Integrated ecological modelling to predict migration processes in support of river restoration and protection management

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RESEARCH GROUP
AQUATIC ECOLOGY

Opportunities

Increase of diversity in pool of modelling methods:

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

More data available:

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

Policy needs and growing interest:

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

Challenges

Modelling methods:

- Even simple models can quickly become complex…
- Quality assessment, based on application needs!
- Standardisation / BAMM

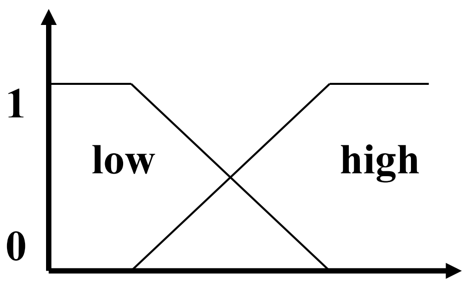
Data:

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

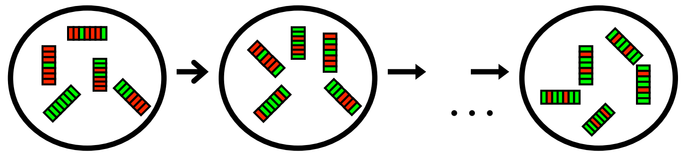
Policy:

- Belief in simulation results vs. ‘personal simulations’
- Actual application of results is still missing

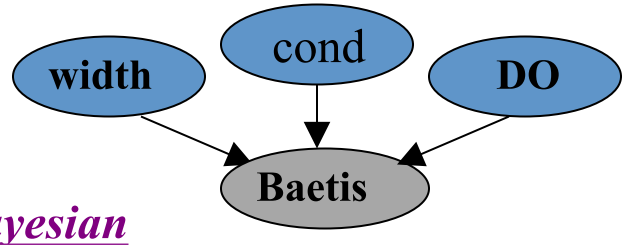
Habitat suitability modelling: diversity of techniques since 2000



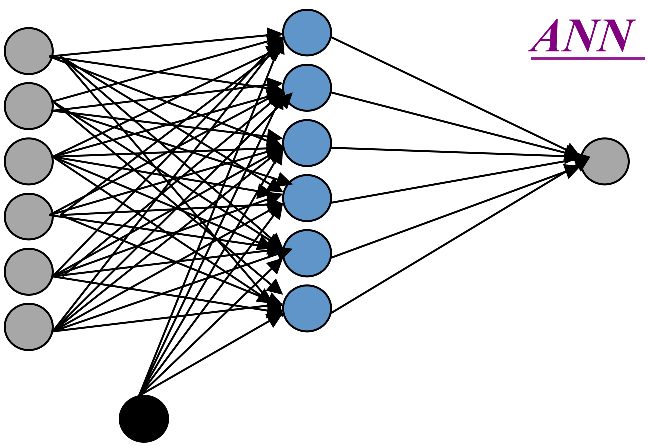
Fuzzy logic



Genetic algorithms

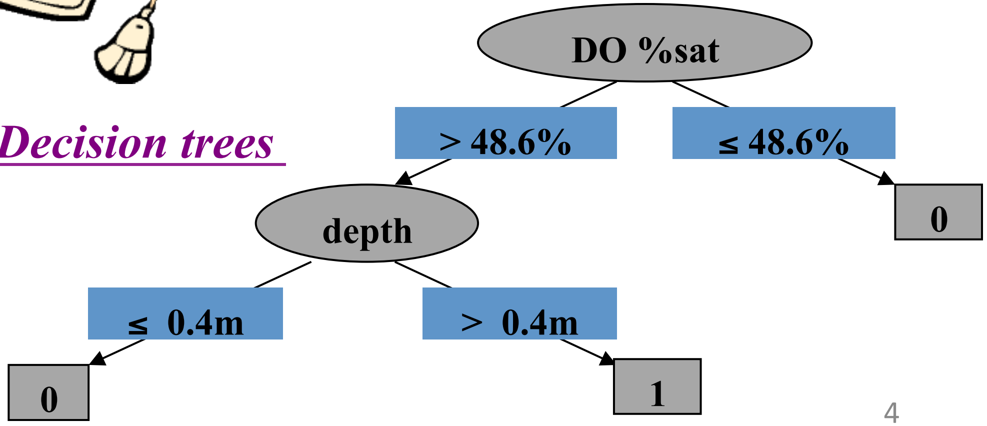


Bayesian Belief Networks



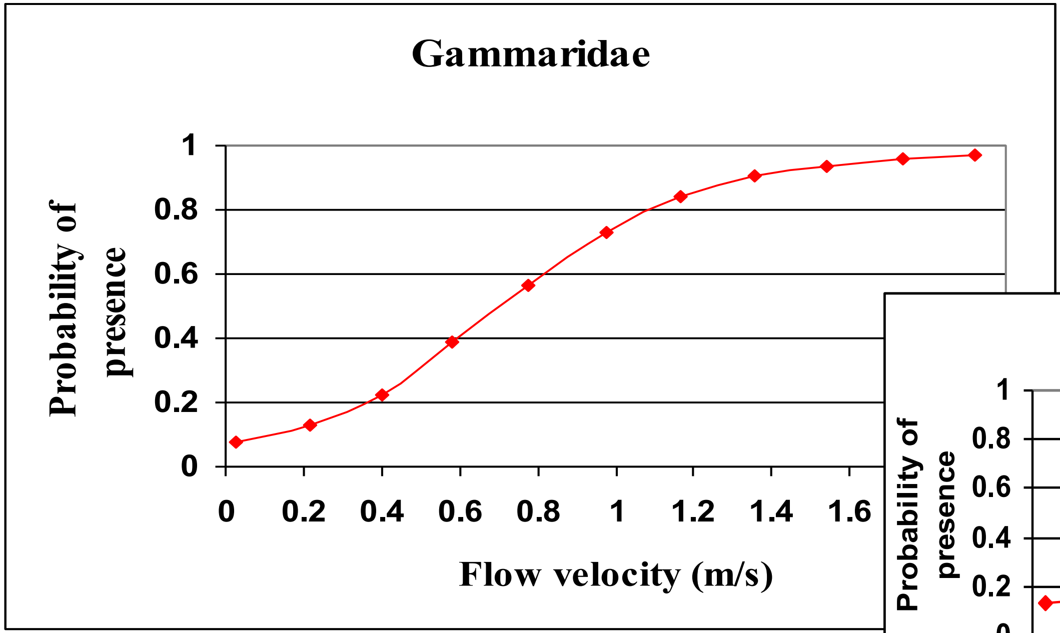
ANN

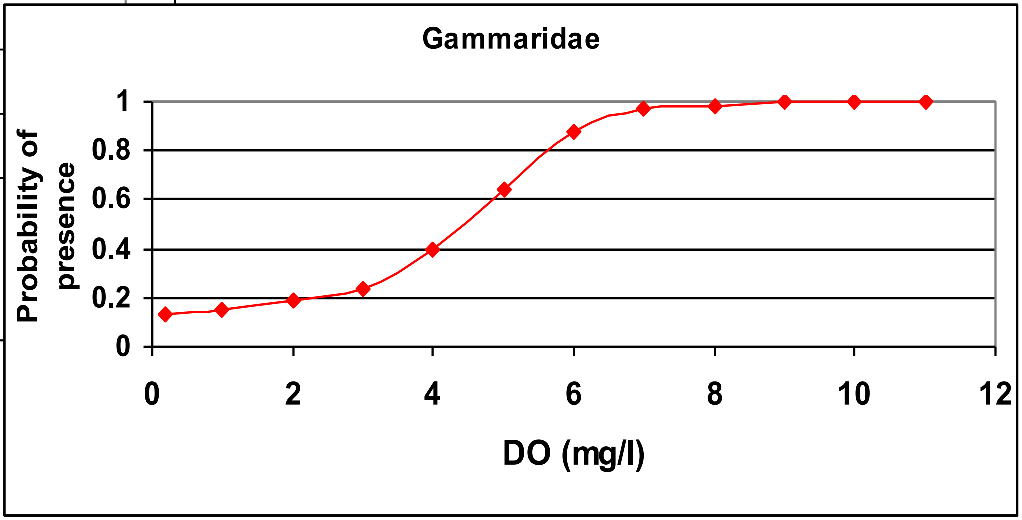
Decision trees



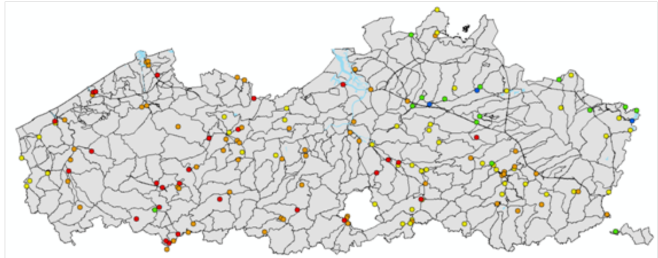
Insights in relations between abiotic and biotic characteristics

