DEVELOPMENT OF MIGRATION MODELS FOR MACRO-INVERTEBRATES IN THE ZWALM RIVER BASIN AS A TOOL IN RIVER ASSESSMENT AND RESTORATION MANAGEMENT

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INTRODUCTION

Human activities have severely deteriorated the Flemish river systems, and many functions such as drinking water supply, fishing, etc. are threatened. Because the restoration of these river systems entails drastic social and economical consequences, the decisions should be taken with enough forethought. Ecosystem models could therefore act as interesting tools to support decision-making in river restoration management. In particular, models that can predict the habitat requirements of organisms are needed to ensure that the planned actions have the desired effects on the aquatic ecosystems. In general however, habitat suitability models, such as artificial neural networks (Dedecker *et al.*, 2004a), fuzzy logic (Adriaenssens *et al.*, 2004), etc. do not include spatial and temporal relationships. Migration dynamics of the predicted organisms and migration barriers along the river may indeed deliver important additional information on the effectiveness of the restoration plans. In this context, migration models for *Gammarus pulex* (Crustacea, Amphypoda), *Baetis* (Insecta, Ephemeroptera), *Ephemera* (Insecta, Ephemeroptera) and Limnephilidae (Insecta, Trichoptera) were developed. These organisms are valuable indicators in water quality assessment (De Pauw & Vannevel, 1991), and provide representative insights in the behaviour of aquatic macroinvertebrate communities and the water quality status of rivers. The development of these migration models was developed on the basis of electricity laws, seen the relation between electrical stream intensity and resistances provides a good basis for the modelling of the movement of macroinvertebrates in function of migration barriers.

MATERIAL AND METHODS

To develop the migration models, an intensive monitoring campaign was set up within the Zwalm river basin (Flanders, Belgium) which is part of the hydrographical basin of the Upper-Scheldt. Therefore, the Verrebeek, the Dorenbosbeek and the upstream part of the Zwalm river itself were selected. These brooks are situated in the southern part of the Zwalm river basin. This part contained river sites characterised by structural and morphological disturbances, while others nearly met reference conditions. In addition, the selected part of the river basin was located in a region with different types of land use. The monitoring campaign consisted of two parts.

First, the selected river parts were split up in stretches of 50 m and an inventory of the structural and morphological characteristics was made. In the second place, 60 sites were selected. At each site, 26 environmental variables, such as dissolved oxygen, pH, flow velocity, width, etc. were recorded. *Gammarus pulex*, *Baetis*, *Ephemera*, Limnephilidae as well as other macroinvertebrates were collected by means of a standard handnet within a river stretch of 10 m and by *in situ* exposure of artificial substrates. To develop the migration models, a Geographical Information System (ArcGis 8.3) was used.

RESULTS AND DISCUSSION

To quantify the potential dispersal of *Gammarus pulex*, *Baetis*, *Ephemera* and Limnephilidae from one site in the river to another, migration models have been developed. This migration model consist of four layers, each representing one resistance map, indicating the ease of macroinvertebrate taxa to migrate over river stretches, air or land. These four maps characterize the migration resistance respectively upstream (R_{up}) and downstream (R_{down}) through the water column and through the air (R_{air}) and land (R_{land}). However, migration through the air and land is not relevant for *Gammarus pulex* because they do not have an aerial or terrestrial phase in their life-cycle. Based on the determining parameters affecting migration (e.g. presence of boulders for *Baetis*), a resistance value was attributed to each 50 m stretch for the upstream and downstream migration. The attribution of these resistances was based on a literature review and expert knowledge (Table 1). Also the migration barriers such as weirs and impounded river sections along the river are considered to determine the total upstream and downstream migration resistance through the water column.

As a nymph *Baetis*, *Ephemera* and Limnephilidae have an aerial phase. As a result, dispersal through the air means an important part of the migration dynamics of these organisms. To this end, a resistance value was given to the surrounding environment according to the land use (urban, agricultural, industrial or forest region) and the presence/absence and width of buffer strips along the river (Table 2).

