Exploration of length-based data-limited assessments for pollack in Bay of Biscay and Atlantic Iberian Waters

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Abstract

Pollack in ICES subarea 8 and division 9a is considered a Data-Limited Stock and classified by ICES in category 5.2. The insufficient data for this stock prevented to perform an analytical assessment with a traditional model. Three length-based approaches were tested for assessing the status of pollack stock: *Length-Based Indicators*, *Length Based Spawning Potential Ratio*, and *Length-based Integrated Mixed Effects*. The three model results indicated that pollack stock was slightly overexploited in 2019 (F > Ftarget) and the SPR is below the SPR target. There is a high uncertainty in the estimation of stock status using these models and, due to their sensitive to input parameters, more sensitivity analysis should be conducted.

1 Introduction

The pollack, *Pollachius pollachius* Linneo, 1758 is a gadid species, that is restricted to the Northeast Atlantic with a main distribution from the Portuguese continental coast northwards around the British Isles, into the Skagerrak and along the Norwegian coast where it is fairly common up to the Lofoten Islands. Juvenile of pollack inhabits in shallow waters and adults migrate to deeper areas 40-100 meters). During the spawning season, adults create groups of high density. The pollack in ICES subarea 8 and division 9a, pol.27.8.9a, is mainly exploited by France, responsible for more than 70% of commercial landings, following by Spain and Portugal. The management advice for this stock is provided on a precautionary approach basis, and considering the trend on commercial landings. Latest ICES advice for pol.27.8.9a recommended that commercial catches in each of the years 2020 and 2021 should be no more than 1131 tones.

In data-limited stocks, length-frequency data from commercial catches are often the primary data type that are collected because to its ease and low cost of being collected. As a result, numerous length-based methods have been recently developed. The overall objective of this study is to analyse the suitability of length-based methods to assess the stock status of pol.27.8.9a.

2. Material and Methods

A set of length compositions of commercial landings, annual and gear-combined, for the period 2010-2019 was considered for three length based approaches (Figure 1). The life history parameters used as input data in the models and their source are presented in Table 1.

The length-based approaches used for this analysis are described below:

Length Based Indicators (LBI)

A set of length-based indicators representing the conservation of large and immature individuals, optimal yield and maximum sustainable yield were defined at WKLIFE2015 (ICES, 2015), and are presented in Table 2. Length-frequency data are often available for exploited stocks, and it was proposed to use them for estimating indicators that reflect size-selective fishing pressure. Indicators of status are compared to reference points that are derived from life-history parameters and ecological theory. The suite of indicators with corresponding reference points, indicator ratio and expected value are shown in Table 2.

The data requirements to estimate LBI are indicated in Table 1. The main assumptions of the LBI theory are that the fishing gear selectivity is asymptotic and the population is in equilibrium: constant selection, fishing mortality and recruitment over time. Analyses were conducted using the R script *utilities.R* available at ICES github repository: https://github.com/ices-tools-dev/LBIndicator_shiny.

Length based spawning potential ratio (LB-SPR)

LB-SPR model uses the characteristics of two life history ratios: M/K and $L50/L_{\infty}$, to analyse the shape of adult length-frequency distributions and to estimate the selectivity ogive, relative fishing pressure (F/M) applied to stocks, and the resulting spawning potential ratio (SPR). SPR is defined as the proportion of the unfished reproductive potential left at any given level of fishing pressure (Hordyk et al., 2015). SPR is 100% in an unexploited stock, and 0% in a stock with no spawning. LB-SPR model relies on many assumptions listed in the referenced papers, being some of them: the assumption of equilibrium conditions, that the length composition data is representative of the exploited population, and a logistic-type selectivity. The input data to LB-SPR are indicated in Table 1. The length-structured version of the LB-SPR model, using growth-type-groups (GTG) to account for size-based selectivity, was applied for pollack stock. The analyses were conducted using the R package LBSPR *v*0.1.5 (Hordyk, 2019).

Length-based integrated mixed effects (LIME)

LIME model relaxes the equilibrium assumptions of LBSPR method, accounting for time-varying recruitment and fishing mortality while assuming constant selectivity for the whole time series (Rudd and Thorson, 2018). Length data and biological information are used to estimate *F* and SPR. LIME uses automatic differentiation and Laplace approximations to calculate the marginal likelihood for the mixed-effects. LIME has the same data-requirements as LB-SPR plus assumed uncertainty for recruitment and fishing mortality (Table 1). The LIME analysis was performed using the R package LIME *v*2.1.3. (Rudd and Thorson, 2018).

