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Integrated ecological modelling of rivers: opportunities and challenges for a successful marriage between science and policy

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Opportunities

Modelling methods:

- Integration of hydrological and ecological models
- Integration of knowledge-based and data driven approaches
- Model simplification techniques (BBN, CA)

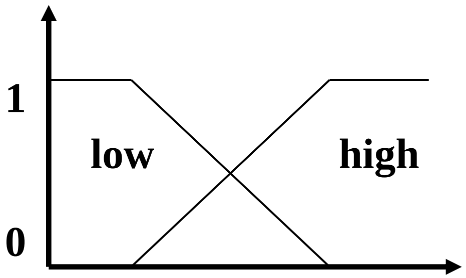
Data:

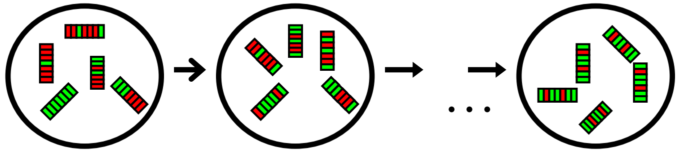
- Data floods…
- New monitoring technologies (sensors, remote sensing)

Policy:

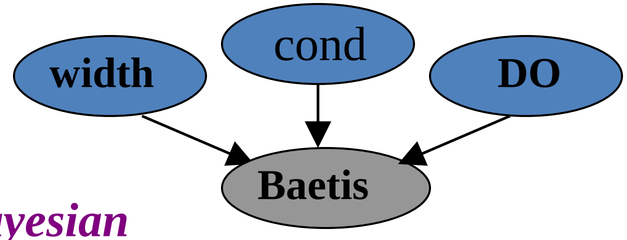
- Managers and policy makers start to gain interest in modelling and simulation

