STARRY RAY

Amblyraja radiata

GENERAL INFORMATION

Starry ray is by far the most abundant elasmobranch species in Icelandic waters. It has a widespread distribution over the Icelandic shelf and upper slope at depths from 20-1000 m but is most common at 30-200 m. In Icelandic surveys, starry ray is rarely caught larger than 70 cm but most commonly at 30-50 cm. Reproduction is believed to occur to some extent throughout the year, however mainly during summer.

THE FISHERY

Starry ray is abundant in Icelandic waters and is a common bycatch in variety of fishing gears. Catches of starry ray are taken all around Iceland but mostly within Faxaflói in the southwest (Figure 1). The increased landings since the 1990s are partly related to an increased retention, compensating for a lower abundance of the *D. batis* complex. However, fishing regulations are likely responsible for the high proportion of landings from Danish seine in the nineties (Figure 2). Since 2007, landings are mainly reported from the longline fishery (Figure 2). Reported landings increased from 500 tonnes in 2007 to more than 1700 tonnes in 2012. Thereafter, landings have shown a steady decline and in 2022 they didn´t exceed 300 tonnes. Last year there are drastic decline in landings from the longline fishery (Figure 2). A large proportion of the landings is for local consumption linked to the yule season. This is reflected in the strong seasonality in landings; most landings are reported from September-November each year (Figure 3).

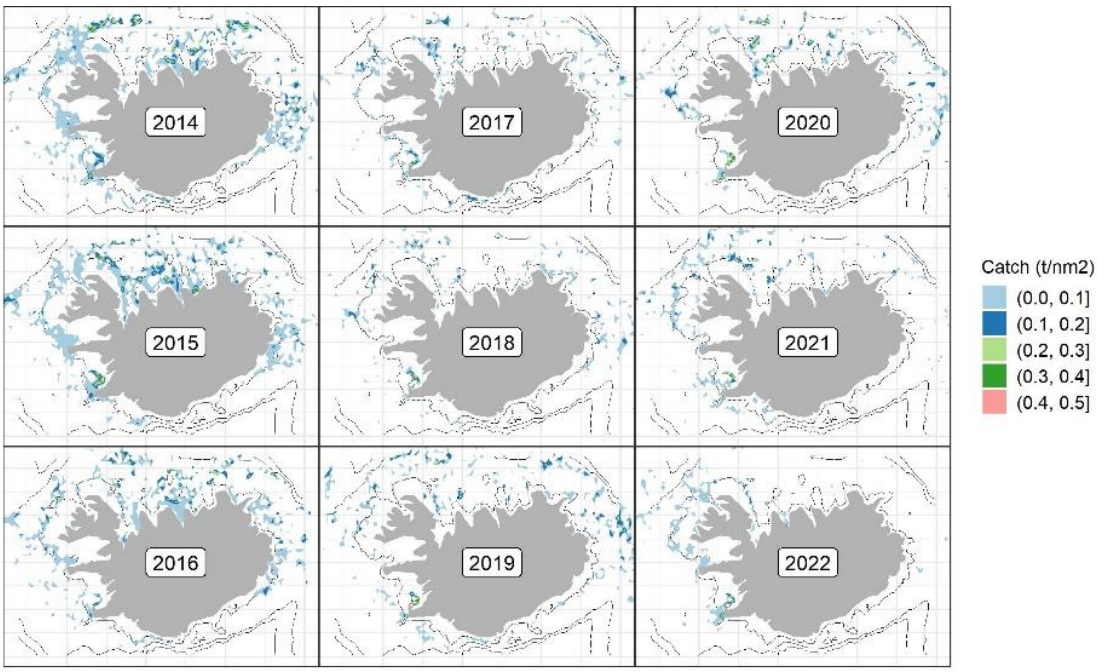

Figure 1. Starry ray. Geographical distribution of the Icelandic fishery since 2014 as reported in logbooks.

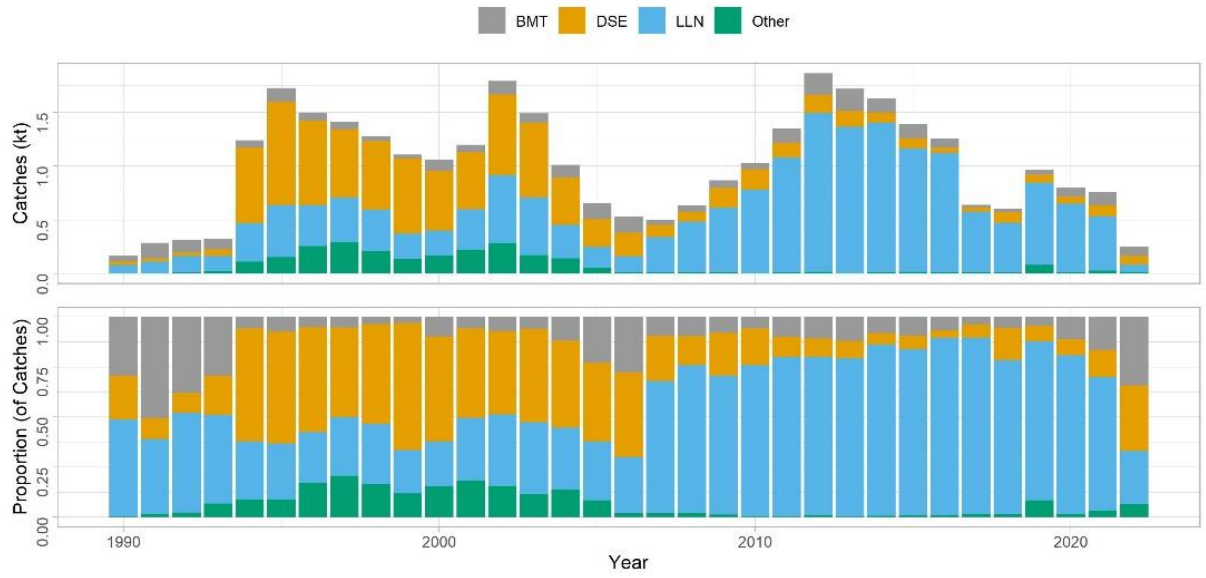

Figure 2. Starry ray. Landings by fishing gear since 1990 according to statistics from the Directorate of Fisheries.

