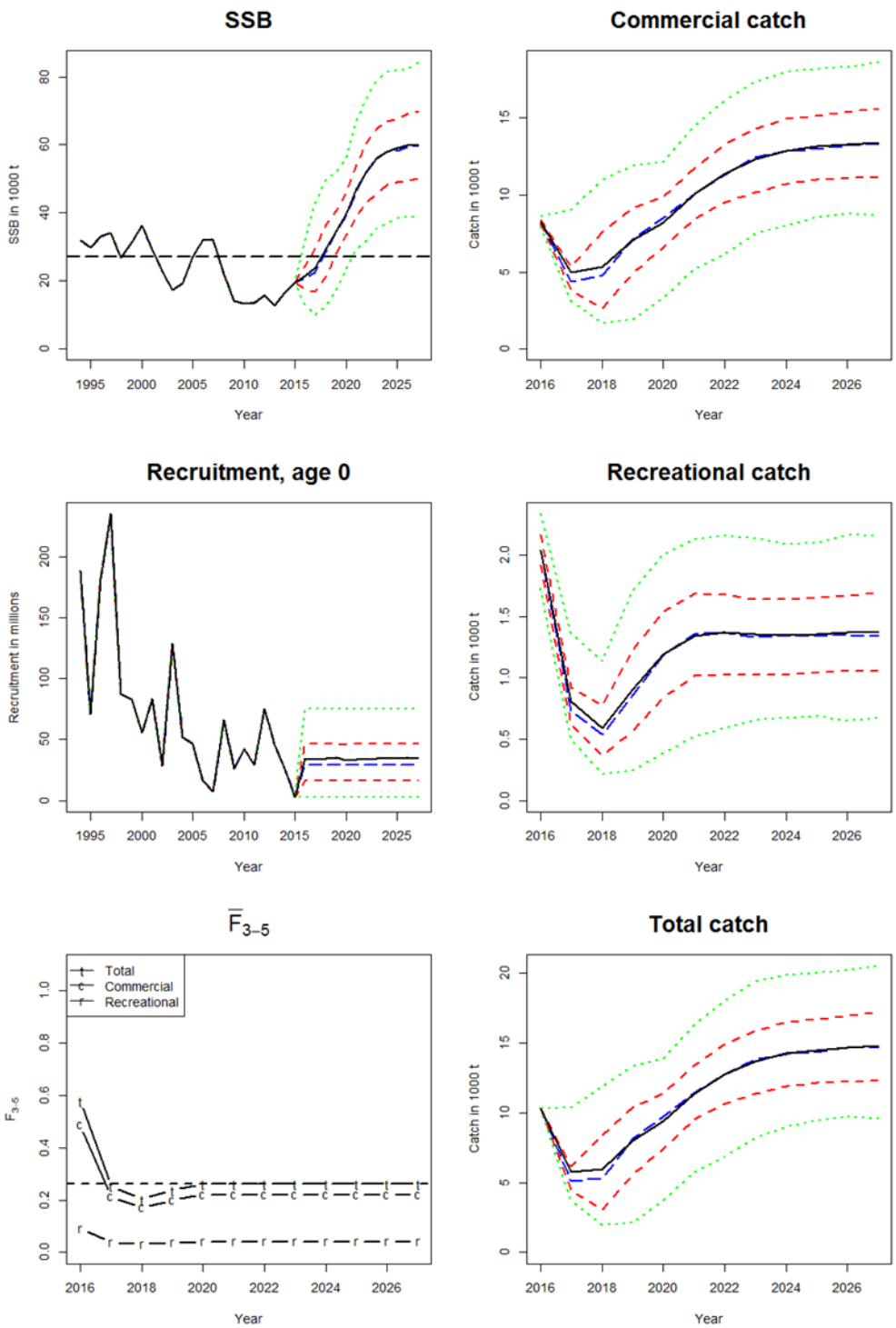

Figure 8.4.3.23 *Scenario d3_60.* Annual reductions of 60% in both the commercial and recreational fisheries until F corresponds to the ICES MSY approach. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