3. Results

The results presented here are not the final versions and they are showed with the purpose of serving as initial point to consider new assessment methods for pol.27.8.9a.

The LBI results are compared to suggested reference points in the traffic light table (Table 3). The conservation parameters for immature were only green ($L_{25\%}/L_{mat}$, Lc/L_{mat}) during 2011-2013. Large fish constitute a small part of landings (Pmega < 0.13). The optimizing yield indicator (Lmean/Lopt) has been below the desirable values of 0.9, showing that the fish caught may be too small. The MSY indicator ($Lc/L_{(F=M)}$) was > 1 in 2017 and 2018, but in 2019 it decreased to 0.97. There is not strong evidence of important overexploitation. The time-series of indicators and indicators ratios (Figure 2) show that the levels of conservation and maximum sustainable yield indicators have been relatively stable throughout the last ten years.

Figure 3 shows annual selectivity curves fitted by the LB-SPR model and the maturity ogive, no particular trend of length in the catch has been detected in recent years. The LB-SPRT smooth results indicated that SPR values were below the SPR 30-40% range in all years (Figure 4) and therefore can be considered to be below proxies that would be consistent with high long-term yields. Except in 2015 and 2017, the F/M ratios were above F/M = 1, what implies an exploitation above F_{MSY} (Table 4). In 2019 the raw F/M was 1.03, slightly above the proxy for F_{MSY}.

LIME model fits an unique selectivity ogive for the whole time series, and for pollack L50 and L95 were estimated at 39 and 50 cm, respectively (Table 5). LIME estimated SPR in 2019 to have been 0.32, but with high uncertainty (95% CI: 0.03-0.61). Fishing mortality estimates were above $F_{40\%}$ reference point (0.25) for the whole time series, indicating that the pollack stock has been overfished (Figure 5).

Figure 6 compares the SPR estimates obtained from LIME and LB-SPR methods for 2019. Both estimates were below the SPR target 0.4, although the LIME SPR_{2019} estimate is more optimistic than the LB-SPR 0.24 (95% CI: 0.21-0.27).

4. Conclusions

The performance of the length-based models indicates that these methods may be a good approach to assess the stock status of pollack. Sensitivity analysis should be conducted to evaluate the impact of input parameter in the results.

5. References

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Table 1. Input data for pollack in 8 and 9a (pol.27.89a) for the three length-based models tested.

Parameter	symbol	value	source	LBI	LBSPR	LIME
Length-frequency data	LD		Annual, gear-combined			
Length were 50% of the fish are mature	L_{50} (cm)	42.3	Alonso *et al*., 2013			
Length were 95% of the fish are mature	L_{95} (cm)	58	Alonso *et al*., 2013			
von Bertalanffy growth parameter	K	0.182	Alemany, 2017			
Von Bertalanffy asymptotic Length	L_{∞}	92.8	Alemany, 2017			
Theoretical age at length=0	t_0 (years)	-0.935	Alemany, 2017			
Length-weight relationship parameter a	a	$1.09e^{-5}$	Leauté *et al*., 2018			
Length-weight relationship parameter b	b	3.0044	Leauté *et al*., 2018			
Natural Mortality (fixed)	M ($year^{-1}$)	0.32	M-metanalysis			
M/K invariant	M/K	1.8	M/K			
Coefficient of variation of von Bertalanffy asymptotic le	CV L_{inf}	0.1	Assumed			
Steepness	h	0.7	Assumed			
Recruitment deviation	σ_R	0.4	Assumed			
Fishing mortality deviation	σ_F	0.1	Assumed			

Table 2. Length-based indicators to assess the stock status. Reference, IndicatorRatio and expected values are indicated.

Property	Indicator	Calculation	Reference	IndicatorRatio	ExpectedValue
Conservation Large individuals	Lmax5%	Mean length of largest 5%	Linf	Lmax5% / Linf	> 0.8
	L95%	95th percentile	Linf	L95% / Linf	> 0.8
	Pmega	Proportion of individuals above Lopt + 10%	0.3-0.4	Pmega	> 0.3
Conservation Immatures	L25%	25th percentile of length distribution	Lmat	L25% / Lmat	> 1
	Lc	Length at first catch (length at 50% of mode)	Lmat	Lc / Lmat	> 1
Optimal yield	Lmean	Mean length of individuals > Lc	Lopt = 2/3 Linf	Lmean/Lopt	-1
	Lmaxy	Length class with maximum biomass in catch	Lopt = 2/3 Linf *	Lmaxy / Lopt	-1
MSY	Lmean	Mean length of individuals > Lc	LF=M = (0.75Lc+0.25Linf)*	Lmean / LF=M	>=1

* If M/K != 1.5: Lopt=3?Linf/(3+(M/k)) ; L(F=M) = (1 ? a) *Lc + a *Linf; a=1/2*(M/k)+1

Table 3. LBI results. Output table with indications of status compared to reference points for pol.27.8.9a. Green cell: indicator suggests that the stock is in a desirable state relative to the reference; red cell: negative state.

