Developing and running data-limited MSEs using FLR

FAO/GFCM SRC-EM 10-13 May 2022

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FLR, Fisheries Library in R

A collection of packages in the R statistical language providing a domain-specific programming language for quantitative fisheries science.

Goals

1. Provide tools for effective and reliable implementation of simulation models of the fishery system.
2. Encourage the use of Management Strategy Evaluation for designing robust fisheries management plans.
3. Facilitate the exchange of ideas and algorithms through the establishment of a *lingua franca* for quantitative fisheries science.
4. To do so under the Free/Open Source ethos of transparency, reproducibility and free exchange of ideas and algorithms.

Computational platform

C++
using std::cpp;

CppAD

admb

HPC

- From CPU cores to HPC clusters

Design principles

- Object-oriented S4 classes for system elements
  - Same methods work on multiple classes, e.g. `plot` vs. plotObjectType
- Modularity
  - MP as a series of modules to be called sequentially
- Flexibility and extendability
  - Write your own MP modules (e.g. HCR, indicator)
- Limited use of default values
  - Choices to be explicit in code
- Adherence to R language conventions
  - e.g. formulas

MSE steps in FLR syntax

1. Identify objectives and performance statistics

```
stats <- list(FMSY=list(~yearMeans(F/FMSY), name="F/F[MSY]"
performance(run, statistics, years=2030:2039)
```

2. Specify uncertainties and operating models
   - Life history + priors
3. Identify and define management procedures

```
mpcontrol <- mpCtrl(list(
  est = mseCtrl(method=sam.sa),
  hcr = mseCtrl(method=hockeystick.hcr,
    args=list(lim=3e5, trigger=4e5, target=0.25))))
```

MSE steps in FLR syntax

4. Simulate application of management procedure

```
run <- mp(om, oem=oem, ctrl=control, args=list(iy=2017))
```

5. Tune management procedure to objective(s)

```
tuned <- tunebisect(om, oem=oem, control=control,
  args=mseargs,  statistic=statistics["green"],
  years=2030:2039, tune=list(target=c(0.1, 0.5)), prob=0.5)
```

6. Present results

```
plotBPs(tuned, statistics)
```

Running an MSE

```
# LOAD om, oem
data(ple4om)

# DEFINE MP
control <- mpCtrl(list(
  est = mseCtrl(method=perfect.sa),
  hcr = mseCtrl(method=hockeystick.hcr,
    args=list(lim=3e5, trigger=4e5, target=0.25))))

# RUN
run <- mp(om, oem=oem, ctrl=control, args=list(iy=2017))

run3 <- mp(om, oem=oem, ctrl=control, args=list(iy=2017, fr
```

Running an MSE

```
> data(ple4om)
>
> control <- mpCtrl(list(
+   est = mseCtrl(method=perfect.sa),
+   hcr = mseCtrl(method=hockeystick.hcr,
+     args=list(lim=3e5, trigger=4e5, target=0.25))))
>
> run <- mp(om, oem=oem, ctrl=control, args=list(iy=2017))
2017  > 2018  > 2019  > 2020  > 2021  > 2022  > 2023  > 2024  > 2025  > 2026  > 2027  > 2028  > 2029
>
> run3 <- mp(om, oem=oem, ctrl=control, args=list(iy=2017, frq=3))
2017  > 2020  > 2023  > 2026  >
```

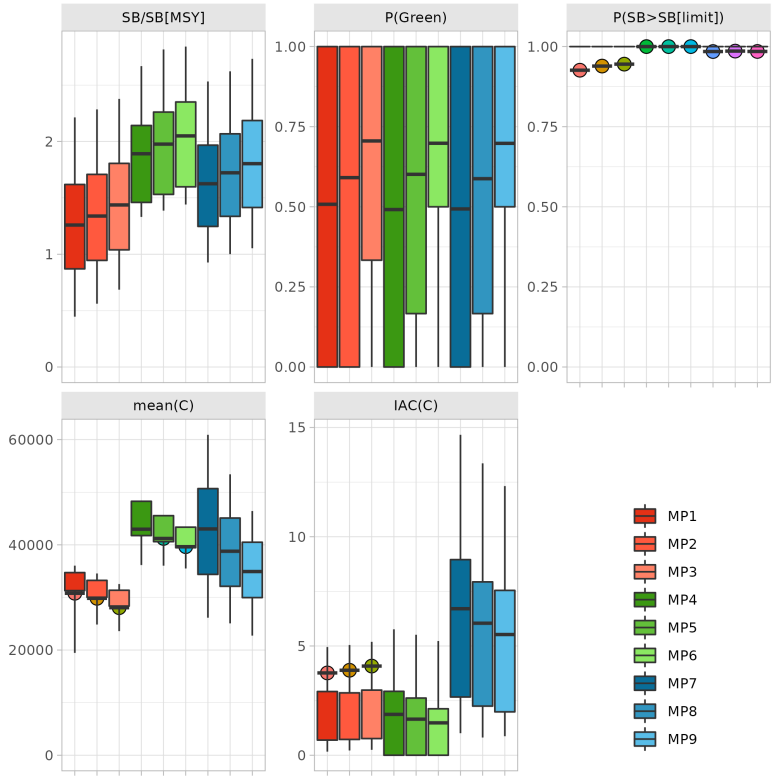
Presenting results

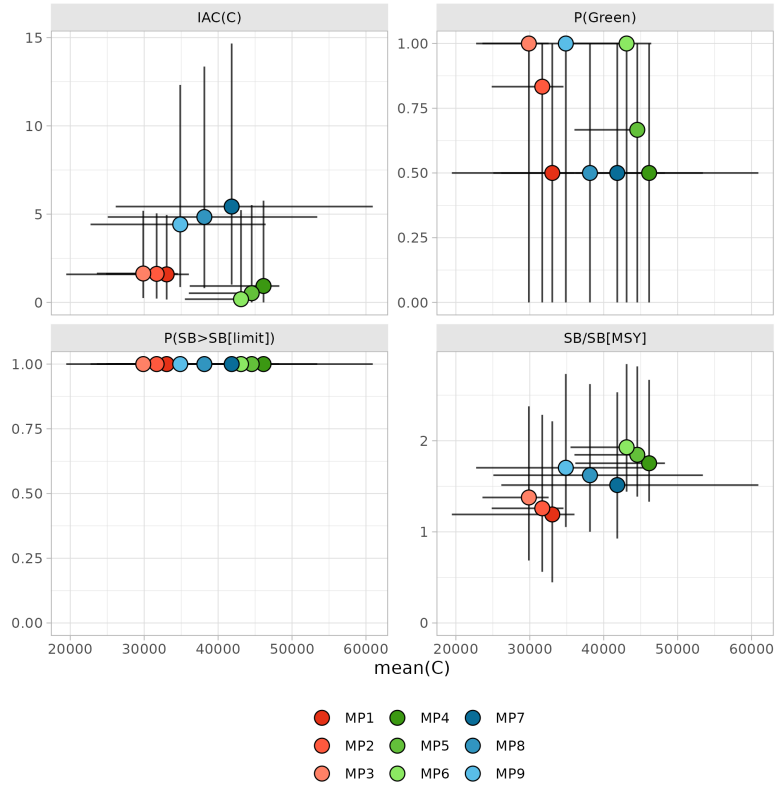
```
# COMPUTE performance statistics
perf <- performance(run3,
  statistics=statistics[c('FMSY', 'BMSY')])

# PLOT performance
plotBPs(perf)

# PLOT trade-offs
plotTOs(perf)
```

