Consideration of risk limits for fisheries management with limited data

CEP PhD symposium 2021

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Fisheries management

- management of fisheries
- data \rightarrow assessment \rightarrow advice \rightarrow quotas
- International Council for the Exploration of the Sea (ICES)
 - provides scientific advice to EU, UK, Norway, ...
- majority of stocks data-limited
 - e.g. bycatch, less valuable species, less data, ...
 - no complex assessment
- how to derive management advice?
 - model-free (empirical) control rules
 - follow trends



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Data-limited control rule

- new: "rfb" rule
 - adapt catch, with:
 - r: biomass **r**atio (survey trend)
 - f: fishing proxy (length data, target)
 - b: **b**iomass safeguard
- some more tuning parameters...

$$C_{y+1} = C_{y-1} r f b$$

$$C_{y+v} = C_{y-1} \left(\frac{\sum_{i=y-n_0-n_1+1}^{y-n_0} (I_i/n_1)}{\sum_{i=y-n_0-n_1-n_2+1}^{y-n_0-n_1} (I_i/n_2)} \right)^{e_r} \left(\frac{\overline{L}_{y-1}}{L_{F=M}} \right)^{e_f} \left(\min\left\{ 1, \frac{I_{y-n_0}}{I_{\text{trigger}}} \right\} \right)^{e_b} \chi$$

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Management Strategy Evaluation

- how to test management strategies?
 - simulations
- simulate entire system
 - fish stock, fishery & management
- stochastic simulations
 - natural variability
 - uncertainty for processes, observations, etc.



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Simulating fish stocks

- data-limited \rightarrow no population models available
- simulate based on life-history traits
 - input: life-history parameters (growth, ...)
- 29 stocks, covering wide range:
 - from slow-growing and long-lived (e.g. sharks) to fast-growing short-lived (e.g. anchovy)
- artificial fishing histories







"Risk"?

- what is risk in fisheries management?
 - risk of stock falling below undesirable stock size/depletion
- precautionary approach (FAO)
 - reduce risk
- ICES: 5% risk limit
 - magic 5%

2

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- evaluated with simulations
- risk $\leftarrow \rightarrow$ uncertainty
 - data-limited: uncertainty uncertain

fas





FAO

Risk sensitivity

- a. example: management with 5% risk
- b. definition of undesirable stock size
- c. starting condition of simulation
- d. length of simulation
- e. uncertainty of observed data
- f. variability in number of young fish

m

fas

0.25

0.00

0.00

0.25

0.50

recruitment steepness (h)

0.75

1.00

g. recruitment at low stock size

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(simulated) uncertainty

Optimisation: genetic algorithm

- genetic algorithm for optimisation
- used in many scientific fields
- on top of management strategy evaluation
- management strategy (parameters)
 "evolve"
- fitness function defines objectives
 - stock size, catch, risk, variability



Figure 1. Conceptual representation of the genetic algorithm as an optimization procedure for a management procedure.

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Fischer et al. (2021) https://dx.doi.org/10.1093/icesjms/fsab018

Optimisation

- 29 stock simulated
- current management strategy not precautionary!
- new rfb rule

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- default: non-precautionary
- but can be optimised
- optimisation without risk limit → higher catch
- optimisation with risk limit
 → lower catch

as

catch stability possible

two fishing scenarios

avoid

6 (worst)

