Pitfall trapping in flooding habitats: a new technique reveals *Archisotoma pulchella* (Collembola: Isotomidae) as new to the Belgian fauna

Johan Mertens[1], Lynda Beladjal[1], Frans Janssens[2] & Paul Matthys[3]

[1] **Terrestrial Ecology Unit, Ghent University, Ledeganckstraat 35, B-9000 Ghent, Belgium**
[2] **Department of Biology, University of Antwerp, Antwerp, B-2020, Belgium**
[3] **Department of Solid State Sciences, Ghent University, Krijgslaan 281/S1, B-9000 Ghent, Belgium**
Corresponding author : Johan Mertens, e-mail: Johan.Mertens@UGent.be

ABSTRACT. Flooding habitats are unique ecosystems with complex land-water interactions. Research on their terrestrial component is seriously hindered by the lack of an adequate and efficient technique for pitfall trapping. This paper focuses on three consecutive items: (1) the description of a new type of trap, developed for use in temporarily submersed areas; (2) evaluation of its potential usefulness by a literature search of pitfall trapping in diverse environments (1998-2003); (3) its application in the trapping of arthropods inhabiting a salt marsh. The literature search demonstrates a bias towards forests, neglecting flooding biotopes. Beetles and spiders are by far the prominent taxa studied that way. Apart from some Diptera, *Archisotoma pulchella*, a new species of Collembolan for the Belgian fauna, is the only arthropod species trapped by the described sampling technique on the mud flats of the intertidal zone of the Ijzer estuary (Belgium), albeit in very high numbers. Additional sampling provided records from the Schelde estuary, and allows reconstructing some characteristics of its population dynamics.

KEY WORDS : pitfall trapping, flooding habitats, *Archisotoma*, Collembola, Belgian new species, sea shore.

INTRODUCTION

Flooding habitats, such as river banks and floodplains, temporary streams, salt marshes, creeks, inundated forests, and mangroves, are unique ecosystems with complex land-water interactions. They are inhabited by faunas of aquatic, as well as amphibious and terrestrial species, adapted to fluctuations of the water table. Terrestrial arthropods are by far the most species-rich group and play an important role in the ecosystem (Desender & Maelfait, 1999). Research on the terrestrial component of tidal marshes and other flooding habitats (Desender & Maelfait, 1999; Adis & Junk, 2002; Bonn et al., 2002; Krumpalova, 2002) is seriously hindered by the lack of an adequate and efficient technique, such as pitfall trapping, a good method of sampling because of its simplicity and ease of operation. It is an effective and cheap way of qualitatively surveying the ground surface-active arthropods over long periods of time, and allows for comparison of assemblages in different habitats (Greenslade, 1964). Even when it comes to diversity and gradient analysis of terrestrial arthropods in tidal marshes, sampling techniques are limited to aspirator and hand capturing with a very restricted effort of catch in time (Desender & Maelfait, 1999).

We developed a pitfall trap suitable for habitats that are regularly or unpredictably inundated. The trap is conceived in such a way that it is enclosed and protected in an air bell from the moment the rising water reaches the rim of the trap. Later on, when the water table falls back under the rim, the original situation is restored. So pitfall trapping continues as long as the trap is not submerged, regardless the time and the frequency of inundation. Other automated sampling methods are not satisfactory for two reasons: a floating pitfall trap captures only the animals on the water surface (Graham et al., 2003), whereas the classic pitfall trapping method is restricted to the permanently dry portions of the habitat (Milford, 1999; Tajovsky, 1999; Wishart, 2000; Irmler et al., 2002; Deidun et al., 2003; Johnson, 2003). This paper focuses on three consecutive items: (1) the description of a new type of trap, developed for temporarily submersed areas; (2) evaluation of its usefulness by literature search; and (3) an evaluation of its usefulness by its application in a salt march. The general design of the pitfall is described, adaptable to all types of habitats according to the specific needs of the researcher.

Archisotoma pulchella (Moniez, 1890) was lacking in the Belgian list of Collembola (Janssens, 2004), although it is a common species of intertidal mud flat communities in the surrounding countries (Sterzynska & Ehrnsberger, 2000). Using our sampling technique, we found not only that species, but moreover we were able to reconstruct some characteristics of the population dynamics of the springtail, even when only one trap was used over a short period of time. So it is finally proved that this type of pitfall trapping yields data that generate new information, adding to knowledge of the biodiversity of flooding habitats and the ecology of their species.