	Conservation				Optimizing yield	MSY
Year	Lc/Lmat	L25/Lmat	Lmax5/Linf	Pmega	Lmean/Lopt	Lmean/LFeM
2010	0.80	0.80	0.72	0.03	0.69	0.89
2011	1.18	1.18	0.80	0.07	0.94	0.95
2012	1.18	1.18	0.80	0.11	0.98	0.99
2013	1.09	1.09	0.79	0.12	0.92	0.98
2014	0.80	0.99	0.77	0.10	0.86	1.10
2015	0.71	0.80	0.74	0.04	0.72	0.99
2016	0.80	0.90	0.71	0.03	0.74	0.94
2017	0.80	0.90	0.80	0.09	0.82	1.04
2018	0.80	0.99	0.82	0.11	0.89	1.14
2019	0.80	0.80	0.76	0.04	0.76	0.97

Table 4. LBSPR annual raw estimates of selectivity (SL50, SL95), fishing pressure (F/M) and spawning potential ratio (SPR).

Year	SL50	SL95	FM	SPR
2010	31.5	33.4	2.00	0.12
2011	50.3	61.7	2.42	0.26
2012	52.0	64.9	1.87	0.32
2013	44.6	52.9	1.34	0.31
2014	62.7	88.9	4.25	0.27
2015	26.9	31.9	0.96	0.24
2016	35.0	40.1	1.93	0.14
2017	34.9	49.8	0.90	0.31
2018	54.5	78.9	1.93	0.32
2019	30.5	35.3	1.03	0.24

Table 5. LIME estimates of selectivity (SL50, SL95), fishing pressure (F/F40%) and spawning potential ratio (SPR).

Year	SL50 (cm)	SL95 (cm)	F/F40%	SPR
2010	39.1	49.9	1.24	0.34
2011	39.1	49.9	1.33	0.32
2012	39.1	49.9	1.55	0.29
2013	39.1	49.9	1.70	0.27
2014	39.1	49.9	1.71	0.26
2015	39.1	49.9	1.46	0.30
2016	39.1	49.9	1.34	0.32
2017	39.1	49.9	1.29	0.33
2018	39.1	49.9	1.35	0.32
2019	39.1	49.9	1.35	0.32

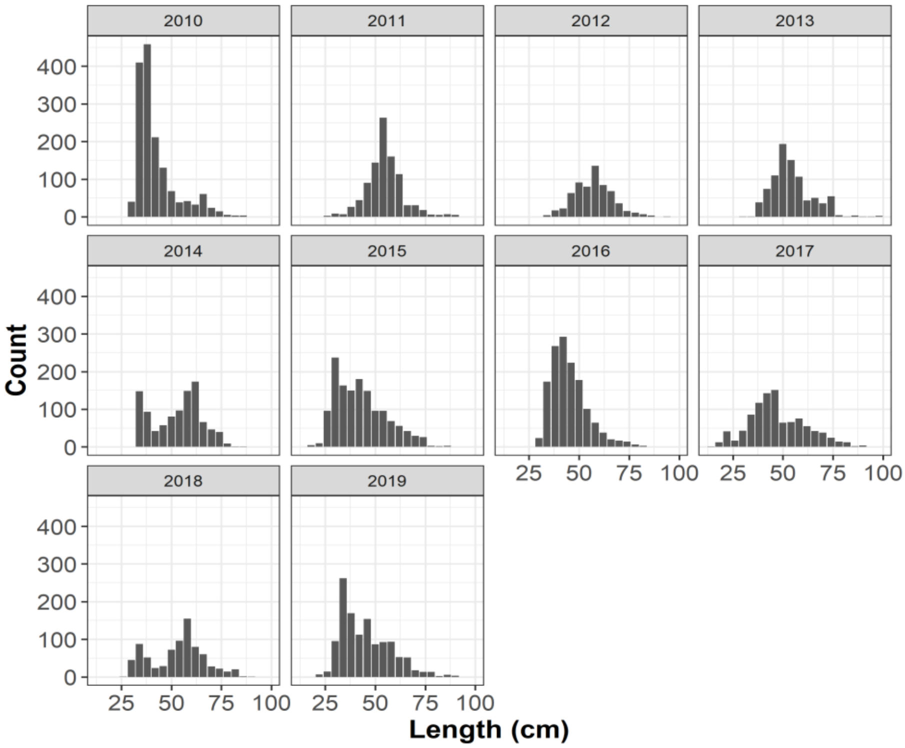

Figure 1. Length frequency distribution of Pollack landings from 2010 to 2019.

