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Modelling effects of temperature and oxygen on the population dynamics of the European sturgeon using Dynamic Energy Budget theory

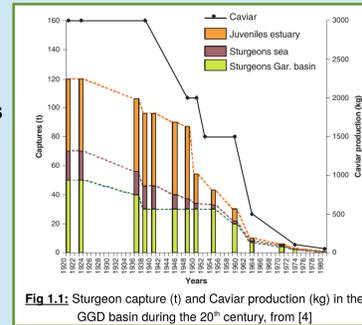
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1) Introduction:

Context:

- *Acipenser sturio*: Critically Endangered species (IUCN [1])
- Dramatic collapse of the population (Fig 1.1): overfishing & loss of habitats [2]
- Last known wild reproduction in the Gironde-Garonne-Dordogne (GGD) basin: 1994 [3]



- Reintroduction: captive stock since 1994, first assisted reproduction & release in 1995, regularly since 2007
- High anthropogenic pressure on first development stages in the GGD basin: pollutants, hypoxic events, high temperature events

→ Survival of the first development stages is fundamental

Focusing on the juvenile stage: the SturTOP project

- 1) - Assessing habitat quality for first development stages
- 2) - Assessing vulnerability of embryos and larvae to pollution, hypoxia and temperature rise
- 3) - Studying survival conditions of the juveniles released into the wild
- 4) - Assessing relationships between habitat quality, contamination level and juvenile health
- 5) - Analysing risks at population scale in the GGD basin by modelling approach (Work began on January 2016)

A multi-scale approach:

→ Investigating effects of temperature & oxygen at individual scale: development of a standard DEB (Dynamic Energy Budget) model

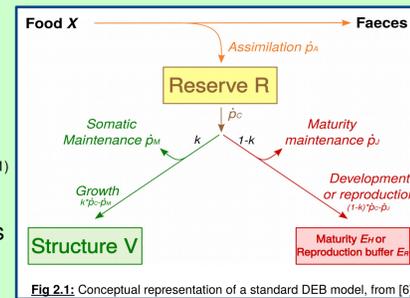
→ Investigating effects of temperature & oxygen at population scale: implementation of the standard DEB model in a spatially explicit IBM of the GGD basin

2) Methods:

Dynamic Energy Budget Theory [5]:

- A generic tool to investigate metabolism at the individual scale: more than 300 species modelled
- A 10-hypotheses-based general pattern of energy acquisition & use: standard model (Fig 2.1)
- A "constrained" modularity: adding reserves and/or structures and/or toxicological modules

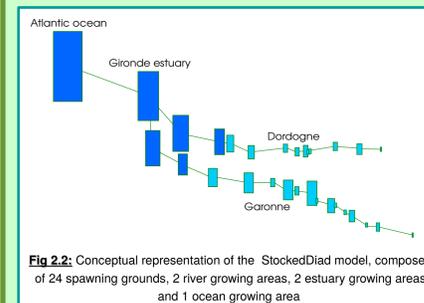
→ Increasing use in theoretical and applied research topics



Building the individual model:

- Parametrisation of a standard DEB model for *Acipenser sturio* with the covariation method [7]: minimisation of weighted sum of squared deviations between data sets and model predictions
- Data sets:
 - 1) Observations from literature: maximum reproduction rate ; age, length & weight at specific moments of life-cycle (birth, hatching, death) for different temperatures
 - 2) Long-term observations of length and weight of selected individuals from a captive stock: selection based on (i) availability of temperature history ; (ii) good health of individuals
- Implementing a module for hypoxia effects based on data from SturTOP project [8]

IBM approach:



- IBMs are built on assumptions at individual scale, but highlight emerging properties at population scale [9]
- The StockedDiad Model (Fig 2.2) [10]: spatially explicit model of the GGD basin
- It integrates information collected during the SturTOP project on habitat quality

→ Testing different release strategies: age and location

3) Results:

Standard DEB model outputs:

- Observations at specific moments of life-cycle are well reproduced (Table 3.1)
- Modelled length and weight of individuals from the captive stock are in accordance with data (Fig 3.1)

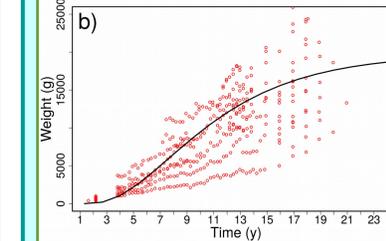
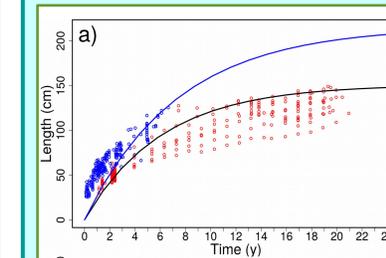


Fig 3.1: a) Modelled length (black line) versus data from the captive stock (red points) and wild stock (blue). b) Modelled weight (black line) versus data from the captive stock (red points)

Table 3.1: Literature and modelled observations at specific moments of the life-cycle. * data not used in parametrisation

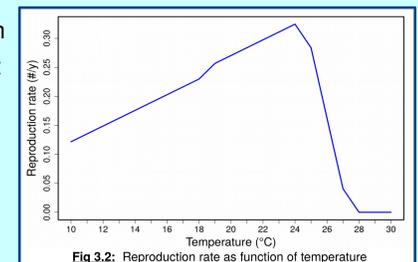
Observations	Ref. Value	Modelled
Age at hatching (d) - 12°C	10.61	10.56
Age at hatching (d) - 16°C	7.31	8.52
Age at hatching (d) - 20°C	6.58	6.91
Age at hatching (d) - 23°C	5.84	5.92
Age at birth (d) - 18°C	16	10.36
Age at puberty* (y) - 18°C	11	8.1
Age at death (y) - 18°C	80	78.9
Length at hatching (cm) - 20°C	0.93	1.17
Length at birth (cm) - 18°C	1.65	1.46
Length at puberty* (cm) - 18°C	120	153
Maximum length (cm)	215	215.7
Weight at hatching (g) - 20°C	0.023	0.012
Weight at birth (g) - 18°C	0.031	0.023
Weight at puberty* (g) - 18°C	12960	25700
Maximum weight (g)	69569	71910
Max.reproduction rate (#/d) - 18°C	433.5	450.1

- Captive individuals are smaller than individuals from the wild:
 - (i) Food quality (blue curve on Fig 3.1) ?
 - (ii) Stressor?
 - (iii) Age estimation accuracy of wild individuals?

→ Individual model accurately reproduces the life-cycle of *Acipenser sturio*

Effect of temperature on reproduction:

- Reproduction occurs when energy invested in reproduction (E_R) reaches a density dependent threshold
- Simulated temperature is constant during the whole life-cycle
- Reproduction interval is between 3 and 6 years depending on temperature (Fig. 3.2)



4) Next steps:

- Integrating a module to model hypoxia effects (see Thomas *et al.* Oral presentation nb: O3.17)
- Implementing the standard DEB model with the model of the GGD basin

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