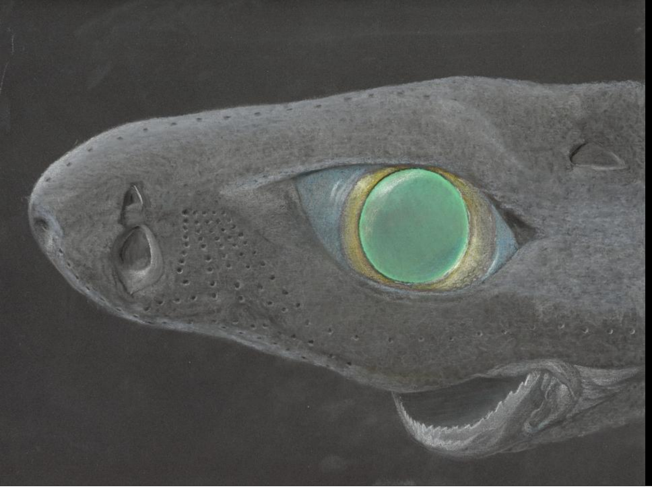

A population dynamics model for a deepsea lantern shark of the NE Atlantic: An application with incorporated parameter uncertainties

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Introduction

- Deepsea shark are amongst the less resilient elasmobranch groups, and in general show high risks of population declines.
- In Portuguese waters, relatively large quantities of deepsea velvet belly lantern sharks, *Etmopterus spinax*, are commonly captured as bycatch in trawl fisheries. They have no commercial value and are discarded.
- Demographic analysis, based mainly on life history parameters, seems to be a good approach to analyze the population dynamics of data-poor species, such as the case of most deepsea elasmobranchs.

Objectives

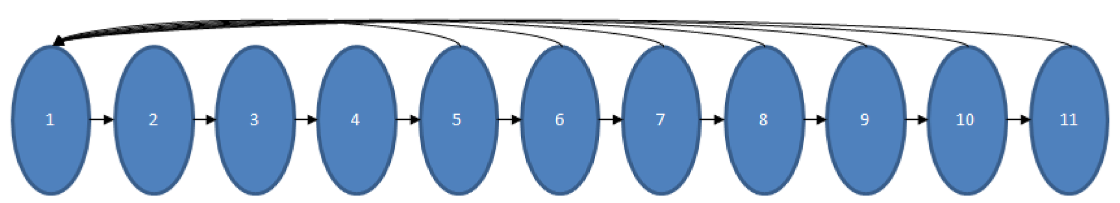
- 1) Develop age-specific demographic models;
- 2) Consider different scenarios in terms of survivorship and life history parameters;
- 3) Evaluate the effects of introducing uncertainty in the analysis.

$$\vec{N}(t+1) = A\vec{N}(t)$$

Methods

- Life history parameters were collected from the literature.
- Mortality was estimated based on empirical equations and with an age-specific catch-curve analysis.
- Demographic analysis was computed with **age-specific Leslie matrices**, for the female part of the population.
- Uncertainty was incorporated by **Monte Carlo simulations**, adding random errors to the parameters.

Age-structured model for analyzing the demography of Etmopterus spinax in the NE Atlantic. Each circle represents one age class, the arrows moving to the right represent survivorship between age classes, and starting at age 5 (age at first maturity) the fertility is represented by the arrows moving to the left.



*Scenarios considered in the study, with varying underlying assumptions for the age-specific survivorship and fecundity estimates. **Deterministic scenarios** used the point estimates while **stochastic scenarios** used random errors based on known distributions. For the reproduction parameters the method used was an age-specific fecundity regression. The uncertainty regarding the periodicity of the reproductive cycle (2 vs. 3 year cycles) was also considered.*

Type	Scenario	Survivorship		Reproduction	
		Method	Parameter	Cycle (years)	Parameter
Deterministic	1	Empirical	Max	2	Point est
	2	Empirical	Min	2	Point est
	3	Empirical	Max	3	Point est
	4	Empirical	Min	3	Point est
	5	Catch curve	Point est	2	Point est
	6	Catch curve	Point est	3	Point est
Stochastic	7	Empirical	Random (Unif.)	2	Random (Normal)
	8	Empirical	Random (Unif.)	3	Random (Normal)
	9	Catch curve	Random (Normal)	2	Random (Normal)
	10	Catch curve	Random (Normal)	3	Random (Normal)