MATERIALS AND METHODS

Fig. 1 presents the principle of a submersible pitfall trap before (Fig. 1A) and during (Fig. 1B) inundation, while Fig. 1C is a technical depiction of the instrument. Fig. 2 shows a photograph of the instrument with (Fig. 2A) and without (Fig. 2B) the cone, as well as the trap as used on the study area (Fig. 2C). When the water level rises (Fig. 1Be), the pitfall (1Ba) is left dry in the air bell (Fig. 1Bf) under the cone (Fig. 1Ad). The pitfall is exposed again when the water surface drops below the rim of the container (Fig. 1Aa, Ba). Its rim has to be elevated above the substrate (Fig. 1Ag, Bg) higher than the base of the cone (Fig. 1Ad), since the air of the bell compresses when the water table rises. In our design the cone is made from a reverse plastic funnel, closed at the top with silicone glue. The difference in level between the rim of the trap and the base of the air bell inside the cone is realized by the sample holder (Fig. 1Ac), a concrete ring that fits around the trap. The instrument requires tight fixation to the substrate, to withstand uplift of the air bell during inundation. This is realized by attaching the cone (Fig. 1Cd) with rubber bands (Fig. 1Ci) to a steel support structure anchored into the substrate by a soil auger (Fig. 1Ch). This steel structure consists of three brackets on radial arms (Fig. 1Cj) welded to the top of the auger (Fig. 1Ch). A 10% formalin solution is used as a fixative (Fig. 1Ab, Cb) for the captured animals.

An exploration of the literature on pitfall trapping of animal taxa in flooding areas is undertaken for five recent years (1998-2003). The search was done on ISI Web of Science using the key words for the sampling technique ‘pitfall trap’ and ‘pitfall trapping’. For the reference collection of habitats the key words mentioned in Fig. 3 were checked. Papers on ornithology, only dealing with avifauna, are omitted.

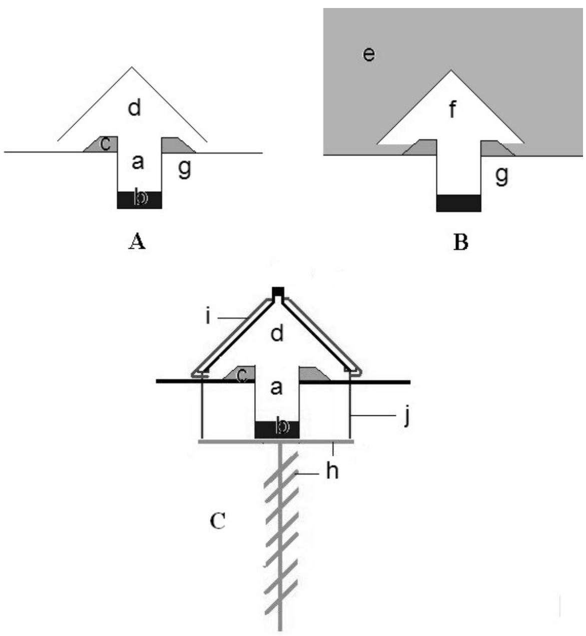

Fig. 1. – The outlines of the submersible pitfall trap before (A), during (B) the inundation, and a technical representation of the instrument (C). a: pitfall container; b: fixative; c: sample holder; d: cone (plastic funnel); e: water column; f: air bell; g: substrate; h: platform on top of the spiral; i: rubber strings; j: metallic rods.

