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The s6 model

An introduction to the ‘single species, size structured, steady state’ (s6) stock assessment model and the application to two unexploited mesopelagic fish species

S6 model

ICES Journal of Marine Science

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Original Article

Estimating uncertainty of data limited stock assessments

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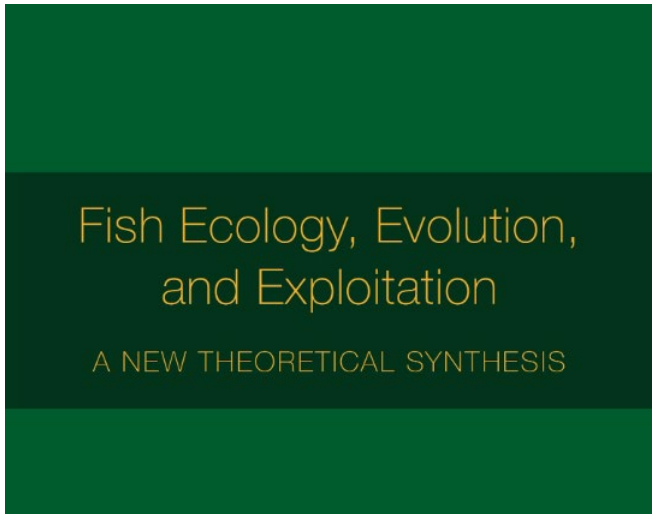

- Assess level of exploitation of data-limited stocks based on information from catches
- Based on classic Beverton-Holt theory and life-history invariants
- Stock status ~ F/Fmsy

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Limits to the reliability of size-based fishing status estimation for data-poor stocks

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Size-based methods

- Fish lengths and weights are easy and cost-effective to collect

- Often routinely collected

- Equivalent representations of demography to age-based methods

- Many vital rates are strongly related to body size e.g. maturity, trophic level, vulnerability to predation

- Sensitive to the accuracy of the life-history information provided

- Sensitive to recruitment variability

- Sensitive to non-representative sampling

    - Biased sampling

    - Insufficient sampling size

    - Sampling frequency

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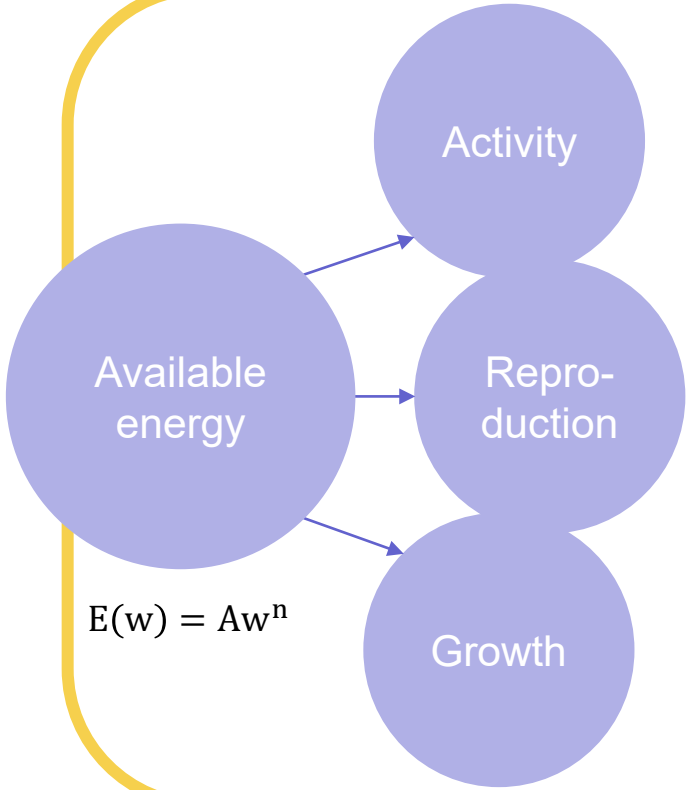
Individual of size *w*

