Length-Based Assessment Approaches

LBB and LB-SPR

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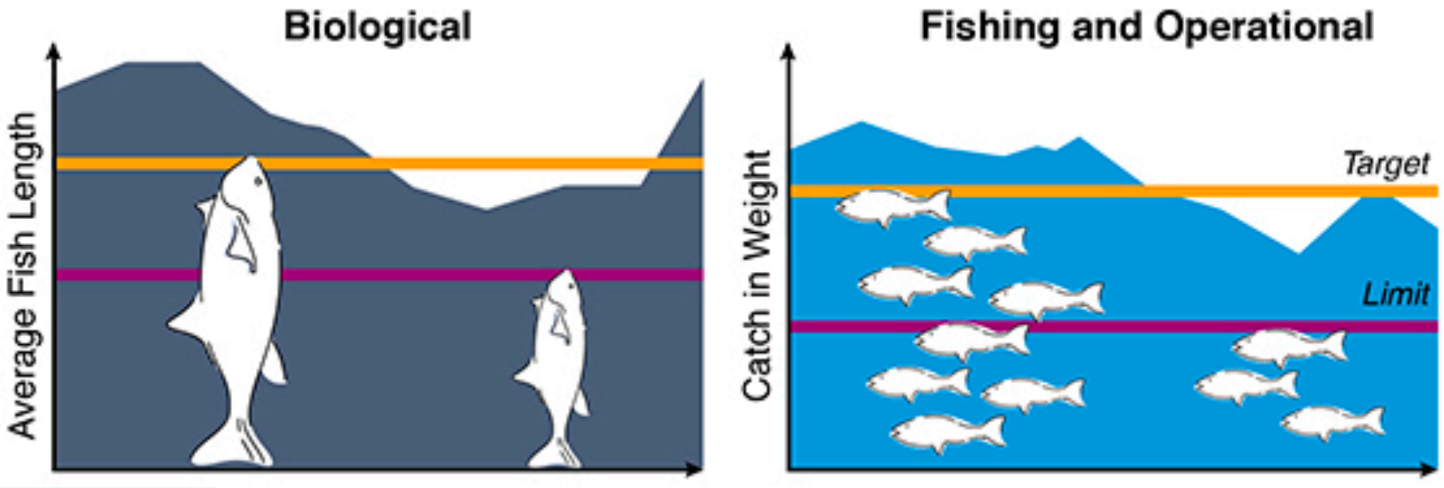
Why Do Data-Limited Assessments Matter?

Traditional stock assessments (such as age-structure population models) require large quantities of data, funding, and capacity to be carried out with research vessels and staff dedicated solely to these assessments. They cannot be applied in many cases, particularly in small-scale fisheries and fisheries in developing countries. However, fishery managers should use indicators and thresholds (reference points) to assess the status of a fishery in terms of its current biomass, reproductive capacity, and sustainability.

Therefore, we need approaches that require a little amount of easily attainable data and provide scientific advice for fish stocks.



Length-Based Approaches

Data-Limited assessments generally use time series of catch, catch per unit effort, and length distributions. Both production and length-based models rely heavily on assumptions. Consequently, results from these indicators are only included when there is sufficient confidence in them. Both methods are used with expert judgment to provide advice on the precautionary management of stocks. Length-based indicators are based on the size distributions (numbers of fish in each length class) of samples taken from catches, which are combined with information on life-history characteristics such as growth rates, maximum size and length at maturity, and length at first capture by the gear. There are quite a lot of length-based methods. Nowadays they are actively developed by many researchers. Two of them are considered in this report:

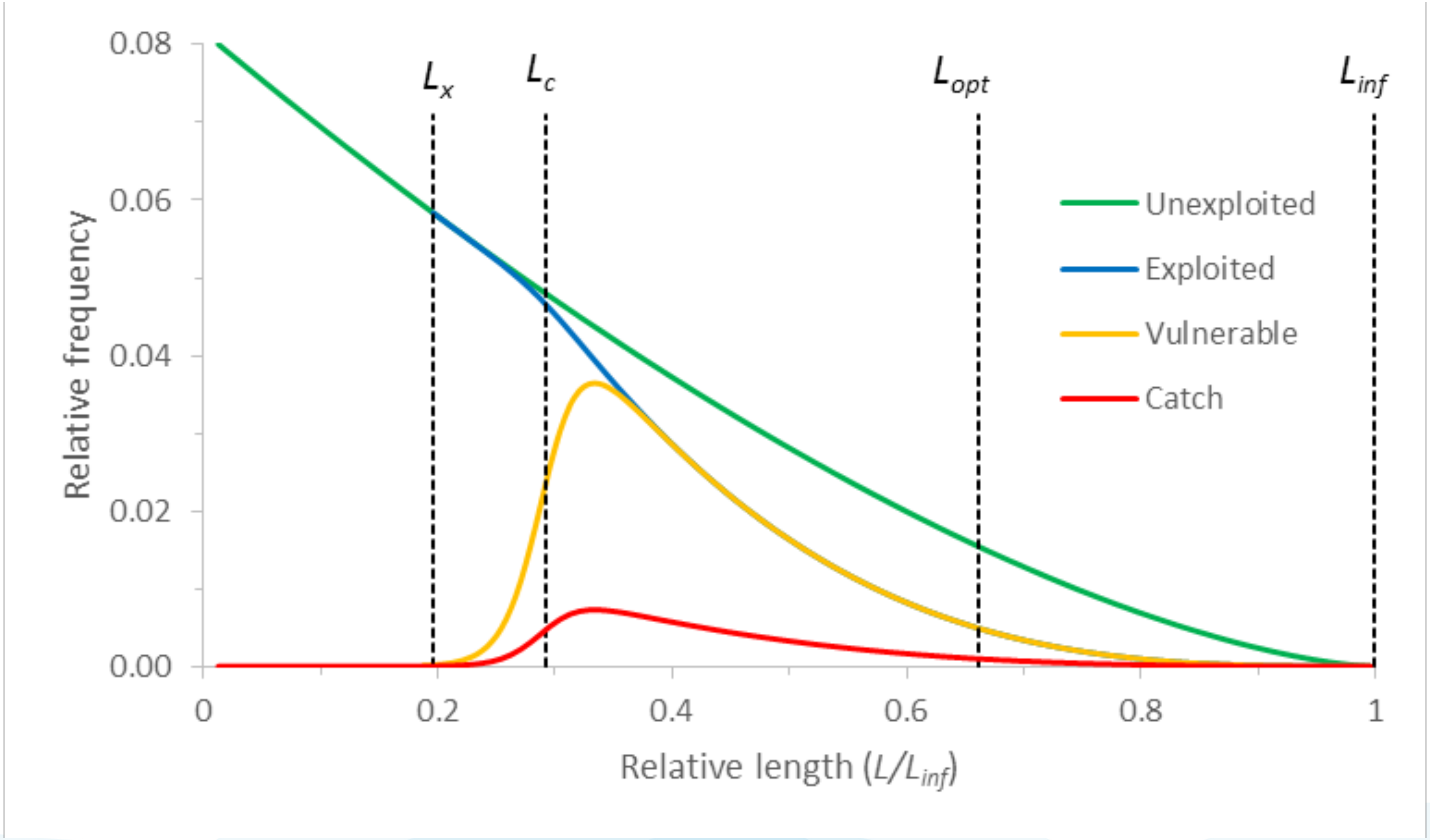
- LBB – Length-based Bayesian Biomass [Froese et al., 2018]
- LB-SPR – Length-Based Spawning Potential Ratio [Hordyk et al., 2015]