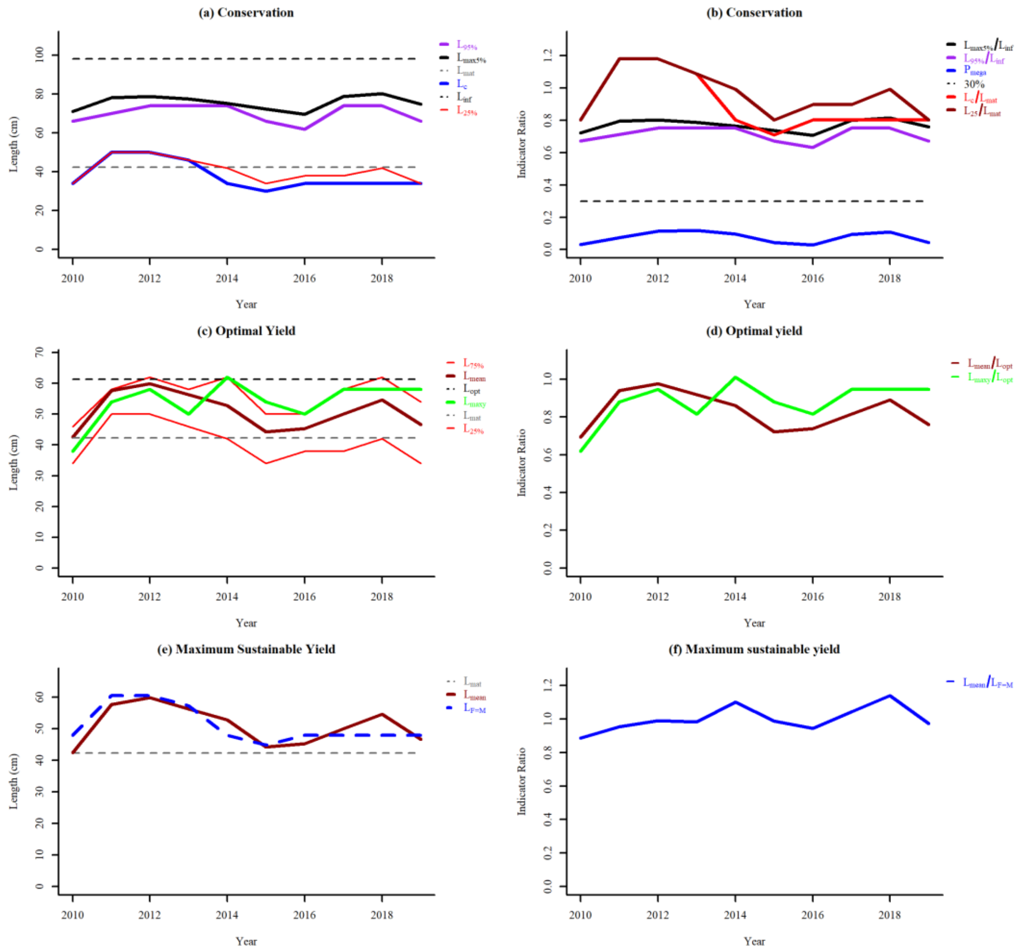

Figure 2. LBI results. Time-series indicators (left side) and indicators ratios (right side).