Growth and reproduction



$$k_a = A\epsilon_a W_\infty^{n-1}$$

$$\psi_m(w) = \left[1 + \left(w/(\eta_m W_\infty)\right)^{-5}\right]^{-1}$$

$$k_r = A(1-\epsilon_a)W_\infty^{n-1}$$

$$E(w) = Aw^n$$

$$g(w) = E(w) - k_a w - \psi_m(w) k_r w$$

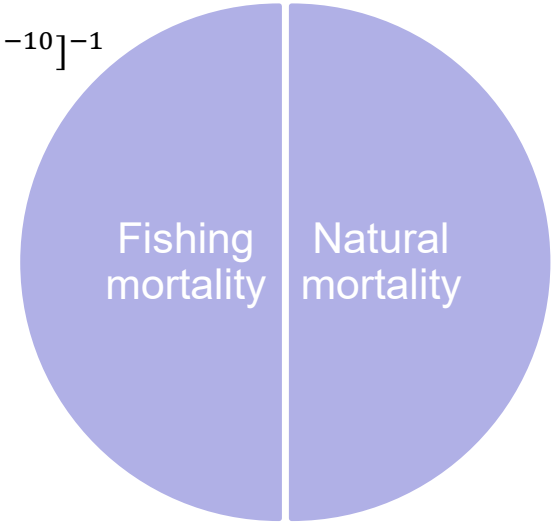
Mortality

$$\mu(w) = \mu_n(w) + \mu_F(w)$$

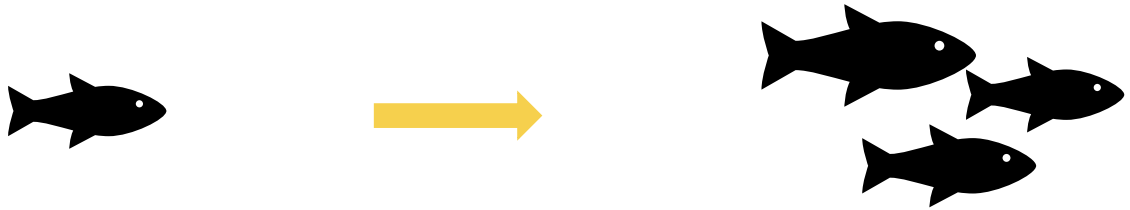
$$\mu_F(w) = F\psi_F(w)$$

$$\mu_n(w) = aAw^{n-1}$$

$$\psi_F(w) = [1 + (w/w_{50})^{-10}]^{-1}$$



S6 model

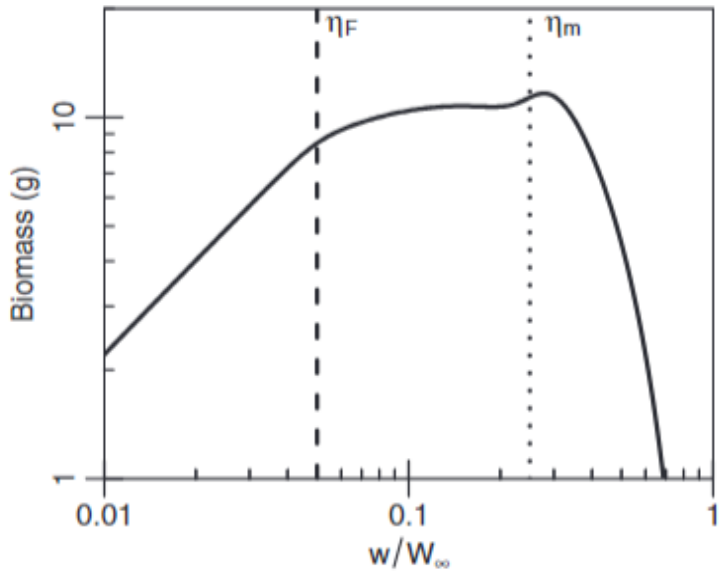


McKendrick-von Foerster mass equation

$$N(w) = \frac{R}{g(w)} \exp\left[-\int_{w_r}^{w} \frac{\mu(\hat{w})}{g(\hat{w})} d\hat{w}\right]$$