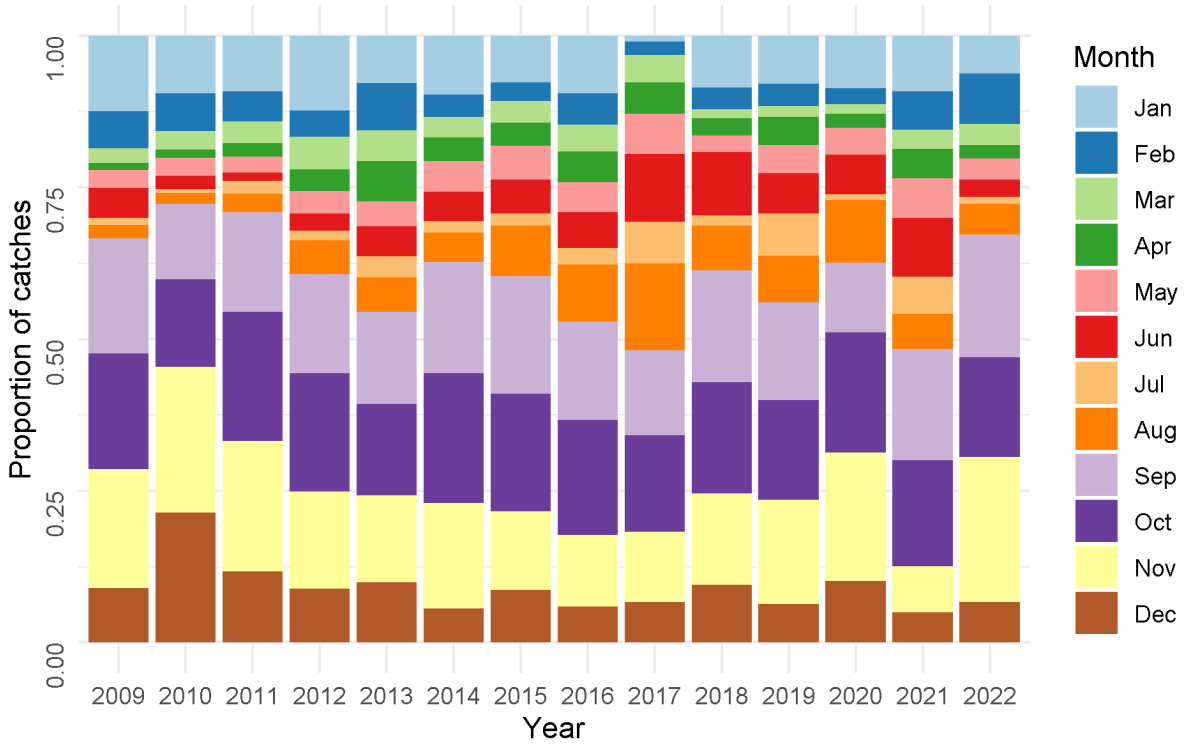

Figure 3. Starry ray. Proportion of monthly catch to each year since 2009 according to statistics from the Directorate of Fisheries.

SURVEY DATA

DISTRIBUTION AND BIOMASS INDICES

Starry ray is a frequent catch in MFRI spring (IS-SMB) and autumn surveys (IS-SMH). Seasonal differences in distributional patterns have been noted, with starry ray much less abundant on the shelf in IS-SMH than in IS-SMB. In IS-SMB, starry ray is found at 86% of all stations, but at about 50% of stations in the IS-SMH (Figure 4).

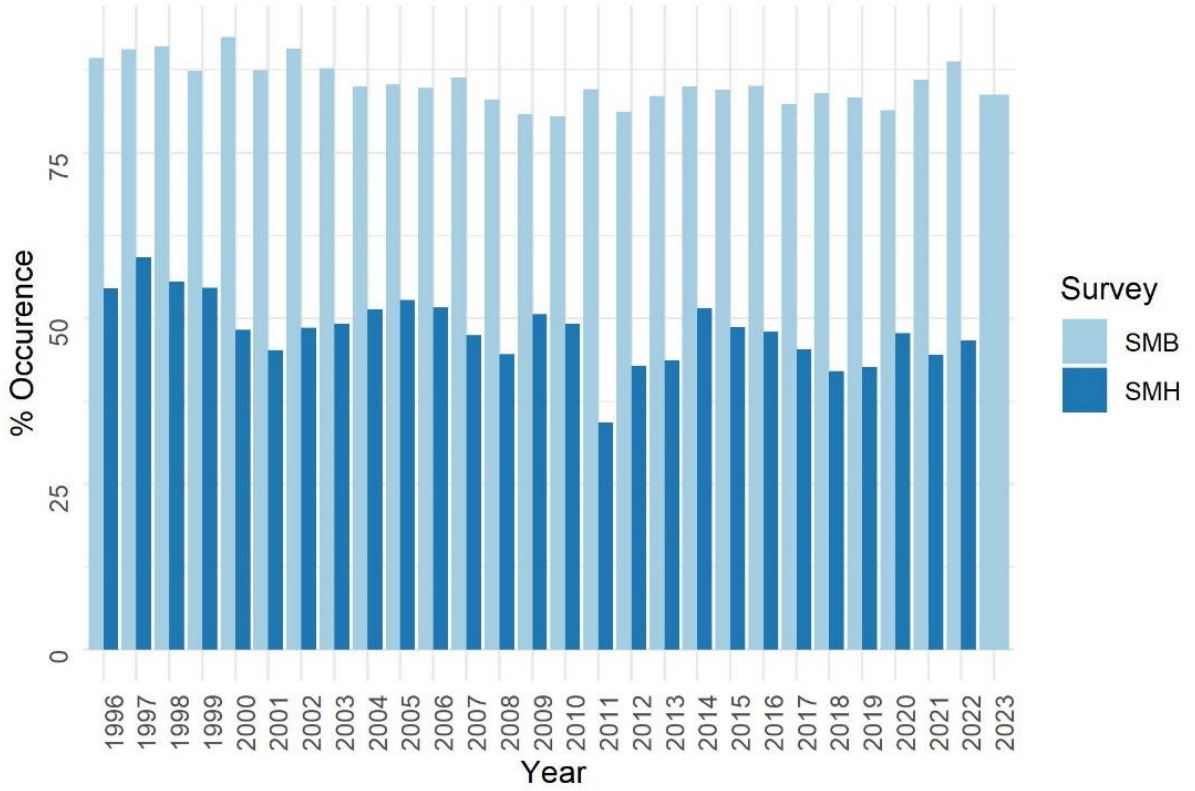

Figure 4. Starry ray. Frequency (occurrence at % stations) in IS-SMB and IS-SMH.

In MFRI groundfish surveys, starry ray is most abundant in the N and the NW (Figures 5, 6 and 7). In IS-SMB there is a high abundance on the shelf off N-Iceland and in near-shore areas in the south and southeast (Figure 5 a,c,e). In IS-SMH, the main distribution is on the shelf break and starry ray is almost absent from the southern area (Figure 5 b,d,f). Seasonal migration could to some extend explain these seasonal differences in distributional patterns. However, the large seasonal difference in occurrence and catches, especially in the smallest length groups (>30 cm, Figure 5c,d) could also be partly explained by differences in survey gear (size and weight).

Starry ray is a frequent bycatch in several other MFRI surveys. The offshore shrimp survey is conducted during summer off N-Iceland and the coastal shrimp survey occurs at various time periods in fjords and near coastal areas and starry ray is widely distributed within the survey areas (Figure 6 a). Similarly, starry ray is a frequent bycatch in the gillnet survey occurring early April each year (Figure 6 b).

