FISHERIES RESEARCH SERVICES

Investigating the mechanisms underlying ecosystem structure –

a multi-species, size-structured model of the North Sea demersal fish assemblage

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presented by

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RECLAIM

General background

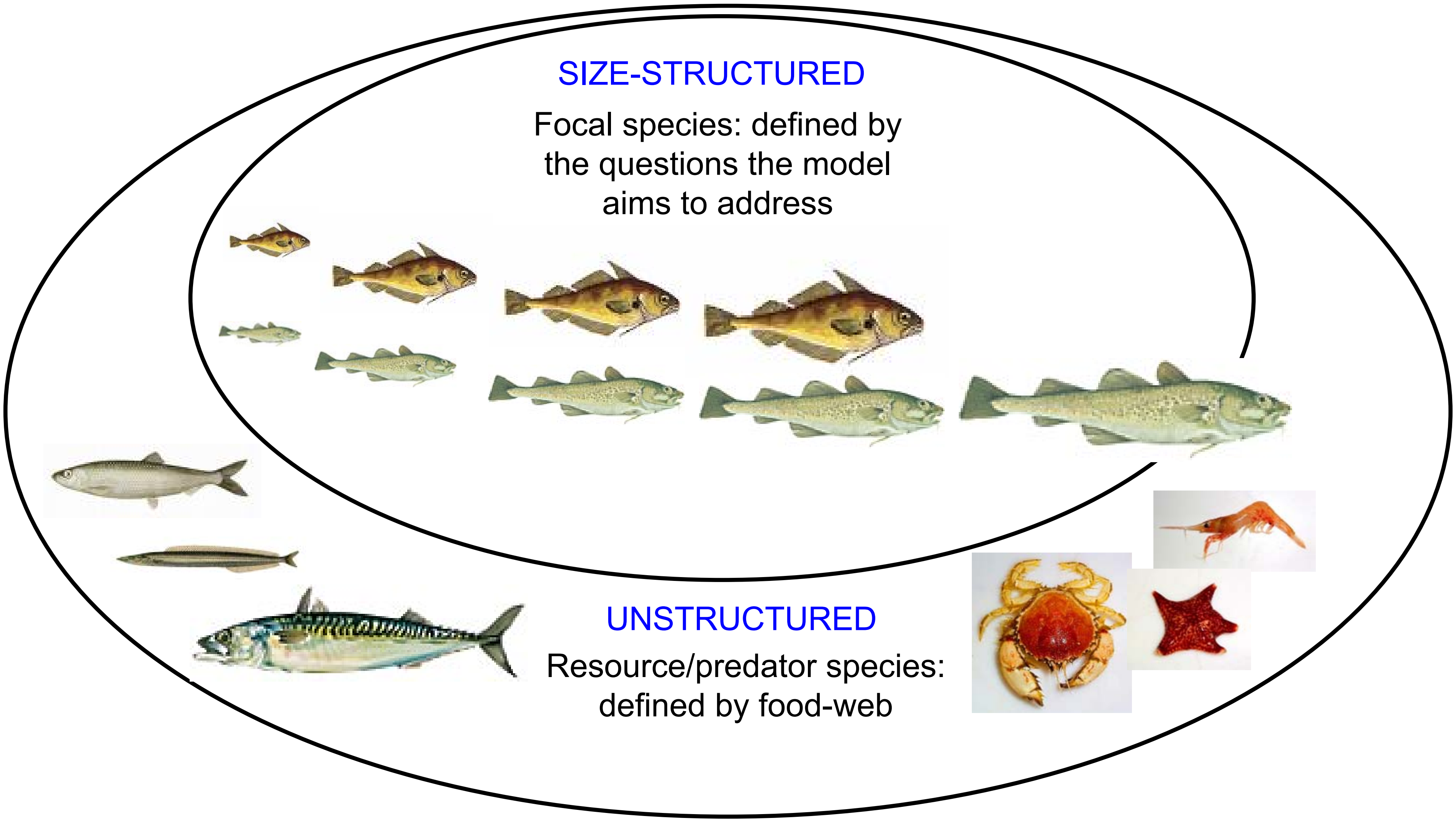
- Why: to investigate effects of fishing(*) on species diversity and community structure.
- How: size-based model of the North Sea demersal fish assemblage
- When: work in progress – no results yet