$$R = R_{max}\left(1 - \frac{W_\infty}{\epsilon_r(1-\epsilon_a)AB_{SS}}\right)$$

$$B_{SS} = \int_{w_r}^{W_\infty} \psi_m(w)N(w)wdw$$



$$Y(F) = F\int_{w_r}^{W_\infty} \psi_F(w)N(W)wdw$$

$$F_{msy} = \text{argmax}_F\{Y(F)\}$$

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Catch-at-size data

Symbol	Description	Default value	
A	Growth constant	4.5 $g^{1-n}y^{-1}$	$\sim A = 3KW_{\infty}{}^{1-n}$
a	Physiological mortality	0.22	$\sim a = M/3K\eta_{\mathrm{m}}^{\mathrm{n-1}}$
ε_a	Allocation to activity	0.8	
ε_r	Recruitment efficiency	0.1	
η_m	50% Maturation size relative to W_∞	0.25	$\sim \eta_m = w_{50}/W_\infty$
n	Allometric exponent	3/4	
w_r	Weight at recruitment (egg size)	0.001 g	
u_m	Width of the maturity ogive	10	
u_f	Width of the selectivity ogive	5	

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Symbol	Description
F	Fishing mortality
η_F	50% Retainment size relative to W_∞
W_∞	Asymptotic weigth

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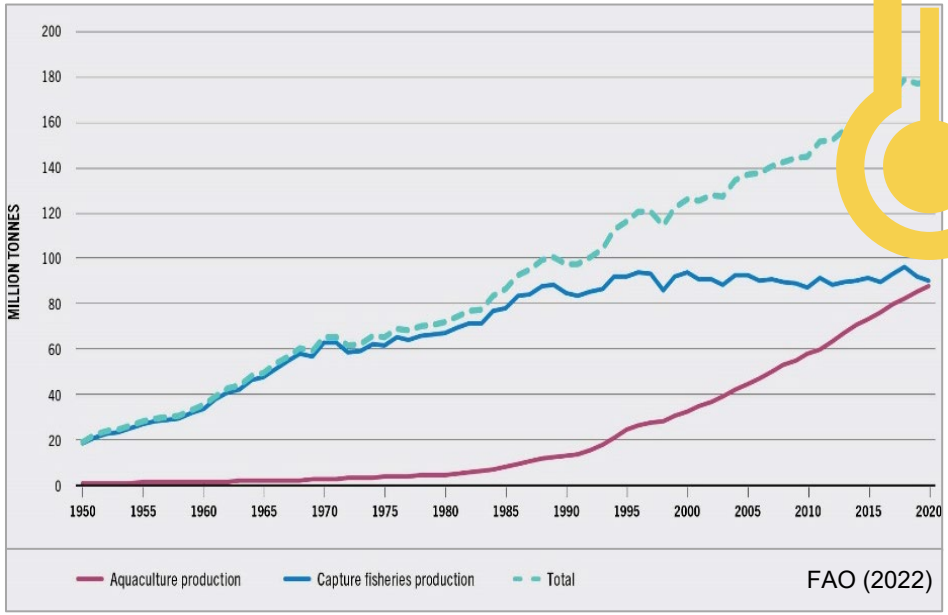
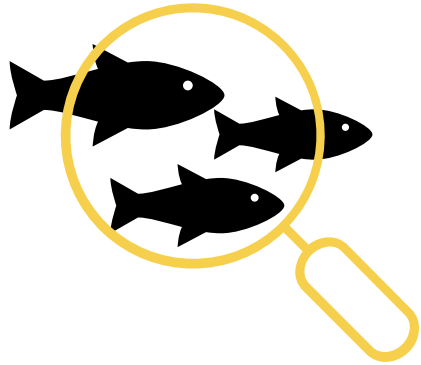
Case study



FAO (2022)



- Access control is necessary from an early stage
- Conservative cap on fishing mortality and fishing capacity
- Establish preliminary biological reference points

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Case study

Unexploited fish stocks

- Limited information on previous catches/landings
- Limited age data

- $F \approx 0$
- $B = B_0$

Uncertainty in population dynamics

F_{MSY} and B_{MSY} estimated directly

Estimation of the physiological mortality *a*

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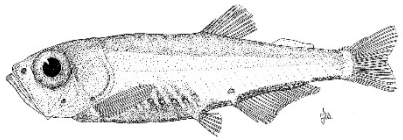
Case study