LBB – Length-based Bayesian Biomass

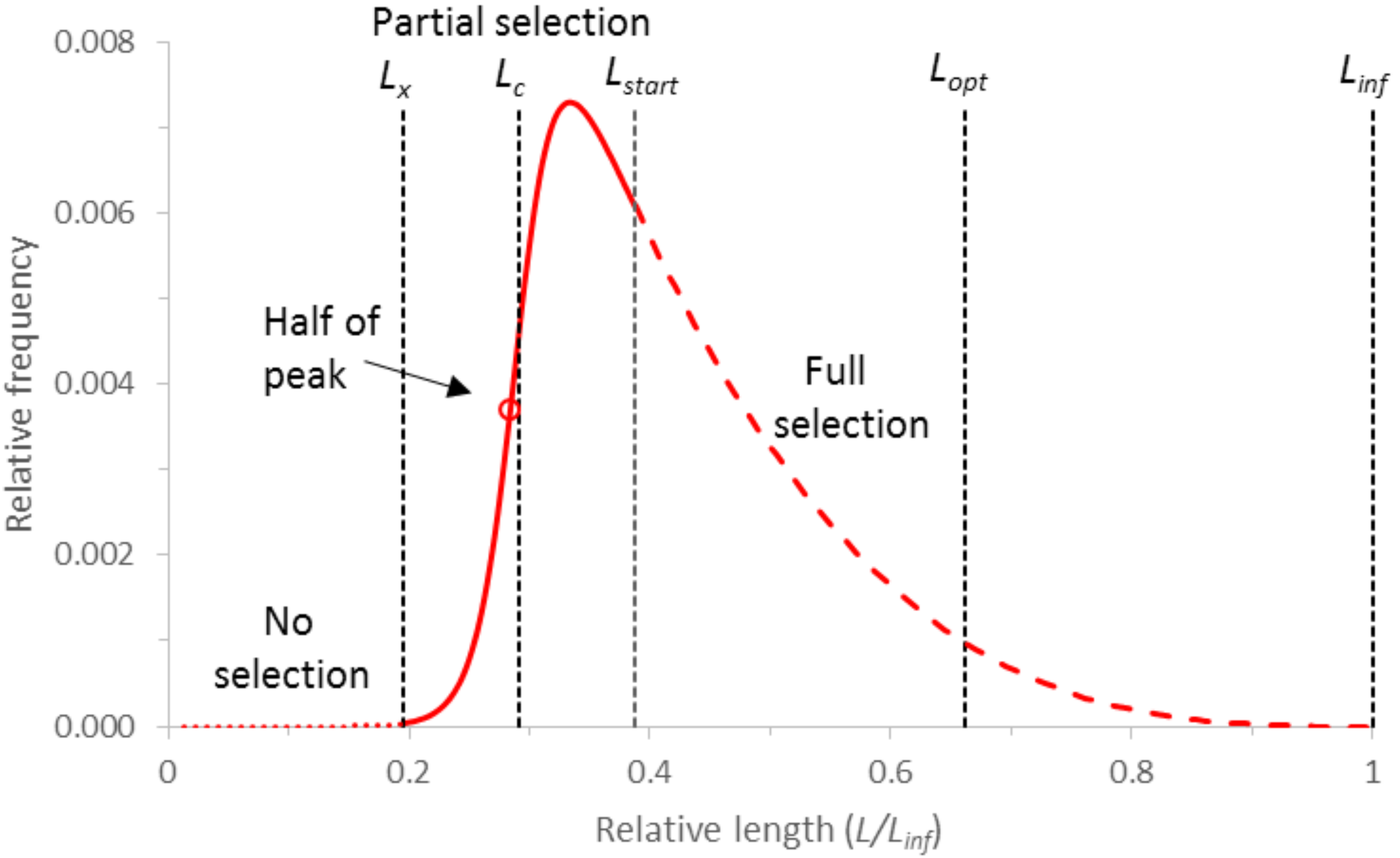
LBB is a newly developed estimation method requiring length frequency distributions that are representative of the fishery. The core of LBB is the vBGF connecting fish age and body length. It uses the Bayesian approach to estimate growth and mortality parameters, relative exploitation level and stock size. In addition, LBB allows to obtain important parameters for fishery management such as the optimal length for the first capture L_{c_opt} and the length at maximum possible yield per recruit L_{opt}. Moreover, LBB results (relative biomass B/B_0) could be used as priors for AMSY and CMSY methods requiring independent estimates as inputs.

Main assumptions: species grows throughout its life.
Required input data: length frequency data distributions.
Additional critical issues: expert knowledge in setting M/K, L_{inf} and L_c priors is important.

Conceptual Framework



Visible Length Frequencies



LBB Equations

Gear-selectivity: $S_{L_i} = \dfrac{1}{1 + e^{-\alpha(L_i - L_c)}}$

Survivors to L_i: $N_{L_i} = N_{L_{i-1}} \left(\dfrac{L_{inf} - L_i}{L_{inf} - L_{i-1}}\right)^{\frac{M}{K}+\frac{F}{K}S_{L_i}}$

Vulnerable/relative catch at L_i :

$$C_{L_i} = N_{L_i}\, S_{L_i}$$

The optimal lengths where where cohort biomass is maximum and at first capture:

$$L_{opt} = L_{inf}\left(\frac{3}{3 + \frac{M}{K}}\right) \qquad L_{c\_opt} = \frac{L_{inf}\,(2 + 3\,\frac{F}{M})}{(1 + \frac{F}{M})(3 + \frac{M}{K})}$$

Froese R., Winker H., Coro G., Demirel N., Tsikliras A., Dimarchopoulou D., Scarcella G., Probst W.N., Dureuil M., Pauly D. 2018. A new approach for estimating stock status from length frequency data. I*CES Journal of Marine Science*, vol. 75 (6). pp. 2004-2015.

