Proxy MSY Reference Points for data poor stocks

Power of length based indicators to detect overfishing.

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Introduction

To provide advice on the status of data poor stocks ICES uses MSY proxy reference points as part of a Precautionary Approach.

Data poor stocks include those for which only trends such as lpue, cpue, and mean length in the catch are available (**Category 3**), and stocks for which only reliable catch data are available (**Category 4**).

Methods currently approved by ICES for calculation of MSY reference points for these stocks are

- Length based indicators
- Z derived from mean length
- Length based spawner per recruit; and
- Surplus Production models

Many approaches have emerged over the last few decades, for example Where length data are available methods include Length Based Spawning Potential Ratio (LBSPR), Length-Based Integrated Mixed Effects (LIME), and Length-Based Bayesian (LBB). While where only catch data are available methods include Catch-Maximum Sustainable Yield (Catch-MSY), State-Space Catch-Only Model (SSCOM), Depletion Based Stock Reduhction Analysis (DBSRA), and Simple Stock Synthesis (SSS) an extension of Catch-MSY (CMSY).

Empirical indicators and reference points can also be used to monitor stocks and these include

- $L_{max5\%}$ mean length of largest 5%
- $L_{95\%}$ 95^{th} percentile
- P_{mega} Proportion of individuals above $L_{opt} + 10\%$
- $L_{25\%}$ 25^{th} percentile of length distribution
- L_c Length at 50% of modal abundance
- L_{mean} Mean length of individuals $> L_c$
- L_{max_y} Length class with maximum biomass in catch
- L_{mean} Meanlength of individuals $> L$

where potential **reference points** include

- $L_{opt} = L_\infty \frac{3}{3+\frac{M}{K}}$, assuming $M/K = 1.5$ gives $\frac{2}{3}L_\infty$
- $L_{F=M} = 0,75l_c + 0.25l_\infty$

Methods

Simulation

Run scenarios with an increasing trend in F that leads to overfishing, then implement a recovery plan that brings fishing to the F_{MSY} level then screen potential empirical MPs by

- Generating length, catch and CPUE indicators using an OEM
- Compare indicators to OM using Reciever Operating Characteristics (ROCs)

Receiver Operating Characteristics

Sort the observed outcomes by their predicted scores with the highest scores first, then calculate cumulative True Positive Rate (TPR) and True Negative Rate (TNR) for the ordered observed outcomes