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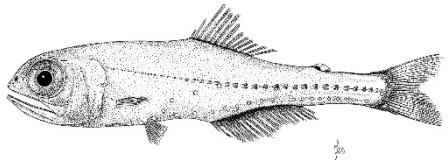
Maurolicus muelleri



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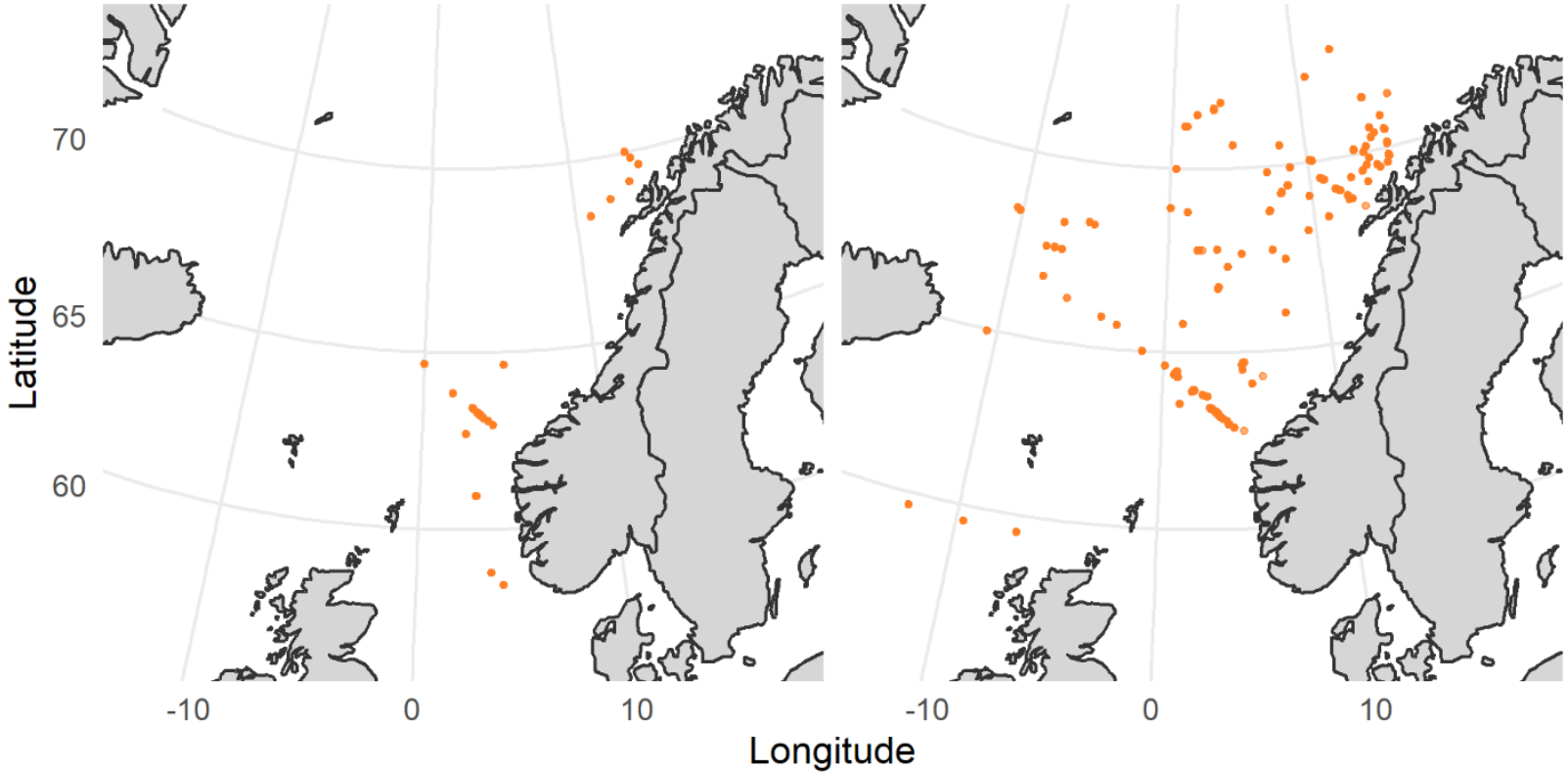
Benthosema glaciale