fitness 0 (best

| slower-growing → | ang3 ($k = 0.08$ year ⁻¹) - rjc2 ($k = 0.09$ year ⁻¹) - smn ($k = 0.11$ year ⁻¹) - wlf ($k = 0.11$ year ⁻¹) - meg ($k = 0.12$ year ⁻¹) - lin ($k = 0.14$ year ⁻¹) - rjc ($k = 0.14$ year ⁻¹) - syc ($k = 0.15$ year ⁻¹) - | -3.9 -3.9 -5.0 -4.2 -4.0 -4.7 | -5.5 -5.6 -5.2 -5.5 -5.8 | -5.8 -5.9 -6.6 -1.9 | -5.6 -5.7 -5.8 -5.8 | -5.2 -5.3 -5.2 | -1.3 -1.2 -3.5 | -0.6 -0.6 -3.0 | -1.8 -1.8 -3.6 | -1.6 -1.5 -3.4 | -1.1 -0.9 -3.1 | -3.8 -3.9 -5.0 | -5.5 -5.5 -5.9 | -5.5 -5.5 -6.1 | -5.4 -5.4 -5.5 | -5.2 -5.2 -5.1 | -3.6 -3.7 -3.8 | -3.4 -3.4 -3.6 | -5.4 -5.4 -3.9 | -5.4 -4.7 -3.7 | -3.4 -3.4 |
|----------------------|--|--|--------------------------------------|------------------------------|------------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|--------------|
| slower-growing → | $rjc2 (k = 0.09year^{-1}) - smn (k = 0.11year^{-1}) - wlf (k = 0.11year^{-1}) - meg (k = 0.12year^{-1}) - lin (k = 0.14year^{-1}) - rjc (k = 0.14year^{-1}) - syc (k = 0.15year^{-1}) - syc (k = 0.15ye$ | -3.9 -5.0 -4.2 -4.0 | -5.6 -5.2 -5.5 -5.8 | -5.9 -6.6 -1.9 | -5.7 -5.8 -5.8 | -5.3 -5.2 -5.2 | -1.2 -3.5 | -0.6 -3.0 | -1.8 -3.6 | -1.5 -3.4 | -0.9 -3.1 | -3.9 | -5.5 -5.9 | -5.5 -6.1 | -5.4 -5.5 | -5.2 -5.1 | -3.7 -3.8 | -3.4 | -5.4 -3.9 | -4.7 -3.7 | -3.4 |
| slower-growing > | smn $(k = 0.11year^{-1})$ - wlf $(k = 0.11year^{-1})$ - meg $(k = 0.12year^{-1})$ - lin $(k = 0.14year^{-1})$ - rjc $(k = 0.14year^{-1})$ - syc $(k = 0.15year^{-1})$ - | -5.0 -4.2 -4.0 -4.7 | -5.2 -5.5 -5.8 | - <mark>6.6</mark> -1.9 | -5.8 -5.8 | -5.2 | -3.5 | -3.0 | -3.6 | -3.4 | -3.1 | -5.0 | -5.9 | -6.1 | -5.5 | -5.1 | -3.8 | -3.6 | -3.9 | -3.7 | 3.6 |
| slower-growing > | wlf $(k = 0.11 \text{year}^{-1})$ meg $(k = 0.12 \text{year}^{-1})$ lin $(k = 0.14 \text{year}^{-1})$ rjc $(k = 0.14 \text{year}^{-1})$ syc $(k = 0.15 \text{year}^{-1})$ | -4.2 -4.0 | -5.5 -5.8 | -1.9 | -5.8 | -5.2 | 1.6 | | | | | | | | | | | | | | -5.0 |
| slower-growing → | meg $(k = 0.12year^{-1})$ - lin $(k = 0.14year^{-1})$ - rjc $(k = 0.14year^{-1})$ - syc $(k = 0.15year^{-1})$ - | -4.0 | -5.8 | | | | -1.0 | -0.5 | -2.6 | -2.0 | -0.7 | -4.3 | -5.6 | -6.4 | -5.5 | -5.1 | -3.5 | -3.3 | -5.3 | -3.5 | -3.4 |
| slower-growing → | lin $(k = 0.14 \text{year}^{-1})$ rjc $(k = 0.14 \text{year}^{-1})$ syc $(k = 0.15 \text{year}^{-1})$ | -4.7 | | -3.0 | -5.9 | -5.2 | -1.6 | -0.5 | -4.3 | -2.2 | -0.6 | -4.0 | -5.6 | -4.0 | -5.6 | -5.2 | -3.3 | -3.1 | -5.4 | -3.3 | -3.2 |
| slower-growing | rjc $(k = 0.14 \text{year}^{-1})$ - syc $(k = 0.15 \text{year}^{-1})$ - | | -5.4 | -5.9 | -5.7 | -5.2 | -3.0 | -1.4 | -4.2 | -3.1 | -1.7 | -4.7 | -5.7 | -5.5 | -5.5 | -5.2 | -3.8 | -3.6 | -5.3 | -3.8 | -3.7 |
| slower-growin | syc $(k = 0.15 \text{year}^{-1})$ - | -4.9 | -5.4 | -5.9 | -5.7 | -5.3 | -3.2 | -2.1 | -5.4 | -3.3 | -1.9 | -5.0 | -5.8 | -5.5 | -5.5 | -5.2 | -3.9 | -3.6 | -4.7 | -4.0 | -3.8 |
| slower-grov | I | -5.3 | -5.3 | -6.1 | -5.7 | -5.2 | -3.7 | -2.1 | -4.6 | -3.7 | -2.8 | -5.4 | -5.9 | -5.6 | -5.5 | -5.2 | -4.1 | -3.6 | -4.4 | -4.1 | -4.0 |
| slower-gr | $sdv(k = 0.15year^{-1})$ - | -4.7 | -5.4 | -5.9 | -5.7 | -5.2 | -3.1 | -1.5 | -4.6 | -3.2 | -2.1 | -4.7 | -5.7 | -5.8 | -5.5 | -5.2 | -3.8 | -3.5 | -5.3 | -3.8 | -3.6 |
| slower- | ang $(k = 0.18 \text{ year}^{-1})$ | -5.1 | -5.4 | -5.7 | -5.7 | -5.2 | -3.8 | -2.9 | -5.4 | -3.8 | -2.2 | -5.1 | -5.9 | -6.0 | -5.5 | -5.1 | -3.9 | -3.8 | -4.4 | -4.0 | -3.7 |