(*) Time-dependent forcing (e.g. to represent environmental variability) can also be introduced

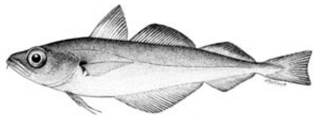
Methodology outline

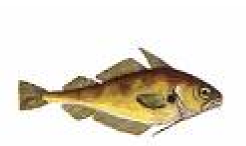
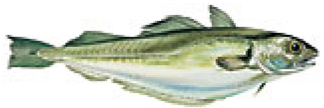
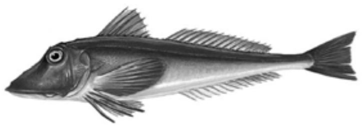
- “Rhomboidal” approach (deYoung *et al.*, 2004):
  - maximum detail for the *focal* species
  - increasing simplifications/decreasing resolution away from the trophic scale of the focal spp.

Methodology outline



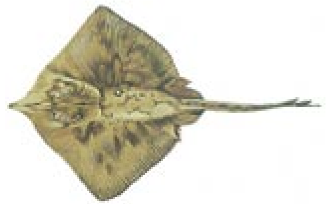
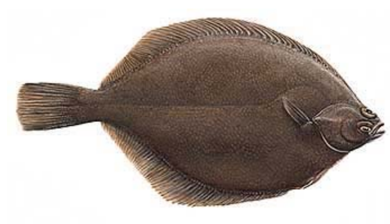
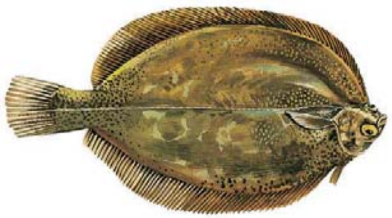
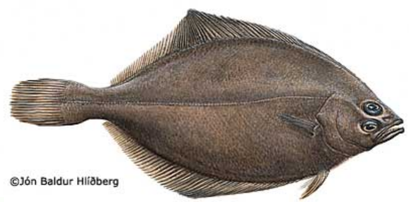
Focal species

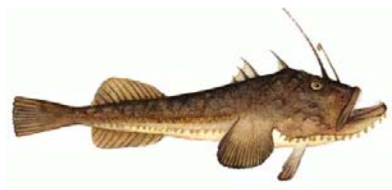


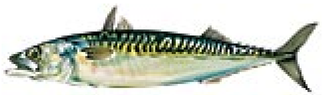

SIZE-STRUCTURED:

- Norway pout
- Haddock
- Saithe
- Plaice
- Common dab
- Starry ray
- Poor cod
- Whiting
- Cod
- Grey gurnard
- Lemon sole
- Long-rough dab
- Ling
- Angler fish
- Hake
- etc.