Conclusions

- Considering natural mortalities from empirical equations, λ tended to be > 1 even when uncertainty was incorporated.
- Considering mortality from trawl catch-curves, λ values tended to be < 1 suggesting declining populations.
- Elasticities were higher in the survivorship of the juvenile ages, and low in the fecundity parameters.
- Even though it is a small sized shark, *E. spinax* shows population dynamics trends typical of the larger and more vulnerable species.
- For conservation purposes, priority should be given to reduce **mortality in the juveniles**.

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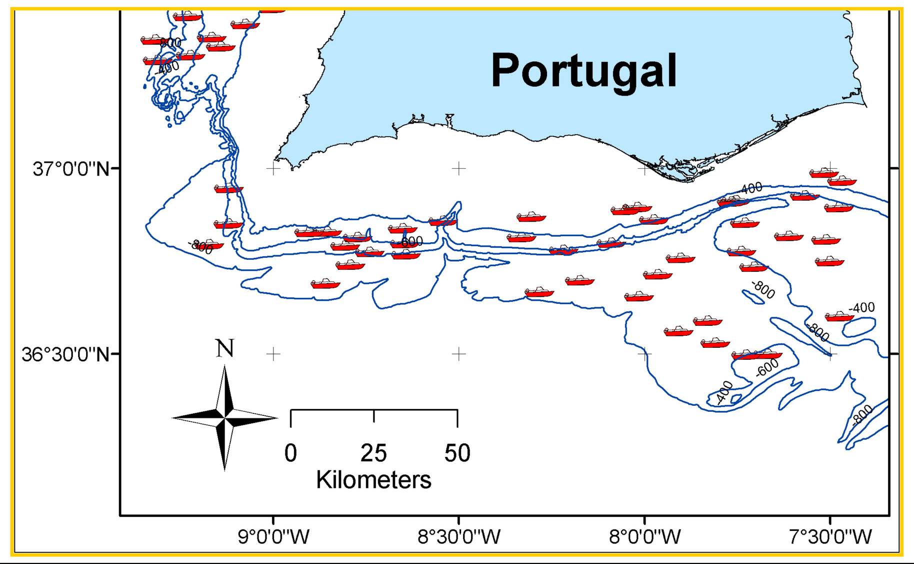
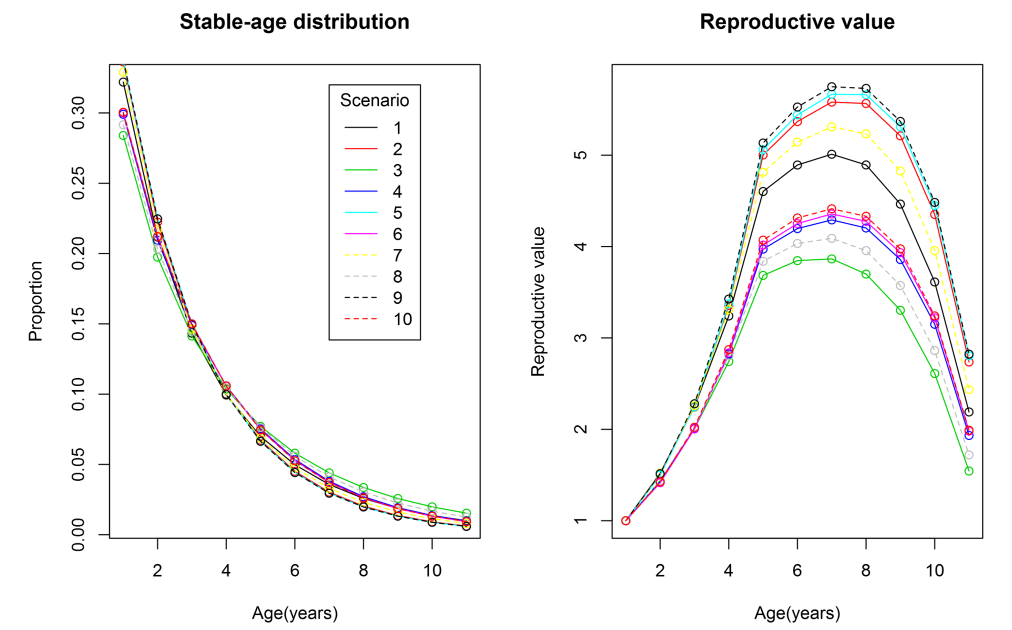


