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SHORT RESEARCH NOTE

Invertebrate dispersal by aquatic mammals: a case study with nutria *Myocastor coypus* (Rodentia, Mammalia) in Southern France

Aline Waterkeyn · Olivier Pineau · Patrick Grillas · Luc Brendonck

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Abstract Many freshwater invertebrates rely on vectors for their passive dispersal. A wide array of vectors has already been investigated, but dispersal mediated by aquatic mammals remains largely unknown. Since nutria (*Myocastor coypus* Molina, 1782) live in a variety of aquatic habitats and frequently move around between these water bodies, they have the opportunity to transport hitch-hiking aquatic invertebrates along with them. We investigated the presence of aquatic invertebrates in their fur to evaluate this hypothesis. This study demonstrates the feasibility of ectozoochory in a broad array of freshwater invertebrates by nutria on a local scale. More than 800 invertebrates of 14 different taxa were retrieved from the fur of 10 nutria specimens, including cladocerans, copepods, ostracods, rotifers, bryozoans, dipterans, nematodes, annelids and collembolans. Many of these freshwater invertebrates could survive at least 30 min in the moist fur of nutria. Therefore, we can state that besides modifying aquatic habitats physically by clearing vegetation or digging, nutria may also alter invertebrate communities by introducing new species or genotypes.

Keywords Passive dispersal · Aquatic mammals · *Myocastor coypus* · Ectozoochory · Zooplankton · Macroinvertebrates

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A. Waterkeyn (✉) · L. Brendonck
Laboratory of Aquatic Ecology and Evolutionary Biology, Katholieke Universiteit Leuven, Charles Deberiotstraat 32, 3000 Leuven, Belgium
e-mail: aline.waterkeyn@bio.kuleuven.be

A. Waterkeyn · O. Pineau · P. Grillas
Research Center for Mediterranean Wetlands, Tour du Valat, Le Sambuc, 13200 Arles, France

Introduction

Dispersal is a crucial process for maintaining species and genetic diversity, facilitating colonization and gene flow (Bullock et al., 2002; Bohonak & Jenkins, 2003; Clobert et al., 2004). Many freshwater invertebrates occur in habitats that are inherently isolated, seemingly closed systems in a matrix of inhospitable land (Bilton et al., 2001). Although some freshwater insects have the capacity to actively disperse by winged stages (e.g. Coleoptera, Odonata and Hemiptera), many invertebrates rely on external agents or vectors to be transported passively (e.g. Cladocera, Copepoda, Ostracoda and Eubranchiopoda). Several vectors for aquatic invertebrate dispersal have already been studied in detail, such as wind (Vanschoenwinkel et al., 2008a), aquatic connections (Michels et al., 2001; Hulsmans et al., 2007), waterfowl (Green & Figuerola, 2005; Brochet et al., 2010), amphibians (Bohonak & Whiteman, 1999), aquatic insects (Van de Meutter et al., 2008; Beladjal & Mertens, 2009), crayfishes (Moore & Faust, 1972), large terrestrial mammals (Vanschoenwinkel et al., 2008b) and recently also man (Havel & Shurin, 2004; Waterkeyn et al., 2010). Peck (1975) also mentioned semi-aquatic mammals, such as muskrats and beavers, as vectors for amphipods, but since then dispersal by this group of organisms remained unstudied.

Coypu or nutria (*Myocastor coypus* Molina, 1782) are large (40–60 cm; 5–9 kg) herbivorous semi-aquatic rodents native to South America. This species was introduced to North America, Europe, Asia and Africa primarily by fur ranchers (Leblanc, 1994). Since nutria live in a variety of aquatic habitats, such as waterways, rivers, ditches, lakes and marshes (Woods et al., 1992) and frequently move around between these water bodies, we hypothesized that they have the potential to mediate dispersal of freshwater invertebrates.

There are two ways in which nutria may transport freshwater invertebrates externally. First of all, they could transport highly resistant propagules (resting eggs or cryptobiotic life stages) capable of surviving extended periods of drought. Secondly, nutria could also transport live invertebrates in their moist fur during short overland dispersal to another water body. Both dispersal ways are investigated in this study.

Although nutria are still valued for its fur in some regions, their destructive feeding and burrowing behaviour makes this invasive species a pest throughout most of its range, including France (Mathevet & Lucchesi, 1996), where control measures are taken to eradicate them. These measures include trapping, chemical control, baiting and shooting (Woods et al., 1992). In the estate of Tour du Valat in the Camargue (Southern France), nutria are regularly shot by hunters. We used 10 shot individuals to assess the invertebrate load they were carrying at their time of death. All animals were shot between April 2008 and July 2009 in ditches on the estate of Tour du Valat. They were retrieved from the water immediately after they were shot and laid to dry outside for about 30 min. Afterwards, each individual was washed above a 64-µm zooplankton net using a hose. Samples were processed immediately afterwards in the laboratory. Live invertebrates were isolated, identified and counted under a stereo microscope and stored in 70% ethanol. Cladocera were identified down to species level (according to Flößner, 2000), Copepoda to order level, Rotifera to genus level (except Bdelloidea) (Ruttner-Kolisko, 1974), Diptera to sub-family level (Tachet et al., 2000), Annelida to family level (Tachet et al., 2000) and Collembola to species level (except Symphypleona) (De Pauw & Vannevel, 1990). We also included the taxa Ostracoda and Nematoda. When invertebrate propagules (resting stages) were encountered, they were also isolated, counted and identified using literature where available (for Cladocera: Flößner, 2000; Vandekerckhove et al., 2004; for Bryozoa: Tachet et al., 2000). Only propagules that were deemed viable were included in our analysis. For cladocerans, only ephippia containing intact eggs without external signs of degradation were included. For some taxa (e.g. bryozoan statoblasts), viability could not be verified from external structure.