Non-focal (unstructured) components



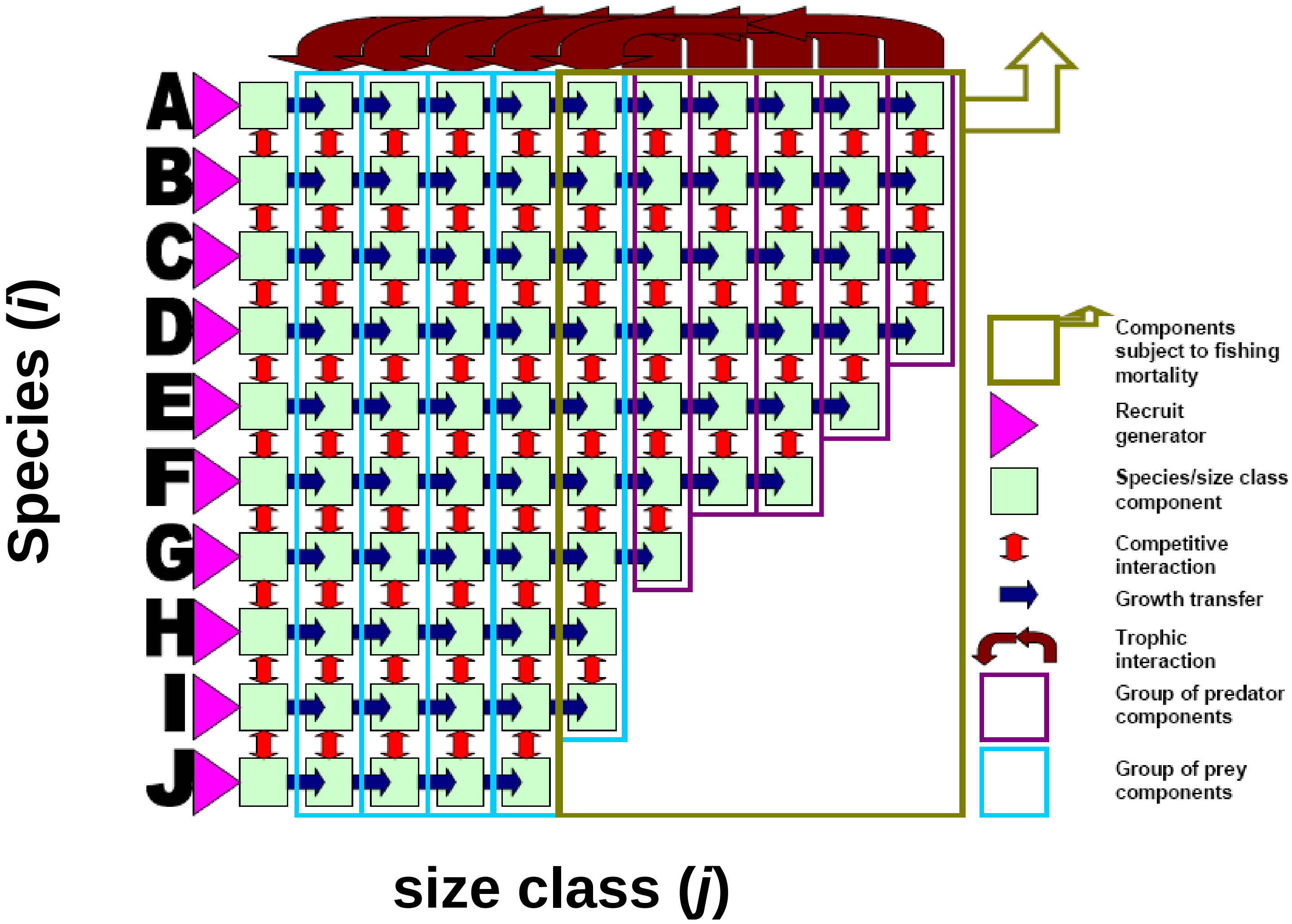
UNSTRUCTURED:

- Other demersal and pelagic fish, e.g. sprat, sandeel, herring, gobies, mackerel.
- Zooplankton, e.g. copepods, mysids, amphipods.
- Zoobenthos, e.g. crabs, echinoderms, bivalve molluscs, polychaetes.