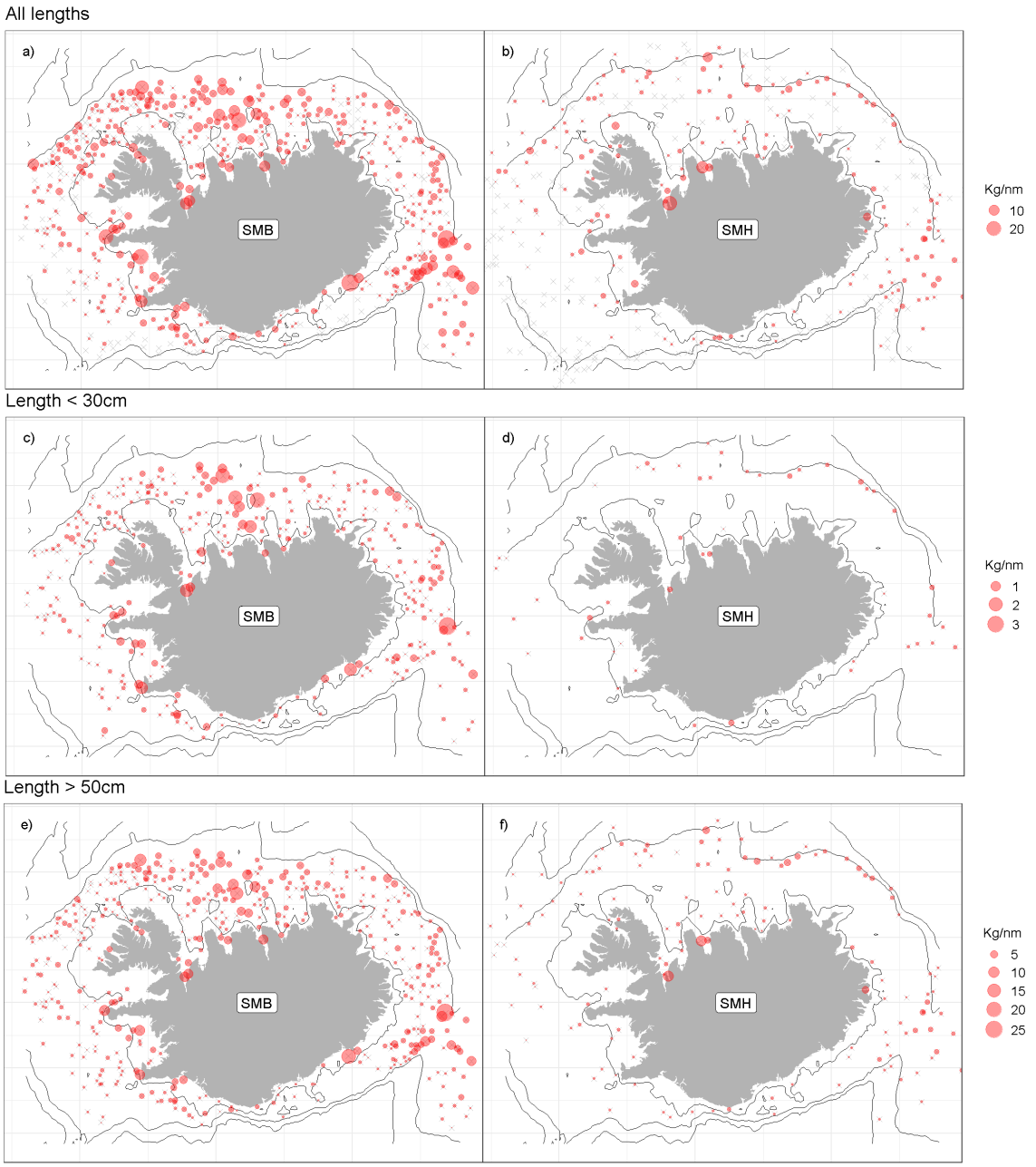

Figure 5. Starry ray. Spatial distribution in IS-SMB 2023 (a,c,e) and in IS-SMH 2022 (b,d,f). The top panel shows all data, the middle panel shows individuals <30 cm, and the bottom panel shows larger individuals (>50cm).

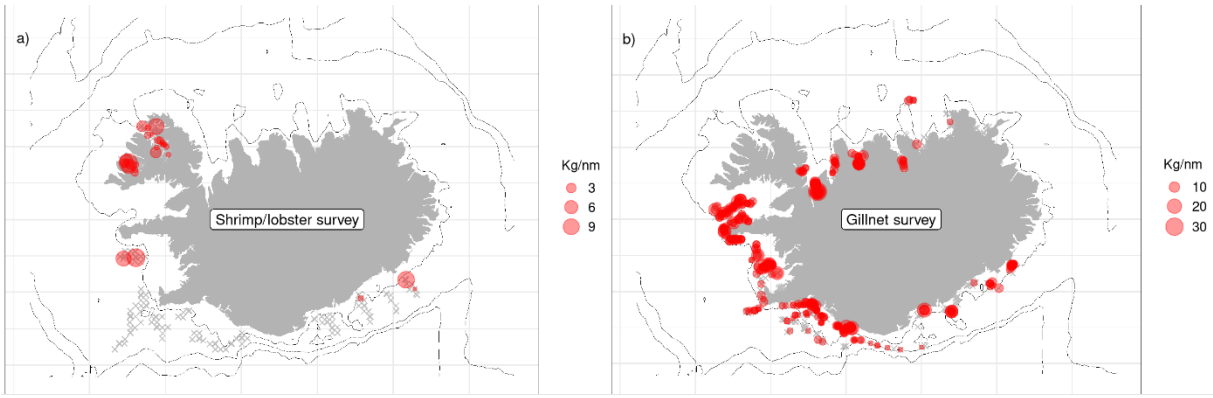

Figure 6. Starry ray. Spatial distribution in a) shrimp and lobster surveys in 2021 and b) the gillnet survey (IS-SMN) 2021.

In general, estimates of total biomass of starry ray in IS-SMB show a declining trend over the survey period 1985-2023 with few exceptions such as the estimate from 2022 which is the highest since 2004 (Figure 7 and 8).The biomass index in IS-SMB has decreased from 19 000 (average 1985-2000) to 14 000 (average 2001-2021). Decreasing trend is in particularly notable for large fish (≥50 cm) in years 1993-2008. Estimated biomass of juveniles (≤20 cm) appears to be stable despite large variations in years 2003-2013 . In IS-SMH, total biomass indices are lower than in IS-SMB and similarly to the IS-SMB the declining trend over the survey period is evident.

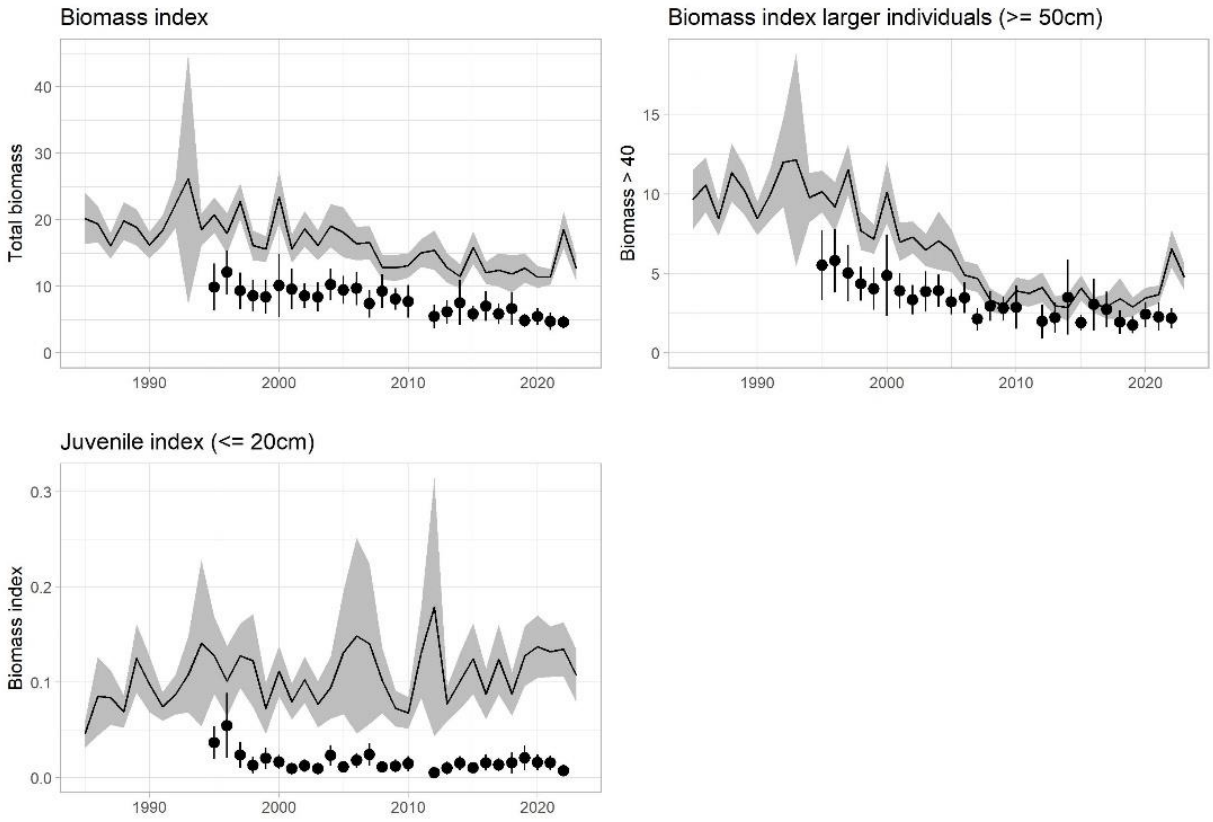

Figure 7. Starry ray. Total biomass indices (upper left), biomass indices of large individuals (≥50 cm, upper right) and juvenile abundance indices (≤20 cm, lower left), from IS-SMB (black line) and IS-SMH (black dots).