Gammaridae (Crustaceans)





Integrated predictions: coupling with water quality models



1. Collecting data by means of sampling campaigns and modeling

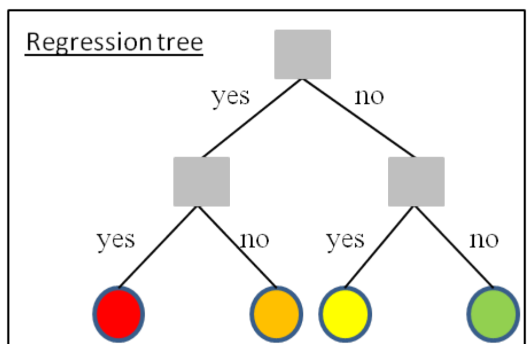
Output: measured dependent and independent variables

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		
…	…	…	…	…	…

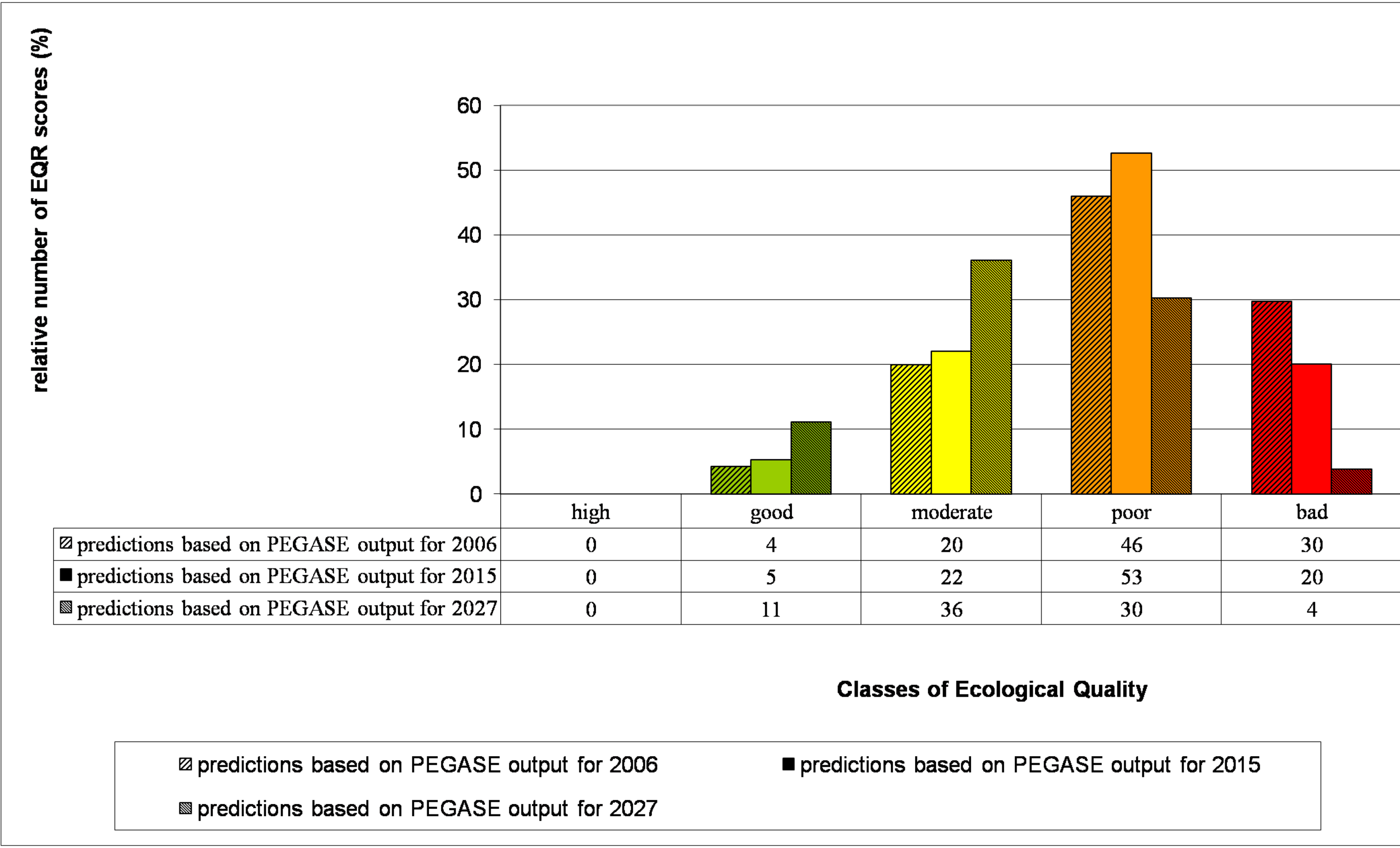
3. Developing regression trees based on the coupled dataset



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

New needs and opportunities: multi-habitat 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

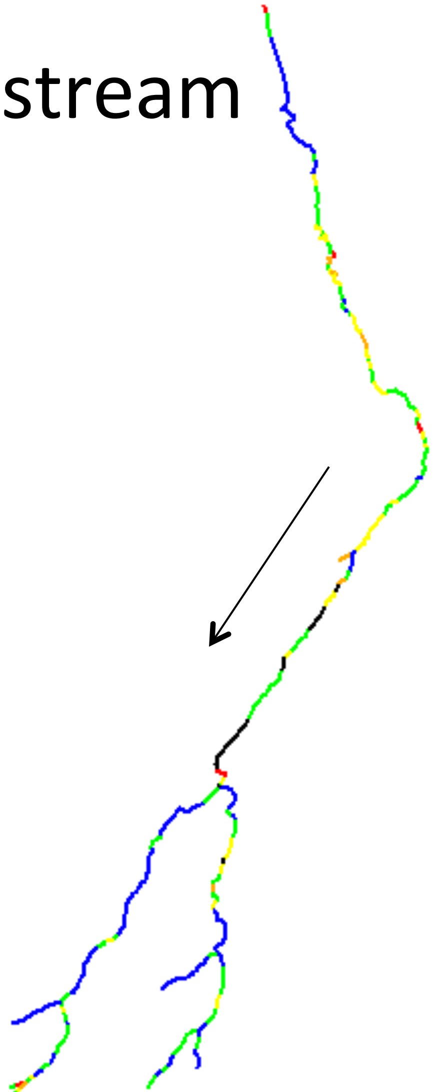
Andy P. Dedecker*, Peter L. M. Goethals, Tom D'heygere and Niels De Pauw

In-stream migration modelling based on electrical circuit analogon for river restoration

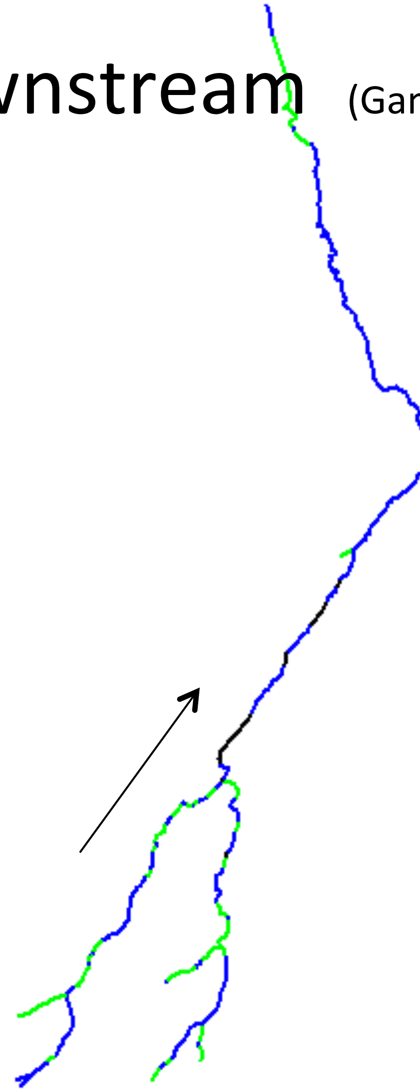
- GIS overlays, calculation of minimal migration time from colonized systems to site of interest
- based on vectors
- migration time = min (migration distance / migration speed)
- with migration speed = 1 / migration resistance