Model dynamically as unstructured populations

Model dynamically as communities of unstructured populations

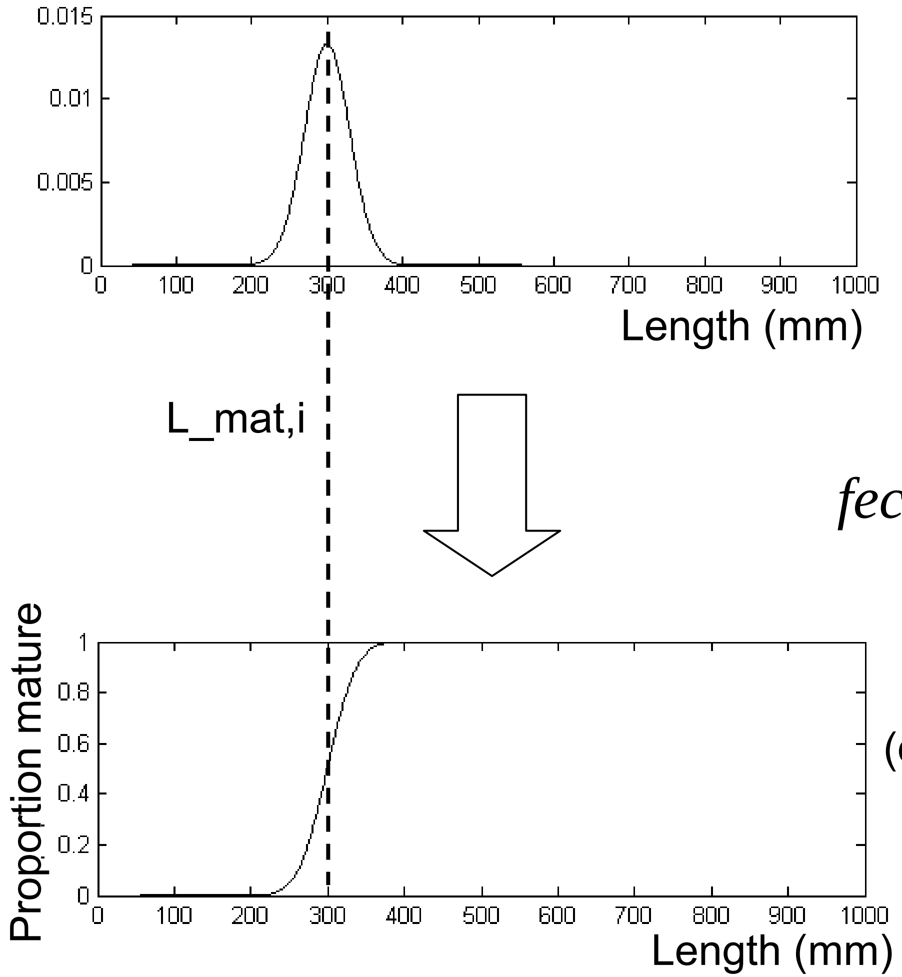
Size-structured components



Size-structured – basic setup

Number of individuals of species i and size class j	=	**Recruits** of species i	for j=1
		Surviving individuals of species i **growing** from size-class (j-1) + **surviving** individuals **remaining** in size-class j	for j>1

Size-structured - RECRUITMENT



Total egg production
E(i) =

$$\sum_j fec_{i,j} \times n_{i,j}$$

where

$$fec(i, j) = p_{mat} \times 0.5 \times w(i, j) \times \mathrm{fec}_{\mathrm{const}} \times \frac{dt}{365}$$