Results

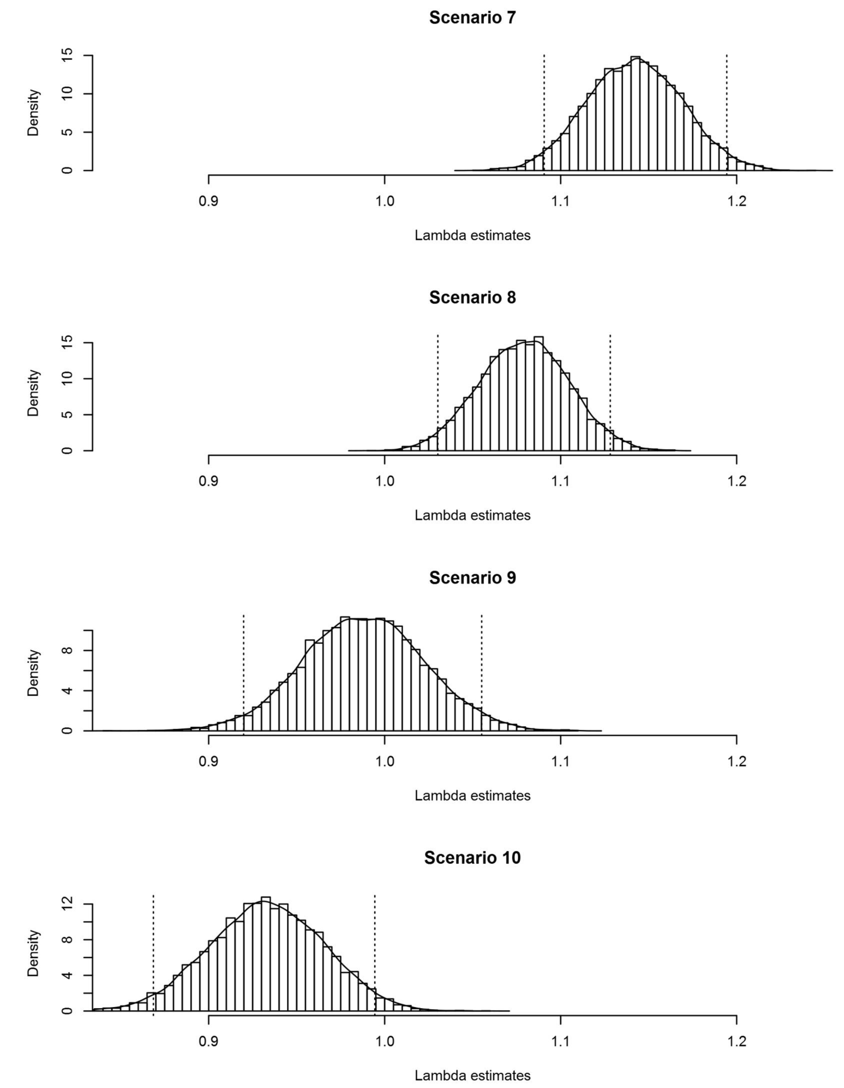
Estimated rates of finite population increase (λ) for Etmopterus spinax in the NE Atlantic, considering the different scenarios analyzed.