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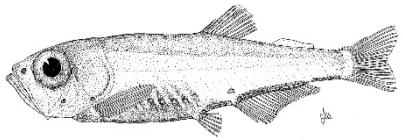
Case study



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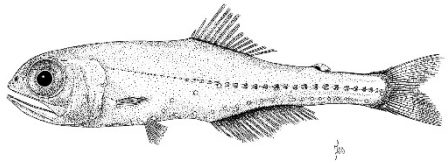

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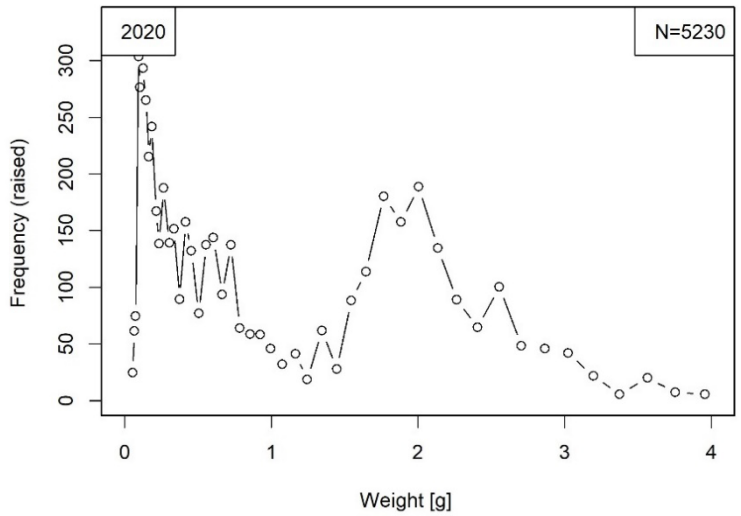