Presenting results





Operating Model

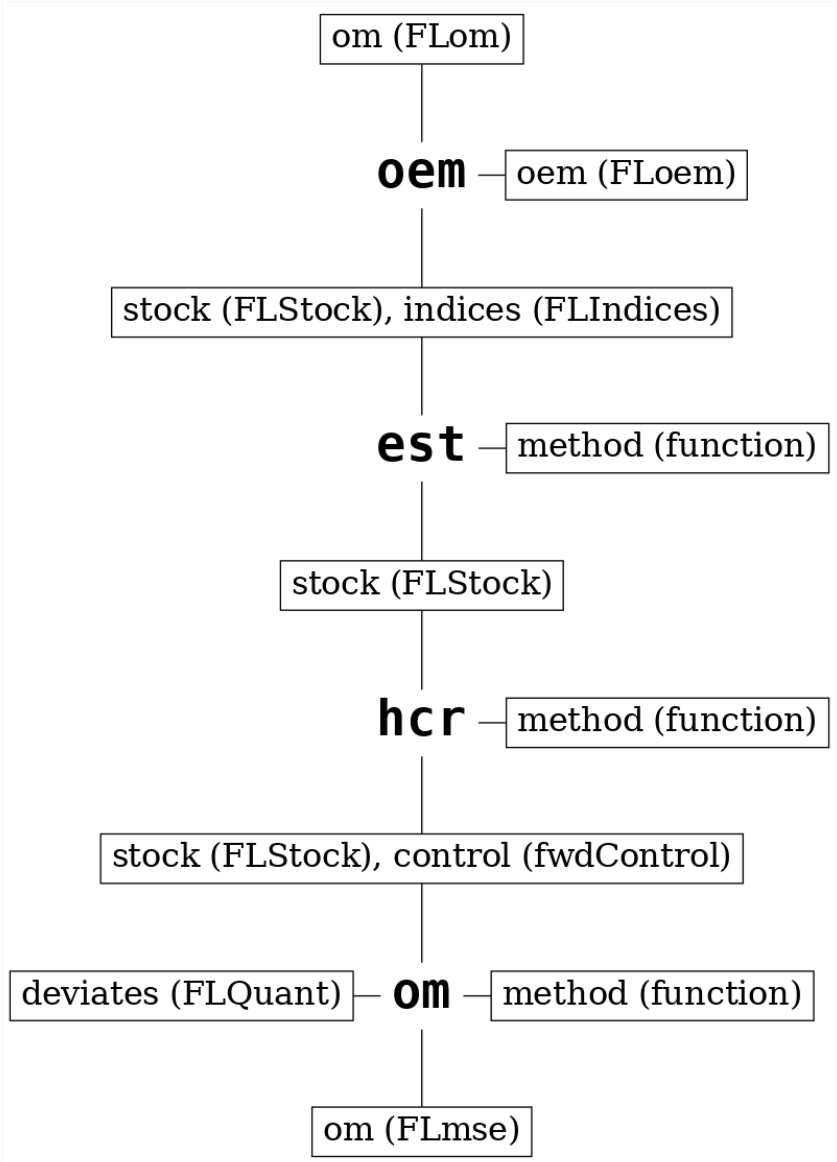
FLom class

- Stock
  - N-at-age, weight-at-age, maturity, fecundity, SRR
- Fishery or fisheries
  - Landings and discards, selectivities, prices
- Reference points

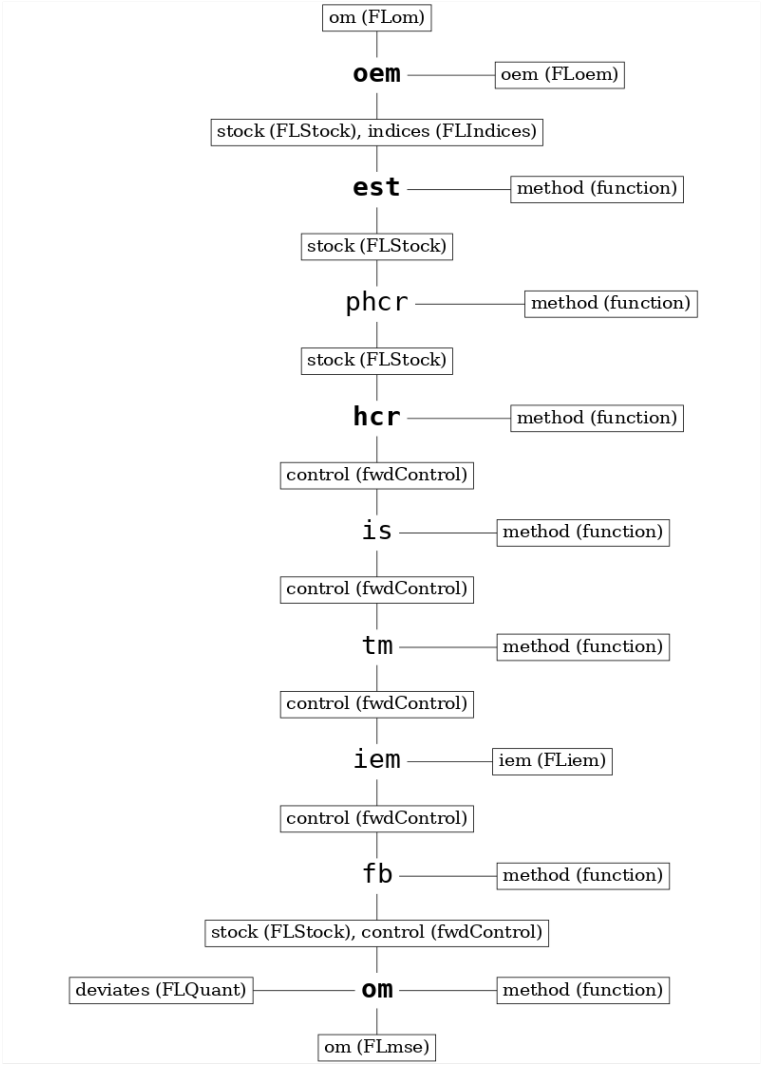
FLoem class

- Observations: stock, indices.
- Deviances: catch,

MSE basic modules



MSE modules


om (FLom)
oem
oem (FLoem)
stock (FLStock), indices (FLIndices)
est
method (function)
stock (FLStock)
phcr
method (function)
stock (FLStock)
hcr
method (function)
control (fwdControl)
is
method (function)
control (fwdControl)
tm
method (function)
control (fwdControl)
iem
iem (FLiem)
control (fwdControl)
fb
method (function)
stock (FLStock), control (fwdControl)
deviates (FLQuant)
om
method (function)
om (FLmse)