In-stream migration modelling based on electrical circuit analogon

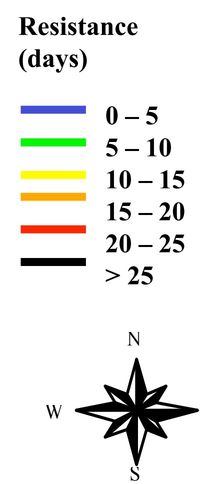
- Upstream



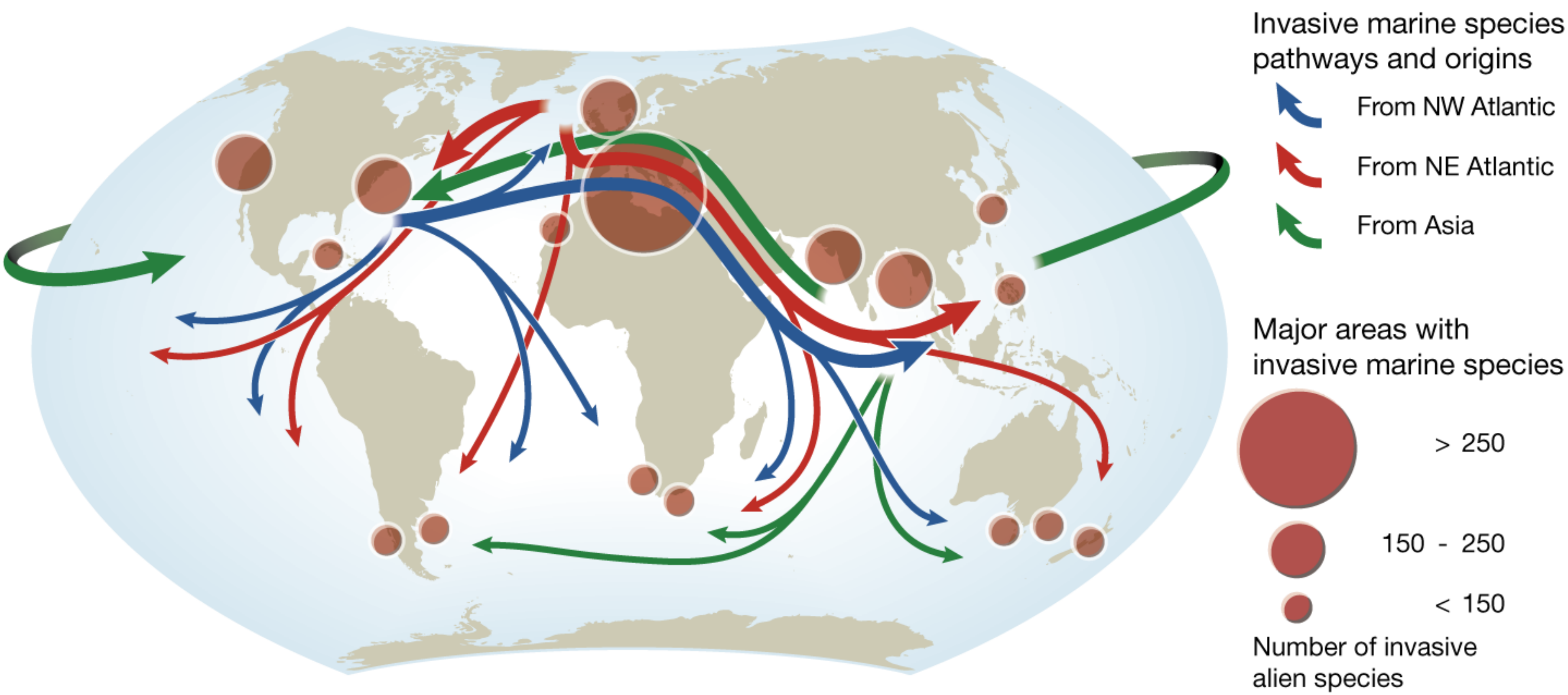
Downstream



(Gammarus migration)



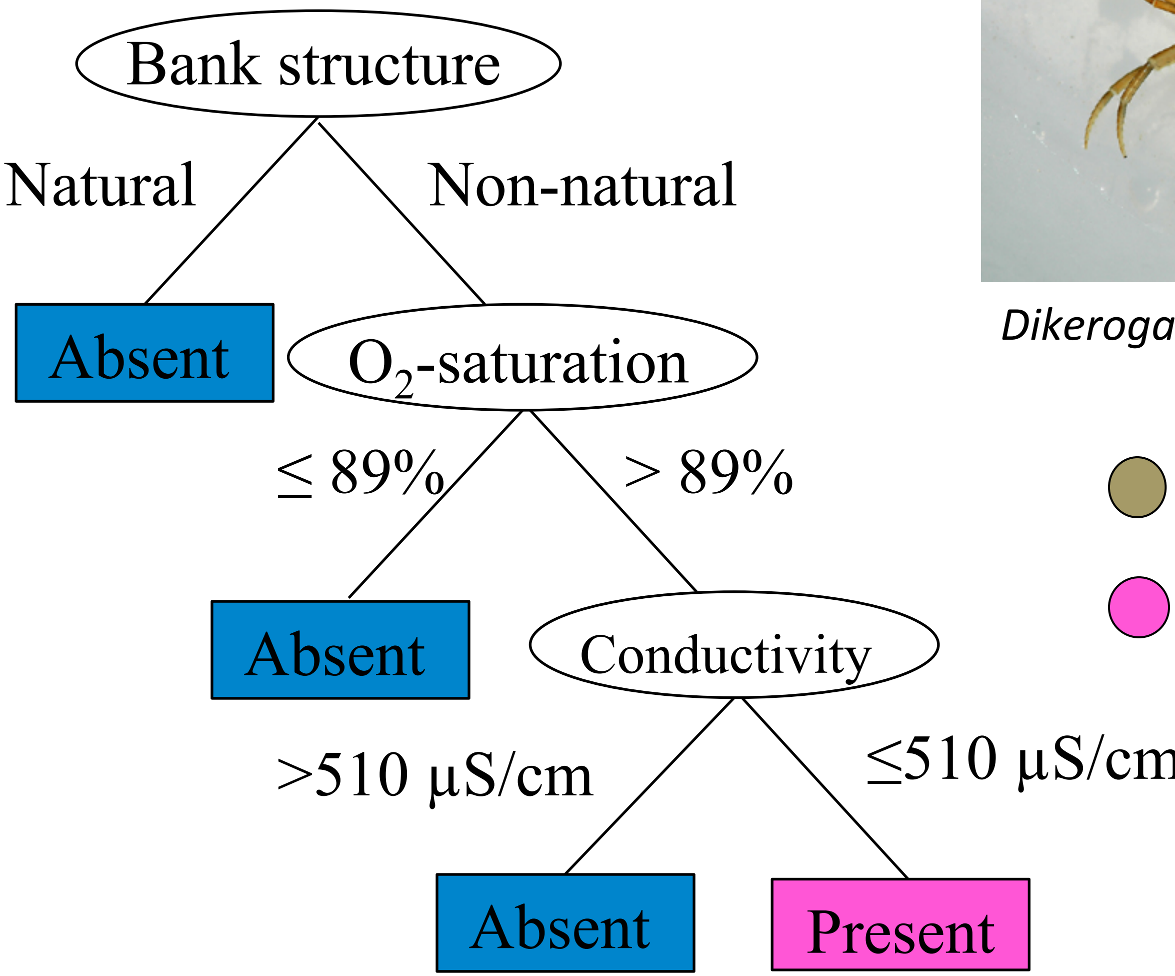
Invasive species: a global but also local problem



Source: Parker, N. (2009) Biofouling Invasions International Measure development. Presentation to International Paint and Printing Ink Council (IPPIC), Antifouling Working group