Habitat suitability modelling: diversity of techniques since 2000

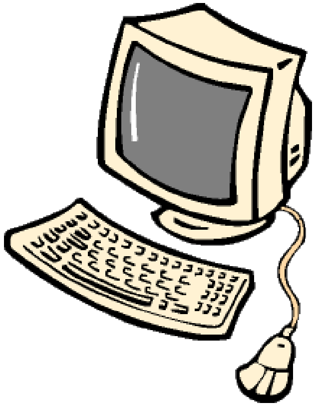




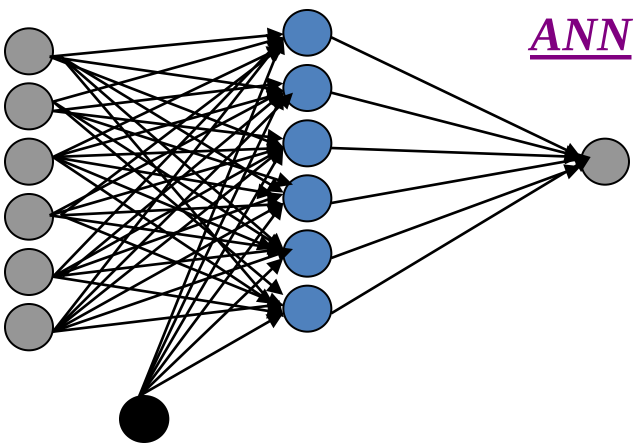
Genetic algorithms



Fuzzy logic

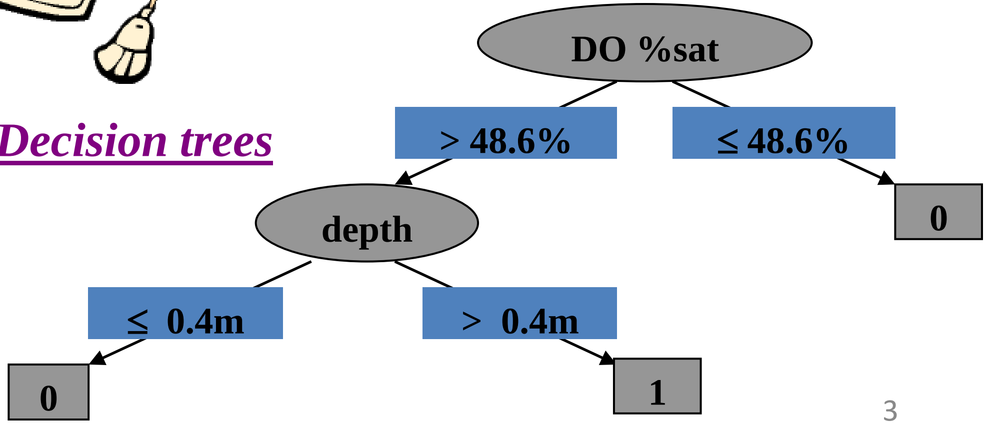


Bayesian Belief Networks



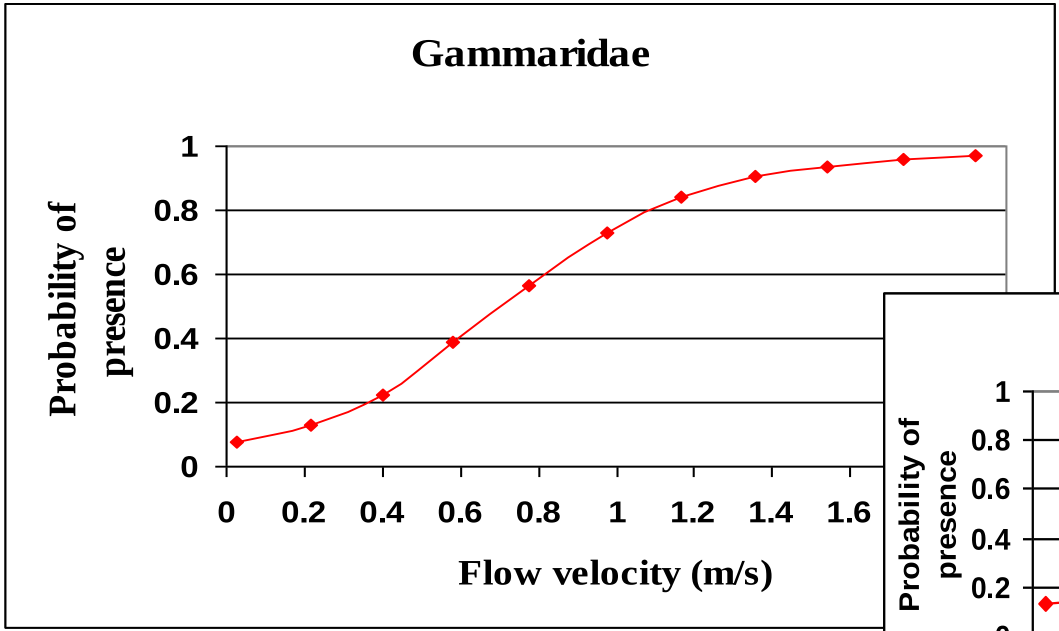
ANN

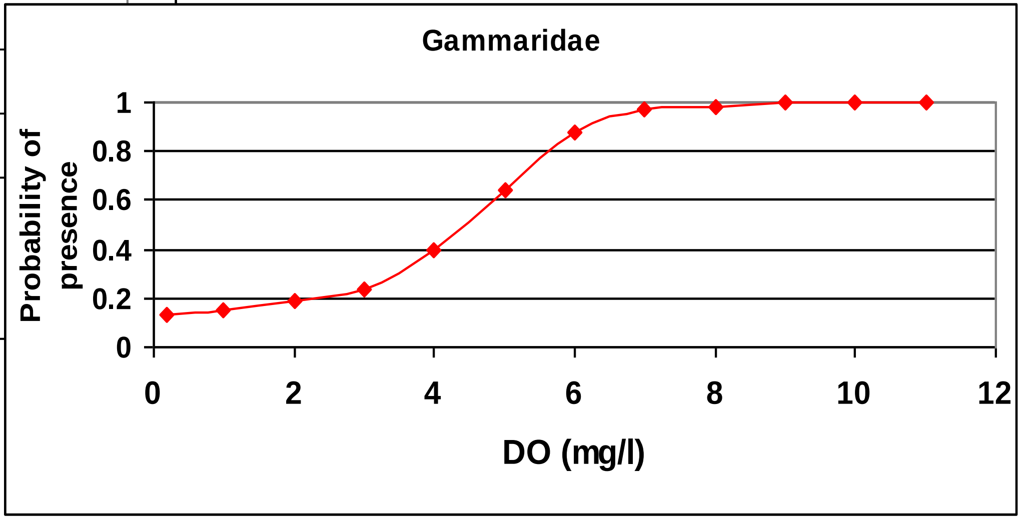
Decision trees



Insights in relations between abiotic and biotic characteristics

Gammaridae (Crustaceans)





Integrated predictions: coupling with water quality models

1. Collecting data by means of sampling campaigns and modeling

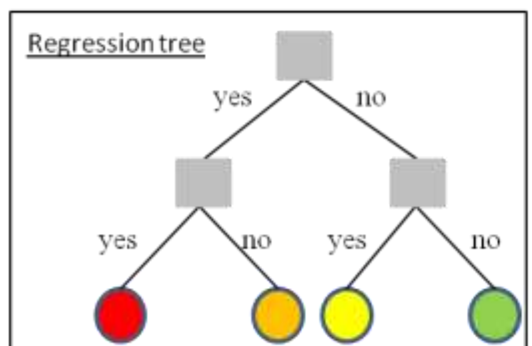
Output: measured dependent and independent variables

Output: modeled independent variables

2. Coupling dependent and independent data following sampling location and date

Sampling Location	Sampling Time	Dependent variable	Independent variables		
Location-code	Year	Score for ecological quality	Physical habitat conditions and physical – chemical variables		
…	…	…	…	…	…

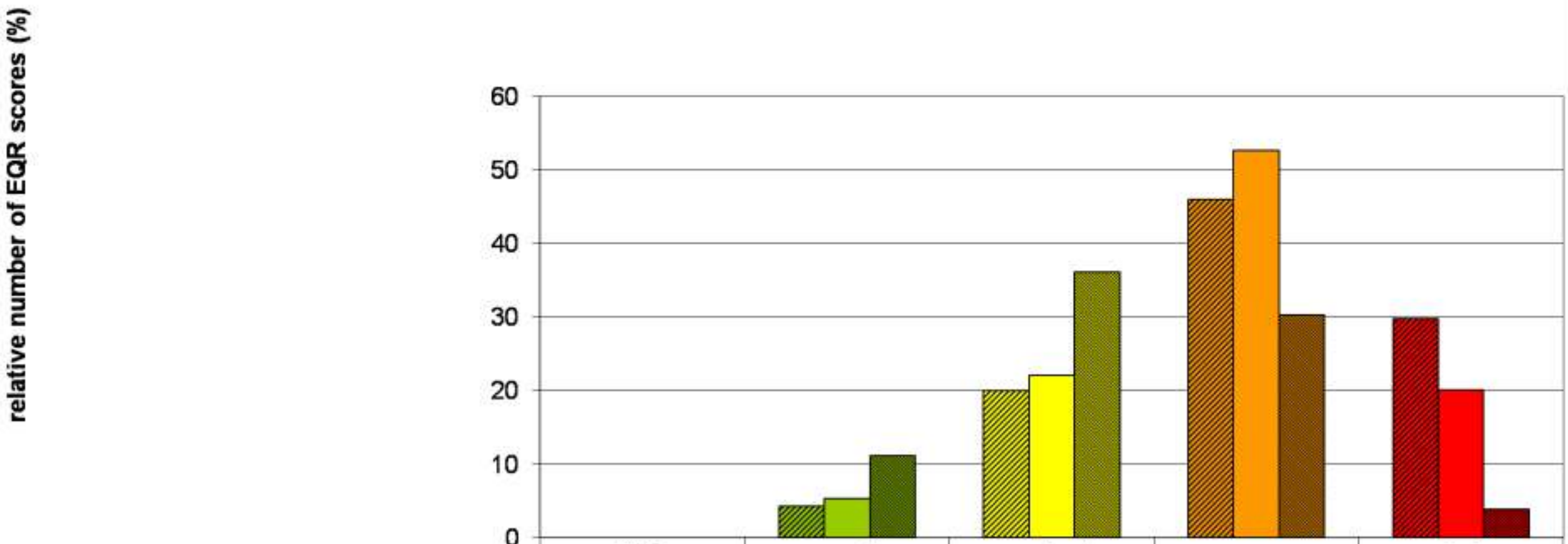
3. Developing regression trees based on the coupled dataset



Dependent variable

Prediction of independent variable

4. Implementation of the regression tree on other independent variables (e.g. water quality variables) to make a prediction about the dependent variable (e.g. the ecological quality)



	high	good	moderate	poor	bad
predictions based on PEGASE output for 2006	0	4	20	46	30
predictions based on PEGASE output for 2015	0	5	22	53	20
predictions based on PEGASE output for 2027	0	11	36	30	4

Classes of Ecological Quality

predictions based on PEGASE output for 2006
predictions based on PEGASE output for 2015
predictions based on PEGASE output for 2027

New needs: multihabitat use and migration

Spatial-explicit and dynamic modelling

Aquatic Ecology (2006) 40:249–261
DOI 10.1007/s10452-005-9022-2

Development of an in-stream migration model for *Gammarus pulex* L. (Crustacea, Amphipoda) as a tool in river restoration management