Length-based indicators

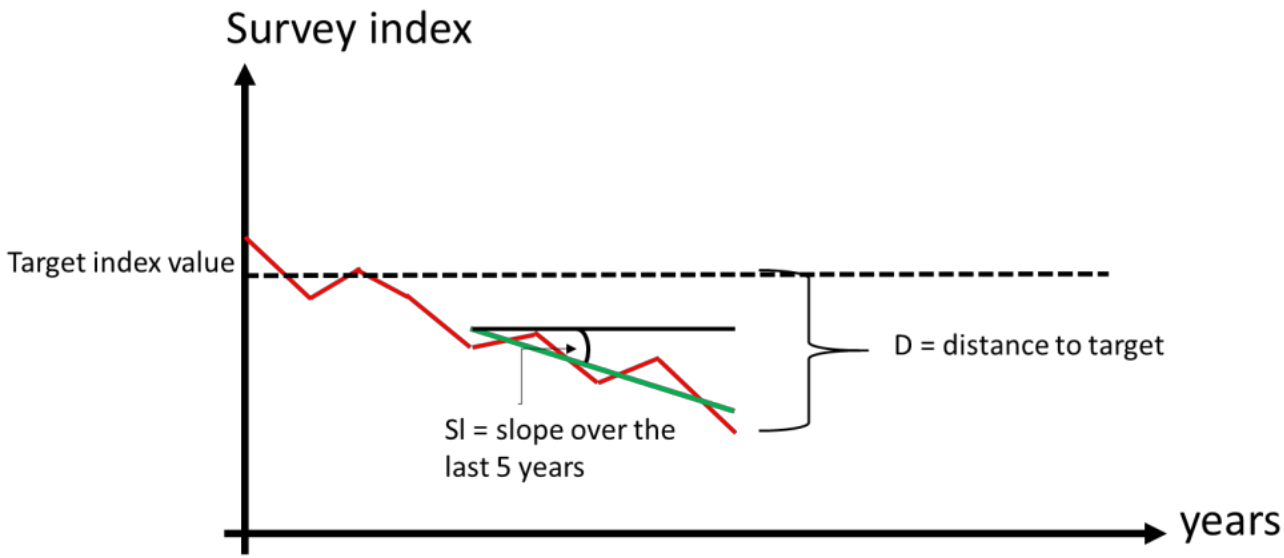
- Length-based indicators `len.ind`
  - observation (catch-at-age), Von Bertalanffy model
  - indicator
  - number of years, CV ALK

LBIs

- Length at 50% of modal abundance, *Lc*
- Mean length, *Lbar*
- Mean length of individuals, *Lmean*
- Mean length of largest 5%, *Lmax5%*

CPUE / survey trends

- CPUE trends `cpue.ind` + `cpue.hcr`
  - observation (index)
  - number of years



OM conditioning

Life-history

- Correlations among life history traits: Linf to OM
- Add data to substitute correlations
- Uncertainties and priors defined for any value

Feasible trajectories

- Priors for steepness (h), carrying capacity (K) and initial depletion (d).
- Simulate initial population, project for catch or survey/CPUE biomass.
- Accept trajectories based on catch, cohort and SSB trends.

ABC

- Approximate Bayesian Computation
- Distance metrics for any data source (catch, lengths, CPUE, effort)

ICES Journal of Marine Science, 2022, **00**, 1–15
DOI: 10.1093/icesjms/fsac043
Original Article

ICES International Council for the Exploration of the Sea
CIEM Conseil International pour l'Exploration de la Mer

Evaluation of the skill of length-based indicators to identify stock status and trends

Laurence T. Kell [1,*], Cóilín Minto [2] and Hans D. Gerritsen [3]

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[2]Marine and Freshwater Research Centre, Galway-Mayo Institute of Technology, Dublin Road, Galway H91 T8NW, Ireland
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- https://doi.org/10.1093/icesjms/fsac043

Relevant examples

ICES
CIEM

TENTH WORKSHOP ON THE DEVELOPMENT OF QUANTITATIVE ASSESSMENT METHODOLOGIES BASED ON LIFE-HISTORY TRAITS, EXPLOITATION CHARACTERISTICS, AND OTHER RELEVANT PARAMETERS FOR DATA-LIMITED STOCKS (WKLIFE X)