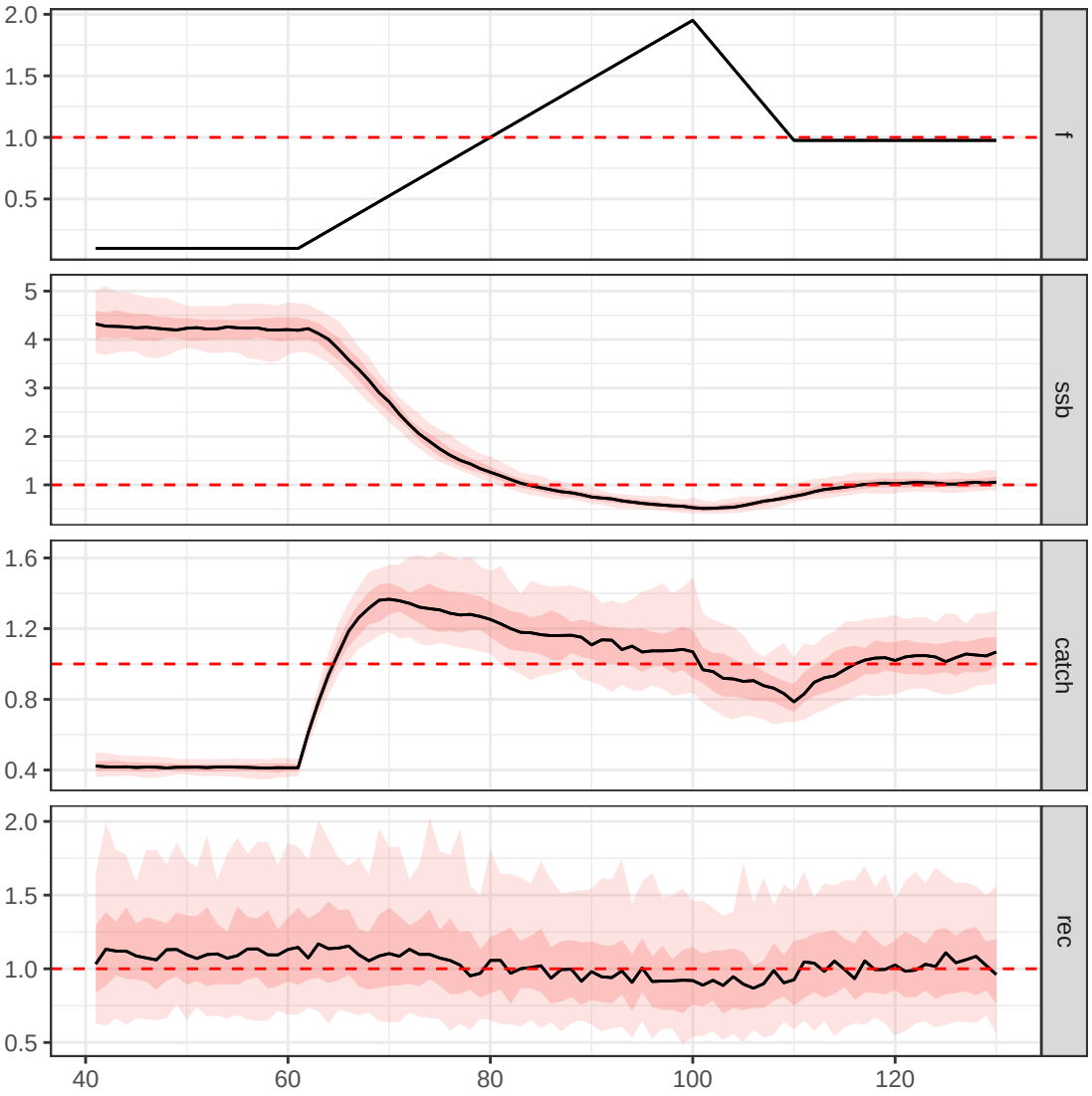

Figure 1 Time series relative to MSY benchmarks.