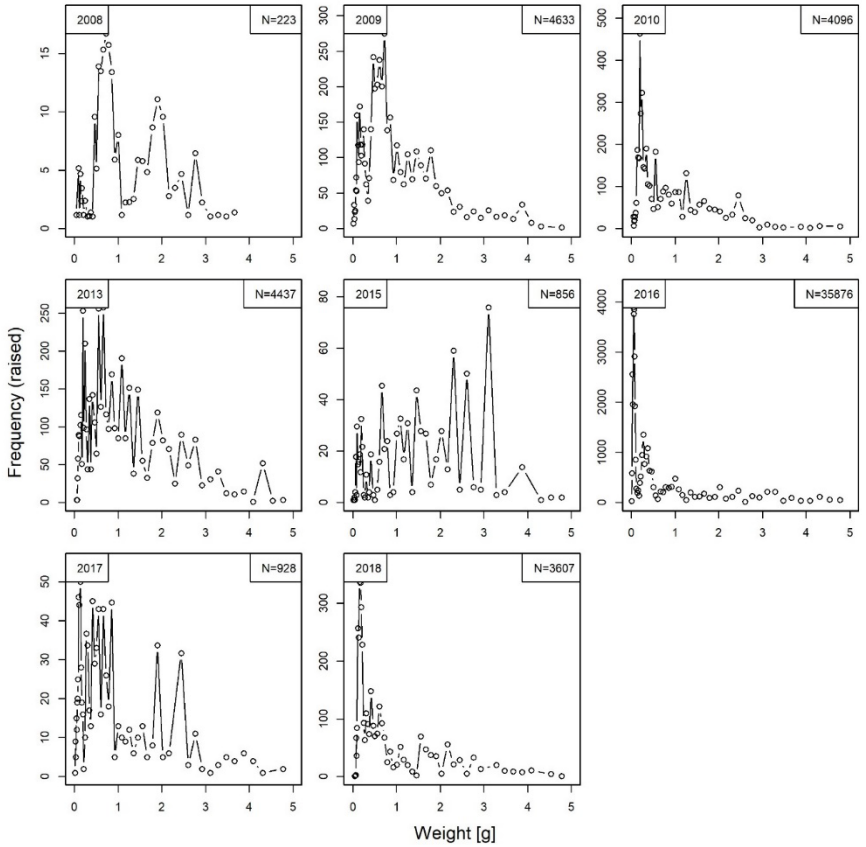

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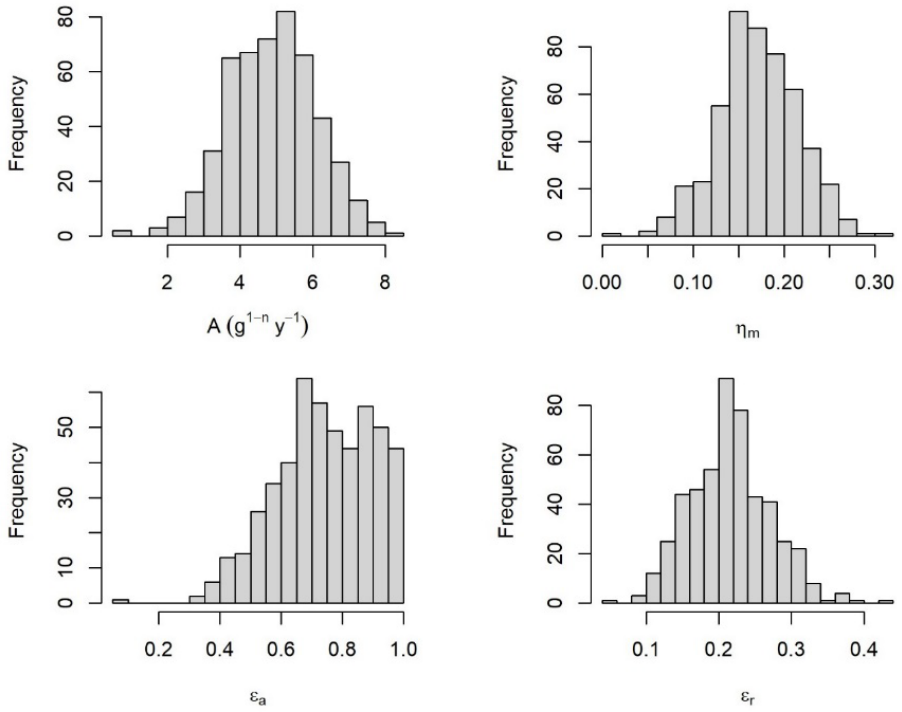
Case study

The physiological mortality a and its uncertainty,

F_{MSY} and its uncertainty due to uncertain life history parameters,

B_{MSY} according to different scenarios of absolute biomass from literature, also accounting for the uncertainty of life-history parameters.



High	56 Mt	22 Mt
Mid	33 Mt	12 Mt
Low	16 Mt	1 Mt

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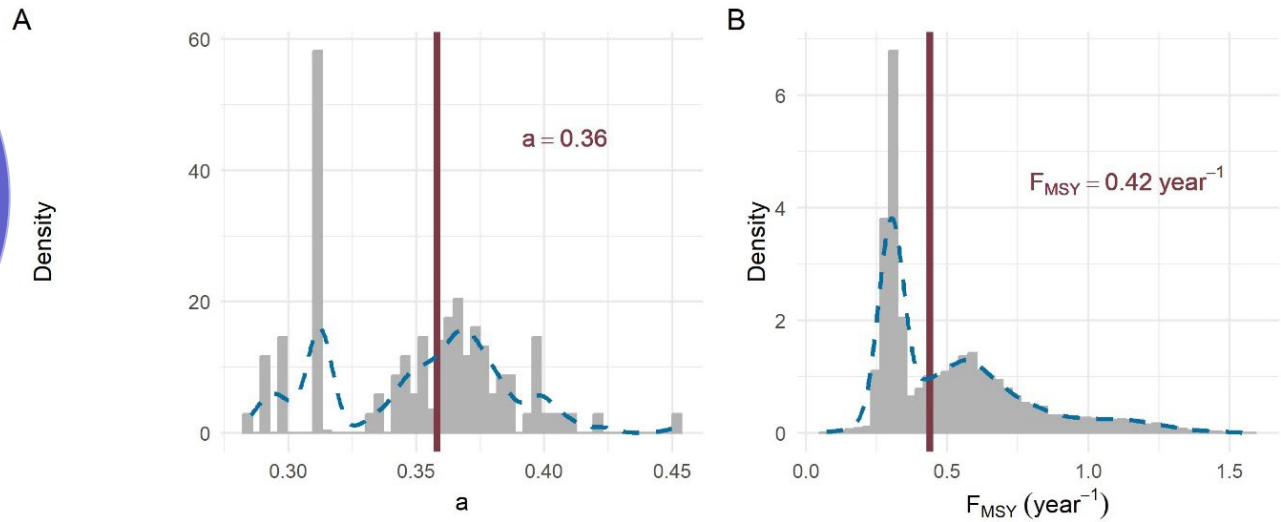