VOLUME 2 | ISSUE 98

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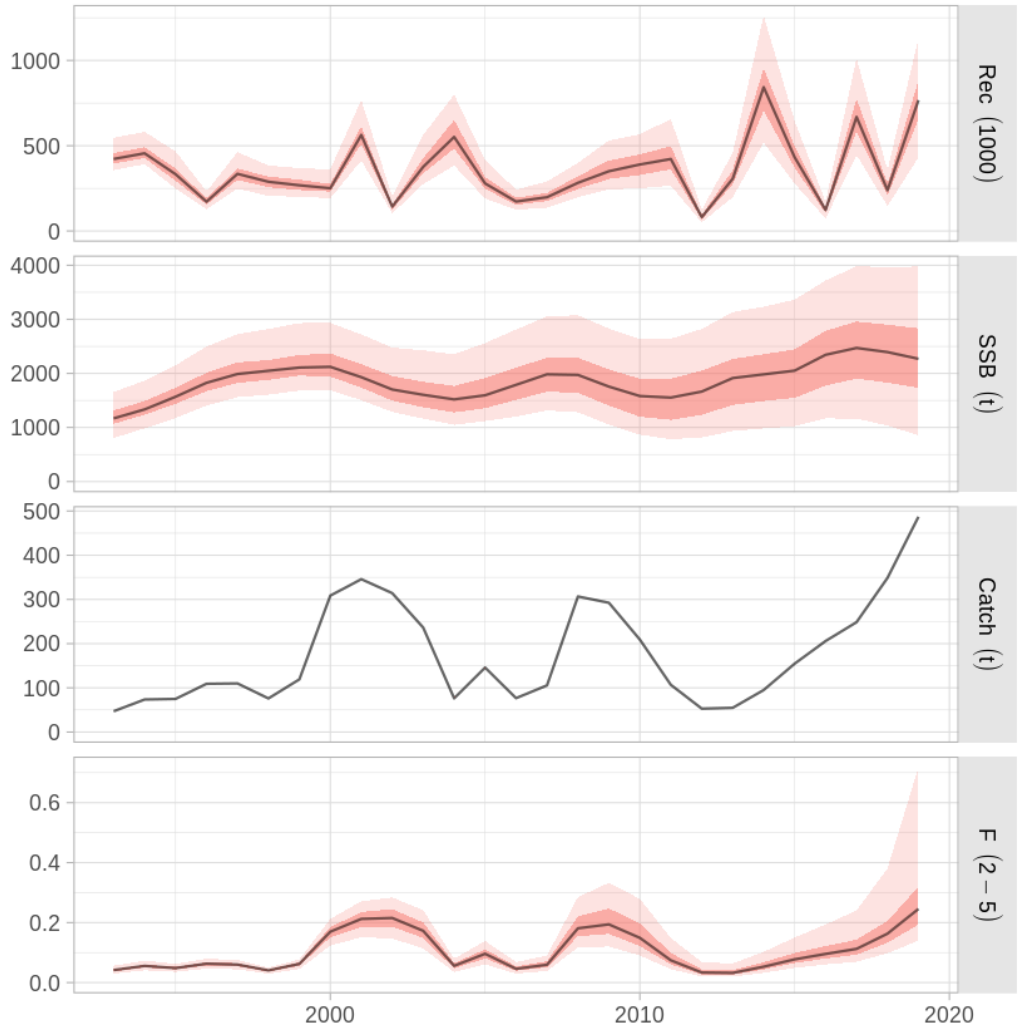
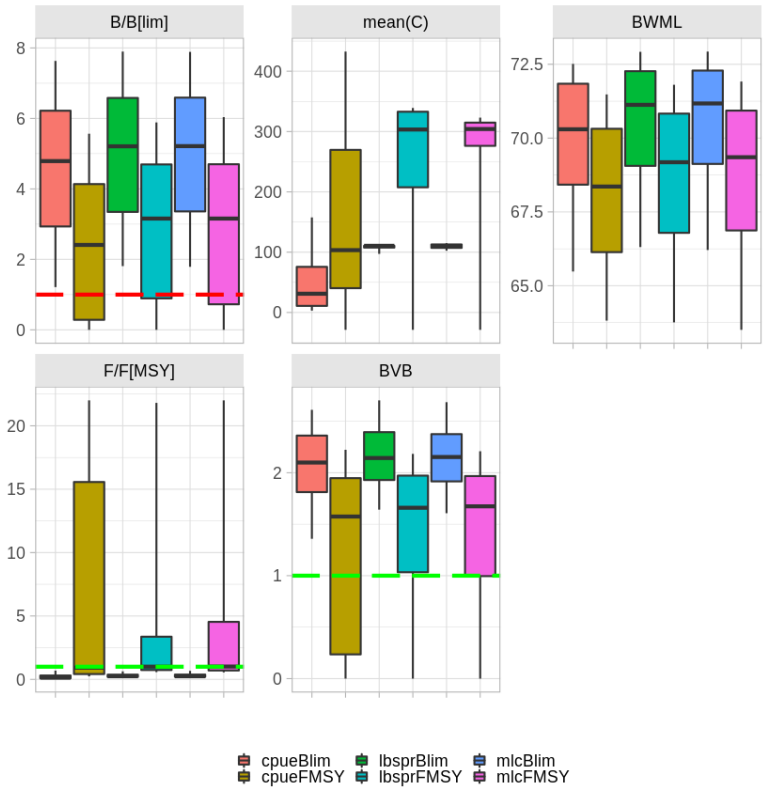
Example: MPs for stocks in the IJsselmeer, NL

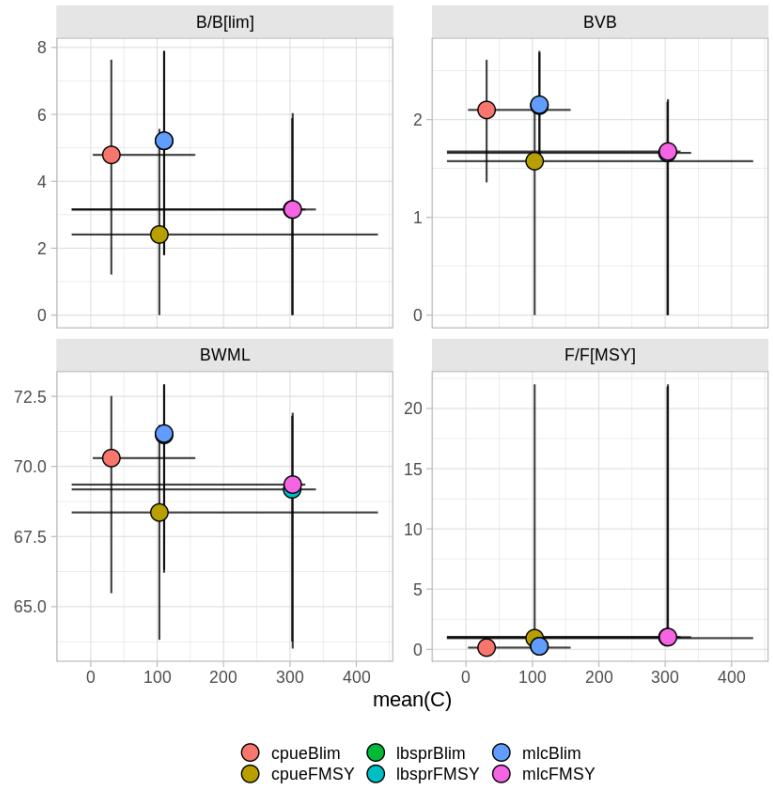
- Stocks of pikeperch, perch, bream and roach.
- Data: total catch, catch at length, survey.
- Issues: short time series, data uncertainty.
- MPs
  - LBSPR + hockey-stick 40/10 HCR
  - Survey biomass + trend HCR
  - Mean length in catch + 40/10 HCR
- MP considers bird food needs.
- Tuning for 60% FMSY or 5% Blim.