In IS-SMB the highest proportion of catch is taken in areas off NW-, NE- and SE- Iceland and the reduction in biomass is most prominent in these areas. In IS-SMH, the highest proportion of catch is taken in areas off NW- and NE-Iceland; the areas where a reduction in abundance has taken place (Figure 8).

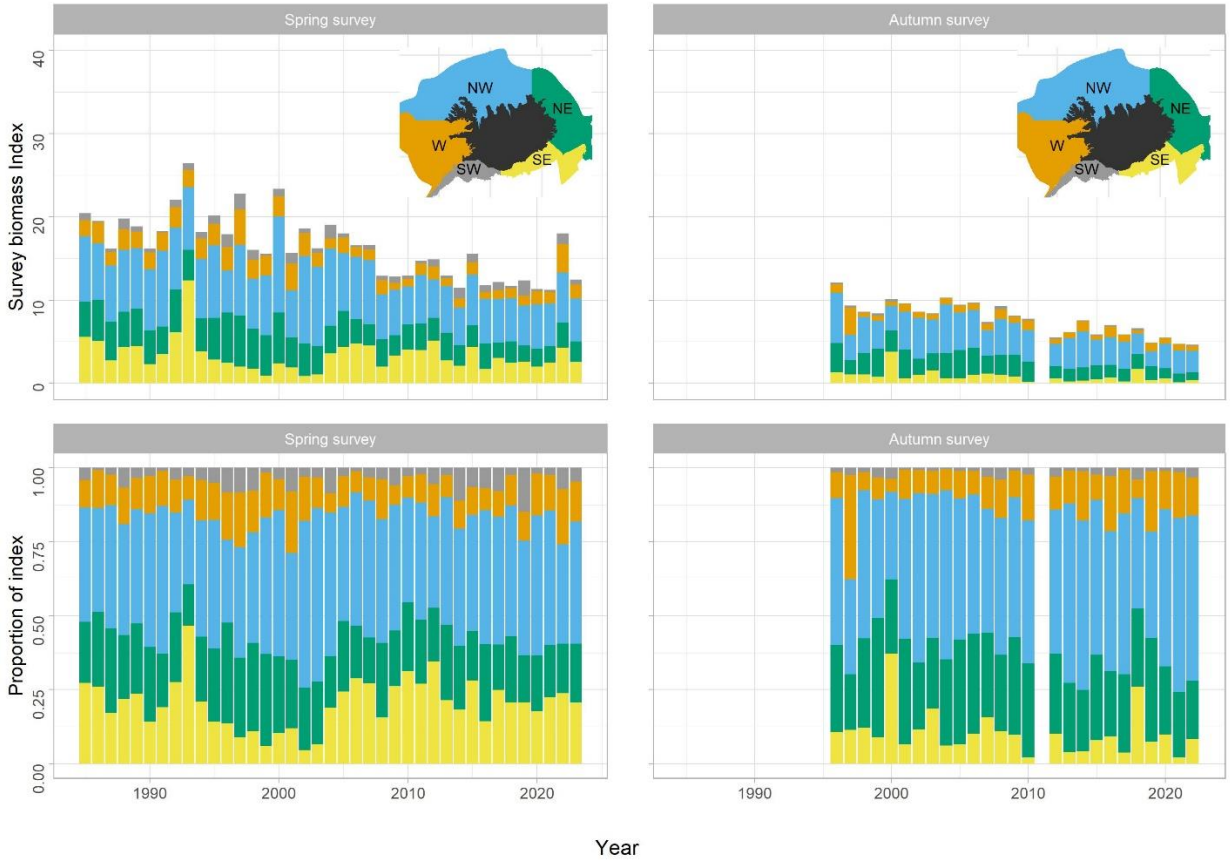

Figure 8. Starry ray. Spatial distribution of biomass indices from IS-SMB and IS-SMH.

LIFE HISTORY INFORMATION

Length distributions from surveys indicate that most specimens are <60 cm . Mean size varies from 35-49 cm depending on surveys (Figure 9). In spring survey (IS-SMB), autumn survey (IS-SMH) and shrimp offshore survey (IS-SMR), the length distribution is negatively skewed as the proportion of large fish decreases quite abruptly (Figures 9-11).

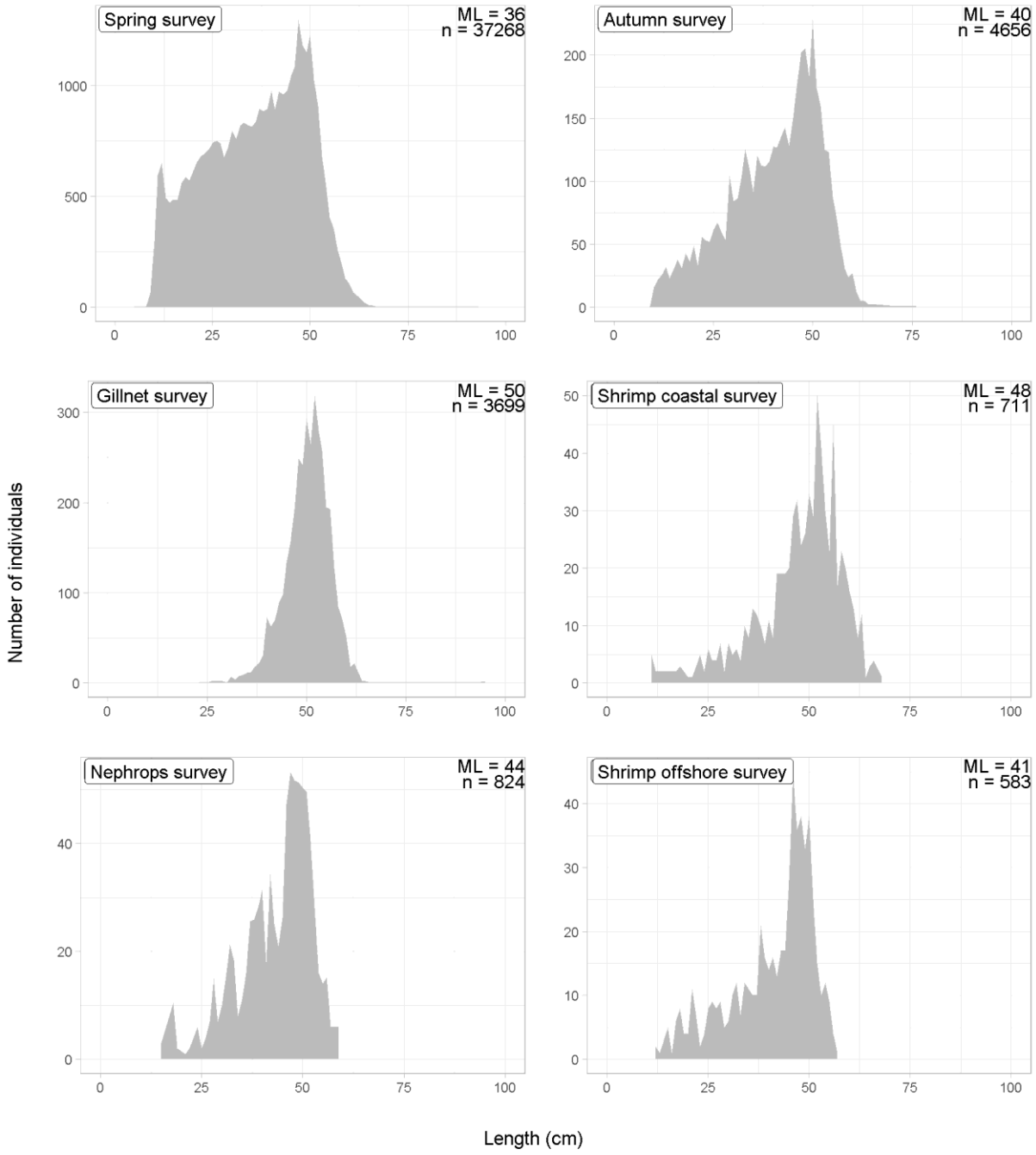

Figure 9. Starry ray. Length distributions in several MFRI surveys in 2017-2022. All surveys use various form of bottom trawls except IS-SMN.