sex ratio

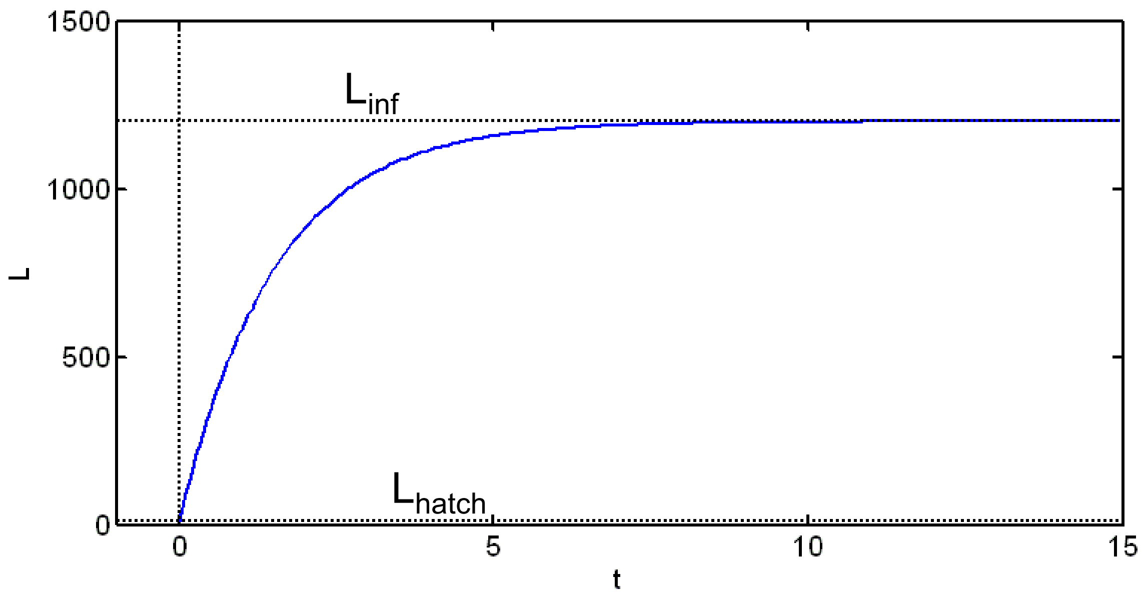
weight

eggs ♀$^{-1}$g^{-1}

(derived from normally distributed spread in maturation lengths)

Size-structured - GROWTH

von Bertalanffy growth



Requires: grow rate λ and lengths L_{hatch} and L_{inf} for each species *i*.

incorporating **growth variability**

$$\frac{\mathrm{dL}}{\mathrm{dt}} = \begin{cases} \lambda(L_{\mathrm{inf}} - L) & \textit{probability} \quad p_{ij} \\ 0 & \textit{probability} \quad (1 - p_{ij}) \end{cases}$$

At each timestep, only a proportion p_{ij} of individuals meet food requirements for growth to next development class – proportion varies with *i*, *j*.

Size-structured – FEEDING (predation)

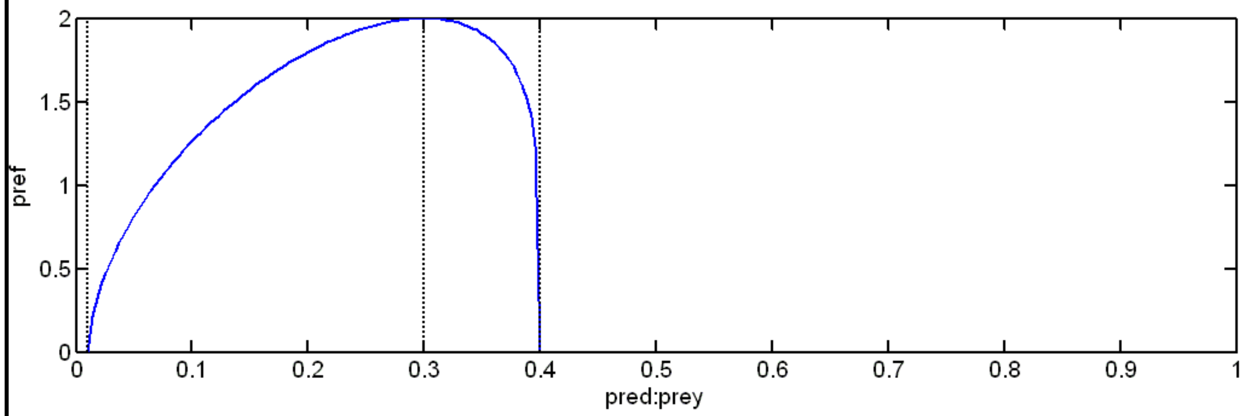
For each predator (i,j), define suitability and preference for prey item (i',j'):

$$\xi_{iji'j'} = \mathrm{suit}_{ii'} \times \mathrm{pref}_{\mathrm{ix}}$$

Suitability: does species i eat species i' at all (any size-classes)?