IJsselmeer pikeperch OM

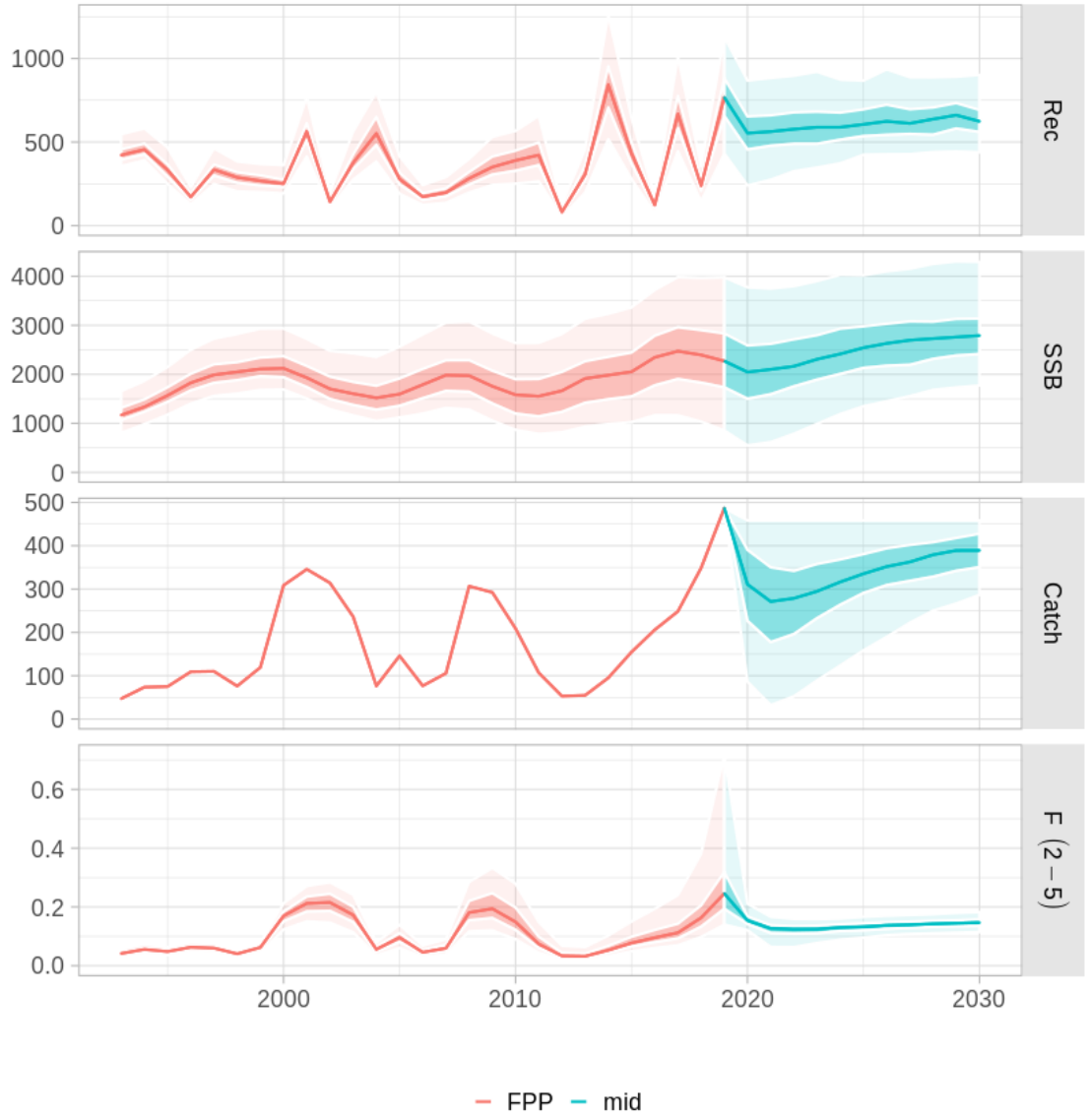


IJsselmeer pikeperch MP performance

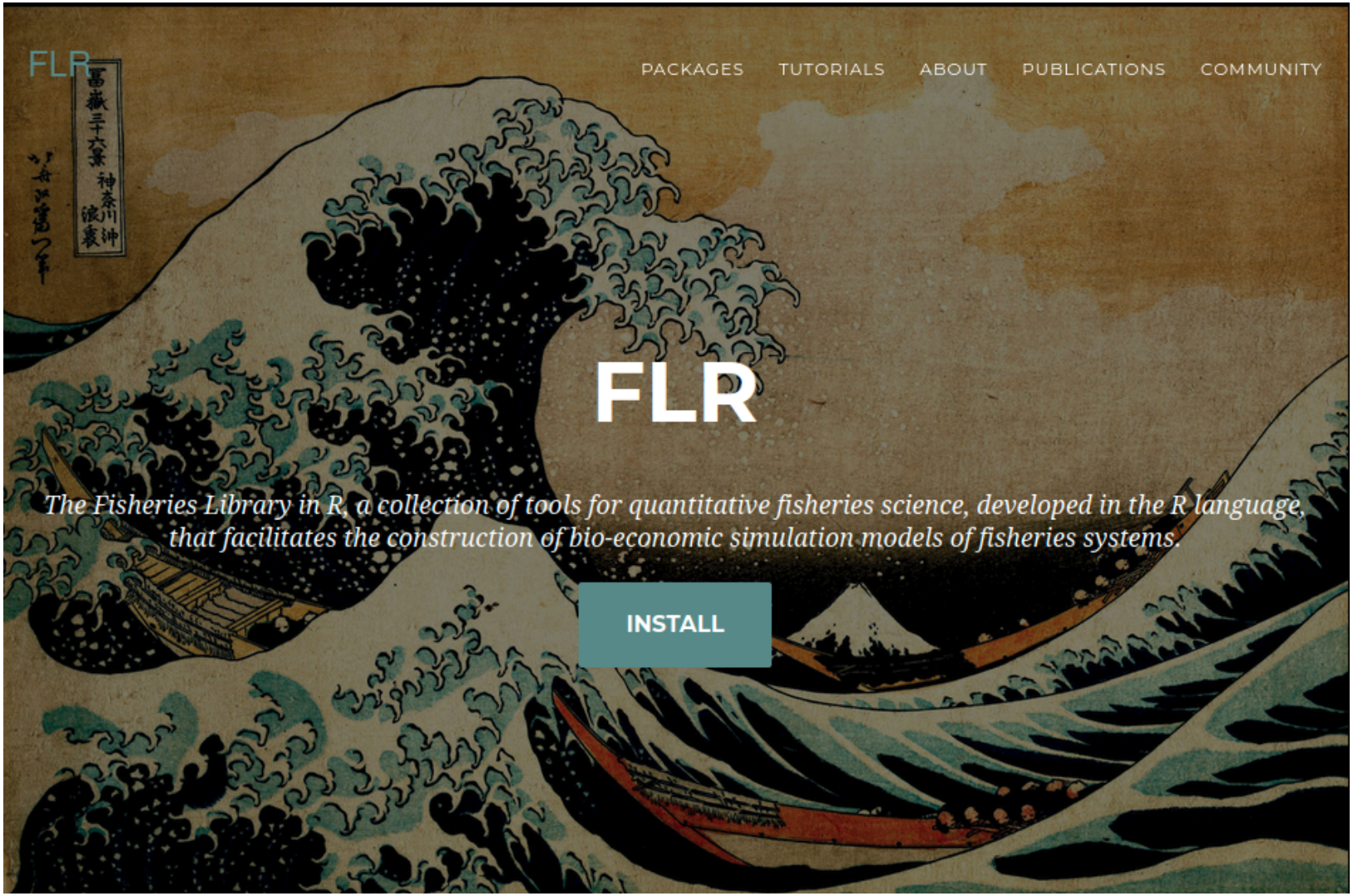




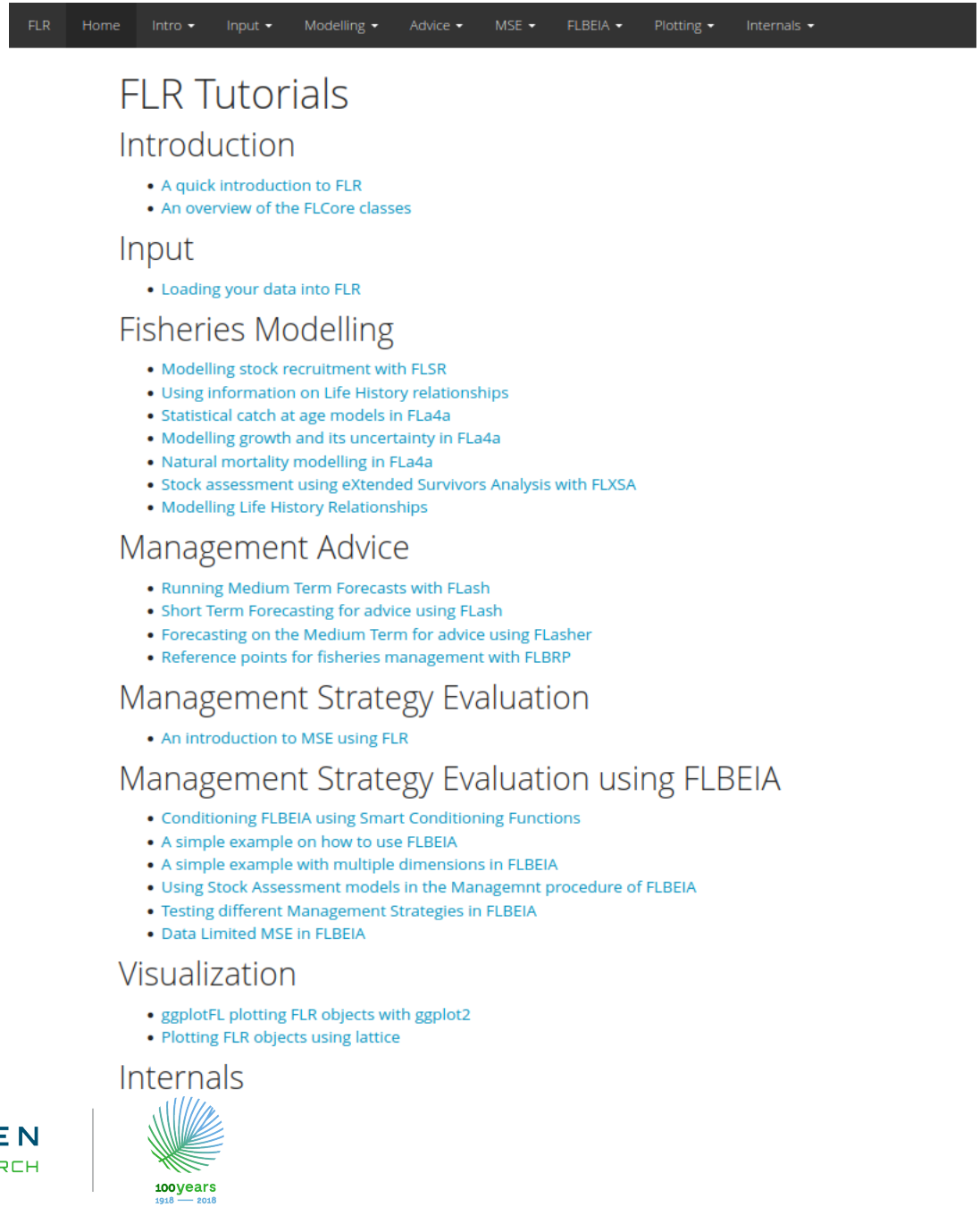