Mean length in the spring survey is the lowest in all six surveys and considerably lower than mean length in IS-SMH (overall mean 35 and 40 cm, respectively). The proportion of larger fish decreases quite abruptly after reaching 50 cm (Figure 10 and 11). In IS-SMB, the mean length has decreased from 38 cm (average 1996-1998) to 35.8 cm (average 2019-2023) (Figure 10). On the other hand, in IS-SMH the mean length has varied (from 38 cm to 43 cm) over the period without any specific direction (Figure 11).

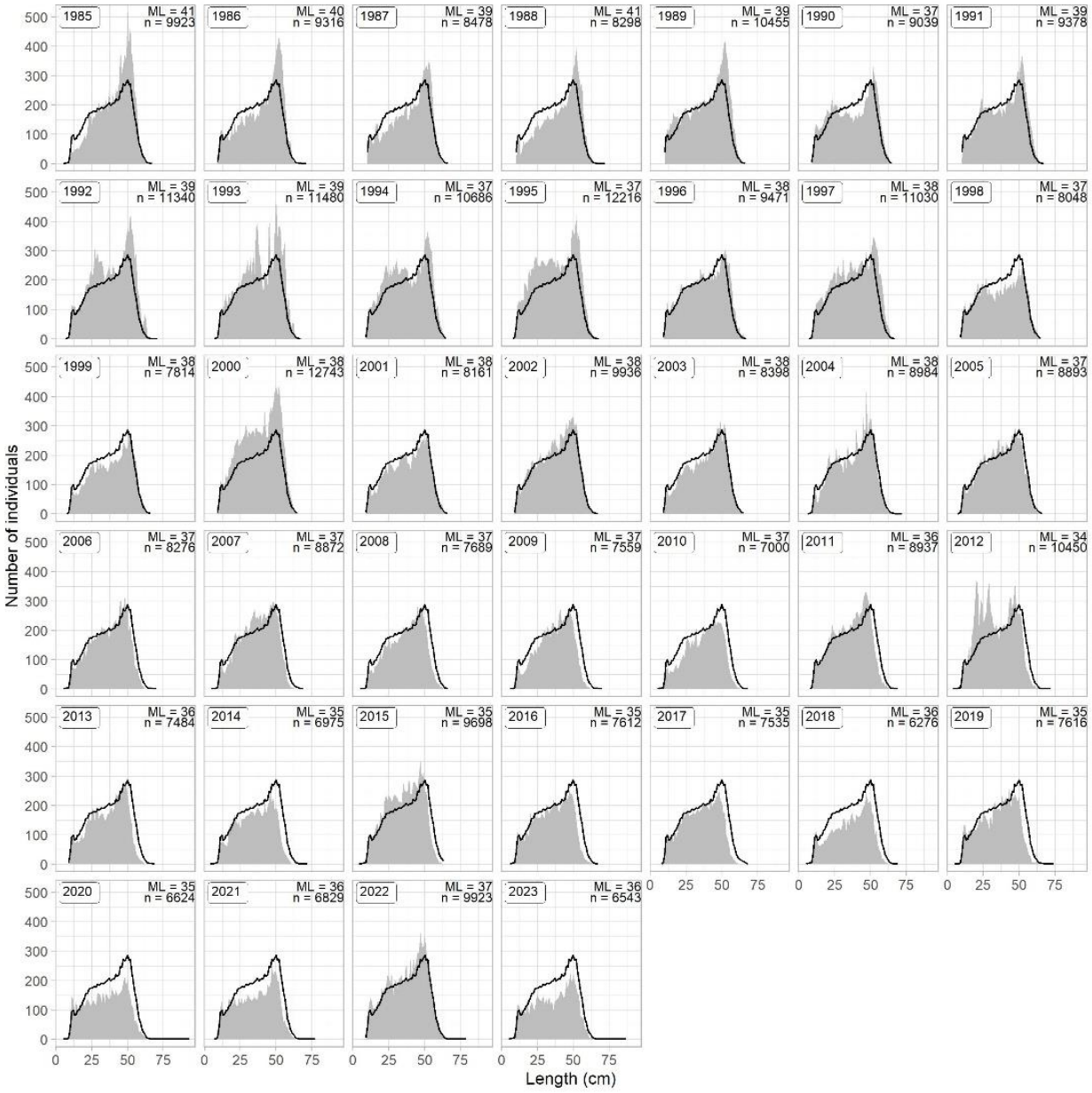

Figure 10. Starry ray. Length distributions in IS-SMB 1985-2023. Mean length (ML, cm) is indicated for each year. Black line is the average mean for the period.