$$\mathrm{suit}_{ii'} = \begin{cases} 1 & \text{if} \quad \text{yes} \\ 0 & \text{if} \quad \text{no} \end{cases}$$

Preference weighting: for predator species i [and size class j, and prey i' in size class j'] normalised predator:prey length ratio x)

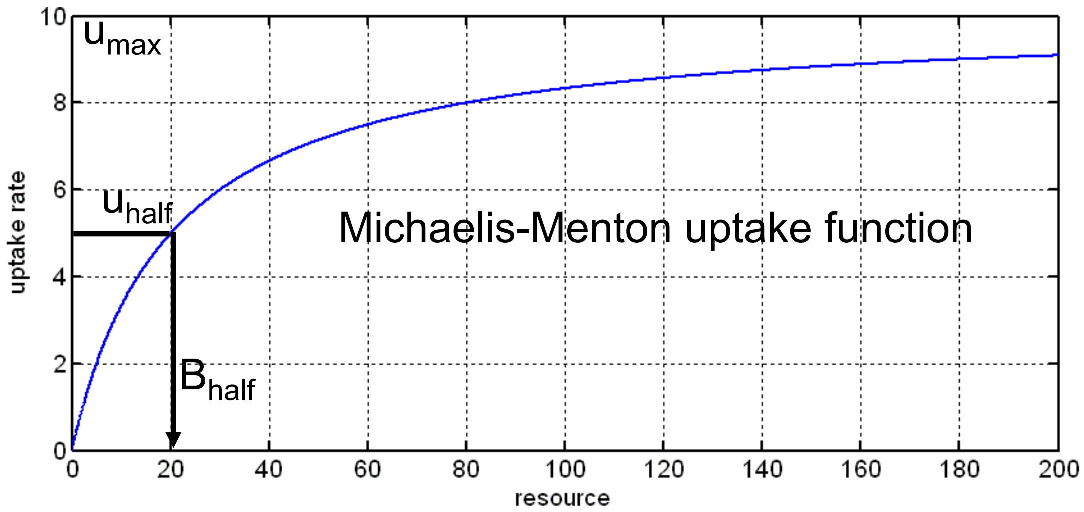


Requires estimates of min, max and opt pred:prey.

Size-structured – FEEDING (uptake)

Total uptake of food by species/stage {i,j} as a function (type II functional response) of total prey availability (B).

$$u(i,j) = \frac{u_{\max} \times B}{B_{\mathrm{half}} + B}$$



Apportioned between prey species/stages {i',j'} according to prey biomass (B) and preference weightings ($\xi_{ij\ i'j'}$):

uptake of prey species {i',j'} by predator {i,j}: u(i,j,i',j')	=	$\dfrac{\text{Maximum uptake} \times \text{pref. weighting} \times \text{biomass of } \{i',j'\}}{\text{Half sat. biomass} + \text{biomass of all pref. weighted prey}}$

Size-structured – population (n_{ij}) evolution

Number of individuals of species i and size class j	=	Recruits of species i	for j=1
		Individuals of species i surviving and growing from size-class (j-1) + individuals surviving and remaining in size-class j	for j>1

$$n_{i,j} = \begin{cases} R_{i,j} & j = 1 \\ (1-p(i))s(i,j)n(i,j) + p(i)s(i,j-1)n(i,j-1) & j > 1 \end{cases}$$