IJsselmeer pikeperch value of information



https://flr-project.org



https://flr-project.org/doc



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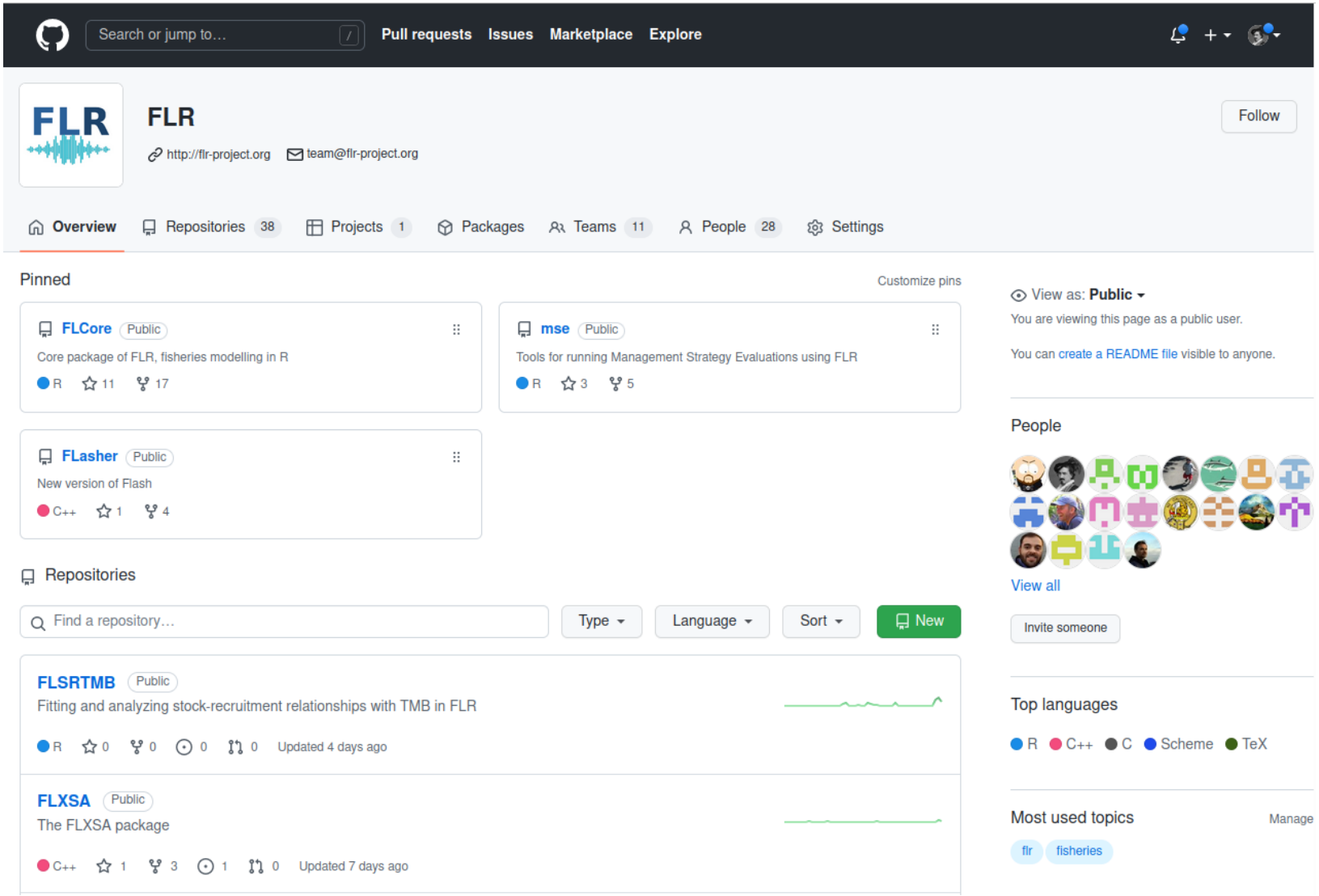
https://github.com/flr