LBB Files

Length: lower border of length class (mm) to which CatchNo refers;
CatchNo: number of individuals;
Years.user: a string of years to be analyzed (you may exclude ‘bad’ years).

Detailed information is in "*A Simple User Guide for LBB*“.

Structure of the ID file (.csv)

	A	B	C	D	E	F	G	H	I	J	K	L
1	File	Species	Stock	StartYear	EndYear	Years.user	Year.select	Gears.user	Lcut.user	Lc.user	Lstart.user	Linf.user
2	LBB_Length.csv	Rapana	RPW	2017	2019	2017,2018,2019	2017	NA	NA	NA	NA	NA

Structure of the input file (.csv)

	A	B	C	D
1	Stock	Year	Length	CatchNo
2	RPW	2017	35	0
3	RPW	2017	40	0
4	RPW	2017	45	1
5	RPW	2017	50	4
6	RPW	2017	55	9
7	RPW	2017	60	29
8	RPW	2017	65	33
9	RPW	2017	70	70
10	RPW	2017	75	87
11	RPW	2017	80	83
12	RPW	2017	85	44
13	RPW	2017	90	16

LBB Results

stock RPW
2017-2019
default settings

Files:
LBB_ID.csv
LBB_Length.csv

```
General reference points (median across years):
Linf       = 9.98 (9.9-10.1) cm
Lopt       = 7.2 cm, Lopt/Linf=0.72
Lc_opt     = 5.9 cm, Lc_opt/Linf=0.59, Lmean if F=M 7.67 cm
M/K        = 1.15 (0.879-1.35)
F/M        = 0.833 (0.557-1.35), F/K=0.926 (0.704-1.33), Z/K=2.07 (1.9-2.31
)
B/B0       = 0.45 (0.2-0.77), B/B0 F=M Lc=Lc_opt 0.38
Y/R'       = 0.061 (0.031-0.11), Y/R' F=M Lc=Lc_opt 0.067

Estimates for 2019 (mean of last 3 years with data):