Habitat suitability modelling

Classification tree



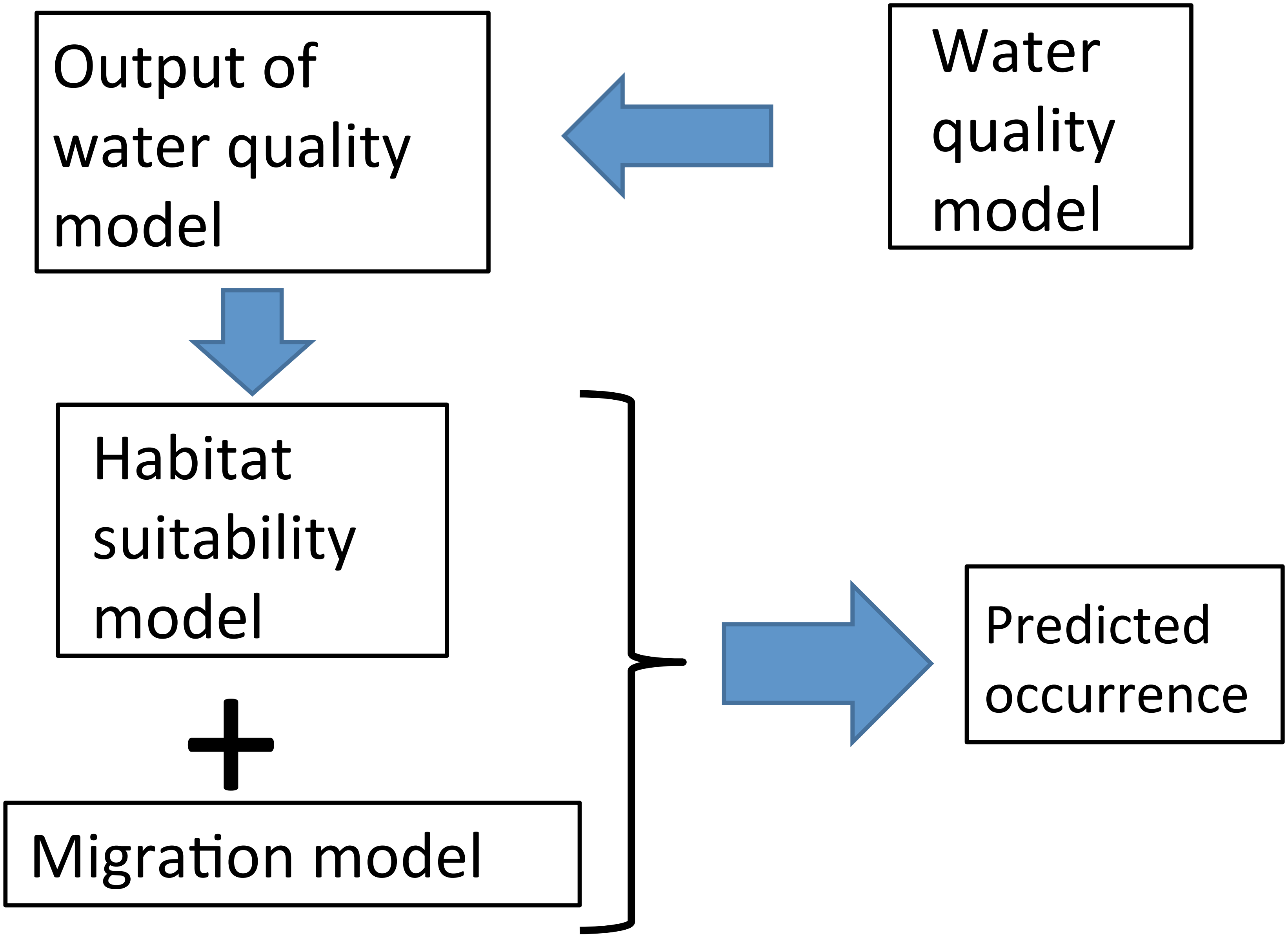
Dikerogammarus villosus

Absent

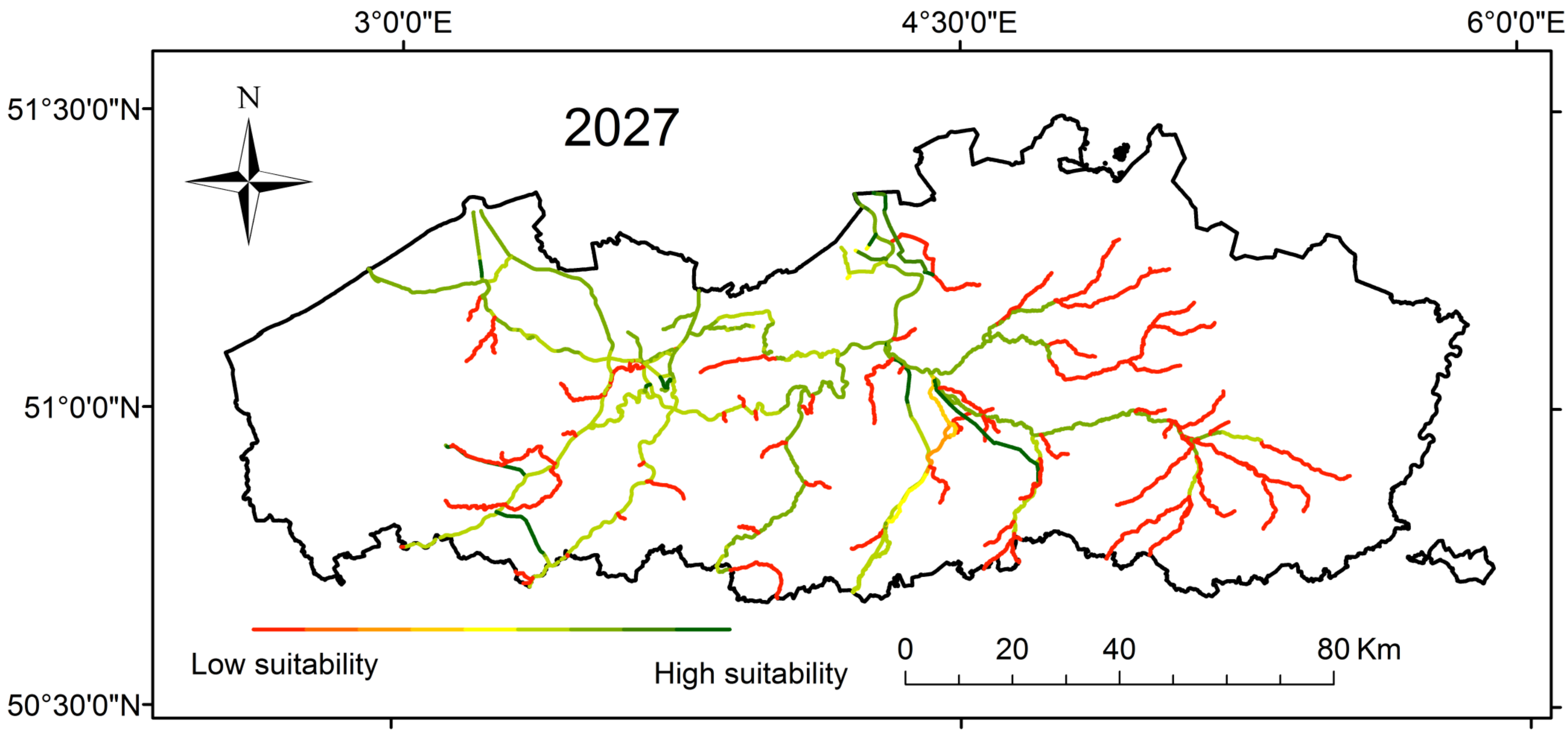
Present

Boets et al. (2010) Ecological Informatics 5: 133-139

Prediction on future distribution



Prediction on future distribution



75% of the rivers are suitable

Boets et al. (accepted) River Research and Applications

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

ECOLOGICAL MODELLING 203 (2007) 72–86

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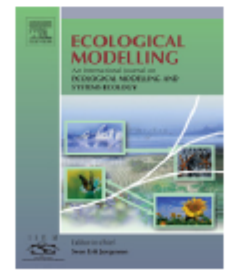
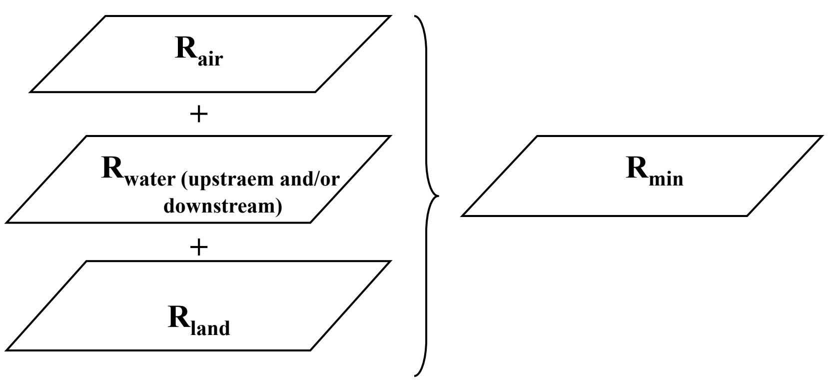


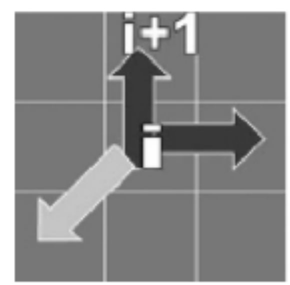
Development of migration models for macroinvertebrates in the Zwalm river basin (Flanders, Belgium) as tools for restoration management

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 ('lowest cost') to migrate between two locations based on raster data