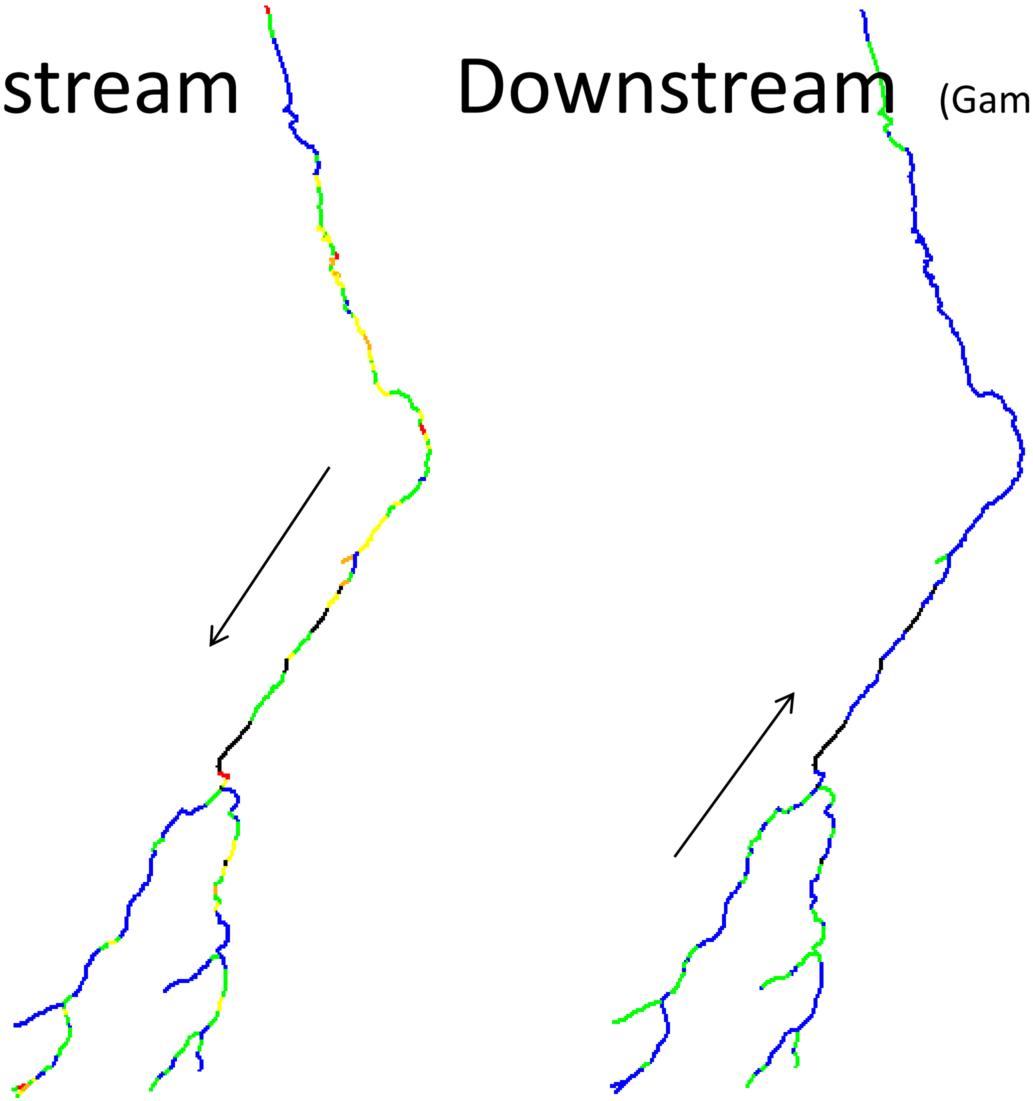
Andy P. Dedecker*, Peter L. M. Goethals, Tom D'heygere and Niels De Pauw

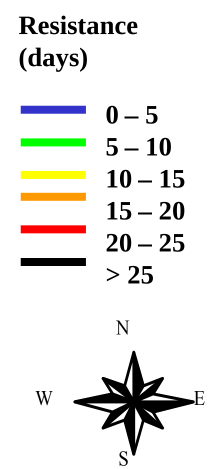
In-stream migration modelling based on electrical circuit analogon

- GIS overlays, calculation of minimal migration time to site of interest
- based on vectors
- migration t = min (migration distance / migration speed)
- with migration speed = 1 / migration resistance

In-stream migration modelling based on electrical circuit analogon

- Upstream Downstream (Gammarus migration)





Extension to air and land via cost-function modelling (ArcGIS)

ECOLOGICAL MODELLING 203 (2007) 72–86

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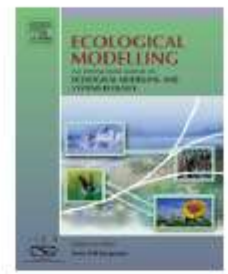
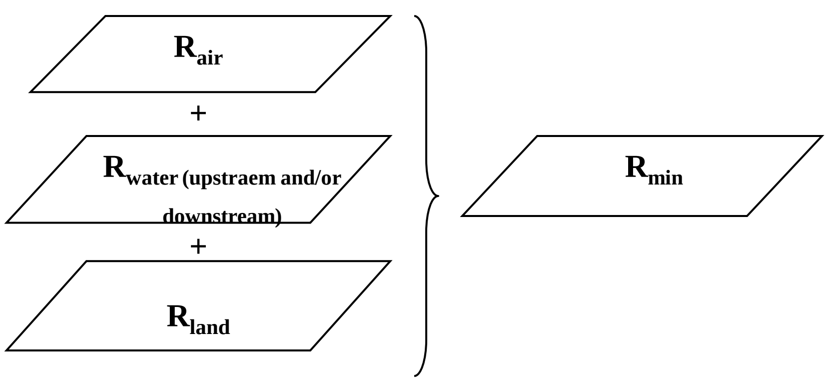


Development of migration models for macroinvertebrates in the Zwalm river basin (Flanders, Belgium) as tools for restoration management

Andy P. Dedecker, Koen Van Melckebeke, Peter L.M. Goethals, Niels De Pauw*

Extension to air and land via cost-function modelling (ArcGIS)