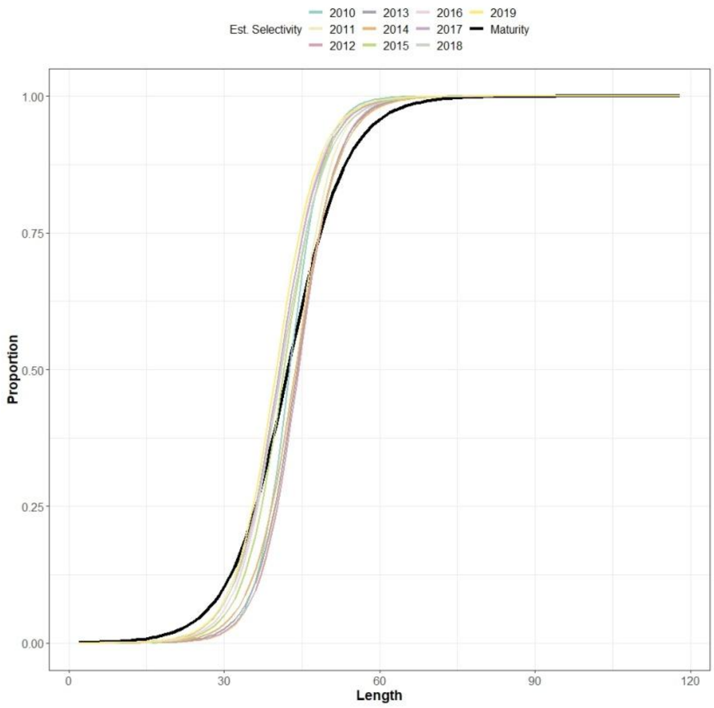

Figure 3. LBSPR results. Maturity at length and selectivity curves for pol.27.8.9a.

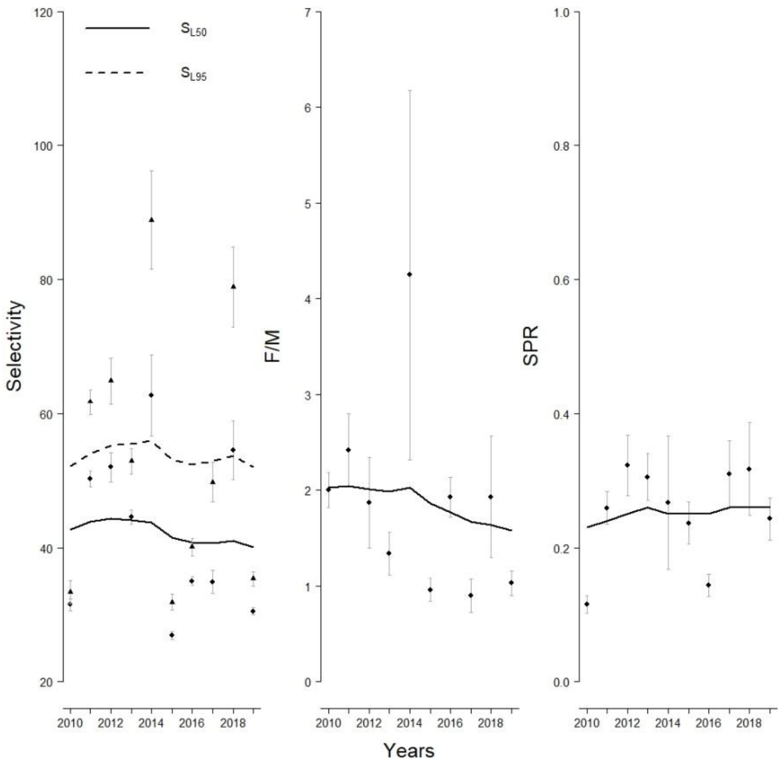

Figure 4 LBSPR results. Proxy of stock status for pol.27.89a stock.