Then, an overlay of the resistance maps was made to obtain an overall resistance for the area. The total resistance to migrate in the downstream ($R_{tot(down)}$) and the upstream ($R_{tot(up)}$) direction is given by Equation 1 and 2 respectively. Because the migration through the water column (larva) and the air (nymph) can act at the same time, both resistances are connected in parallel.

$$\frac{1}{R_{tot(down)}} = \frac{1}{R_{down(active)}} + \frac{1}{R_{down(passive)}} + \frac{1}{R_{air}} \tag{1}$$

$$\frac{1}{R_{tot(up)}} = \frac{1}{R_{up}} + \frac{1}{R_{air}} \tag{2}$$

At the end, the 'Cost weighted distance' function in ArcGis 8.3 was applied to find the least accumulative cost from each point in the river to the nearest source population. The functions that perform 'Cost weighted distance' mapping compute the accumulative cost of travelling from each cell to the nearest taxon population, based on the cell's distance from each remaining population and the cost to travel through the environment. More detailed information about the migration models of *Gammarus pulex* and *Baetis* can be found in respectively Dedecker *et al.* (2004b) and Dedecker *et al.* (2004c).

Table 1. Attribution of the resistance for the upstream (R_{up}) and downstream (R_{down}) migration of *Gammarus pulex*, *Baetis*, Limnephilidae and *Ephemera* through the water column based on the determining parameters (n.a. = not applicable, n.s. = not significant).

Determining parameters	*Gammarus pulex*		*Baetis*		
	R_{up}	$R_{down(active + passive)}$	$R_{up(active)}$	$R_{down(active)}$	$R_{down(passive)}$
• Boulders					
- presence	n.a.	n.a.	2	7	n.a.
- absence	n.a.	n.a.	4	13	n.a.
• Flow velocity	0.06-0.49	0.02-0.12	n.a.	n.a.	1-50
• Macrophytes					
- presence	n.a.	n.a.	n.a.	n.a.	1-50
- absence	n.a.	n.a.	n.a.	n.a.	1-50
• Natural banks					
- presence	n.a.	n.a.	n.a.	n.a.	n.a.
- absence	n.a.	n.a.	n.a.	n.a.	n.a.
• Impounded river section	10	10	50	50	30
• Weir	200	100	200	100	100

	Limnephilidae			*Ephemera*		
	$R_{up(active)}$	$R_{down(active)}$	$R_{down(passive)}$	$R_{up(active)}$	$R_{down(active)}$	$R_{down(passive)}$
• Boulders						
- presence	n.a.	n.a.	n.s.	n.s.	n.s.	n.s.
- absence	n.a.	n.a.	n.s.	n.s.	n.s.	n.s.
• Flow velocity	n.a.	n.a.	n.s.	n.s.	n.s.	n.s.
• Macrophytes						
- presence	3-6	3-6	n.s.	n.s.	n.s.	n.s.
- absence	6-11	6-11	n.s.	n.s.	n.s.	n.s.
• Natural banks						
- presence	3-6	3-6	n.s.	n.s.	n.s.	n.s.
- absence	6-11	6-11	n.s.	n.s.	n.s.	n.s.
• Impounded river section	50	50	n.s.	n.s.	n.s.	n.s.
• Weir	200	100	n.s.	n.s.	n.s.	n.s.

Table 2. Attribution of the resistance (R_{air}) for migration of *Baetis*, *Ephemera* and Limnephilidae through the air in relation to the surrounding environment

Surrounding environment	R_{air}		
	Baetis	Limnephilidae	*Ephemera*
• Water surface	1	1	1
• Buffer strip (if present)	1	1	1
• Land use			
- Urban region	20	20-100	20
- Industrial area	20	20-100	20
- Forest	1	1-5	2
- Meadow	1	1-5	2
- Arable land	1	1-5	2
- Nature reserve	1	1-5	2
• Impounded river section	10-20	10-20	10-20
• Weir	10-20	10-20	10-20

CONCLUSIONS

The combination of both migration models and habitat suitability models could allow for a more rational selection among different restoration scenarios. Habitat suitability models can then be used to predict if restored river sections are suitable again for the modelled organisms while the migration models can check for the possibilities of recolonization. This type of models can thus help to support decision making about river restoration management. However, validation experiments are necessary to get quantitative insight in the migration resistances of the different taxa, because expert literature contains ample information on this matter.

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