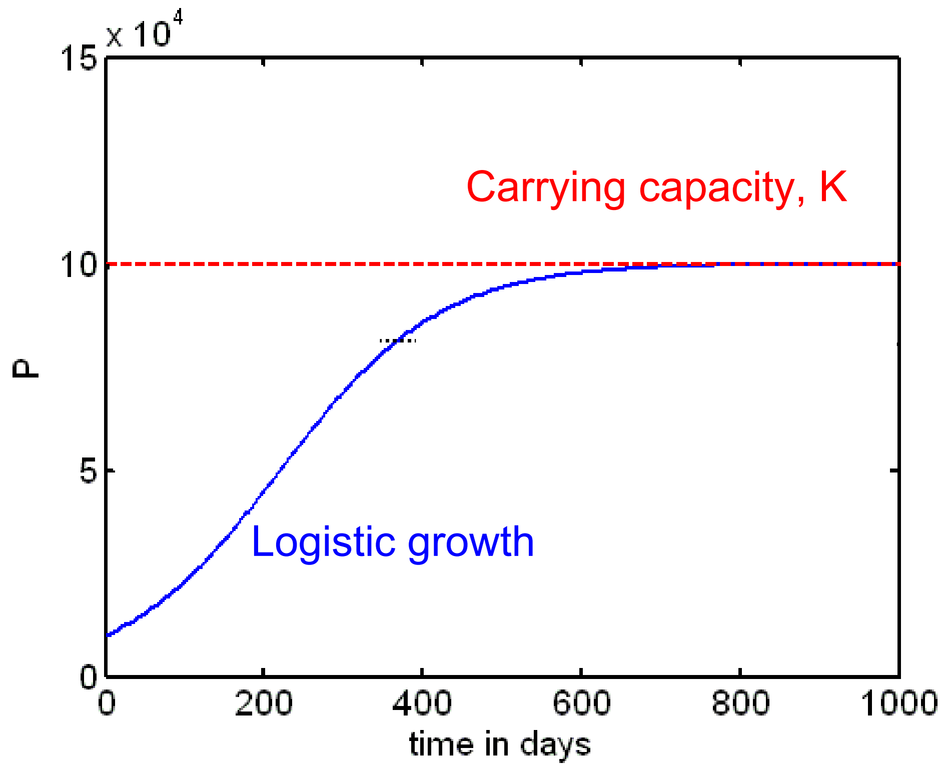
fraction p(i) of growers Φ(i,j-1) surviving s(i,j-1) from class j-1

fraction (1-p(i)) of non-growers Φ(i,j) surviving s(i,j) in class j

$$\Phi(i,j) = \frac{u(i,j)}{u_{\max}(i,j)}$$

s(i,j) = $e^{-\mu.dt}$

Unstructured populations (1)



OTHER DEMERSAL AND PELAGIC FISH

Mainly small prey species, e.g. sprat, sandeel.

Modelled as population of individuals of fixed length-class and weight W.

Population growth (e.g. logistic growth) modified by predation (f(P)) by other species:

$$\frac{dP}{dt} = rP\left(1 - \frac{P}{K}\right) - f(P)$$

$$\text{Predation rate on species (i',j')} = \frac{\text{Total uptake of species \{i',j'\} by all predators}}{\text{Biomass of species \{i',j'\}}}$$