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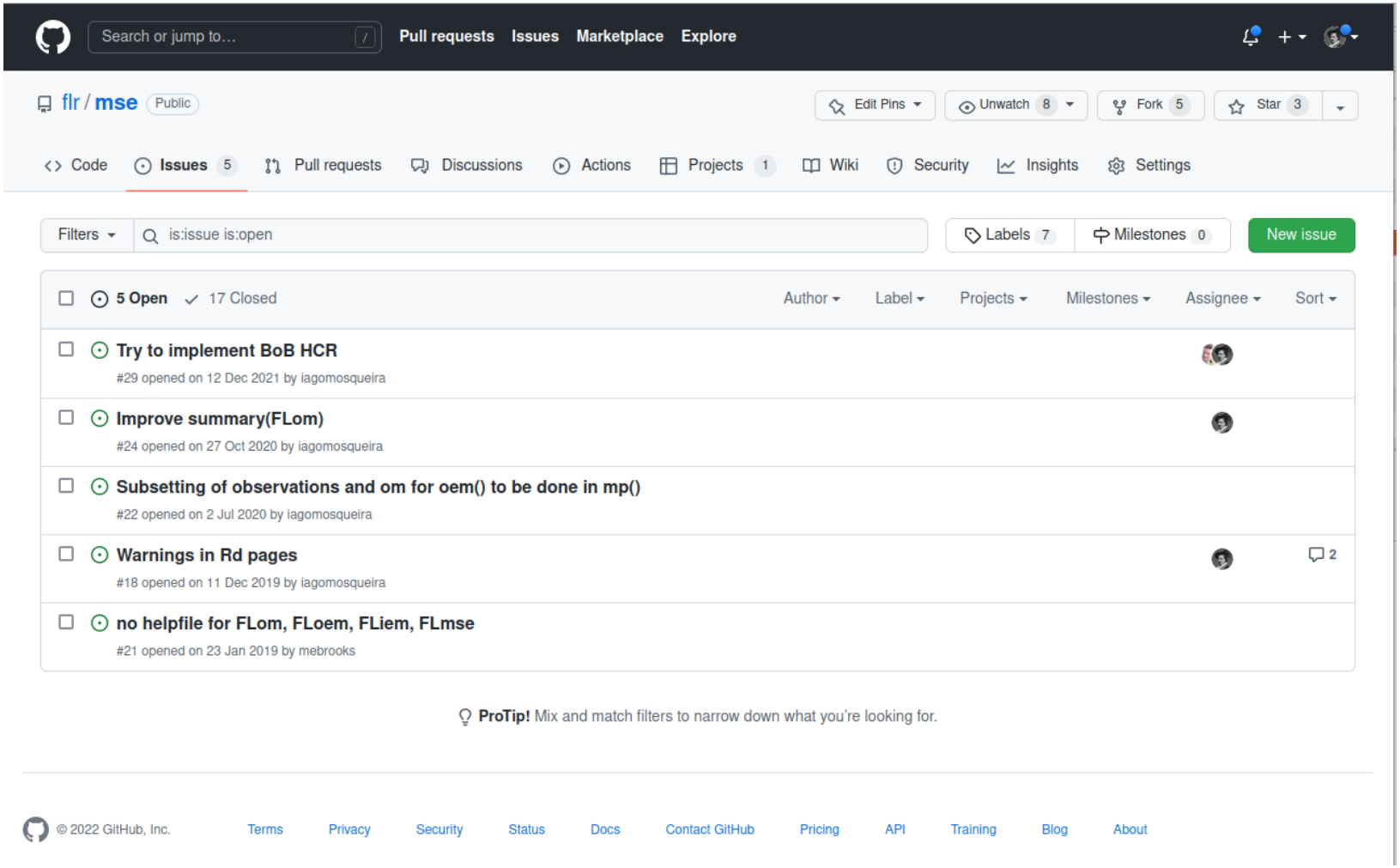
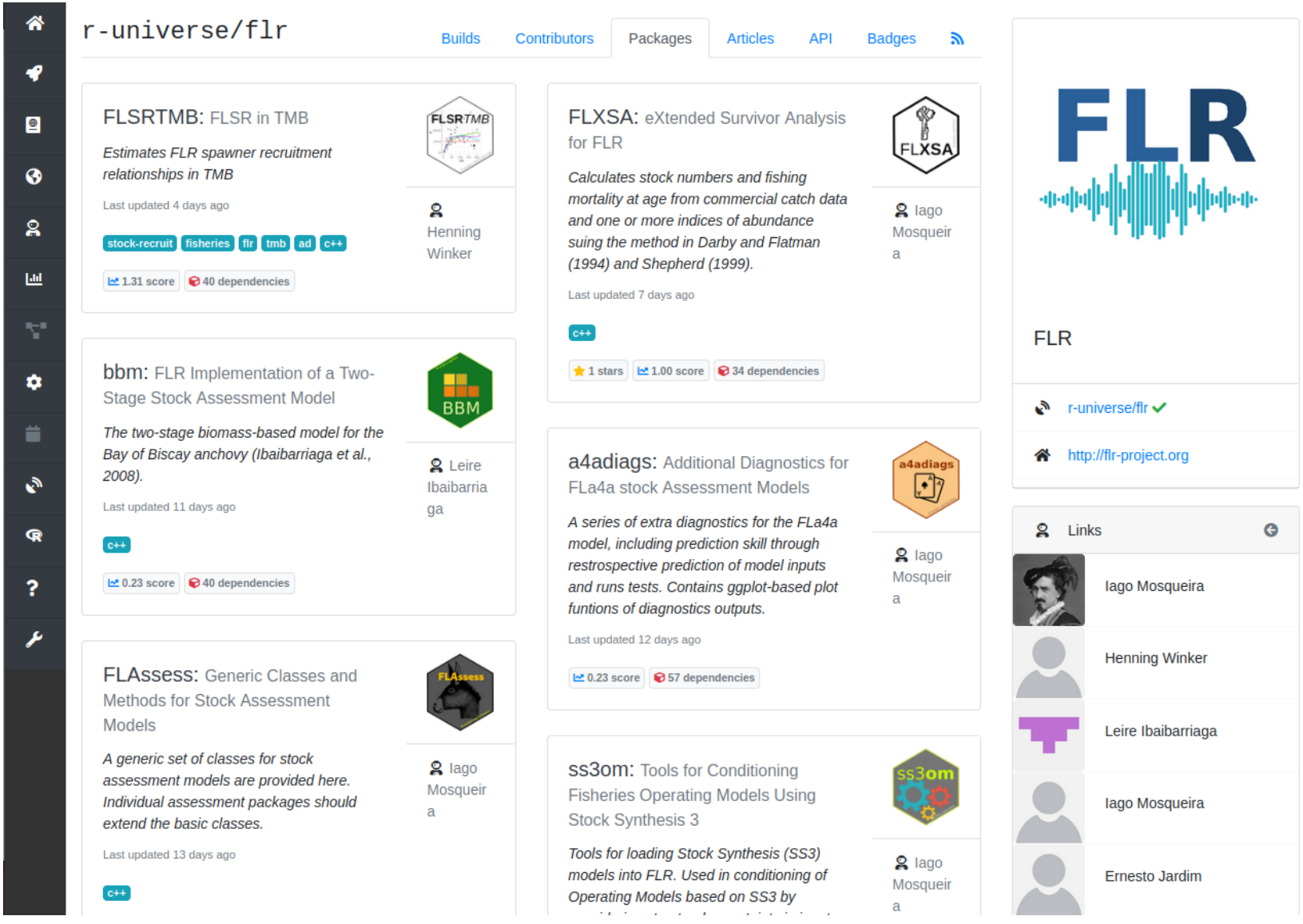
Github issues