Lc50        = 6.73 (6.64-6.83) cm, Lc/Linf=0.67 (0.66-0.68)
Lc95        = 8.36, alpha=1.81 (1.75-1.86)
Lmean/Lopt= 1.1, Lc/Lc_opt=1.1, L95th=9.5 cm, L95th/Linf=0.95, Mature=100
%
F/M         = 0.97 (0.53-1.8), F/K=1 (0.66-1.4), Z/K=2.3 (2-2.5)
Y/R'        = 0.067 (0.023-0.14)
B/B0        = 0.46 (0.17-0.83), best LF fit year 2017=0.63 (0.2-1.1)
B/Bmsy      = 1.2 (0.45-2.2), selected B/B0 2017 = 0.63 (0.2-1.1)
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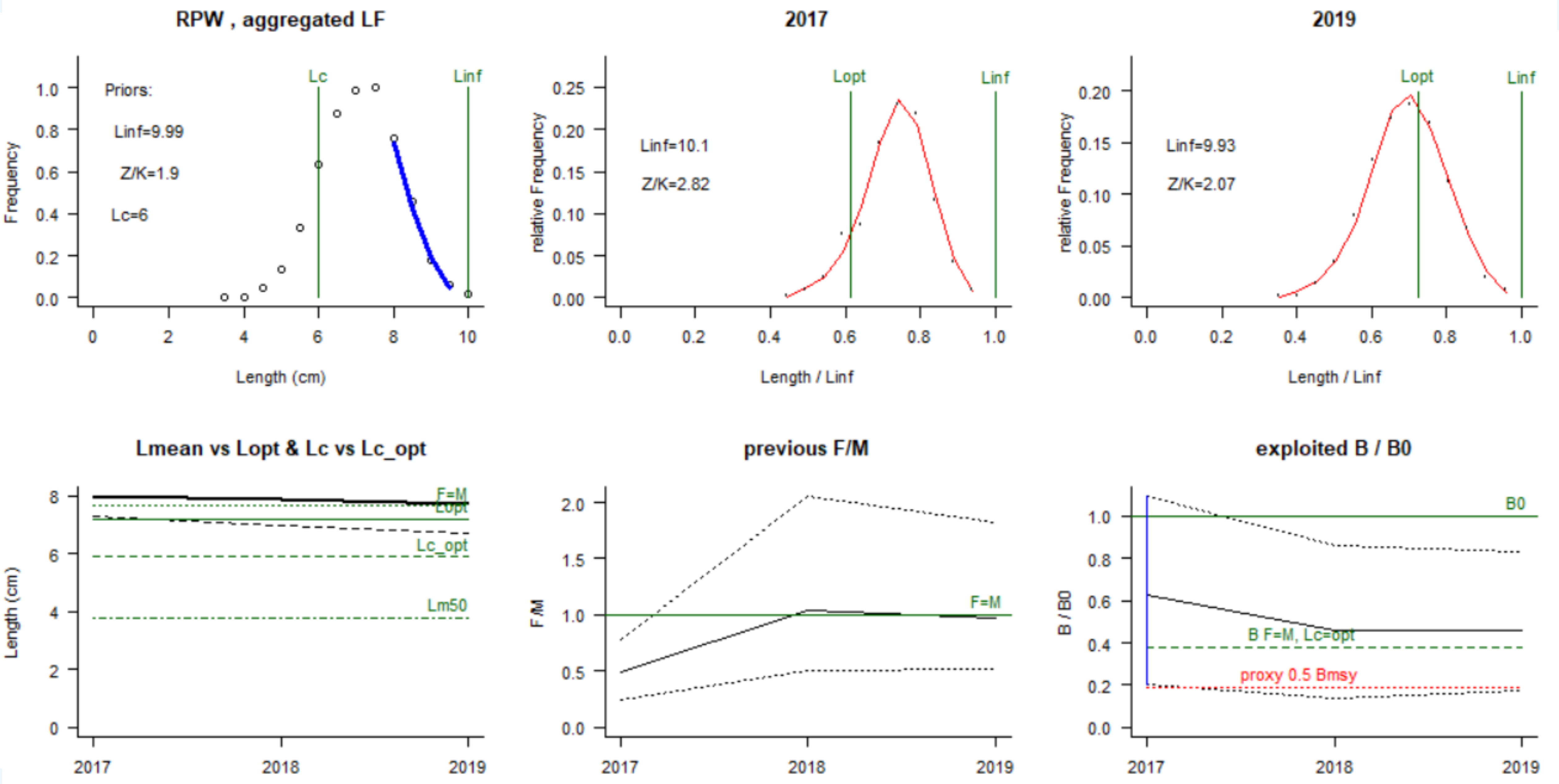


RPW , aggregated LF
Priors:
Linf=9.99
Z/K=1.9
Lc=6
Lc
Linf
Frequency
Length (cm)
2017
Linf=10.1
Z/K=2.82
Lopt
Linf
relative Frequency
Length / Linf
2019
Linf=9.93
Z/K=2.07
Lopt
Linf
relative Frequency
Length / Linf
Lmean vs Lopt & Lc vs Lc_opt
F=M
Lopt
Lc_opt
Lm50
Length (cm)
previous F/M
F=M
F/M
exploited B / B0
B0
B F=M, Lc=opt
proxy 0.5 Bmsy
B / B0

LB-SPR – Length-Based Spawning Potential Ratio

The LBSPR method does not require knowledge of the natural mortality rate *M*, but instead uses the ratio (*M*/*K*) of natural mortality to the vBG coefficient *K*, which is believed to vary less across stocks and species than *M* and *K* themselves.
Like any assessment method, the LB-SPR approach relies on a number of simplifying assumptions. In particular, the models are equilibrium based, and assume that the length composition data is representative of the exploited population at steady state.