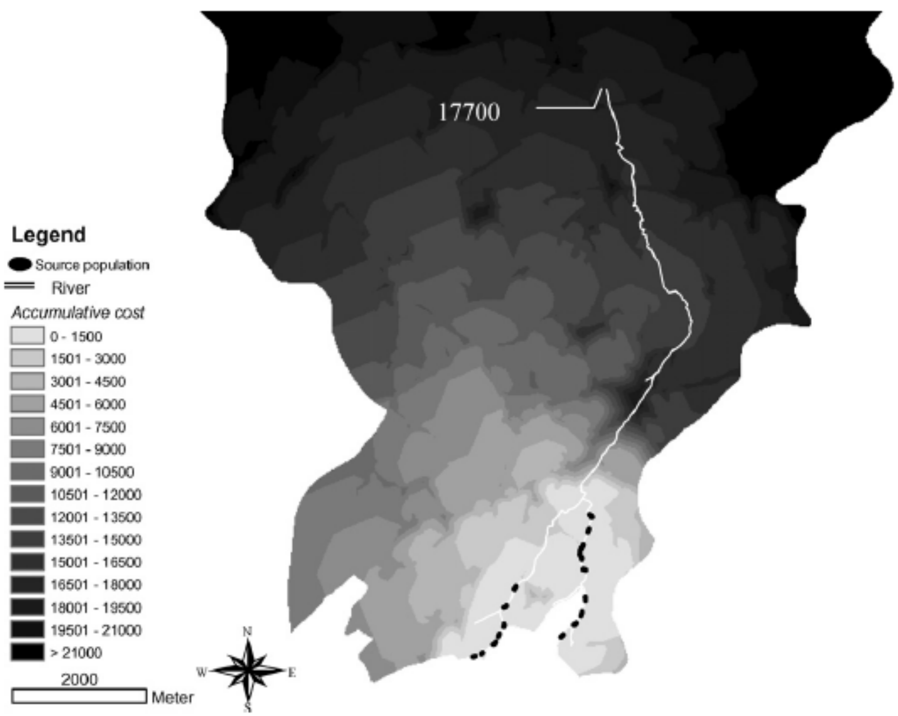


$$N_{i+1} = N_i + (R_i + R_{i+1})/2$$

$$N_{i+1} = N_i + \sqrt{2}(R_i + R_{i+1})/2$$

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)



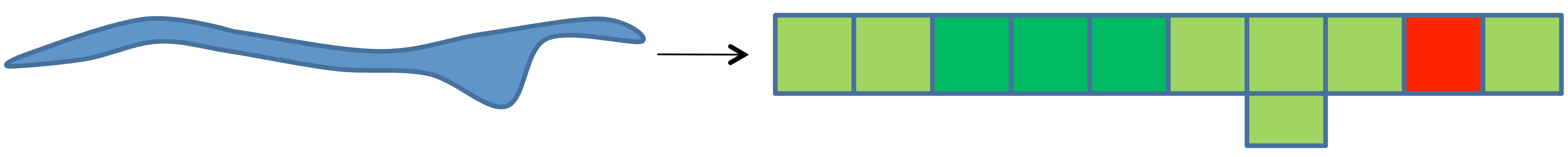
Ephemera

Limnephilidae

- Limitations related to population dynamics and need for age based habitat suitability…

Potential of cellular automata to analyse migration potential (and spatial-explicit population changes): Pauwels et al. (2013)

- 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



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

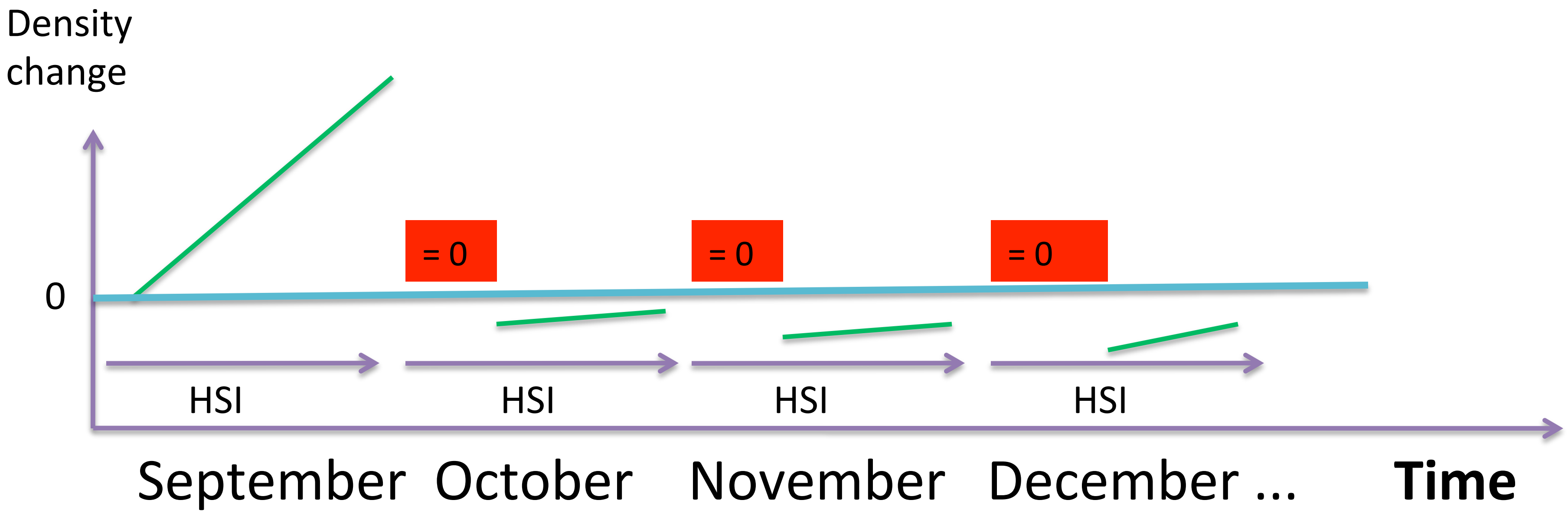
Need for spatial-explicit and dynamic models

- 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

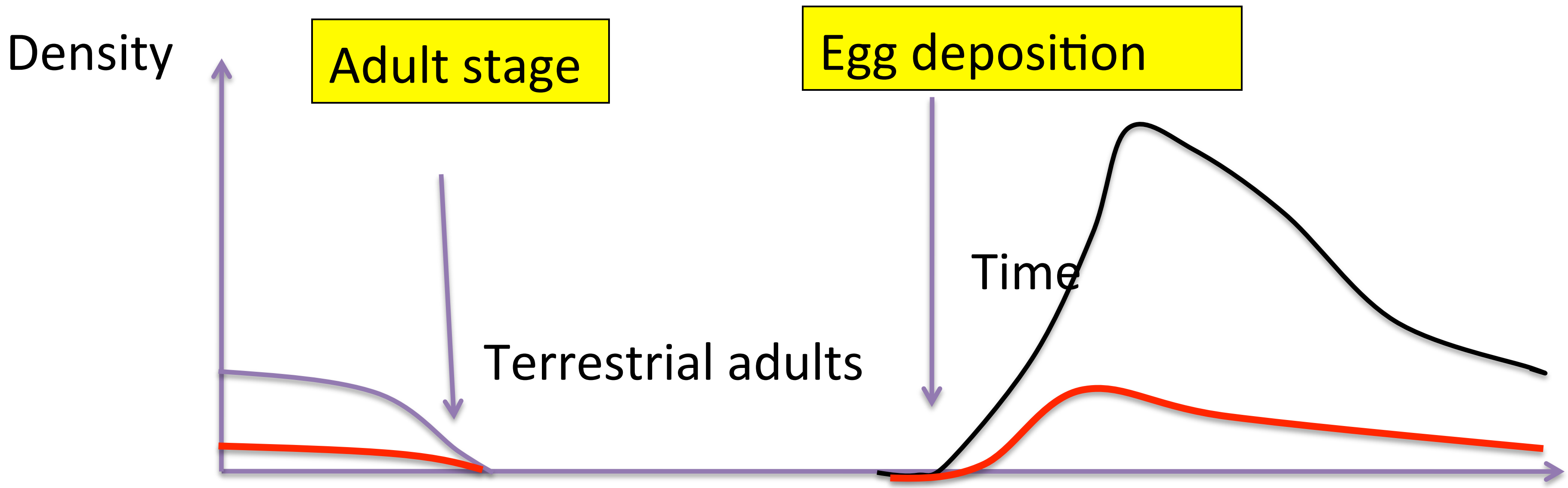
- Result of reproduction + mortality (+ predation + competition))
- F(t, HSI): time explicit regression lines/curves F(HSI)