- Minimal time to migrate between two locations based on raster data



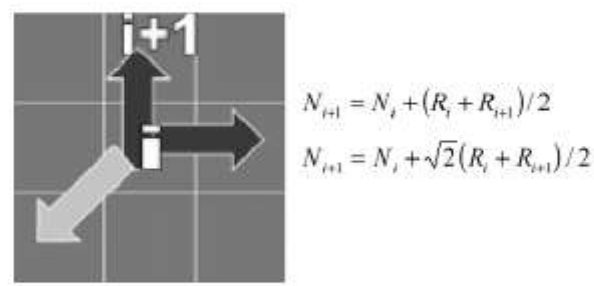
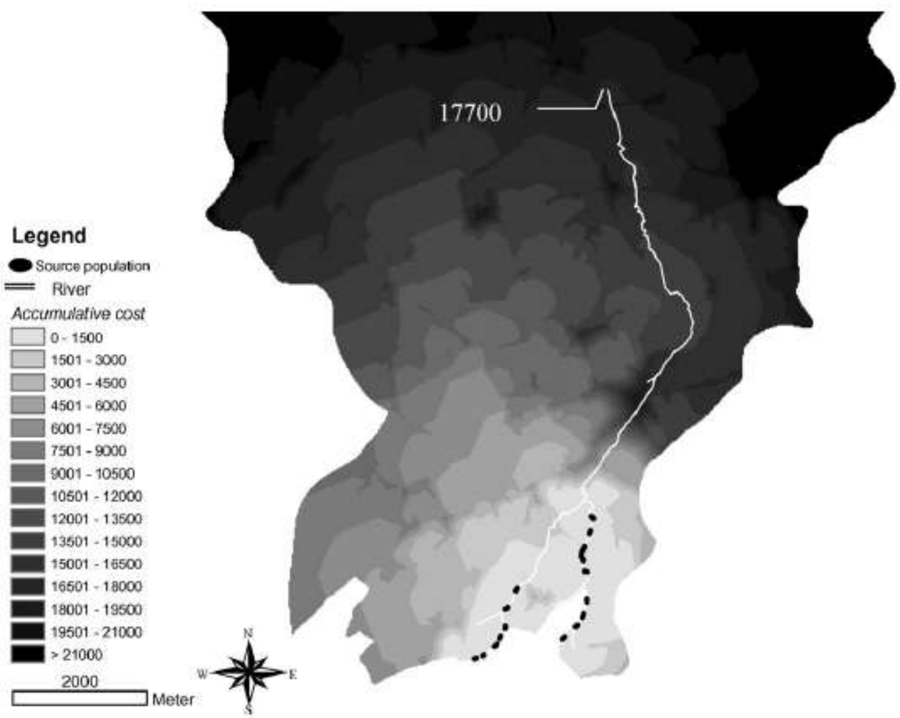


Fig. 4 – The algorithm underlying the Cost Weighted Distance function. i: source cell; i + 1: target cell; N_i: accumulated resistance to reach cell i; R_i: the resistance to migrate through cell i.

Extension to air and land via cost-function modelling (ArcGIS)

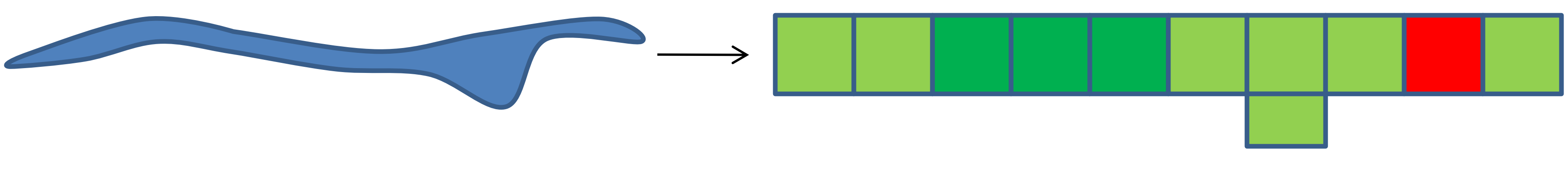


Ephemera

Limnephilidae

Potential of cellular automata to analyse migration potential (and spatial-explicit population changes): Pauwels et al. (submitted)

- Extra insights via inclusion of population dynamics and interspecies processes (competition, predation, foodweb)
- Transparant
- Limited set of rules
- Limited data and information requirements
- Short simulation time



Two examples of CA model use

- Ecosystem interactions and processes + integration between systems (e.g. aquatic-terrestrial cf. Stoneflies)
- Water system functions/services: balanced uses (e.g. Biodiversity versus fisheries/recreation, cf. Pike)

Stoneflies: two very distinct habitats needed during life cycle

- Aquatic stage (larvae)
- Related to stones, high flow velocities and unpolluted water
- Period: October - April

- Terrestrial stage (adults)
- In vegetation along river banks
- Period: May - September

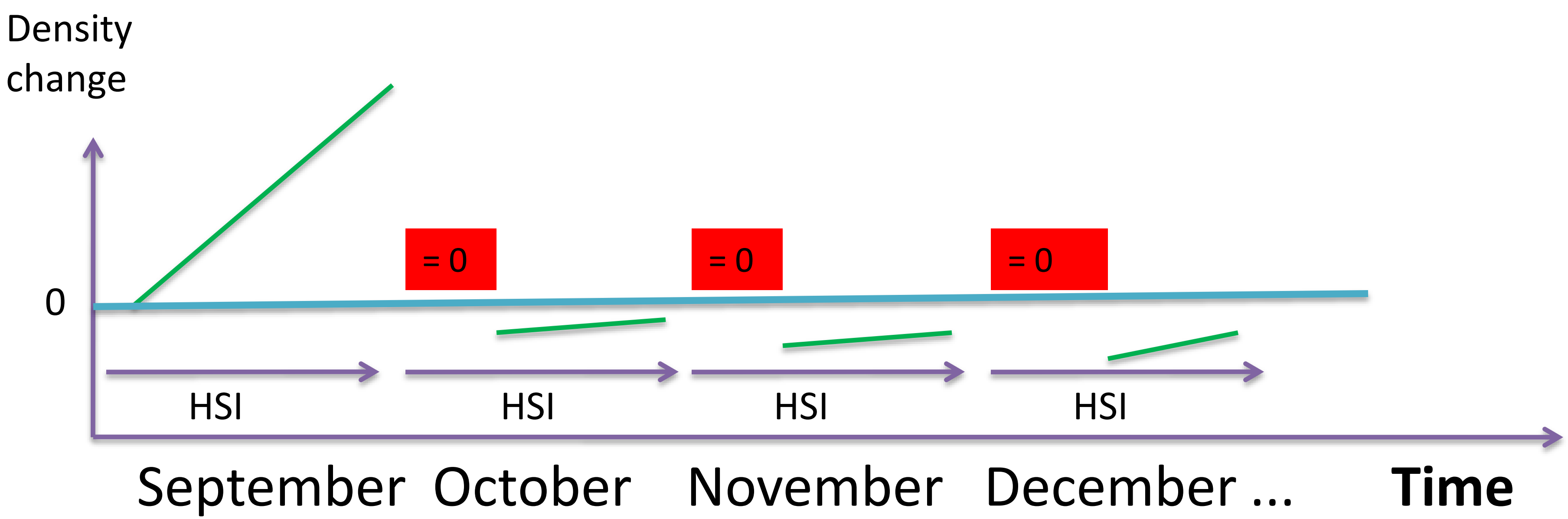
Need for spatial-explicit and dynamic models

- aquatic and terrestrial habitat suitability models development: HSI model based on regression (or knowledge based) method as basis for rules

- RULE 1: Population increase/decrease (reproduction + mortality (+ predation + competition)) = F(t, HSI): time explicit regression line/curve F(HSI)
- RULE 2: Population migration = F (t, HSI cel and neighbouring cells, including resistance factor)