Mean length indicators

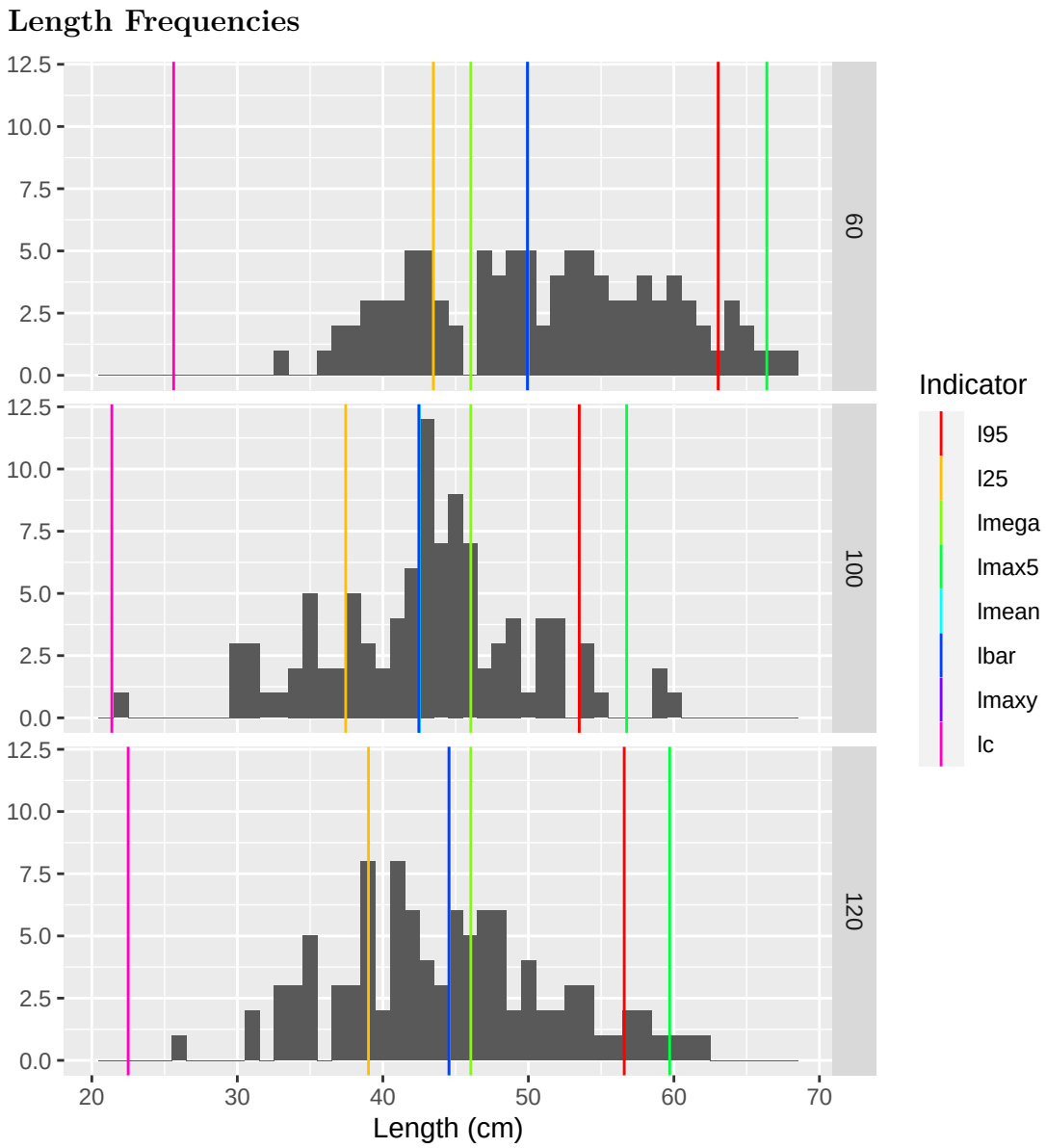

Figure 2. Simulated length frequencies distributions with indicators.