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

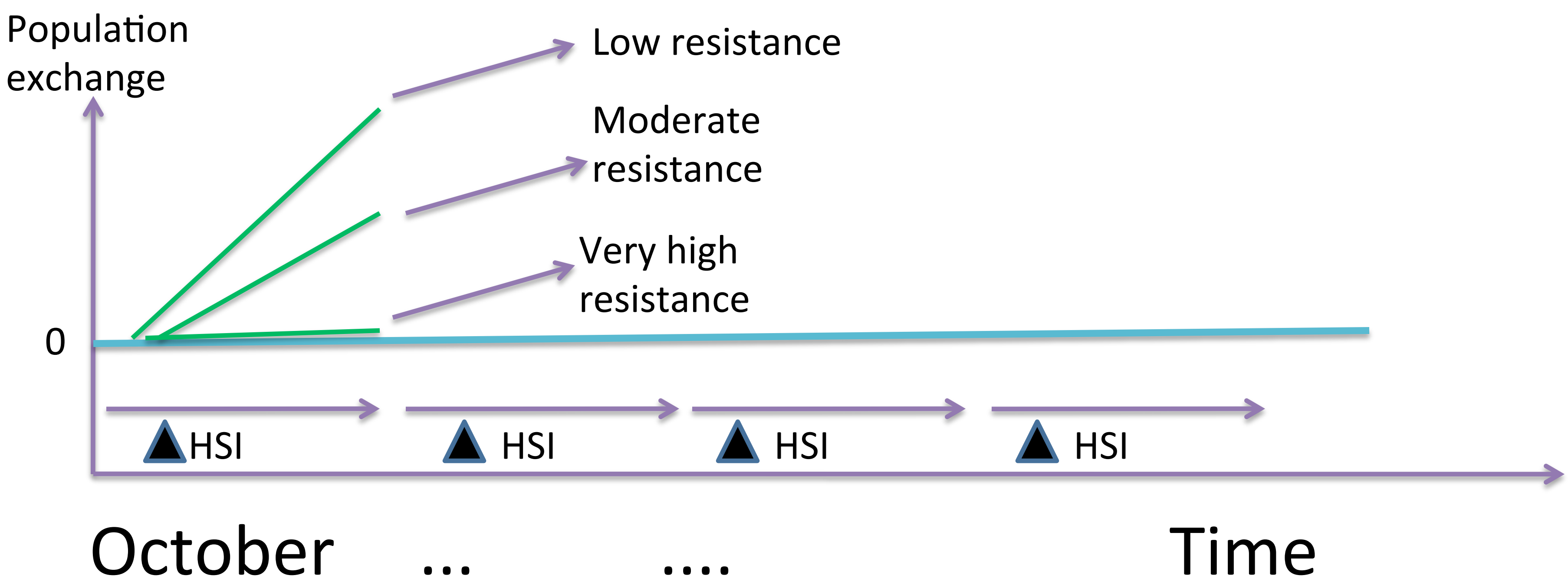
RULE 1: Population increase/decrease

- Typical pattern in aquatic system with good and moderate HSI



RULE 2: Population migration

- Rule examples in aquatic system

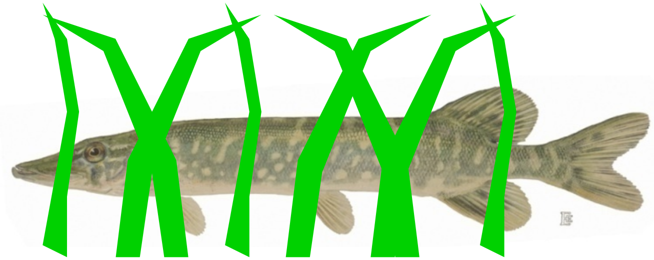


Potential insights

- 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



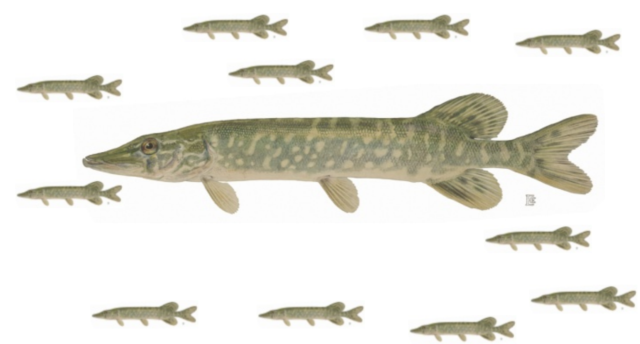
Hunt near obstacles

Different activities

Different *habitats*

Develop in vegetation-rich area

Reproduce in shallow areas



Habitat diversity and suitability is

very important

River management questions

shipping > **agriculture** > ecology

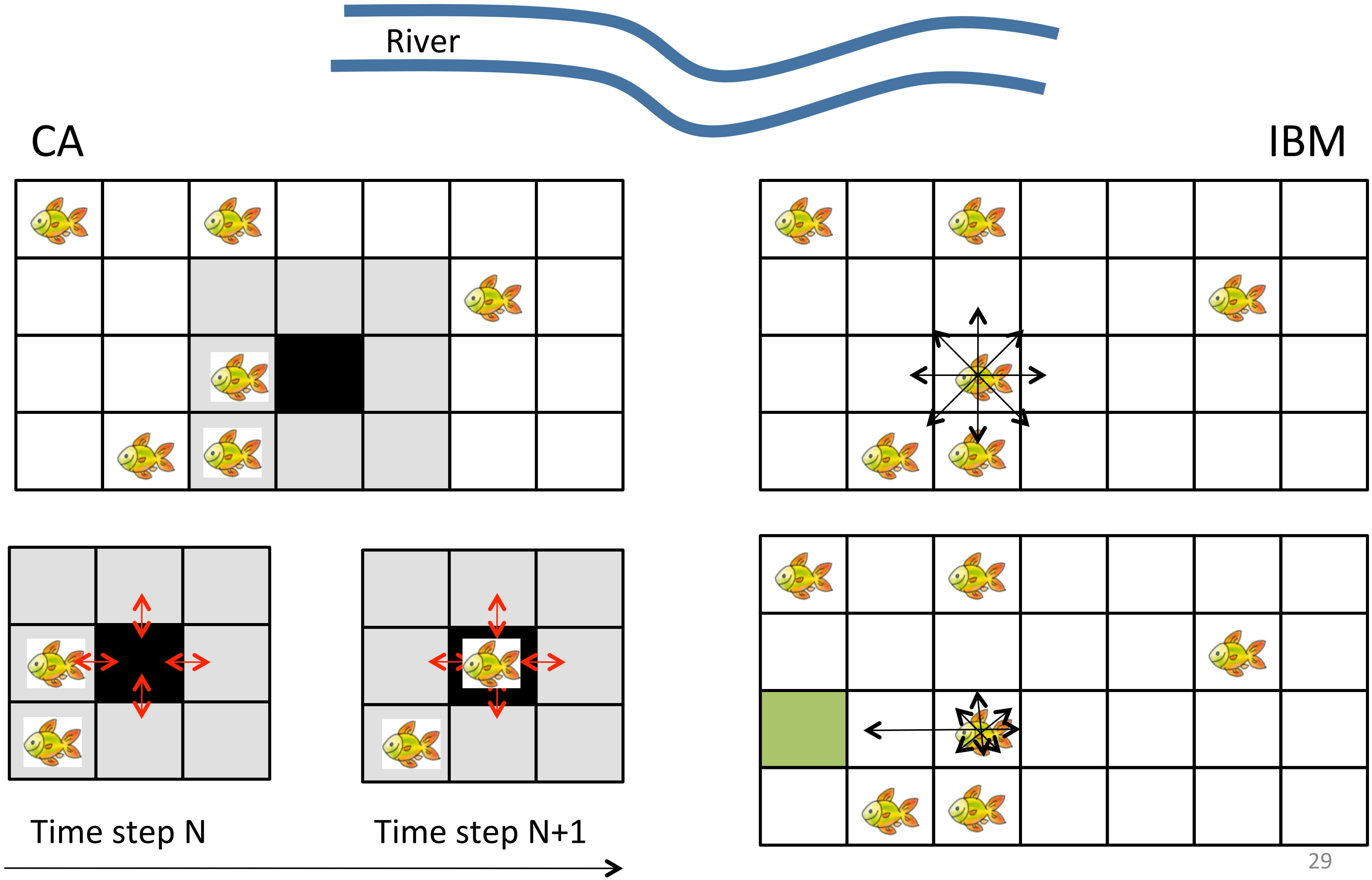
River management questions: restore pike populations in rivers