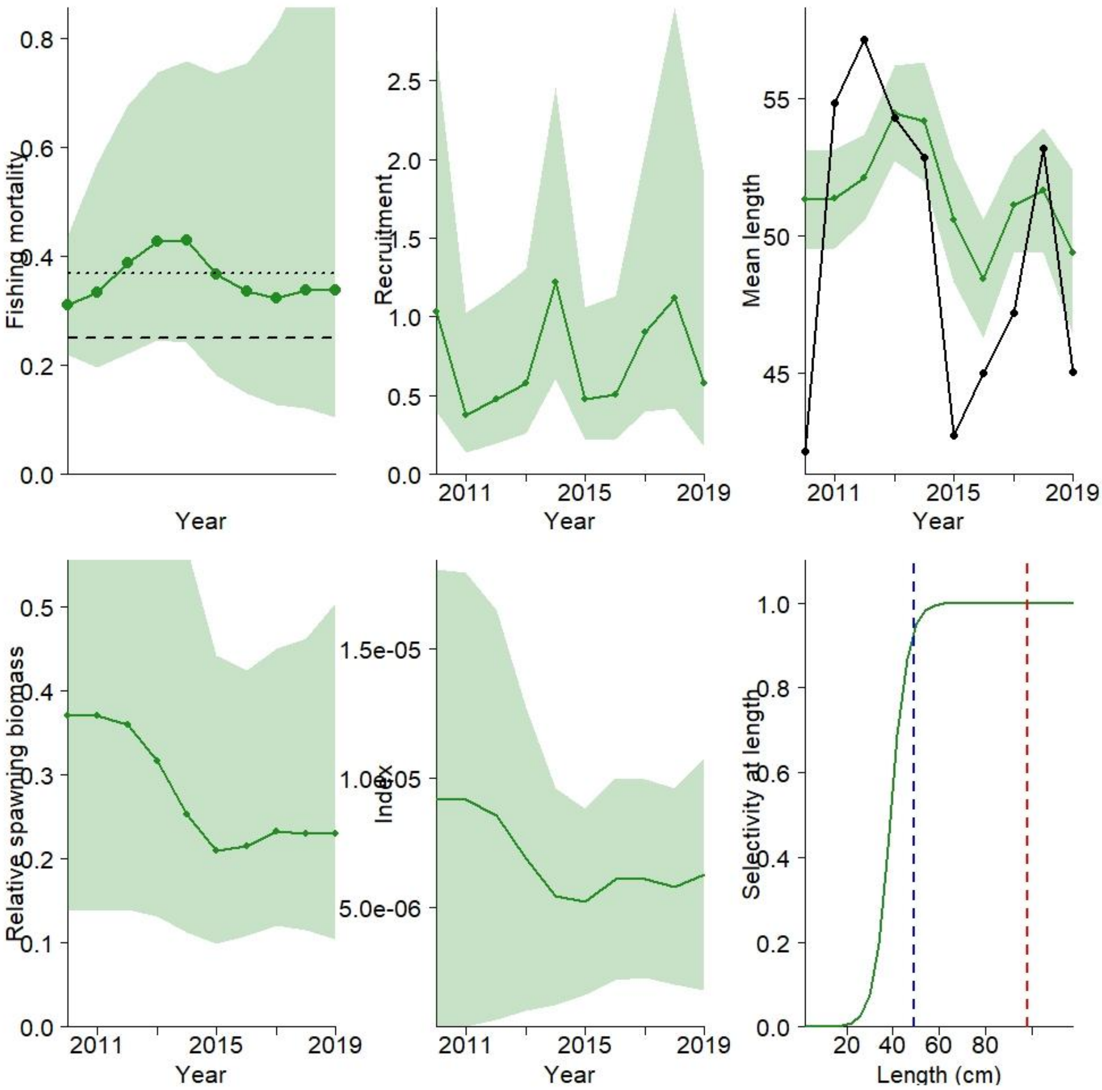

Figure 5. LIME estimates for pollack fishing mortality, recruitment, mean length, relative spawning biomass, and selectivity (blue line: mean-length of catches, red line=Linf) using the annual length composition data.

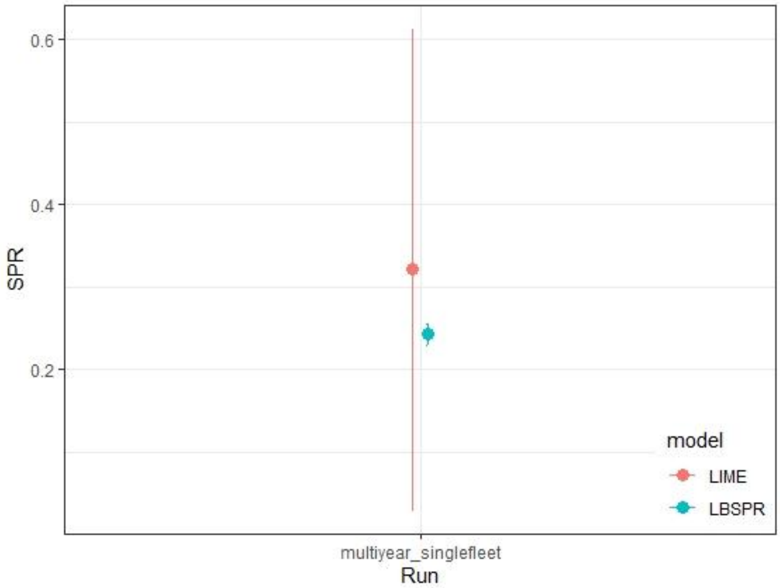

Figure 6. Comparison of SPR estimates obtained by LIME and LB-SPR.