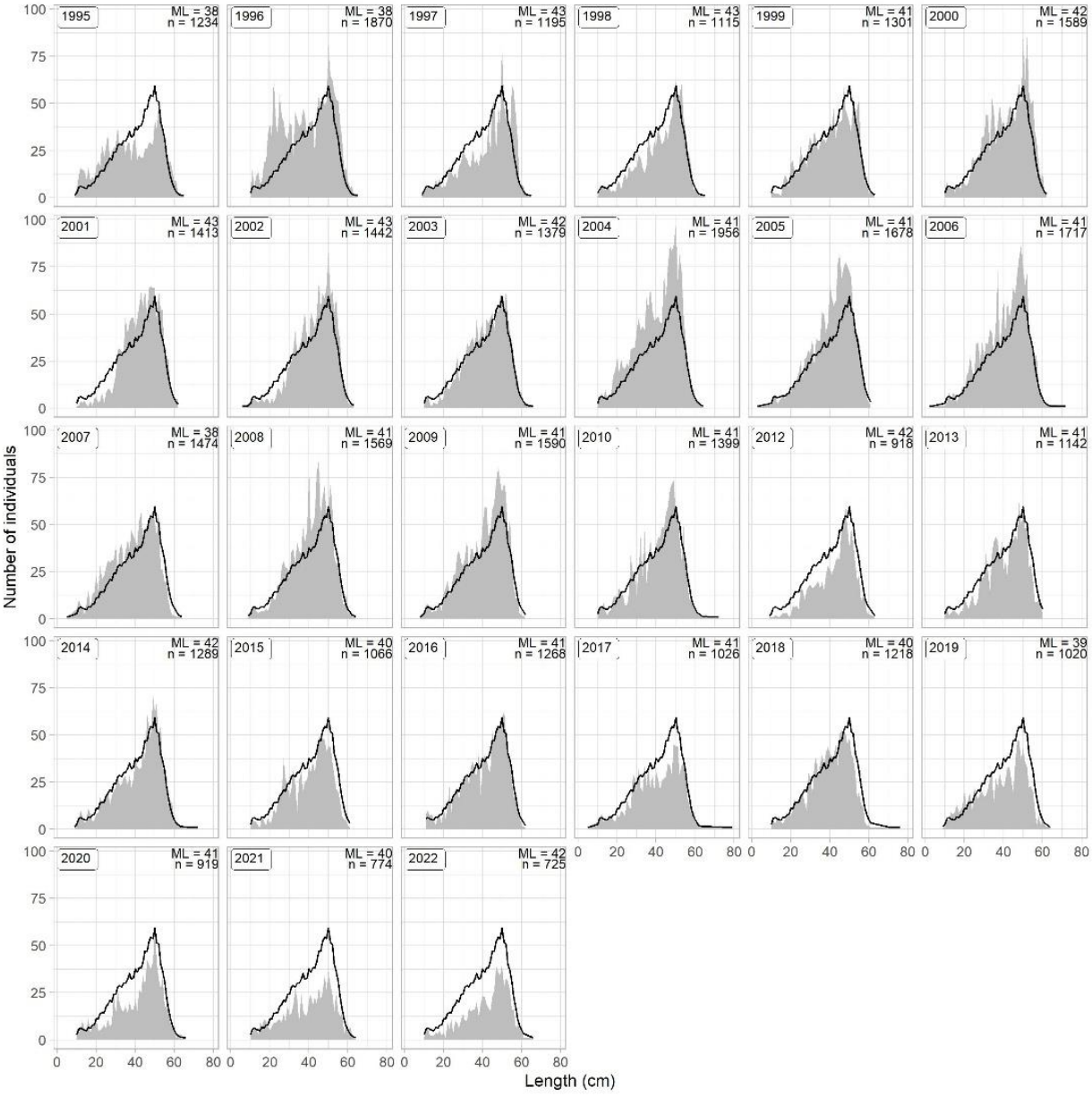

Figure 11. Starry ray. Length distributions in IS-SMH 1995-2022. Mean length (ML, cm) is indicated for each year (upper, right). Black line is the average mean for the period. No survey was conducted in 2011.

The sex ratio is 1:1 in the spring survey, but in the autumn survey the ratio is skewed towards females (male:female ratio 1:1.57). Males are on average larger than females (40.5 cm and 38.8 cm, respectively).

Data on maturity is sampled in the autumn survey allowing for calculations of maturity ogives. Length-at-50%-maturity (L_{50}) is 42.9 cm and 41.0 cm for males and females, respectively (Figure 12).

Anecdotal information suggests that starry ray undertakes seasonal migrations related to egg-laying activity. Recently, both surveys have started to sample data on egg case distribution, but trawl survey data may provide useful information on catches of viable skate egg cases and/or nursery grounds.

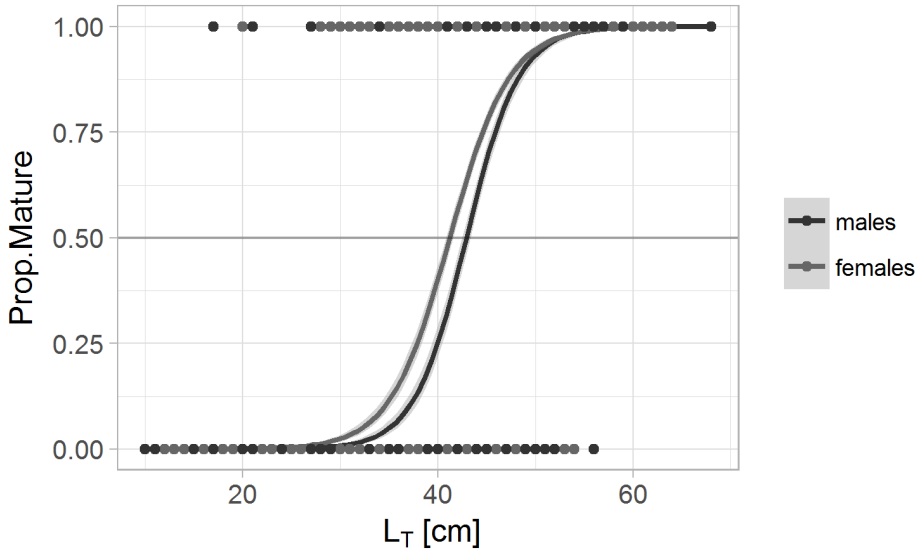

Figure 12. Starry ray. Length at maturity. Males: L_{50}= 42.9 cm , L_{95}=51.1 cm . Females: L_{50}=41.0 cm, L_{95}=50.0 cm.

STOCK ASSESSMENT

This is the first attempt to perform an analytical assessment of starry ray in Icelandic waters, based recommendations from ICES (2022). The starry ray is considered a data limited stock and follows the ICES framework for such (category 3.1, ICES 2021). A stochastic surplus production model in continuous time (SPiCT; Pedersen and Berg, 2017) is one of the official assessment methods for stocks in this category. The model quantifies observation and process errors and estimates stock status and reference levels with associated confidence intervals. SPiCT estimates MSY based reference levels, which can be used to calculate quantities relevant for fisheries management and ICES recommends using the 35th percentile for all quantities (Mildenberger et al., 2021)

INPUT DATA

The model synthesizes information from input priors, landings series from 1991-2022 and survey indices from the Icelandic Groundfish survey (IS-SMB) from 1985-2023). Priors used for the model were the intrinsic growth rate, $\bar{r}$, and the medium initial biomass depletion, $\bar{P}$ and the n is fixed at 2 to resemble the Schaefer production curve (ICES 2021) (Table 1).

Table 1. Starry ray. Priors in model.

Priors	Value	Standard deviation
$\bar{r}$	log(0.4)	0.04
$\bar{P}$	log(0.5)	0.25

RESULTS

The output from the model is shown below in table 2 and 3. Model results are shown in Figure 13, the model diagnostics in Figure 14 and the analytical retrospective analysis in Figure 15. Following the checklist for the acceptance of SPiCT model (Mildenberger et al., 2021), one minor issue was found i.e. the Shapiro test indicate some non-normality in the residuals. However, slight violations of these assumptions do not necessarily invalidate model results. Apart from that issue, there are no violations of model assumptions based on one-step ahead residuals, the production curve is realistic (B/K = 0.5) (Figure 13) and the patterns in the retrospective analysis are consistent (Figure 15). B_{MSY} is estimated at 11.6 kt.

Table 2. Starry ray. Summary of model results.

	Estimate	95% upper CI	95% lower CI
alpha	68.1292	46599.1	0.10048
beta	0.00494	92.9948	0.00002
r	0.16056	0.27822	0.09266
rc	0.16056	0.27822	0.09266
rold	0.16056	0.27822	0.09266
m	933.952	1077.16	809.782
k	23266.5	35704.8	15161.3
q	0.00115	0.00175	0.00075
sdb	0.00248	1.53027	0.000003
sdf	0.51203	0.66429	0.39471
sdi	0.15385	0.19517	0.12128
sdc	0.00253	43.7284	0.00001

Table 3. Starry ray. Summary of model results. Estimates of reference points.

Reference points	Estimate	95% upper CI	95% lower CI
B_{MSY}	11633.29	17852.44	7580.67
F_{MSY}	0.0802	0.1391	0.04633
MSY	933.952	1077.162	809.782