| slow6 | ang2 $(k = 0.18 \text{year}^{-1})$ - | -5.2 | -5.5 | -5.8 | -5.8 | -5.2 | -3.8 | -2.3 | -5.4 | -3.8 | -1.6 | -5.2 | -5.9 | -6.1 | -5.6 | -5.2 | -3.7 | -3.7 | -4.3 | -3.8 | -3.4 |
| s s | pol $(k = 0.19 \text{ year}^{-1})$ | -4.7 | -5.6 | -6.0 | -5.9 | -5.2 | -3.4 | -1.5 | -5.4 | -3.5 | -1.9 | -4.7 | -5.8 | -5.7 | -5.6 | -5.2 | -3.4 | -3.0 | -3.9 | -3.5 | -3.2 |
| S , | had $(k = 0.2 \text{year}^{-1})$ | -4.4 | -6.2 | -7.2 | -5.9 | -5.3 | -3.7 | -2.7 | -5.5 | -3.7 | -3.0 | -4.5 | -5.8 | -6.8 | -5.7 | -5.2 | -3.4 | -3.4 | -4.0 | -3.5 | -3.1 |
| r | nep $(k = 0.2 \text{year}^{-1})$ | -4.8 | -6.0 | -7.6 | -5.9 | -5.4 | -3.8 | -3.5 | -5.5 | -3.9 | -2.6 | -4.9 | -5.9 | -7.3 | -5.7 | -5.2 | -3.8 | -3.5 | -4.0 | -3.7 | -3.1 |
| | mut $(k = 0.21 \text{ year}^{-1})$ - | -5.7 | -6.7 | -8.3 | -6.1 | -5.5 | -4.9 | -4.9 | -5.6 | | -4.2 | -5.7 | -6.1 | -8.1 | -6.0 | -5.3 | -4.8 | -4.8 | -4.9 | | -4.1 |
| 5 | sbb $(k = 0.22 year^{-1})$ - | -5.2 | -6.6 | -6.7 | -6.0 | -5.4 | -4.6 | -4.5 | -5.6 | -4.5 | -4.3 | -5.3 | -6.0 | -6.4 | -5.9 | -5.3 | -4.4 | -4.4 | -4.6 | -4.4 | -4.2 |
| ہ <u>م</u> | ple $(k = 0.23 \text{ year}^{-1})$ | -5.6 | -6.4 | -7.9 | -6.0 | -5.4 | -4.8 | -4.5 | -5.6 | | -4.1 | -5.7 | -6.2 | -7.7 | -5.9 | -5.3 | -4.7 | -4.6 | -4.8 | | -3.7 |
| ÷ Ľ | $syc2(k = 0.23year^{-1})$ - | -5.9 | -5.3 | -6.5 | -5.8 | -5.2 | -4.5 | -3.8 | -4.8 | -4.4 | -3.7 | -6.0 | -6.3 | -6.2 | -5.6 | -5.1 | -4.4 | -4.1 | -4.6 | -4.3 | -4.0 |
| S a | $\arg(k = 0.23 \text{ year}^{-1})$ | -5.7 | -5.3 | -6.1 | -5.8 | -5.2 | -4.5 | -3.8 | -5.5 | -4.5 | -4.0 | -5.8 | -6.2 | -5.8 | -5.6 | -5.2 | -4.4 | -4.3 | -4.7 | -4.3 | -4.0 |
| | tur $(k = 0.32 \text{year}^{-1})$ - | -4.7 | -6.9 | -8.0 | -6.0 | -5.4 | -4.0 | -3.8 | -5.6 | -4.0 | -3.4 | -4.8 | -6.1 | -7.8 | -5.9 | -5.3 | -3.8 | -3.2 | -3.9 | -3.9 | -3.2 |
| | gut $(k = 0.32 \text{year}^{-1})$ - | -5.3 | -7.2 | -6.4 | -6.1 | -5.5 | -4.7 | -4.6 | -5.7 | -4.5 | -4.4 | -5.3 | -6.2 | -6.2 | -6.0 | -5.4 | -4.4 | -4.3 | -4.5 | -4.4 | -4.3 |
| , te | whg $(k = 0.38 \text{year}^{-1})$ - | -6.2 | -7.2 | -7.3 | -6.3 | -5.8 | -5.7 | -5.5 | -6.0 | -6.1 | -5.4 | -6.3 | -6.4 | -6.8 | -6.3 | -5.6 | -5.7 | -5.5 | -5.8 | | -5.4 |
| a ŋ | bll $(k = 0.38 \text{year}^{-1})$ | -5.7 | -7.2 | -7.0 | -6.3 | -5.7 | -5.3 | -5.0 | -6.2 | -6.1 | -4.9 | -5.7 | -6.1 | -6.6 | -6.2 | -5.6 | -5.2 | -5.1 | -5.9 | -6.0 | -5.0 |
| $\overline{\Lambda}$ | $lem(k = 0.42 year^{-1})$ - | -5.4 | -6.8 | -6.6 | -6.0 | -5.5 | -4.8 | -4.6 | -5.7 | -4.6 | -4.4 | -5.4 | -6.3 | -6.5 | -6.0 | -5.4 | -4.6 | -4.5 | -4.6 | -4.5 | -4.1 |
| • a | ane $(k = 0.44 \text{ year}^{-1})$ - | -6.6 | -7.2 | -6.9 | -6.4 | -5.9 | -6.1 | -5.9 | -6.0 | -6.1 | -5.8 | -6.7 | -6.6 | -6.8 | -6.2 | -5.7 | -6.1 | -5.8 | -5.8 | | -5.7 |
| j | jnd $(k = 0.47 \text{year}^{-1})$ - | -6.1 | -7.2 | -7.5 | -6.5 | -6.0 | -5.8 | -5.6 | -6.3 | -6.2 | -6.1 | -6.1 | -7.2 | -7.4 | -6.4 | -5.9 | -5.8 | -5.5 | -6.1 | -6.2 | -5.9 |
| 5 | $sar(k = 0.6year^{-1})$ - | -6.5 | -7.2 | -7.4 | -6.6 | -6.1 | -6.2 | -6.1 | -6.4 | -6.2 | -6.1 | -6.5 | -7.2 | -7.4 | -6.5 | -6.0 | -6.1 | -5.8 | -6.2 | -6.2 | -5.9 |
| ł | her $(k = 0.61 \text{ year}^{-1})$ - | -6.6 | -7.2 | -7.4 | -6.4 | -6.0 | -6.3 | -5.9 | -6.4 | -6.3 | -6.1 | -6.6 | -6.8 | -7.4 | -6.4 | -5.9 | -6.2 | -5.9 | -6.2 | -6.2 | -5.9 |
| 5 | $\operatorname{san}(k = 1\operatorname{year}^{-1})$ | -6.1 | -7.2 | -7.5 | -6.6 | -6.2 | -5.8 | -5.5 | -6.3 | -6.2 | -6.2 | -6.1 | -7.2 | -7.4 | -6.4 | -6.0 | -5.7 | -5.3 | -6.3 | -6.2 | -6.2 |
| | | | | | it - | - | mult* - | - all* | lt - | ped): _ | ped): | | | | ult - | | mult*- | - all* | lt . | ped): _ | - :(pədc |