RULE 1: Population increase/decrease

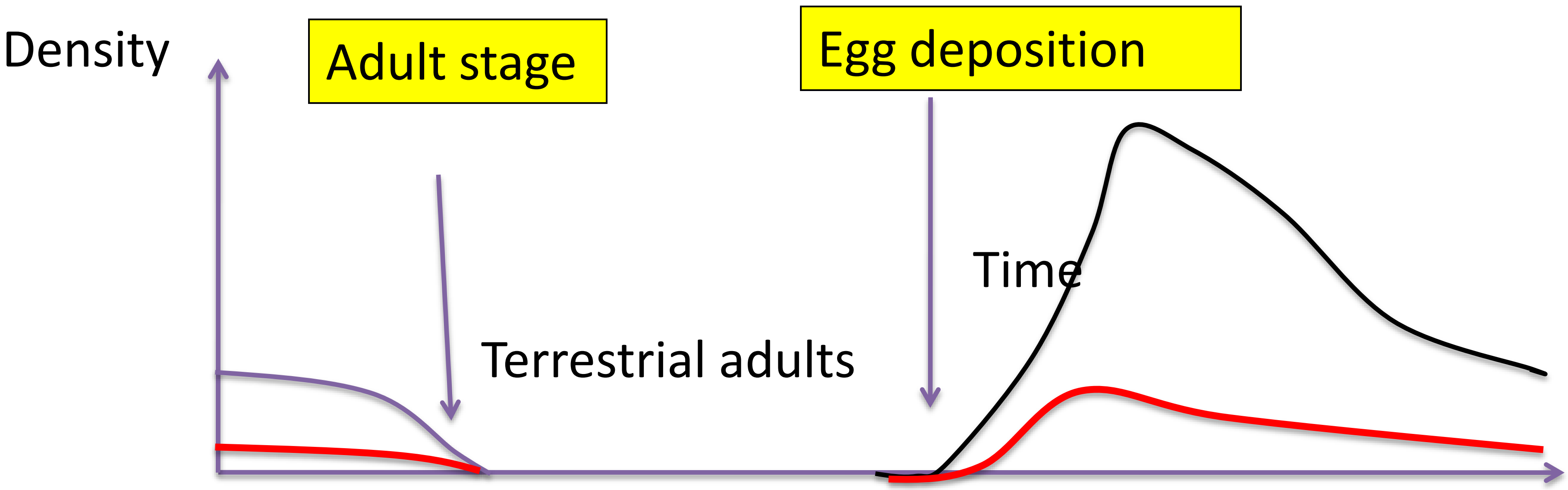
- Result of reproduction + mortality (+ predation + competition))
- F(t, HSI): time explicit regression lines/curves F(HSI)



- Maximum per cell (suppose linear increase to certain maximum density/abundance)

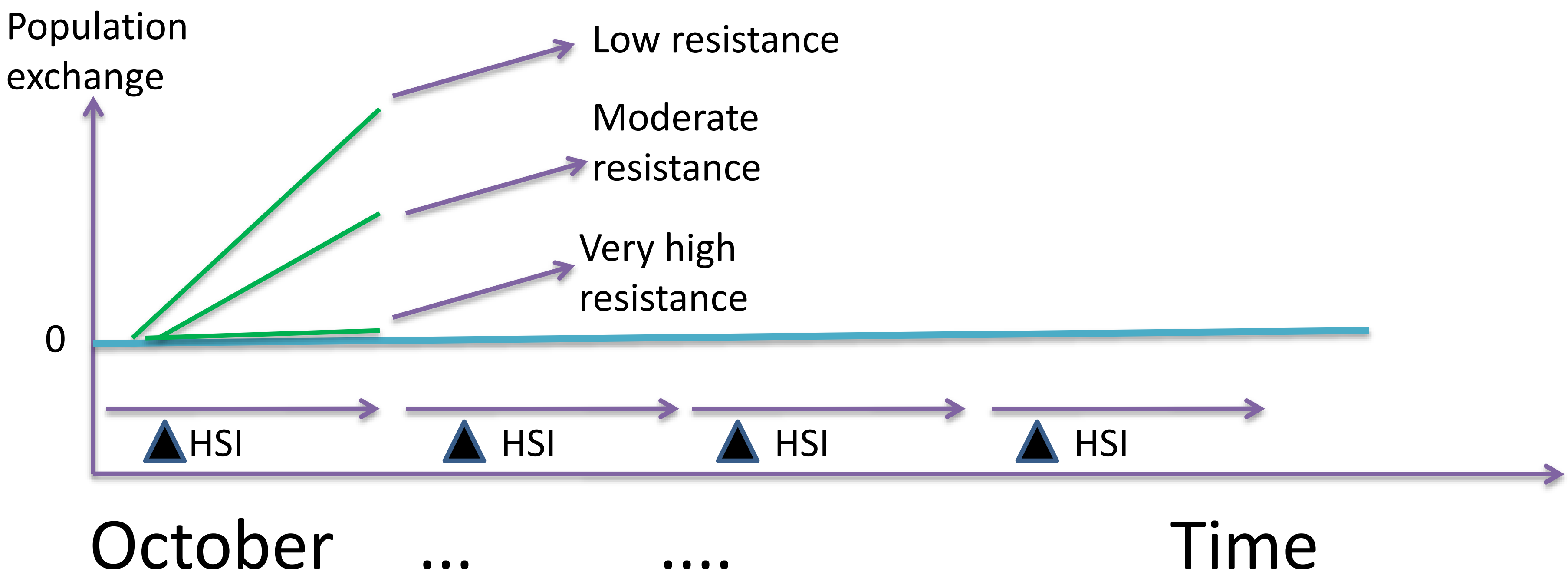
RULE 1: Population increase/decrease

- Typical pattern in aquatic system with good and moderate HSI



RULE 2: Population migration

- Rule examples in aquatic system

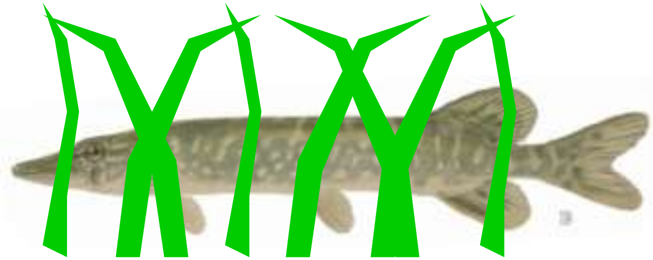


Potential insights

- Habitat and water quality improvement needs
- Zones with highest criticality and highest added value for restoration actions
- Design of buffer zones (width, vegetation type, connectivity, relation with aquatic conditions)
- Stocking?
- Timing of the expected effects of restoration actions + what are the critical factors to consider

The life of pike (*Esox lucius* L)