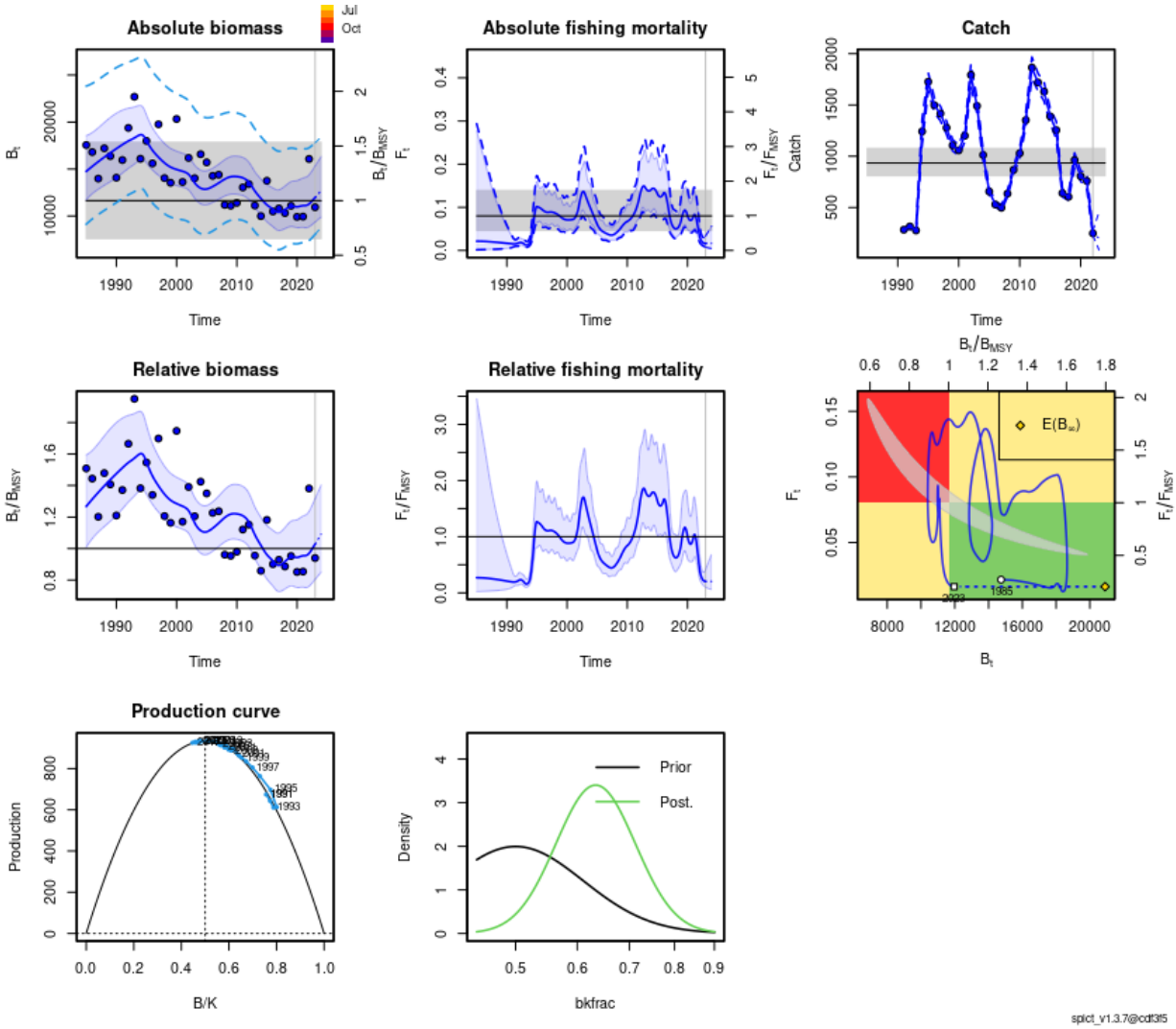

Figure 13. Starry ray. SPiCT-model results.

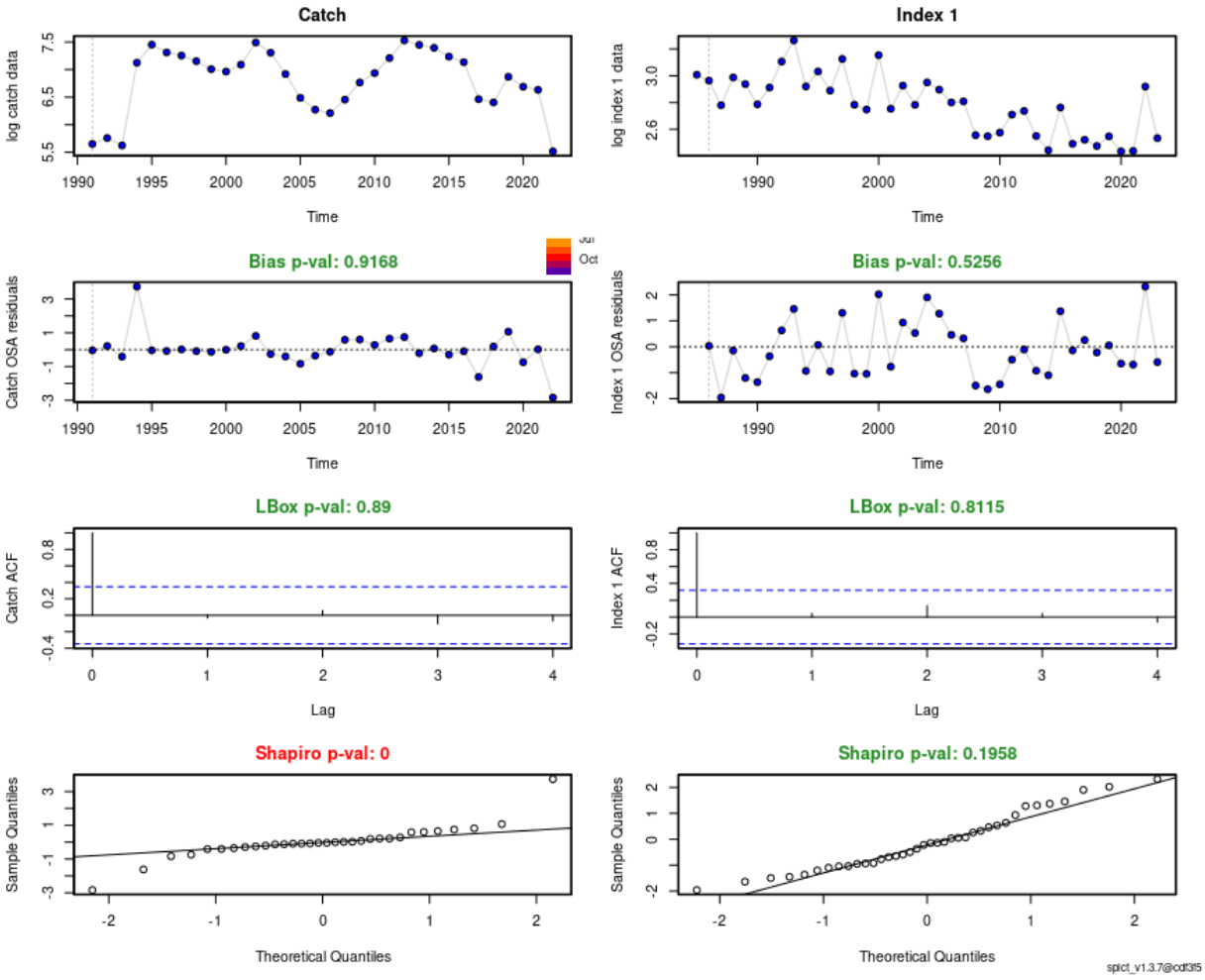

Figure 14. Starry ray. SPiCT-model diagnostics.