shipping > **agriculture** > ecology

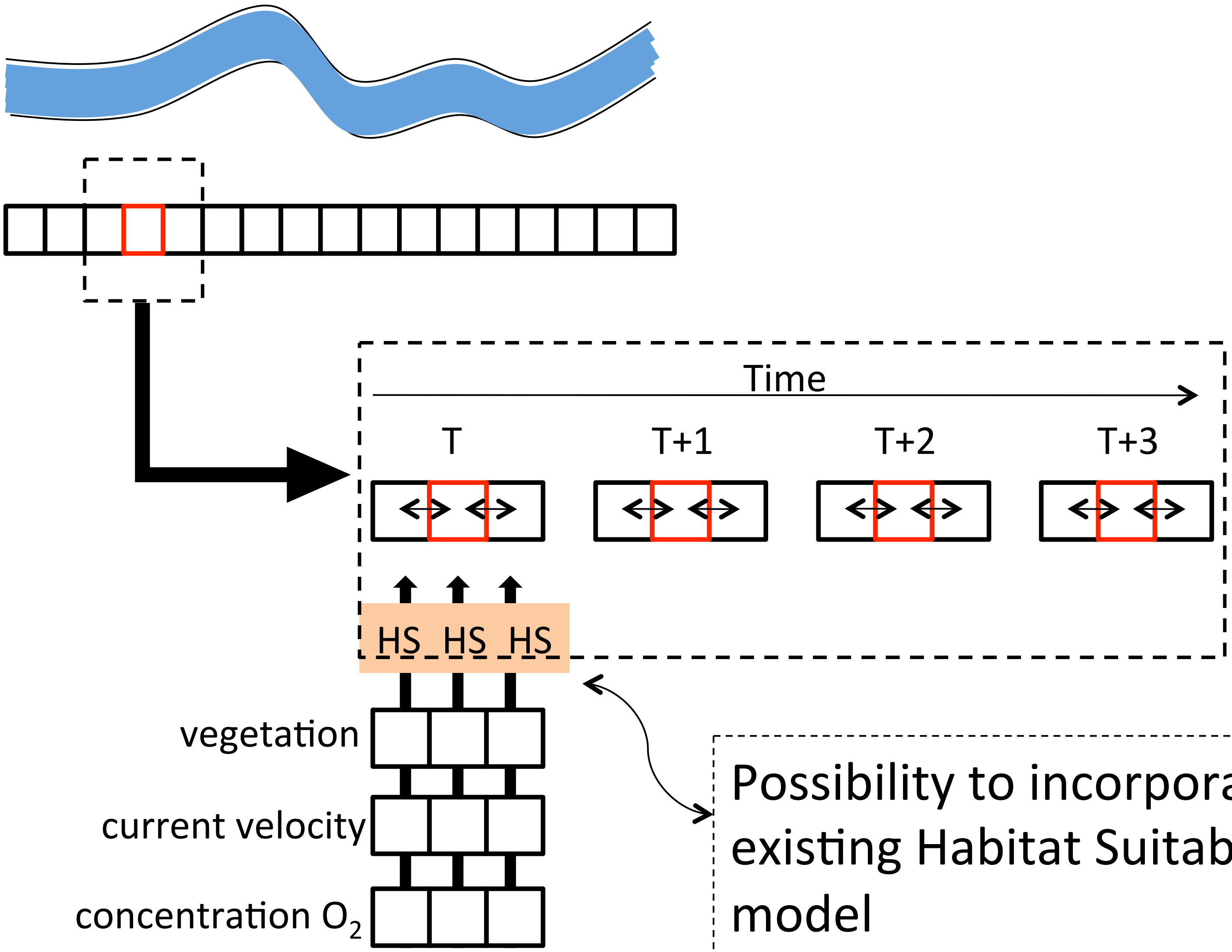
Shipping + ecology

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

Pike migration modelling: CA vs IBM

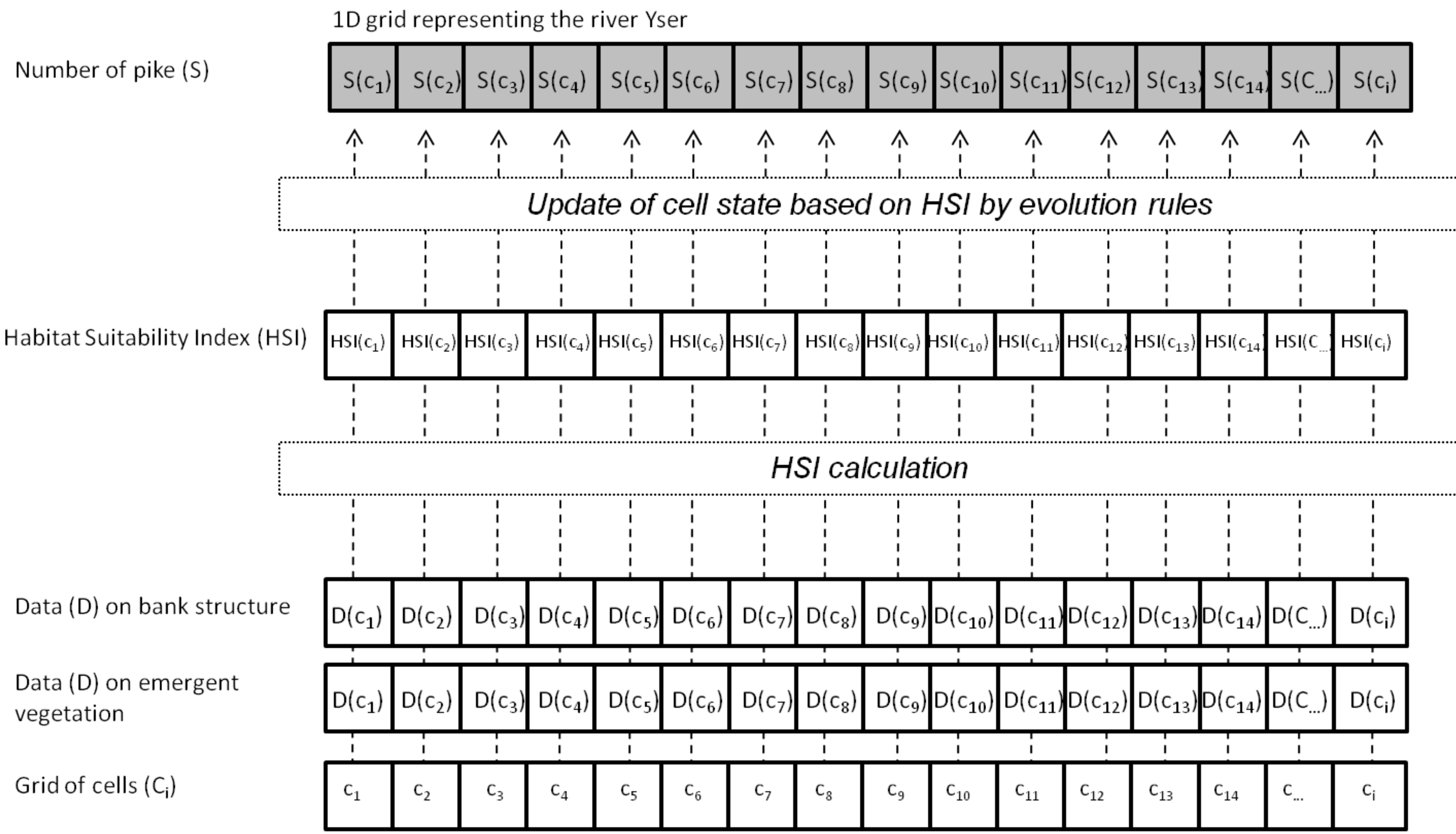


CA simulating pike migration (no population dynamics included yet)



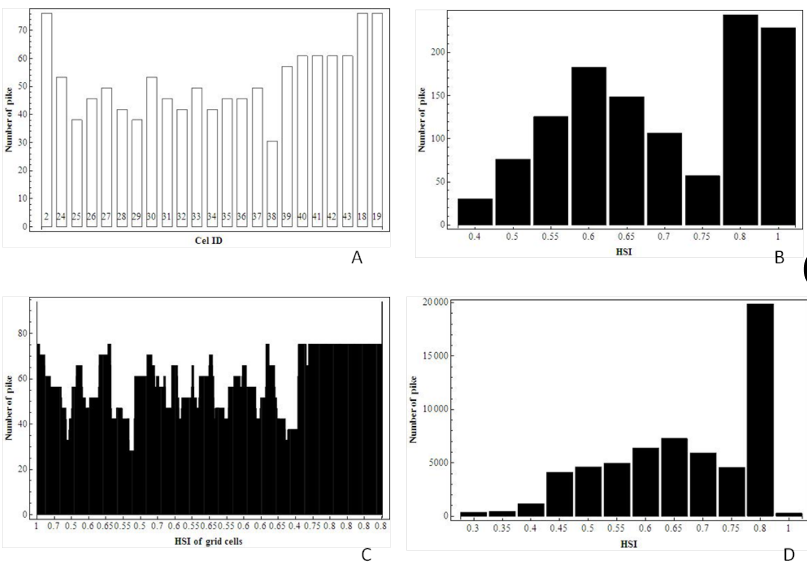
Possibility to incorporate existing Habitat Suitability model