Hide and rest in vegetation



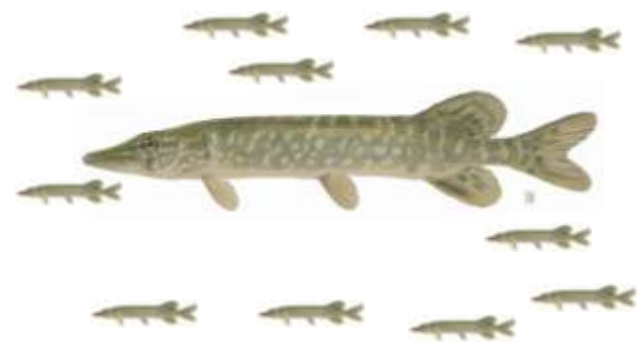
Foerage and hunt near obstacles

Different activities

Different *habitats*

Grow up in vegetated area

Reproduce in vegetated shallow areas



Habitat diversity and suitability is very important

River management questions

shipping > **agriculture** > ecology

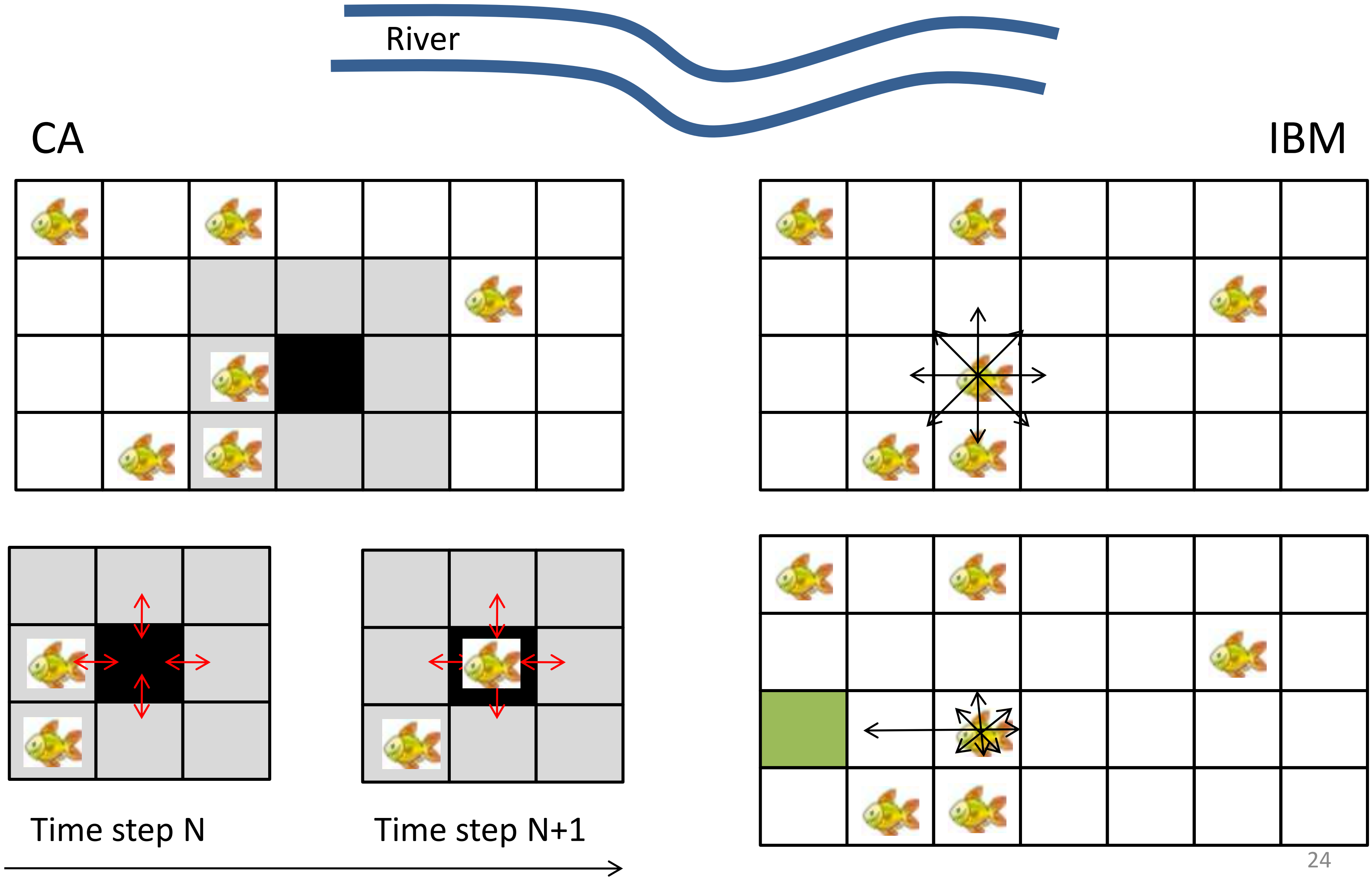
River management questions: restore pike populations in rivers