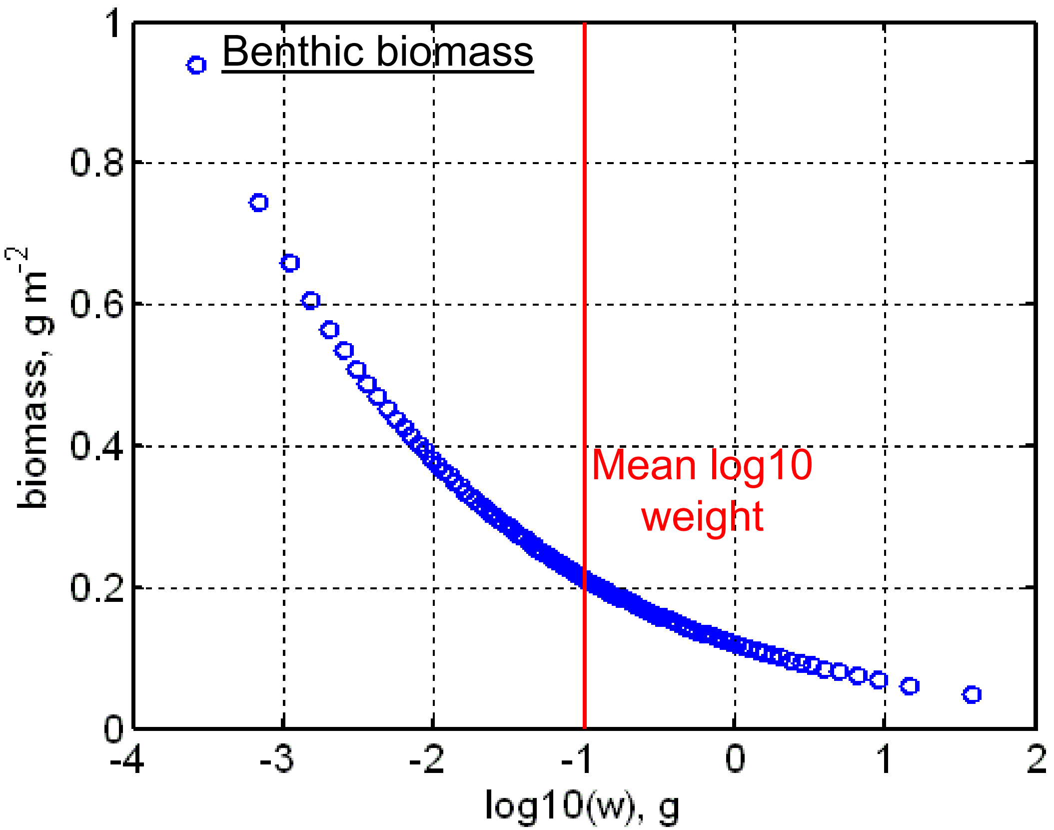
Unstructured populations (2)

BENTHOS AND ZOOPLANKTON - essential food for demersal fish.

Modelled dynamically (= resource for structured species) as size-structured (biomass spectrum) community of unstructured "pseudo-species", to distribute available biomass appropriately across lengths classes.

Each "pseudo-species" modelled as unstructured resource with particular weight, carrying capacity (K) and growth rate (r).

$$\frac{dP}{dt} = rP\left(1 - \frac{P}{K}\right) - f(P)$$



Fishing and environmental variability

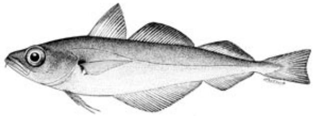
- **Fishing will be implemented as another mortality term for each species *i* and stage *j***

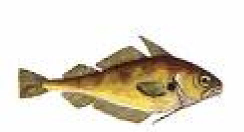
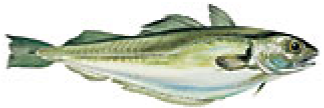
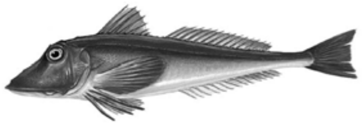
$$s(i,j) = e^{-(\mu+F)dt}$$

- **Time-dependent environmental forcing to be implemented as influencing**
  - **growth rates**
  - **carrying capacity, etc.**

Space

- **Current version not spatially explicit**
- **Spatial resolution *can* be implemented**
  - Additional difficulties, e.g.
    - Data availability at the right resolution
    - Interactions between spatial units (e.g. migration rates)




Thank you