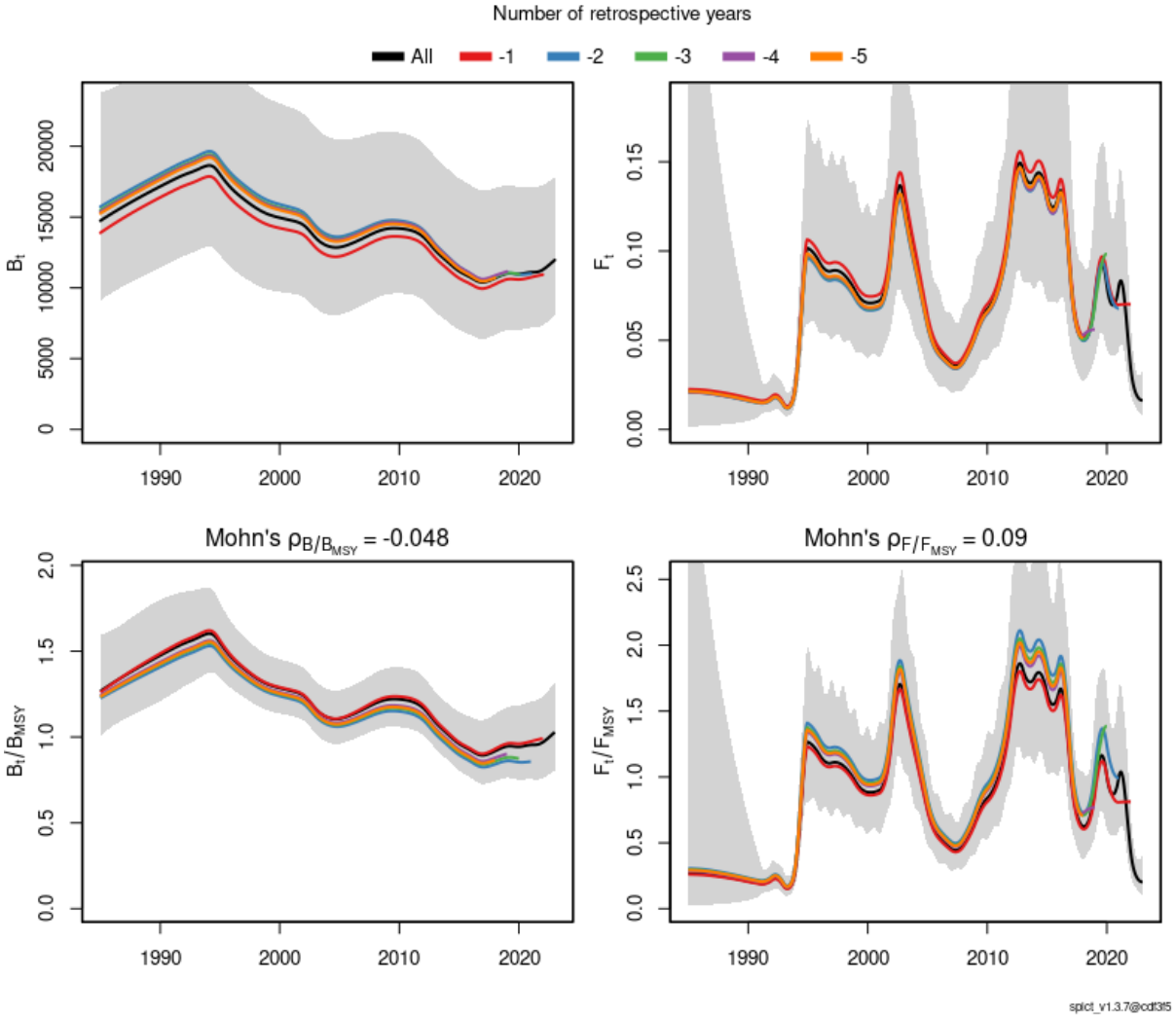

Figure 15. Starry ray. **Analytical retrospective analysis from the SPiCT-model.**

QUALITY OF THE ASSESSMENT

More tests, particularly the choice of priori distributions, may be considered. Retrospective pattern is often related to uncertainty about the shape n parameter and fixing it or constraining it using prior, often reduce the retrospective patterns. Shorter landing series was used (1991-2022) because the artefact of initial states is possible if catch series starts earlier than index (Maguire and Berg, 2020). Also, reporting on less valued/no valued species such as starry ray was inaccurate in the hayday of landing reports. There is a high seasonality in landings data that doesn't reflect biological attributes of the species but rather increased demand of the fish in the last quarter of the year (MFRI technical report 2023). This could be explored for estimation of discard rate but discard rates are not known for starry ray in Icelandic waters. Also, studies elsewhere suggest resilience of this species to discard and thus relatively low discard mortality (Ellis et al. 2017, Knotek et al. 2019). Finally, discard mortality or survival of starry ray in Icelandic waters should be estimated.

Table 5. Starry ray. Estimates of B/Bmsy and F/Fmsy with 95% confidence intervals from the SPiCT model.

	95% lower CI	B/B_{msy}	95% upper CI	95% lower CI	F/F_{msy}	95% upper CI
1985	1.0069827	1.2671414	1.594513	0.02099908	0.2693461	3.4547852
1986	1.0621955	1.3130430	1.623130	0.02523782	0.2656049	2.7952485
1987	1.1040248	1.3563420	1.666325	0.03083768	0.2563812	2.1315257
1988	1.1390697	1.3976788	1.715001	0.03805830	0.2428321	1.5493966
1989	1.1729808	1.4372438	1.761043	0.04764306	0.2269830	1.0814018
1990	1.2096203	1.4753662	1.799495	0.06313363	0.2085009	0.6885812
1991	1.2509643	1.5121967	1.827981	0.10315570	0.1922760	0.3583910
1992	1.2946599	1.5457164	1.845457	0.13827481	0.2229134	0.3593597
1993	1.3335881	1.5738671	1.857438	0.10440769	0.1706709	0.2789886
1994	1.3723535	1.6023774	1.870956	0.20900523	0.3392580	0.5506848
1995	1.3445403	1.5489327	1.784396	0.80371537	1.2641344	1.9883105
1996	1.2804763	1.4606083	1.666081	0.73840871	1.1623650	1.8297351
1997	1.2314425	1.3974917	1.585931	0.70566739	1.1073506	1.7376819
1998	1.1880921	1.3450906	1.522836	0.69289780	1.0815537	1.6882121
1999	1.1556012	1.3070933	1.478445	0.61603864	0.9612894	1.5000314
2000	1.1372213	1.2853357	1.452741	0.56545917	0.8844332	1.3833397
2001	1.1228808	1.2684932	1.432988	0.57233195	0.8995770	1.4139325
2002	1.0970014	1.2401972	1.402085	0.84322883	1.3189863	2.0631705
2003	1.0213685	1.1634588	1.325316	1.04711171	1.6188056	2.5026284
2004	0.9702594	1.1141197	1.279310	0.75769237	1.1756846	1.8242684
2005	0.9613566	1.1063385	1.273185	0.48531969	0.7570106	1.1807991
2006	0.9826385	1.1288902	1.296909	0.34287458	0.5393740	0.8484862
2007	1.0121831	1.1617710	1.333466	0.28672340	0.4542778	0.7197470
2008	1.0415584	1.1964639	1.374408	0.30527424	0.4872798	0.7777978
2009	1.0586704	1.2184246	1.402286	0.41913347	0.6683182	1.0656492
2010	1.0582984	1.2201126	1.406668	0.52557325	0.8393415	1.3404299
2011	1.0462516	1.2080843	1.394949	0.63512025	1.0196750	1.6370713
2012	1.0109033	1.1690852	1.352019	0.95798866	1.5298069	2.4429404
2013	0.9362038	1.0880624	1.264553	1.13904162	1.8100480	2.8763423
2014	0.8688689	1.0203768	1.198304	1.10505214	1.7650365	2.8191917
2015	0.8059995	0.9609492	1.145687	1.02225498	1.6383613	2.6257909
2016	0.7611837	0.9215315	1.115657	1.02561420	1.6480288	2.6481682
2017	0.7263920	0.8935707	1.099225	0.63476685	1.0251678	1.6556773
2018	0.7432339	0.9178954	1.133603	0.37623750	0.6252425	1.0390464
2019	0.7623767	0.9457935	1.173338	0.55071823	0.9130023	1.5136110
2020	0.7525135	0.9434154	1.182746	0.60493763	1.0036128	1.6650290
2021	0.7546751	0.9541911	1.206454	0.59762272	0.9992437	1.6707664
2022	0.7600286	0.9694572	1.236594	0.25366391	0.4290707	0.7257699
2023	0.8032479	1.0283199	1.316458	0.09976555	0.2032305	0.4139969
2024	0.8488978	1.0911617	1.402565	0.05939150	0.2032325	0.6954438

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