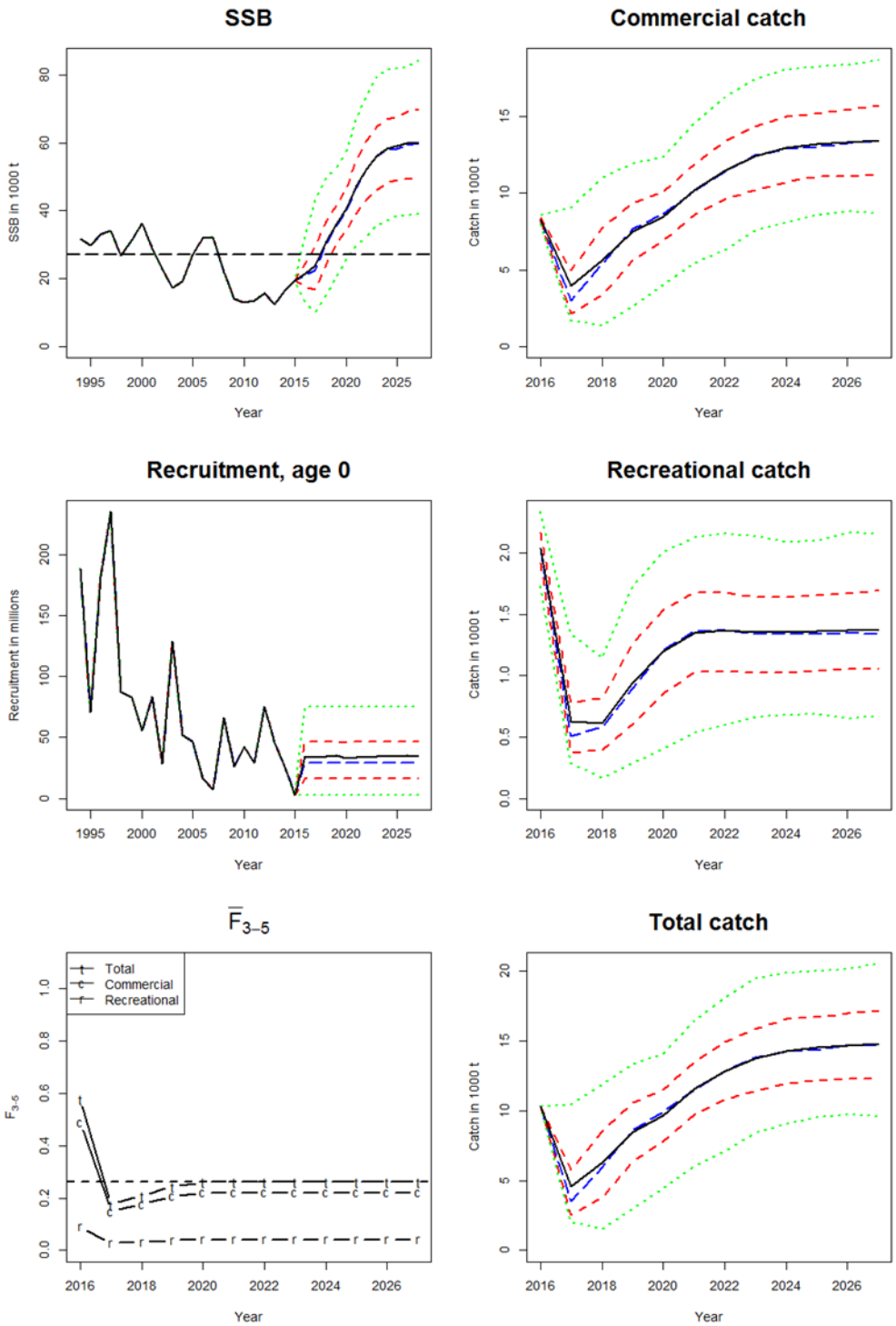

Figure 8.4.3.24 *Scenario d3_80.* Annual reductions of 80% in both the commercial and recreational fisheries until F corresponds to the ICES MSY approach. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