Scenario	Lambda			Model assumptions
	Est.	95% CI		
1	1.27	-	-	2 year cycle, max empirical survivorship
2	1.02	-	-	2 year cycle, min empirical survivorship
3	1.20	-	-	3 year cycle, max empirical survivorship
4	0.96	-	-	3 year cycle, min empirical survivorship
5	0.99	-	-	2 year cycle, catch-curve survivorship
6	0.94	-	-	3 year cycle, catch-curve survivorship
7	1.14	1.09	1.16	2 year cycle, random empirical survivorship
8	1.08	1.03	1.13	3 year cycle, random empirical survivorship
9	0.99	0.92	1.06	2 year cycle, random survivorship from catch curve
10	0.93	0.87	0.99	3 year cycle, random survivorship from catch curve

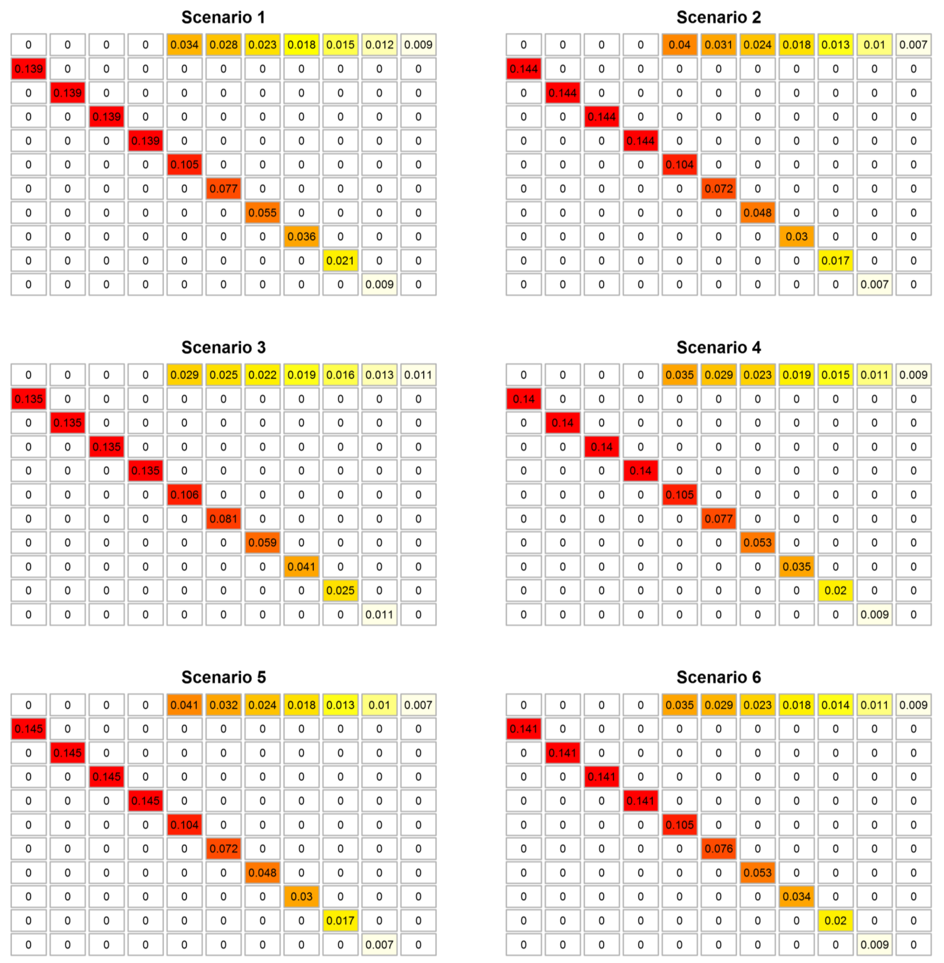
Stable age (w) and reproductive value (v) distributions of the Etmopterus spinax age classes, considering the various scenarios analyzed.



Estimates of λ (finite rate of population increase) in the stochastic demographic scenarios that include uncertainty in the input parameters. Each model was run 10,000 times by Monte Carlo simulation.



Matrix elasticities (referring to fecundities and survivorship) for each of the deterministic scenarios considered



$$e(x) = x\frac{\partial\lambda}{\partial x} = \frac{x}{\lambda}\sum_{i,j}\frac{\partial\lambda}{\partial a_{ij}}\frac{\partial a_{ij}}{\partial x}$$