We found a total of 1,129 freshwater invertebrates of 18 different taxa in the fur of 10 shot nutria, including cladocerans, copepods, ostracods, rotifers, bryozoans, dipterans, nematodes, annelids and collembolans (Table 1). Each nutria carried on average (±SD) 113 (±161) invertebrates of 6.3 (±3.4) different taxa. Invertebrate loads per nutria were highly variable, ranging from two invertebrates to a maximum of 518 invertebrates representing 12 different taxa.

A large number of both live invertebrates and resistant propagules were found to hitch-hike along in the fur of nutria, including zooplankton and bryozoans as well as larger macroinvertebrates that do not produce drought-resistant propagules (such as dipterans). Peck (1975) already reported muskrats and beavers to transport amphipods, but in this study we confirm the feasibility of semi-aquatic mammals as vectors for a much wider array of freshwater invertebrates. Based on a temporary wetland survey (Waterkeyn et al., 2008), a wild boar dispersal study (Vanschoenwinkel et al., 2008b) and a human-mediated dispersal study (Waterkeyn et al., 2010) on the same site, we can confirm that the taxa encountered in the fur are common in the area, especially the very abundant *Chydorus sphaericus* which appears to be transported by many nutria in very large numbers.

Compared to ectozoochory of resistant propagules via vectors such as terrestrial mammals (Vanschoenwinkel et al., 2008b), waterfowl (Green & Figuerola, 2005; Brochet et al., 2010) or human footwear (Waterkeyn et al., 2010), ectozoochory of live organisms in moist fur of semi-aquatic mammals may be a

Table 1 List of invertebrates that were washed from nutria ($n = 10$)

		Taxa	No. of individuals	% Occurence
Live organisms				
	Cladocera	*Chydorus sphaericus* (O.F. Müller 1766)	478	90
		Alona guttata Sars 1862	144	50
		Alona rectangula Sars 1861	43	30
		Simocephalus exspinosus (Koch 1841)	3	10
		Ilyocryptus agilis (Kurz 1878)	1	10
	Copepoda	Cyclopoida	47	80
	Ostracoda	Unidentified	42	80
	Rotifera (>64 µm)	*Euchlanis* sp.	360	30
		Lecane sp.	29	40
		Brachionus sp.	3	10
		Bdelloidea	10	10
	Diptera	Chironomidae (Othocladiinae)	25	40
		Scyomizidae	1	10
	Collembola	*Podura aquatica* (Linneaus 1758)	4	30
		Symphypleona	1	10
	Annelida	Naididae	5	30
	Nematoda	Unidentified	5	30
Viable propagules				
	Cladocera	Chydoridae	7	20
	Bryozoa	*Plumatella* sp.	21	60

Both the total number of live individuals/viable propagules and the percentage of samples in which the taxa were encountered are presented

highly efficient mode of dispersal. Organisms arriving in a suitable habitat can start reproducing right away and can build up large populations very fast without having to go through the vulnerable process of hatching and surviving as a juvenile. Even more, for clonally reproducing organisms (such as cladocerans), one individual is enough to start a new population.

Our samples contained many macrophyte-related cladoceran species (such as chydorids, *Simocephalus* and *Ilyocryptus*). This is not surprising considering the herbivorous feeding mode of nutria, spending ample time amongst macrophytes. Furthermore, since the diet of nutria also includes roots of submerged aquatic vegetation (Abbas, 1991), we hypothesize that nutria may also be good candidates for endozoochory through the ingestion of invertebrate propagules in the sediment attached to the roots, as was demonstrated for wild boar in Vanschoenwinkel et al. (2008b).

In the Camargue nutria densities range between 1.7 and 3.3 individuals ha^{-1} marsh habitat (average: 2.5 individuals ha^{-1}) (Stauffacher, 1998). Considering these high densities and the limited scale of our study, the high numbers and diversity of dispersers encountered in our samples indicate that dispersal of freshwater invertebrates mediated by nutria may be frequent. A recent field survey investigating invertebrate community structure in the temporary wetlands on the same study site revealed patterns suggesting dispersal was not limited within the studied area (1,500 ha) (Waterkeyn et al., 2008, 2009). Nutria may be one of the vectors contributing to these high dispersal rates.

Although dispersal by nutria can be frequent, the scale on which it plays a role may be rather local. Nutria have a home range varying from 2 to 5 ha (exceptionally 12 ha) (Jouventin, 1996) and often travel distances between 40 m and 1.25 km, although most do not go further than 400 m a day (Adams, 1956; Robicheaux, 1978). Their importance as dispersal vectors may be therefore be restricted to a very local scale and mainly to aquatic habitats near channels and riverbanks where they mostly live.

However, even though most nutria stay in the same area throughout their whole life (Woods et al., 1992), some individuals have been observed to travel 40–50 km (Aliev, 1965). Therefore, occasional transport over longer distances is possible, but likely very rare.

To conclude, this study demonstrates the feasibility of ectozoochory of a wide array of freshwater invertebrates via semi-aquatic mammals over local distances. Besides their ability to modify aquatic habitats physically by clearing vegetation or digging (Lagaude, 1975), nutria may therefore also alter invertebrate communities by introducing new species or genotypes.

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