- To report bugs, share ideas, ask questions



r-universe.org/flr



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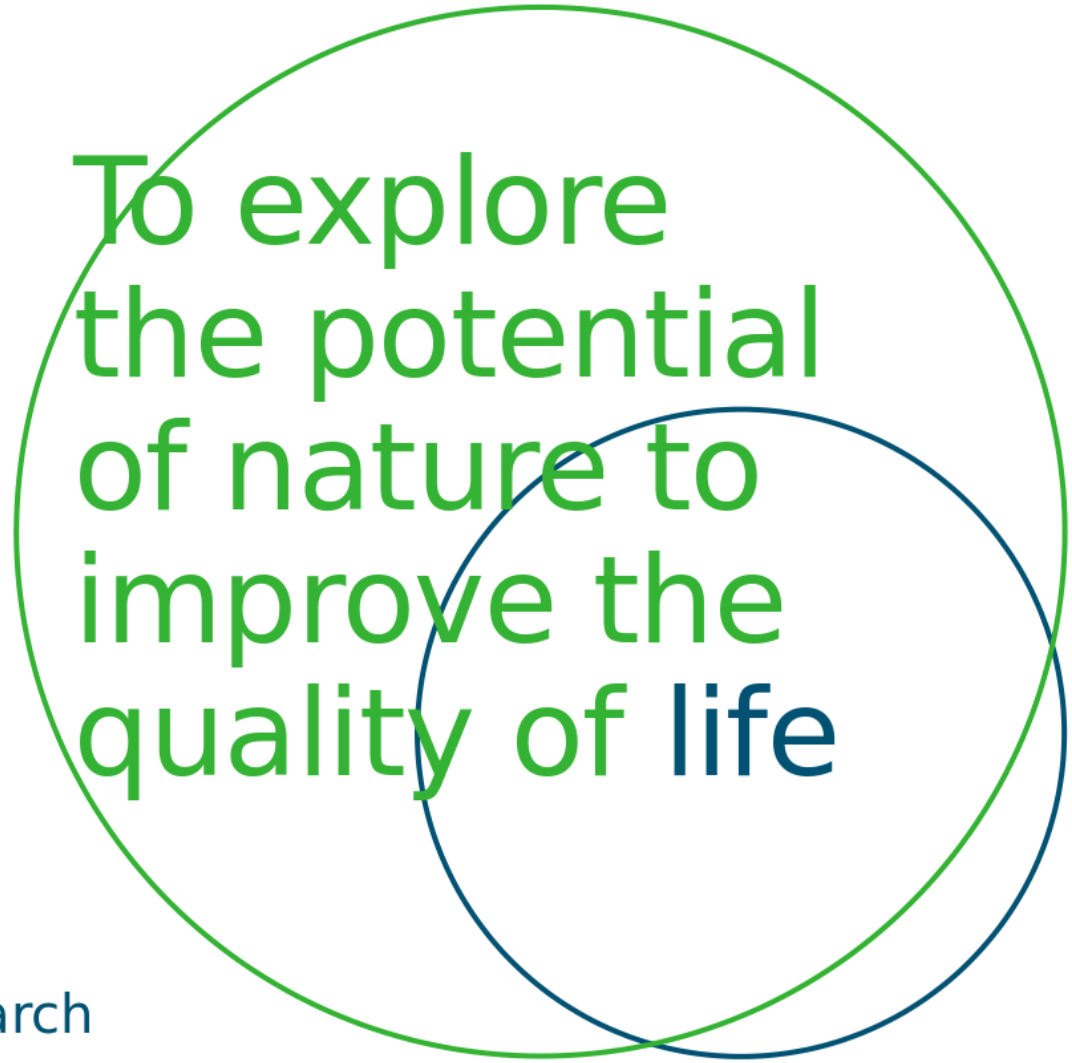

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