shipping > **agriculture** > ecology

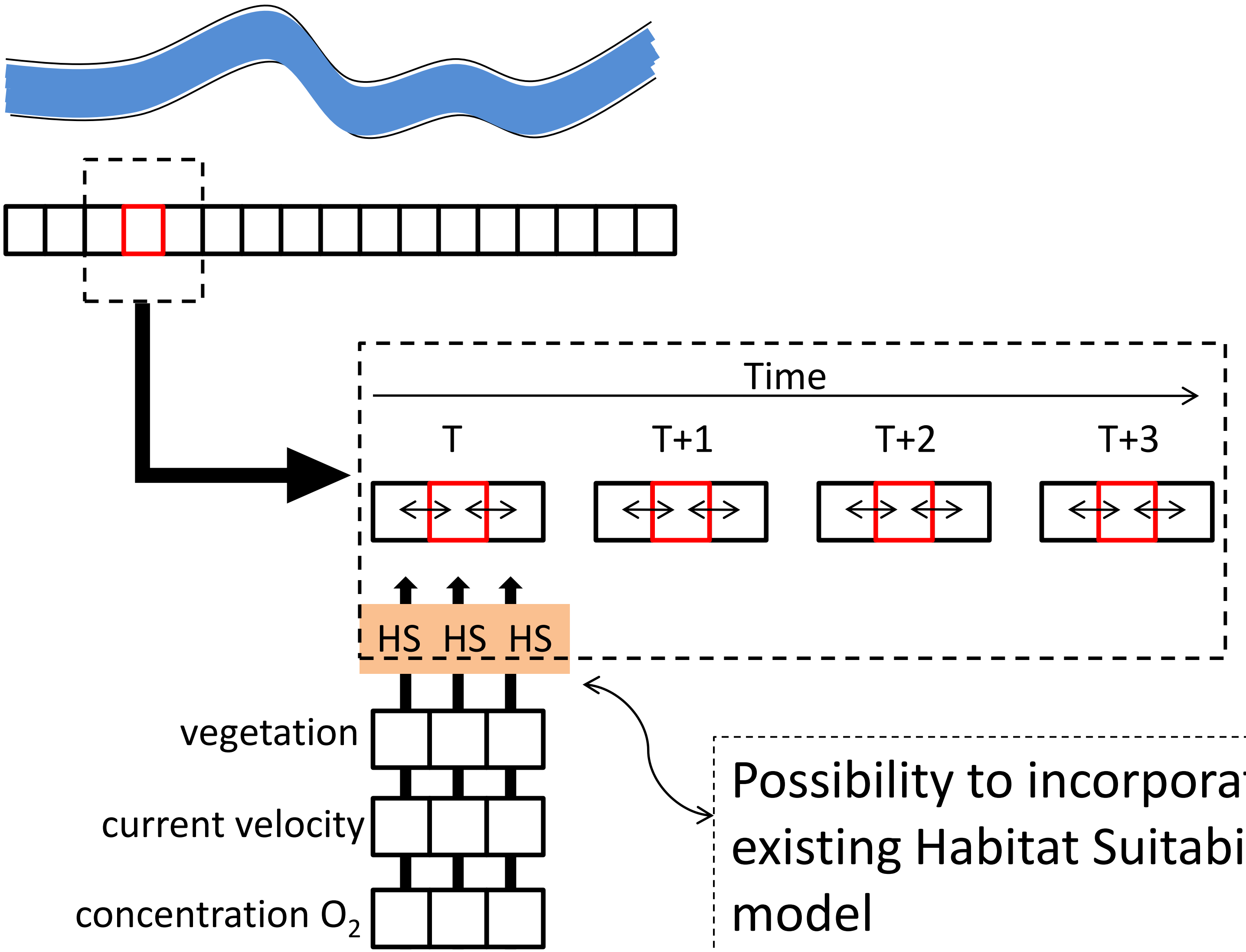
Shipping + ecology

BUT … restoration and protection of natural banks not always possible: what is optimal / minimal investment in spawning habitats

Pike migration modelling: CA and IBM

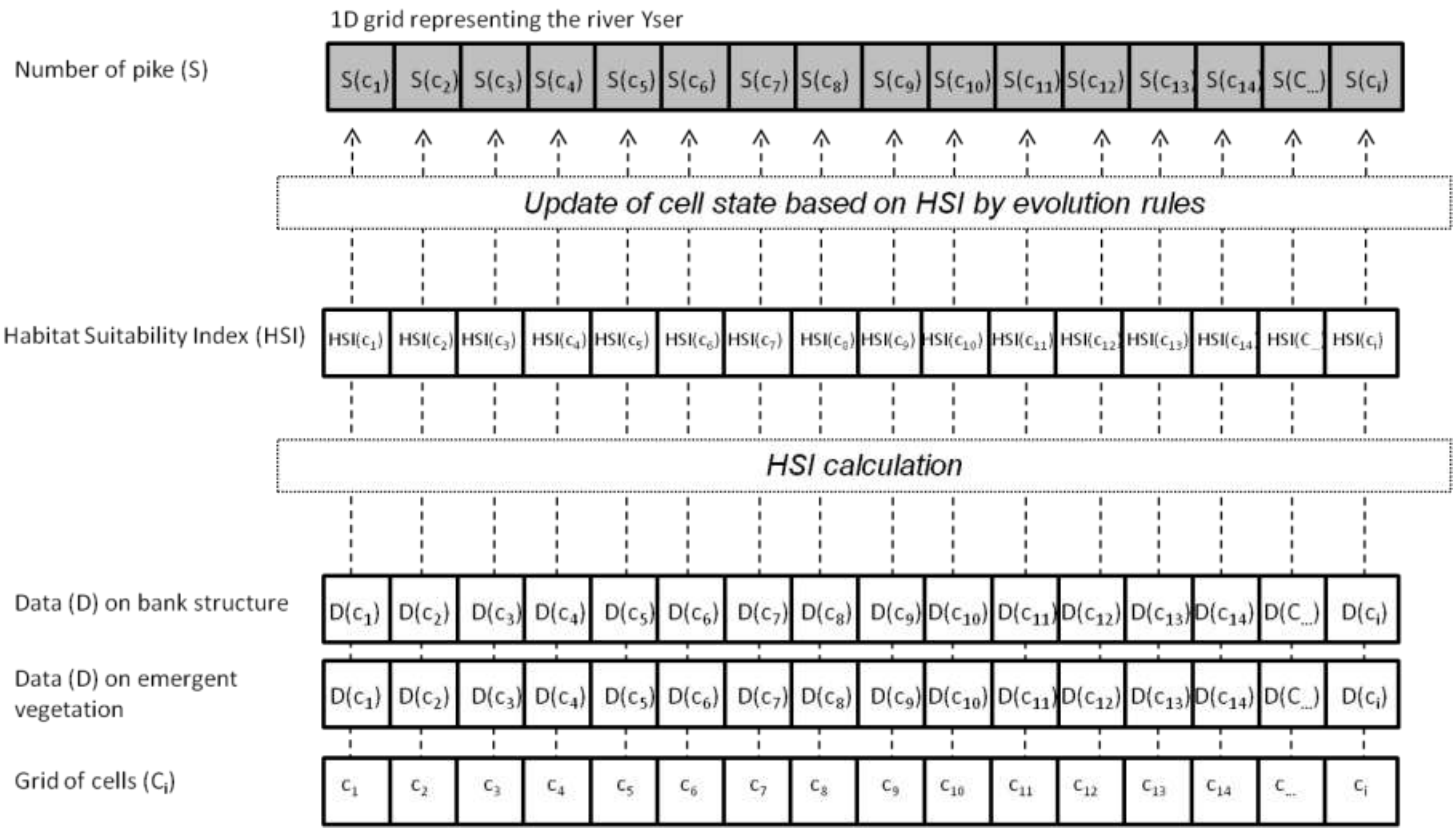


CA simulating pike migration (no population dynamics included yet)



Possibility to incorporate existing Habitat Suitability model

Results CA model: application on Yzer river



Sensitivity CA model

How sensitive is this model to …
- pike density
- initial distribution over the study area
- grid resolution

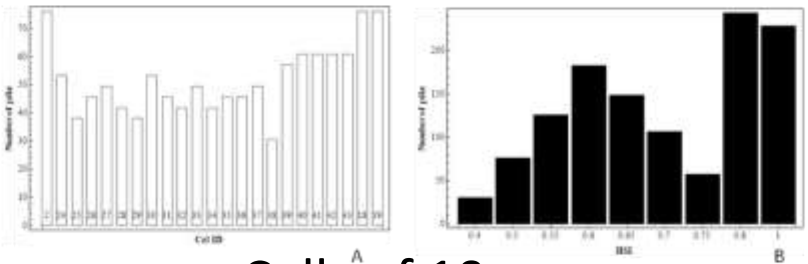
12 simulations conducted to analyze this

-Pike distribution over study area
-Pike distribution over the HSIs
-Entropy of the distribution
-Convergence time