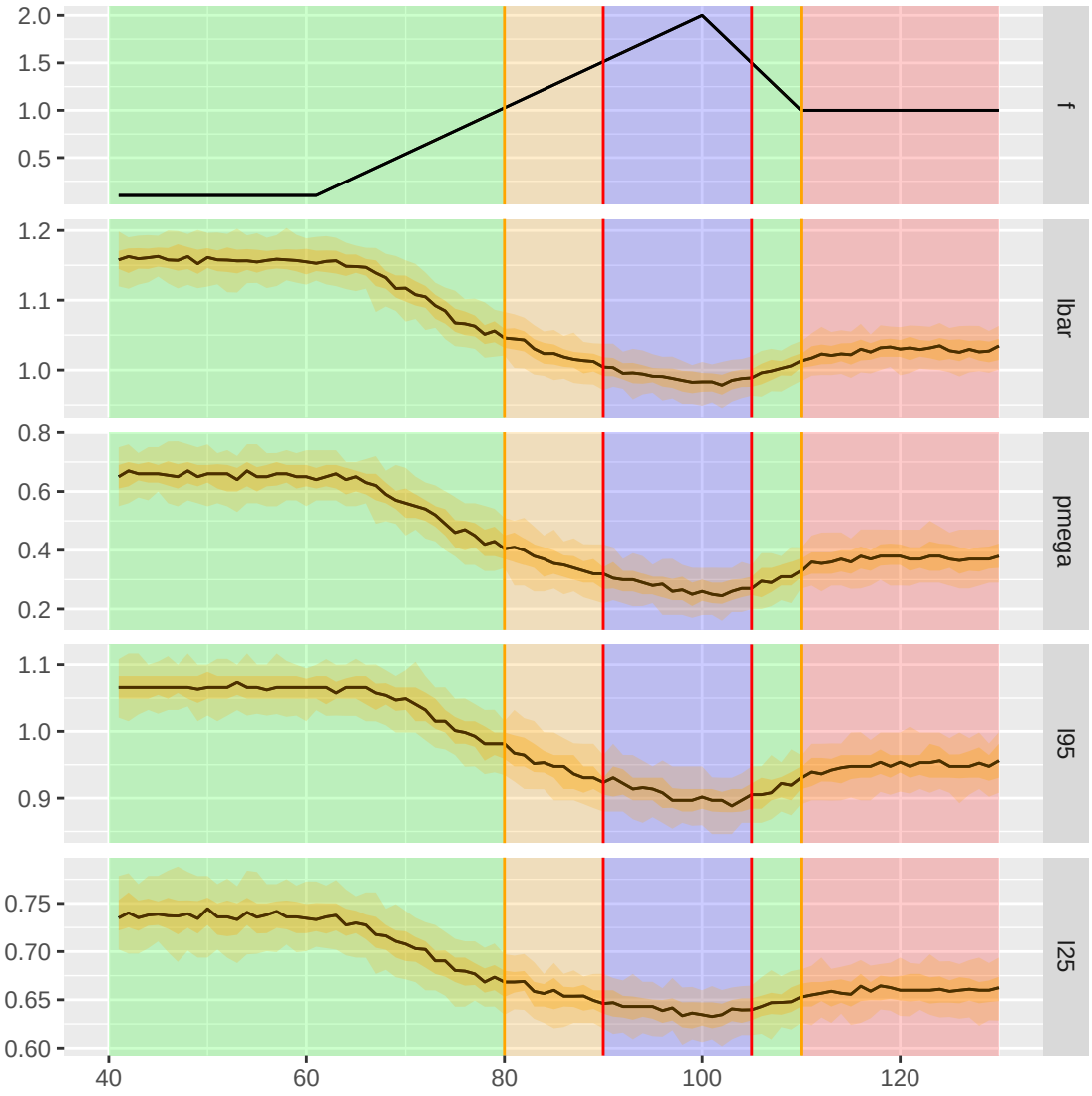

Figure 3. Time series of indicators compared to $F : F_{MSY}$, vertical lines indicate 1 (green), 1.5 (orange) and 2 (red) times F_{MSY}.

Receiver Operating Characteristics

Detection of overfishing

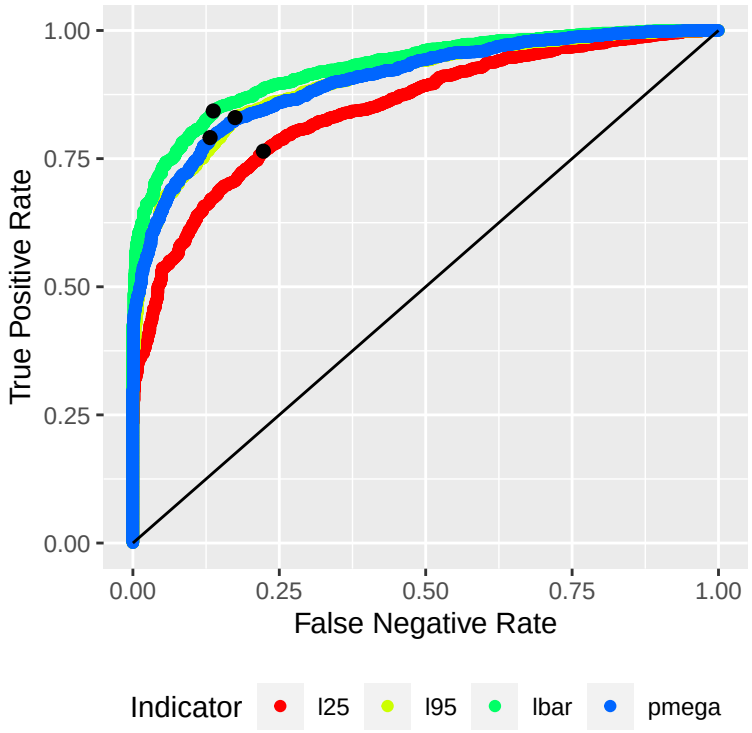

Figure 4. ROC curve of the three indicators of overfishing, points indicate the optimum value of the indicator.

```
    .id    TPR       FPR    scores
1   l25 0.7645 0.2227273 0.6636586
2   l95 0.8300 0.1745455 0.9644670
3  lbar 0.8430 0.1372727 1.0365318
4 pmega 0.7910 0.1318182 0.3800000
```