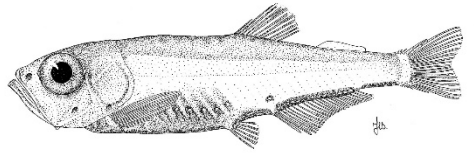

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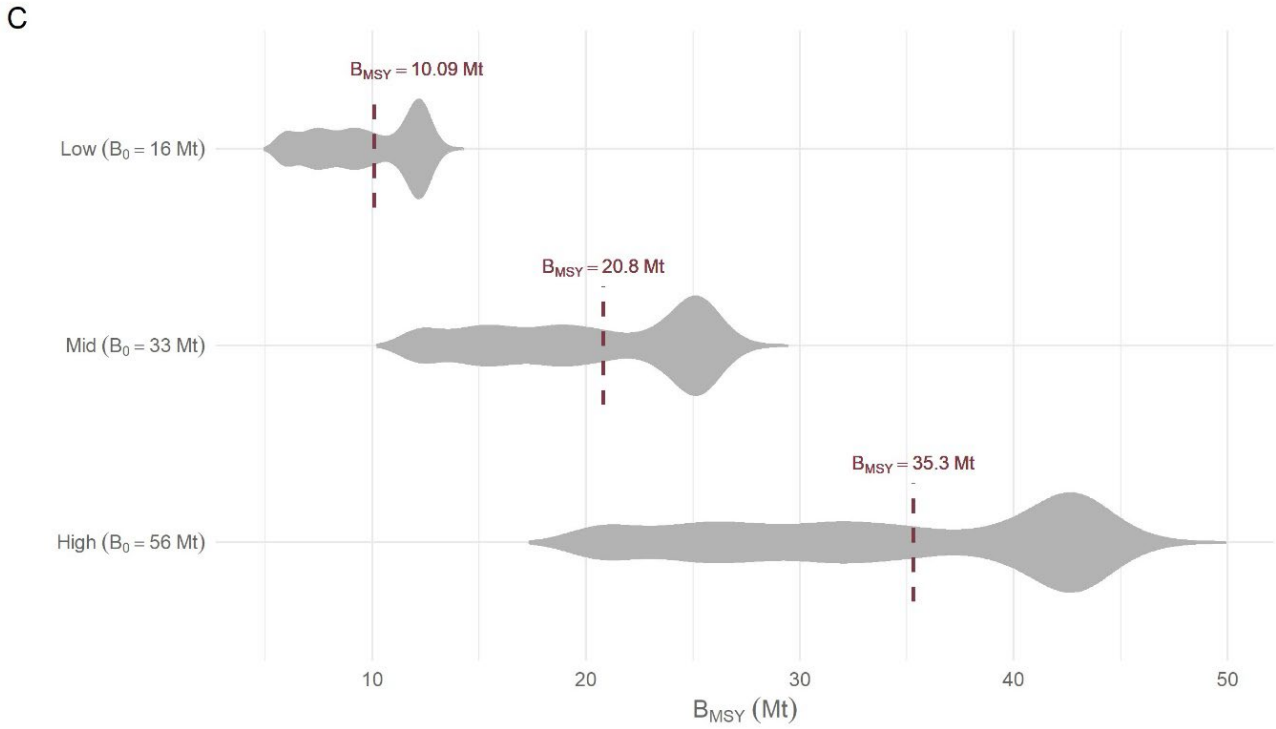