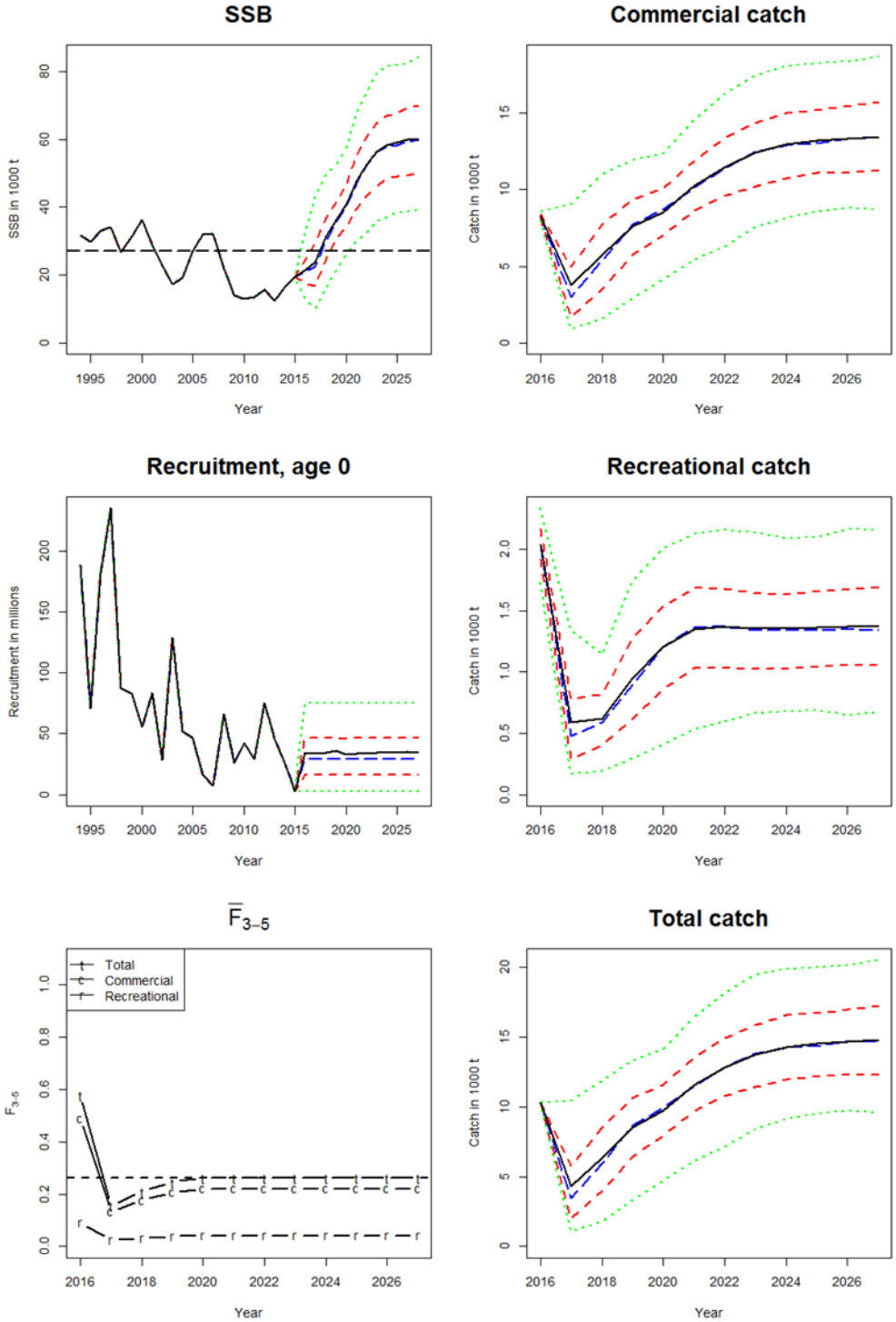

Figure 8.4.3.25 *Scenario d3_90.* Annual reductions of 90% in both the commercial and recreational fisheries until F corresponds to the ICES MSY approach. SSB, recruitment, and catch in the forecast period are presented as the mean and 5th, 25th, 50th, 75th, and 95th percentiles of the 1000 simulations.

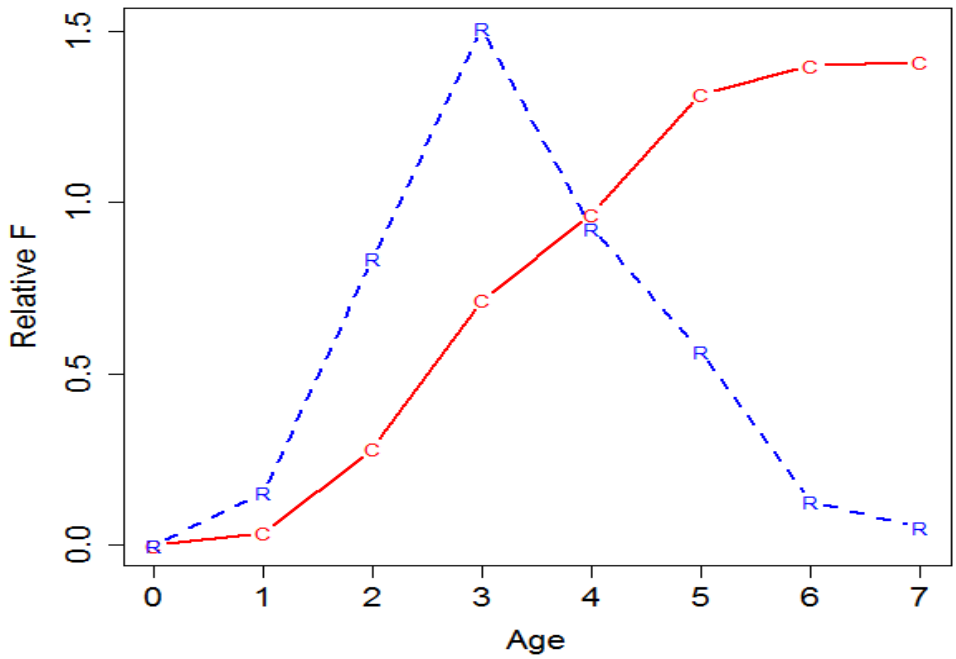

Figure 8.4.3.26 Exploitation patterns of the commercial (C) and recreational (R) fisheries.