Detection of recovery

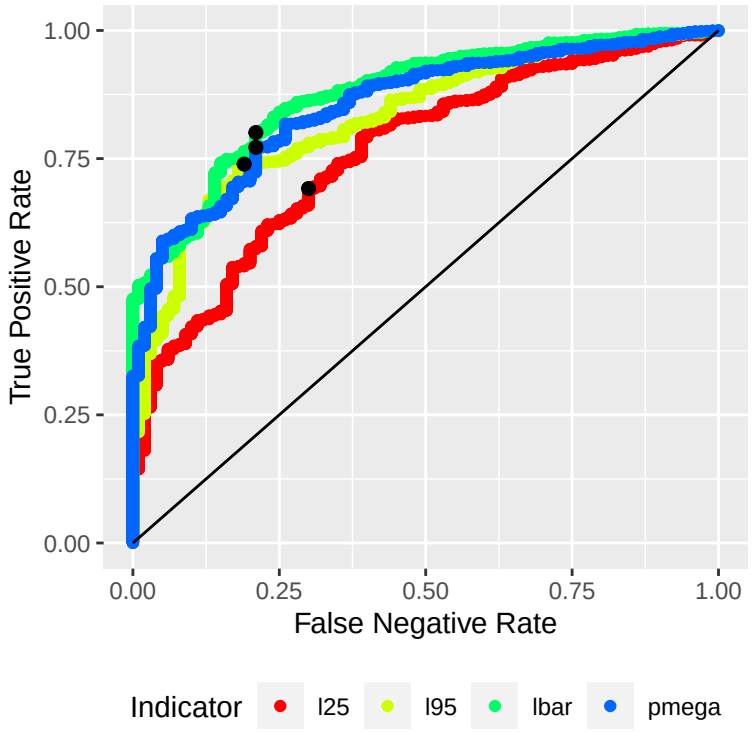

Figure 5. ROC curve of the three indicators of recovery, points indicate the optimum value of the indicator.

```
    .id    TPR  FPR    scores
1   l25 0.6916 0.30 0.6655386
2   l95 0.7392 0.19 0.9602369
3  lbar 0.8008 0.21 1.0395376
4 pmega 0.7720 0.21 0.4000000
```

References

Session Info

```
R version 4.0.3 (2020-10-10)
Platform: x86_64-pc-linux-gnu (64-bit)
Running under: Ubuntu 20.04.3 LTS

Matrix products: default
BLAS:   /usr/lib/x86_64-linux-gnu/blas/libblas.so.3.9.0
LAPACK: /usr/lib/x86_64-linux-gnu/lapack/liblapack.so.3.9.0

locale:
 [1] LC_CTYPE=en_GB.UTF-8       LC_NUMERIC=C
 [3] LC_TIME=en_GB.UTF-8        LC_COLLATE=en_GB.UTF-8
 [5] LC_MONETARY=en_GB.UTF-8    LC_MESSAGES=en_GB.UTF-8
 [7] LC_PAPER=en_GB.UTF-8       LC_NAME=C
 [9] LC_ADDRESS=C               LC_TELEPHONE=C
[11] LC_MEASUREMENT=en_GB.UTF-8 LC_IDENTIFICATION=C

attached base packages:
[1] stats     graphics  grDevices utils     datasets  methods   base

other attached packages:
 [1] spatstat_1.64-1      rpart_4.1-15         nlme_3.1-149
 [4] spatstat.data_1.4-3  popbio_2.7           reshape_0.8.8
 [7] dplyr_1.0.7          plyr_1.8.6           mydas_1.2.2
[10] FLife_3.4.0          FLasher_0.6.8        FLFishery_0.3.7.9003
[13] FLBRP_2.5.8          ggplotFL_2.6.10.9001 ggplot2_3.3.5
[16] FLCore_2.6.18.9002   iterators_1.0.13     lattice_0.20-41
[19] knitr_1.34

loaded via a namespace (and not attached):
 [1] Rcpp_1.0.7            deldir_0.1-28         assertthat_0.2.1
 [4] digest_0.6.28         utf8_1.2.2            R6_2.5.1
 [7] stats4_4.0.3          evaluate_0.14         tensor_1.5
[10] highr_0.9             pillar_1.6.4          rlang_0.4.12
[13] data.table_1.14.2     Matrix_1.2-18         goftest_1.2-2
[16] rmarkdown_2.11        labeling_0.4.2        splines_4.0.3
[19] stringr_1.4.0         polyclip_1.10-0       munsell_0.5.0
[22] compiler_4.0.3        xfun_0.26             pkgconfig_2.0.3
[25] mgcv_1.8-33           htmltools_0.5.2       tidyselect_1.1.1
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[31] fansi_0.5.0           crayon_1.4.2          withr_2.4.2
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