Hordyk A., Ono K., Sainsbury K., Loneragan N., and Prince J. 2015. Some explorations of the life history ratios to describe length composition, spawning-per-recruit, and the spawning potential ratio // ICES Journal of Marine Science, vol. 72 (1). – pp. 204-216.

The SPR index

This approach focuses on the effect of fishing on the spawning potential of the stock. The SPR index is defined as the proportion of the unfished reproductive potential left in the population at any given level of fishing pressure. It is based on the concept that without fishing a fish population can complete 100% of its natural potential for spawning, but that fishing reduces the population's SPR.

This index can be calculated as the ratio of the equilibrium reproductive output per recruit that would occur with the current year's fishing intensity and biological parameters of fish, to the equilibrium reproductive output per recruit that would occur with the same biological parameters without fishing activity.

$$SPR = \frac{\text{Total Egg Production}_{\text{Fished}}}{\text{Total Egg Production}_{\text{Unfished}}}$$

It can be estimated in terms of M/K, F/M and L_{m50}/L_{inf} using a length distribution.

The SPR index ranges between 0 and 1, with a value of 1 representing an unexploited stock. Therefore, the status of stock can be classified into three different groups, which are:

- Underexploited ($SPR > 0.4$)
- Moderate exploited ($0.2 < SPR < 0.4$)
- Overexploited ($SPR < 0.2$)

Unlike fishing mortality-based approaches, which directly relate to some part of the population removed each year by fishing, SPR method reflects the cumulative effect of fishing and ecological impacts on the spawning potential of exploited stocks for a few previous years (a life span period approximately). SPR can be used to set targets and limit reference points for monitoring of population statuses. Moreover, SPR_{MSY} can be considered as the main reference point instead of F_{MSY} for fisheries.

Data File

The data file must be in CSV format.
Multiple years of data should be placed in separate columns.
Length frequency data must have the midpoints of the length classes (the length bins) in the first column.

http://barefootecologist.com.au/lbspr.html

Download the files: Shiny app LBSPR R Package

LBSPR R Shiny App

LBSPR Application | Instructions | Upload Data | Plot Data and Fit Model

	A	B	C	D
1	Length	2017	2018	2019
2	37.5	0	0	5
3	42.5	0	0	7
4	47.5	1	4	42
5	52.5	4	23	107
6	57.5	9	71	246
7	62.5	29	146	410
8	67.5	33	240	534
9	72.5	70	223	575
10	77.5	87	235	524