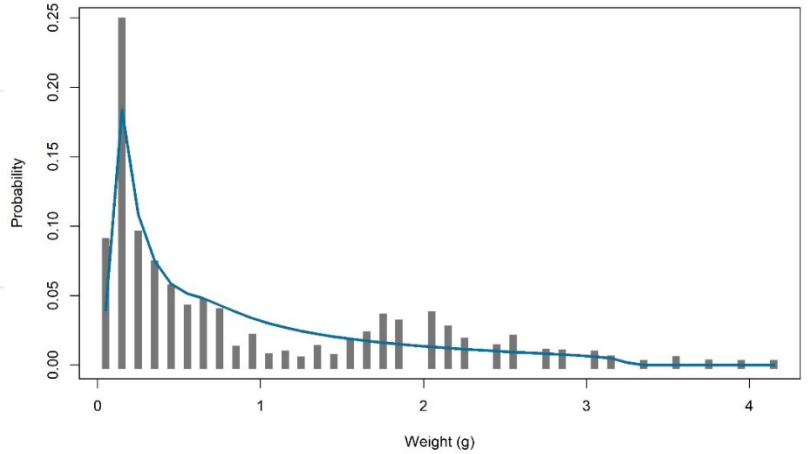

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S6 model

https://github.com/alko989/s6model

Installation using the ‘remotes’ package

```
## install.packages('remotes')
install.packages('TMB')
library(remotes)
## Stable version
install_github("alko989/s6model")
## Development version
install_github("alko989/s6model", ref = "dev")
```

Vignettes/manuals

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- Kokkalis, A., Thygesen, U. H., Nielsen, A., and Andersen, K. H. (2015). Limits to the reliability of size-based fishing status estimation for data-poor stocks. *Fisheries Research* 171, 4–11. doi: 10.1016/j.fishres.2014.10.007

- Kokkalis, A., Eikeset, A. M., Thygesen, U. H., Steingrund, P., and Andersen, K. H. (2017). Estimating uncertainty of data limited stock assessments. *ICES Journal of Marine Science* 74, 69–77. doi: 10.1093/icesjms/fsw145

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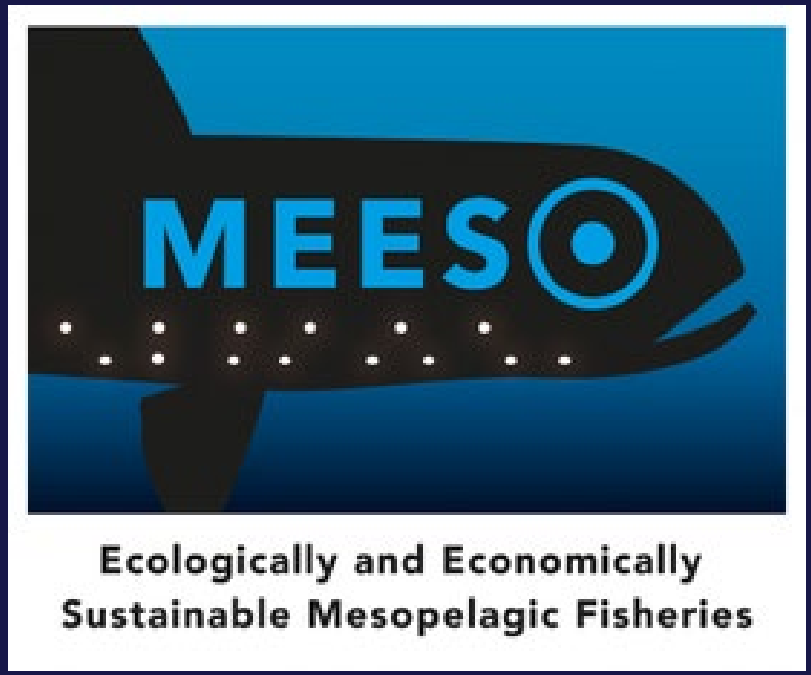
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