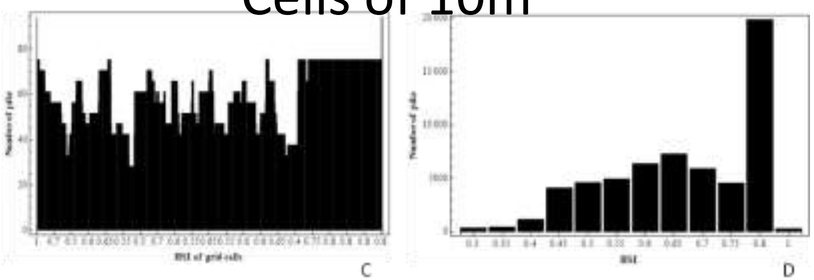
Cell length	Pike density in the grid (# pike.grid^{-1})	Initial pike distribution (initial)
representing 500m	20	Evenly distributed
representing 500m	20	All initially in one cell
representing 500m	200	Evenly distributed
representing 500m	200	All initially in one cell
representing 500m	1200	Evenly distributed
representing 500m	1200	All initially in one cell
representing 10m	1000	All initially in one cell
representing 10m	1000	Evenly distributed
representing 10m	10000	All initially in one cell
representing 10m	10000	Evenly distributed
representing 10m	60000	Evenly distributed
representing 10m	60000	All initially in one cell

Example simulations CA model

Cells of 500m

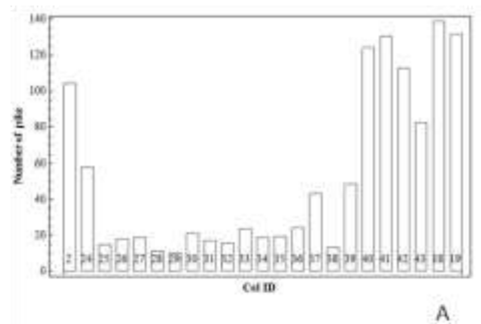


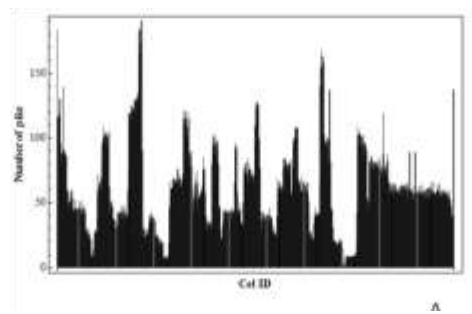
Cells of 10m



Stream location HSI

Expected pike distributions based on habitat suitability



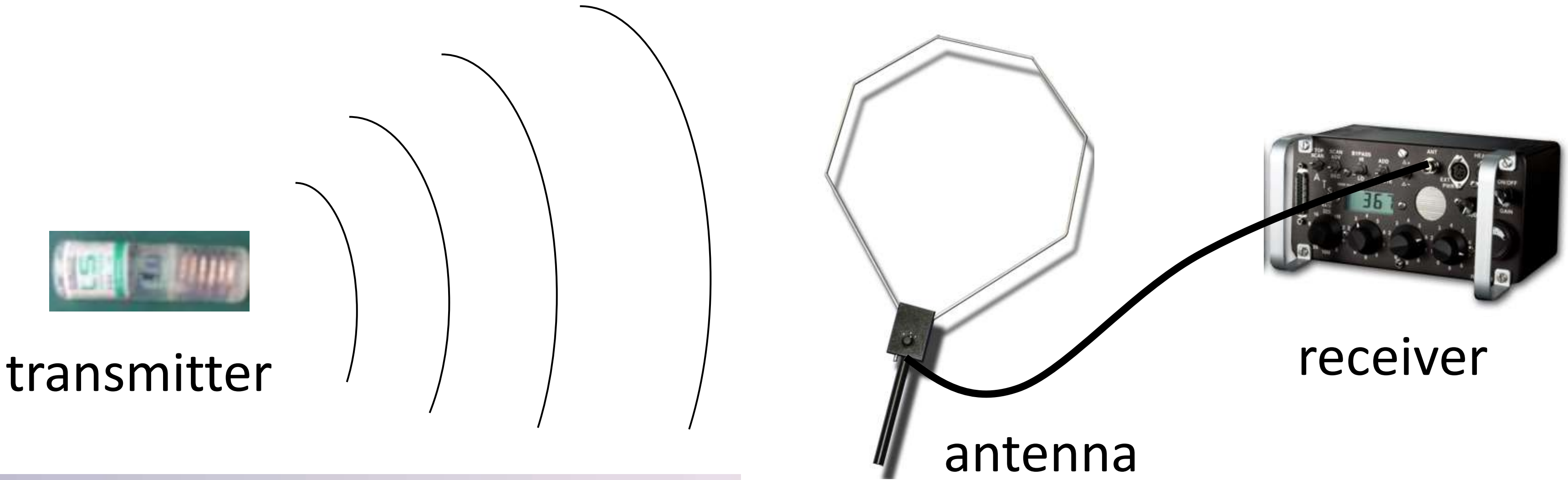


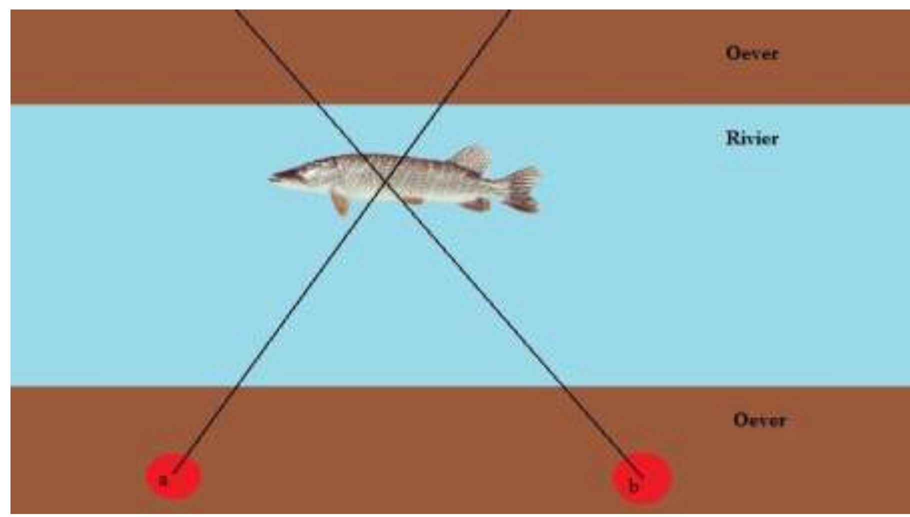
CA-simulated pike distributions: How to validate? Spatial-explicit and dynamic data needed

Model calibration and validation via Radio-telemetry River Yser

- During November and December 2010 15 pike were caught and tagged

Radio-telemetry River Yser





River management questions

- Specific questions of river managers

  - Ideal distance between spawning places?
  - Ideal dimensions of natural banks?
  - Effect of connecting natural areas to the river?
  - Effect of solving migration barriers?
  - Ideal water level management?

Challenges: collection of data and information

Modelling methods:

- Even simple models can quickly become complex in their application/validation…
- Missing interest in model simplification in science
- Quality assessment, based on application needs
- Standardisation

Data:

- Data quality / standardized data collection
- New monitoring technologies: how to integrate in efficient manner (data compatibility)

Policy:

- Belief in simulation results
- Actual application of results is still missing