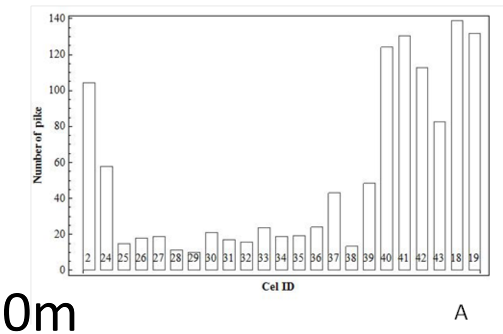
Results CA model: application on Yzer river



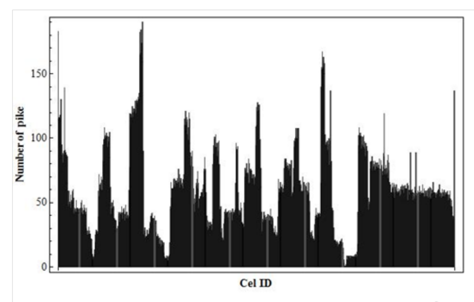
Example simulations CA model

Cells of 500m





Cells of 10m



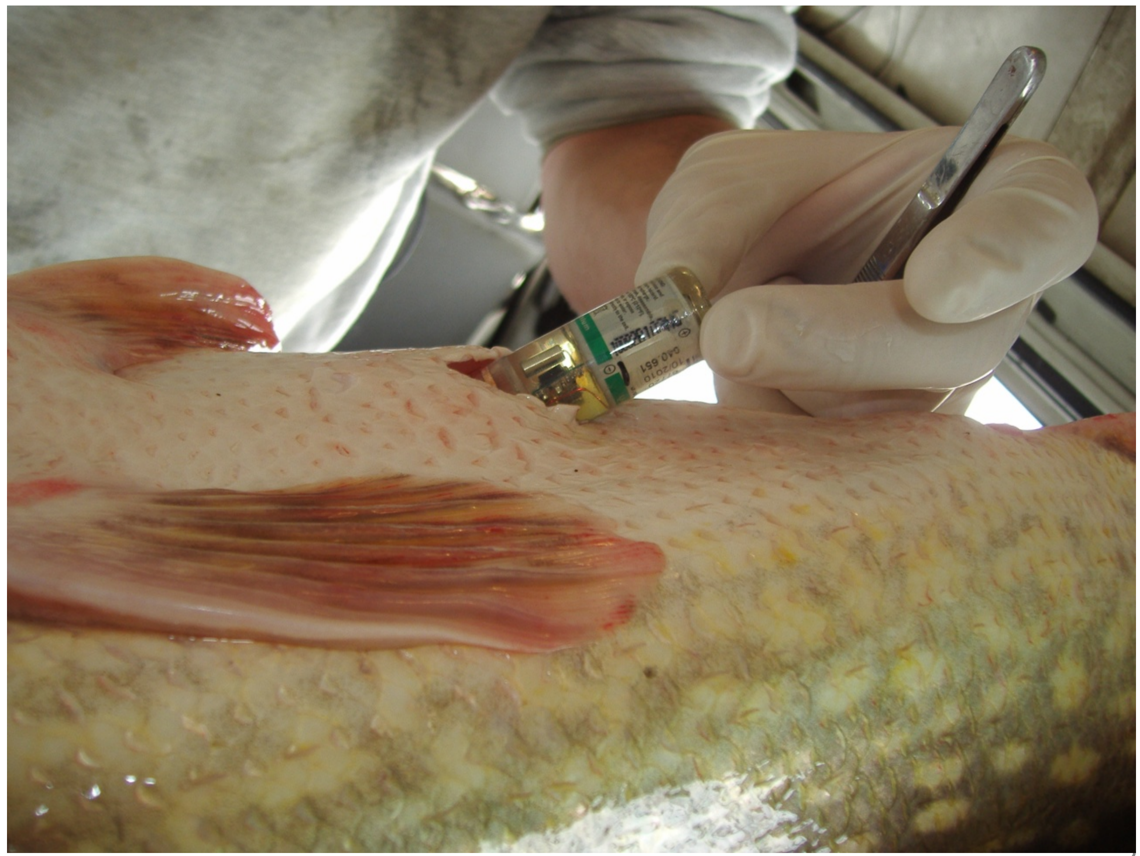
Stream location HSI

Expected pike distributions based on habitat suitability

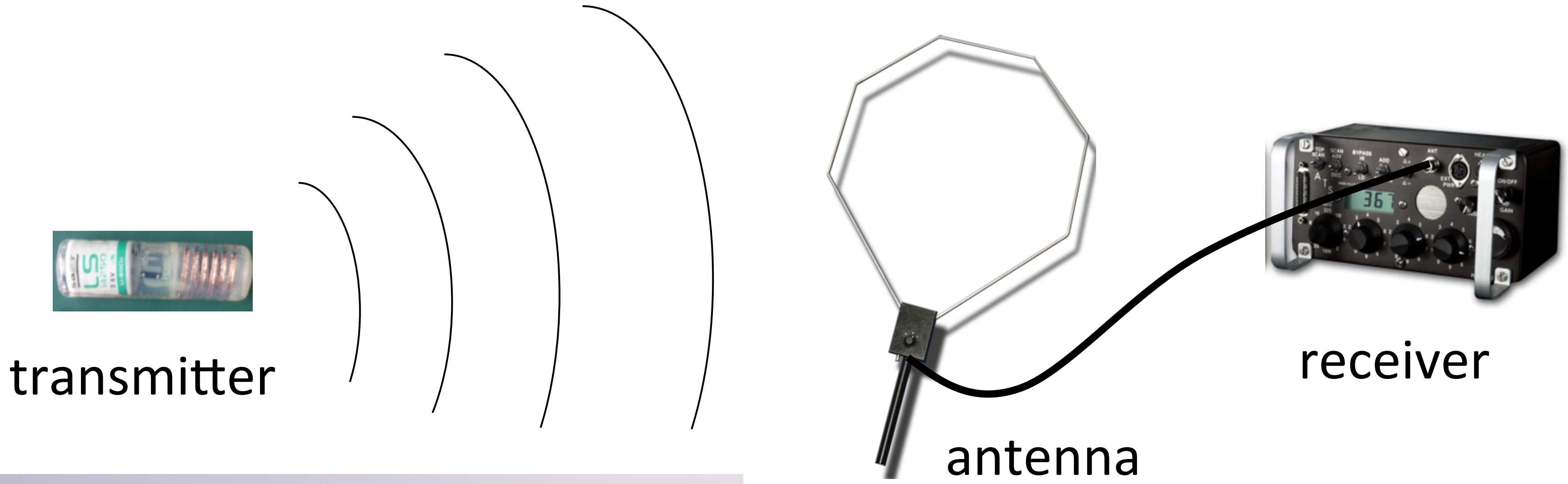
CA-simulated pike distributions: How to validate? Spatial-explicit and dynamic data needed

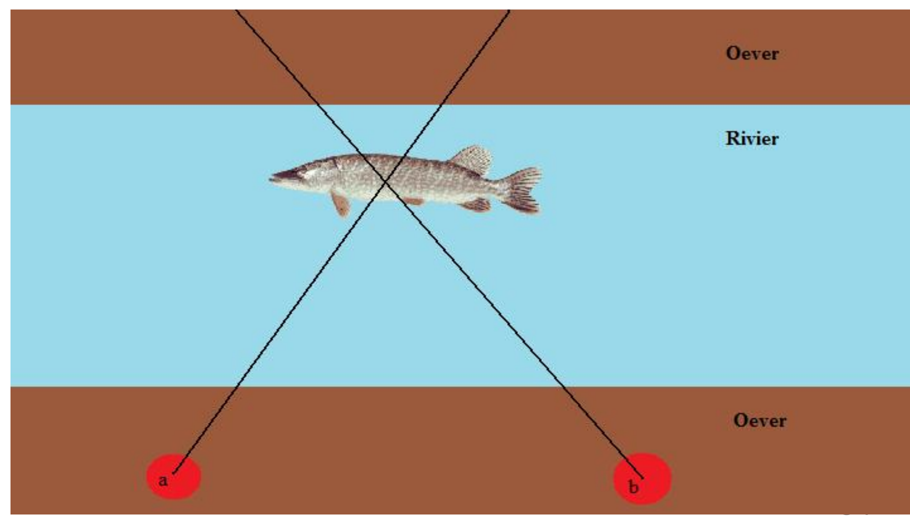
Model calibration and validation via Radio-telemetry River Yser

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



Radio-telemetry River Yser





River management questions

- Specific questions of river managers

Waterwegen en Zeekanaal NV
weg van water

Agentschap voor
Natuur en Bos

provincie Limburg

Provincie
West-Vlaanderen
Door mensen gedreven

  - 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?