11	82.5	83	176	349
12	87.5	44	119	208
13	92.5	16	61	60
14	97.5	4	20	25
15	102.5	1	5	7
16	107.5	0	0	0
17	112.5	0	0	0

Histogram of Length Data

Asymptotic Length

◉ Absolute ○ Relative

Species

RPW

Life history ratios

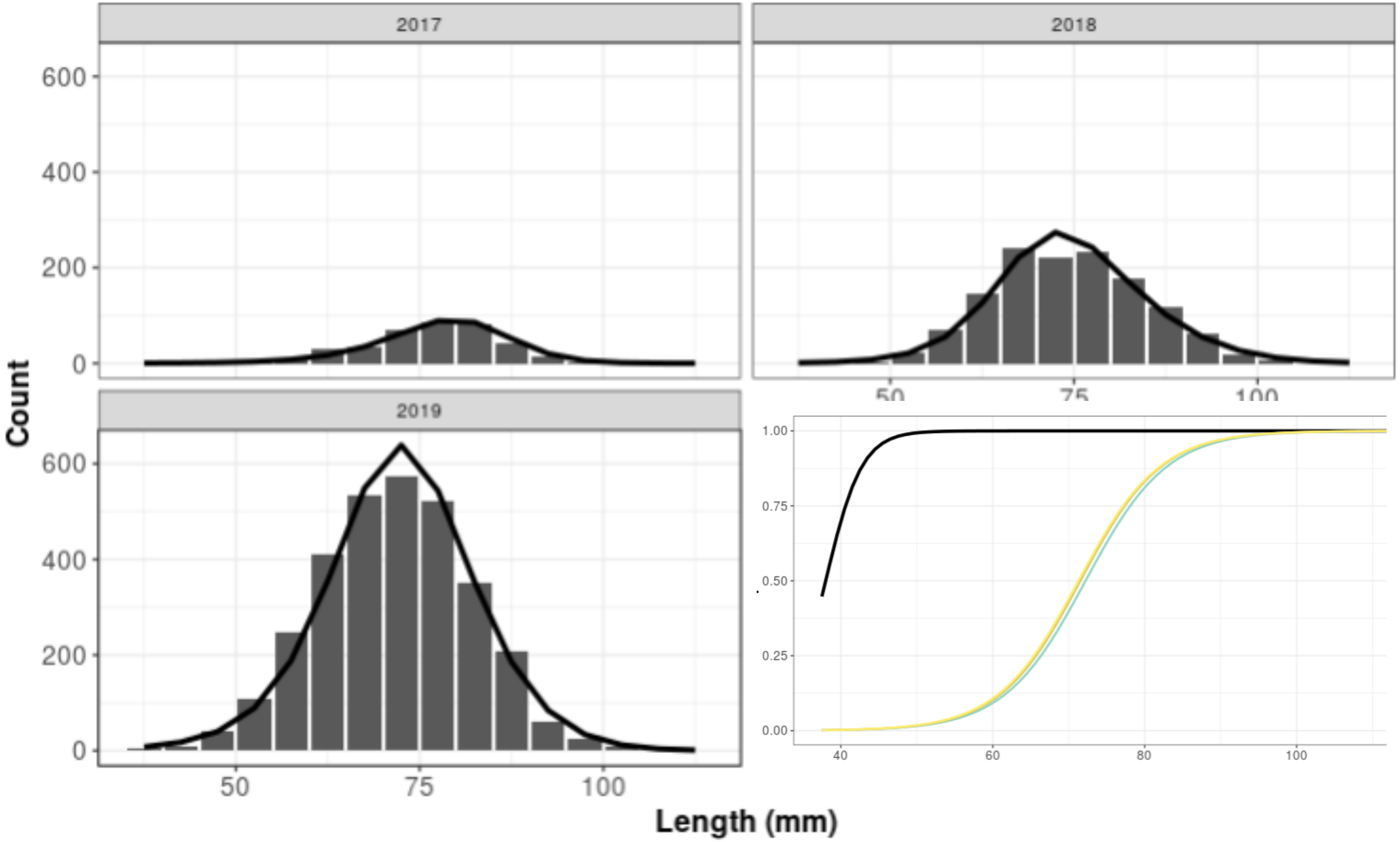
M/K ratio	L_∞
1.5	110

Length-at-Maturity

L_{50}	L_{95}
38	45

Length units

◉ mm ○ cm ○ inch

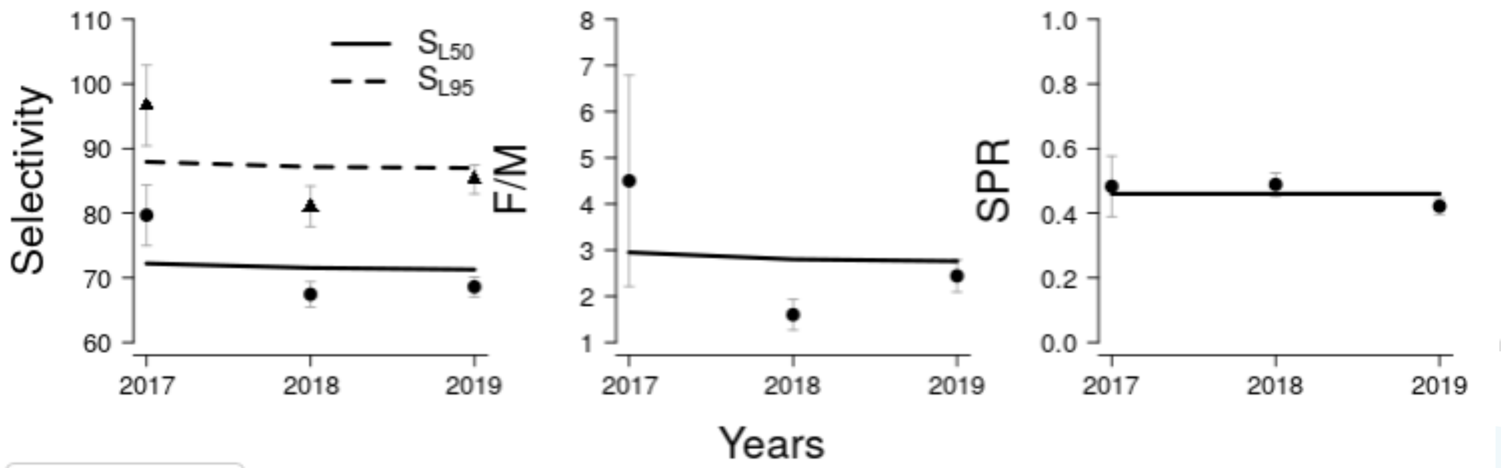


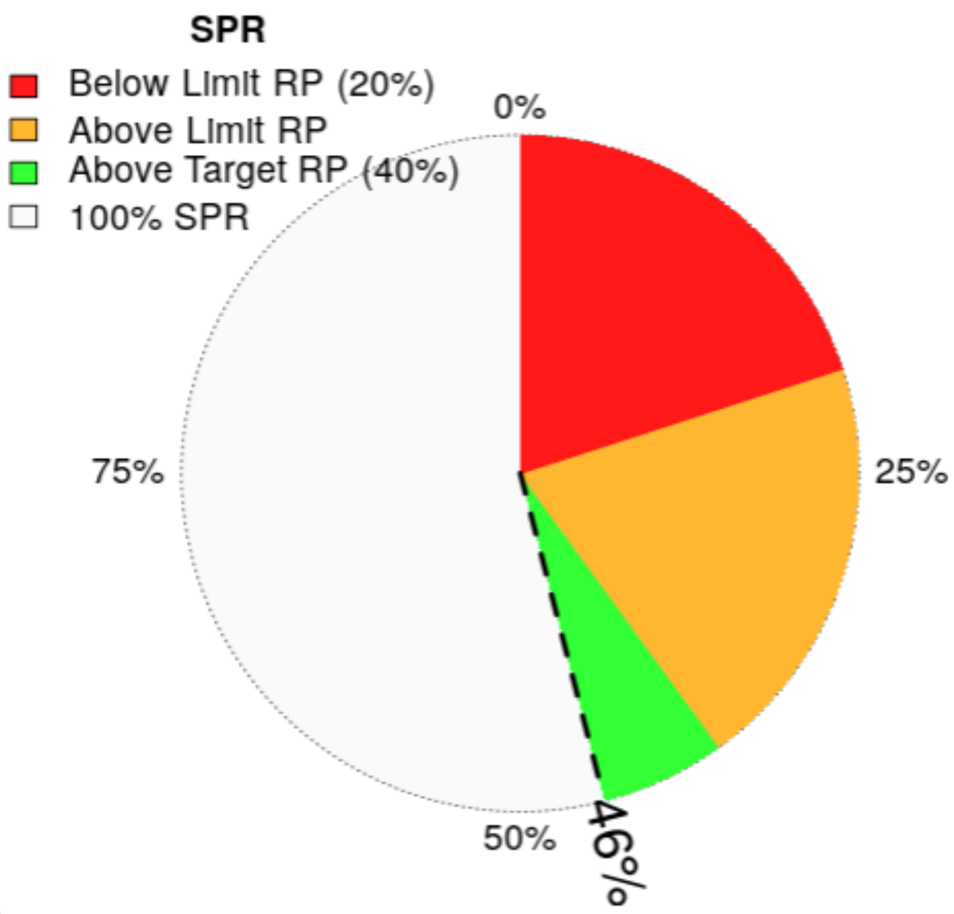
LB-SPR Results

Model Estimates (95% confidence intervals)

	Years	SPR	SL50	SL95	F/M
1	2017	0.48 (0.39 - 0.58)	79.69 (74.98 - 84.4)	96.66 (90.42 - 102.9)	4.5 (2.21 - 6.79)
2	2018	0.49 (0.45 - 0.52)	67.44 (65.49 - 69.39)	81.06 (77.92 - 84.2)	1.6 (1.27 - 1.93)
3	2019	0.42 (0.4 - 0.45)	68.6 (67.07 - 70.13)	85.24 (82.98 - 87.5)	2.44 (2.09 - 2.79)

Estimates by Year (with 95% confidence intervals)





Conclusion

The relative biomass and the length at first capture estimated by LBB as well as the SPR index estimated by LB-SPR can then be used directly for precautionary management of data-poor stocks:

1) If relative stock size B/B_0 is smaller than B_{MSY}/B_0, reduce catches;
2) If length at first capture L_c is smaller than L_{c_opt}, start fishing at larger sizes;
3) If SPR is in the “red zone” or smaller than SPR_{MSY}, reduce catches.

Measure fish!

Thank you for your attention!