Impact (I)

- Part of ICES workshop on data-limited methods ("WKLIFE")
 - annual meeting
- Publications

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Science

- Fischer et al. (2020) <u>https://doi.org/10.1093/icesjms/fsaa054</u>
 - initial simulation testing of rfb-rule
 - performance linked to life-history
- Fischer et al. (2021) <u>https://doi.org/10.1093/icesjms/fsab018</u>
 - application of genetic algorithm

efas

- improve performance
- Fischer et al. (in revision)
 - risk considerations

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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ICES Journal of Marine Science (2020), 77(5), 1914–1926. doi:10.1093/icesjms/fsaa054

Original Article

Linking the performance of a data-limited empirical catch rule to life-history traits

Simon H. Fischer 💿 ^{1,2}*, José A. A. De Oliveira¹, and Laurence T. Kell²





ICES Journal of Marine Science (2021), doi:10.1093/icesjms/fsab018

Using a genetic algorithm to optimize a data-limited catch rule

Simon H. Fischer 💿 ^{1,2}*, José A. A. De Oliveira¹, John D. Mumford², and Laurence T. Kell 💿 ²

Manuscripts submitted to ICES Journal of Marine Science



Application of explicit precautionary principles in datalimited fisheries management

Impact (II): Policy

- ICES provides advice
- guidelines are being revised
- rfb rule applied to first stock in 2021 (plaice in division 7.h-k)
 - catch advice for 2022
 - more to follow next year



ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 114 tonnes.





Thank you for listening

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