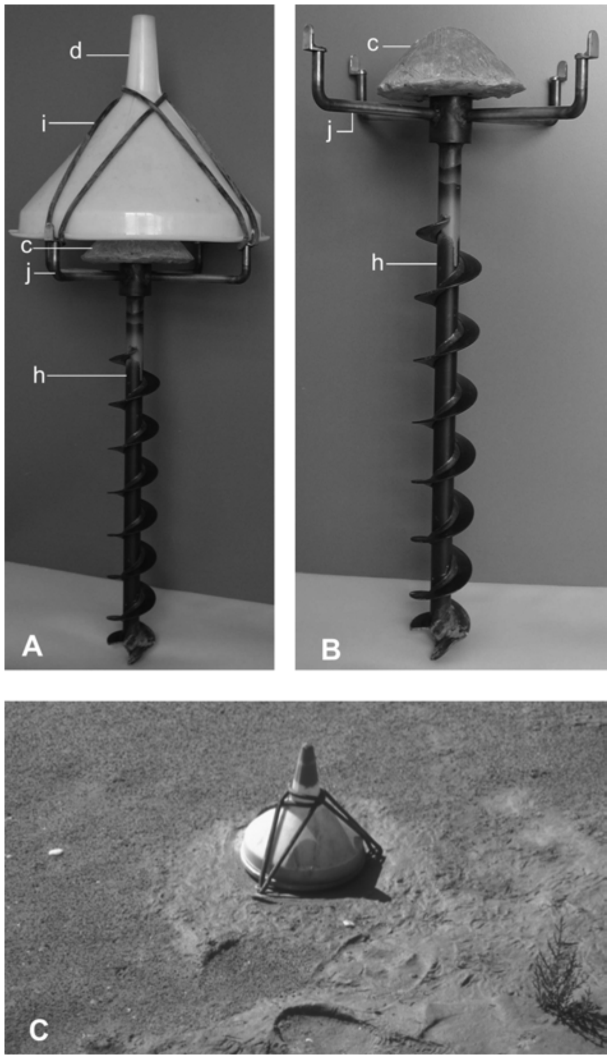

Fig. 2. – A photograph of the trap: with (A), without the cone (B), and as used on the study area (C). The numbers correspond to these of Fig 1.

The prototype of the pitfall trap was used in a salt marsh (Nature Reserve at the Estuary of the river Ijzer, Nieuwpoort, Belgium, UTM10x10: DS86) from 4 August till 15 September 2003, as shown in Fig. 2C. At intervals of two weeks the content of the pitfall was harvested (one interval corresponds to one sample), and sorted out at the lab. Apart from a few Diptera (Brachycera), the harvest was a single species collection of *Archisotoma pulchella* (Moniez, 1890). These springtails were counted and measured under a stereomicroscope (Wild M5). When a sample was too rich in specimens, a representative subsample was taken for this quantitative analysis.

Additional samples of *A. pulchella* were collected from the Estuary of the river Schelde (Kallo, UTM 10x10: ES87) at low tide on peat outcrops of the river banks, by means of a mouth-operated aspirator, on 2003 September 3, and 25 (9 and 18 specimens; legit: Frans Janssens & Jos Bruers). The taxonomic identification is based on Gisin (1960); Thibaud & Palacios-Vargas (2001); and Potapov (2001).

RESULTS AND DISCUSSION

The rising water surrounding the pitfall trap causes an air bell in the trap as well as under the protecting cone. Moreover, the pressure on the air bell will increase in accordance with the rising water column above the instrument. When the height between the rim of the cone and the water surface is substantial, one needs a careful evaluation of the compression of the air bell and the corresponding increase of the water level approaching the rim of the trap. Inaccurate evaluation causes flooding of the trap and loss of the sample. Those who are less mathematically inclined will arrive at acceptable results by trial and error, when simulating the trap in the appropriate environment. For whom it may concern, we could mail a detailed calculation of the physical changes when the water rises around the trap, followed by a FORTRAN code and a numerical evaluation. One has to keep in mind that the submersible pitfall is not protected against beating of waves nor strong irregular horizontal water currents. If not sheltered by one or another type of screen, each incoming wave flows over the sample holder into the pitfall, inundating the sample.

The results of the literature survey are visualised as a ranking in Fig. 3. By splitting up the references into habitat types (Fig. 3A) one observes that pitfall trapping is practised to a considerable extent in forests (35.1%) and agricultural ecosystems (31.0%); to a lesser degree in grasslands like pastures (9.3%), but only 7.2% in potentially or regularly submerged habitats. This confirms our suspicion that information based on pitfall trapping is biased towards forests and some preferred habitats, neglecting others including many types of inundated biotopes.

References of faunistic research, based on pitfall trapping, are summarised in Fig. 3B. When it comes to flooding areas, the pitfall technique is omitted in periods of risks of inundation. It has to be concluded that our apparatus opens a novel sampling methodology for pedofauna research in frequently flooded areas. Most references report on mangroves, but no information is available on their pedofauna, since the terrestrial component is limited to arboreal foraging groups, prominently ants, although arthropods on mud flats, like decapods (ASHTON et al., 2003), spiders or some insect groups (MORRISEY et al., 2003) are cited as frequently occurring inhabitants. The bulk of the papers describe the aquatic environment. Mangroves are followed by papers on floodplains and salt marshes. Here too we observe a pattern in favour of the aquatic element. If not on mammals, pedobiology focuses on beetles and spiders. Al other submersible habitats, like temporary or intermittent streams, are scarcely studied. Sampling is restricted to inundation periods (creeks) or to prolonged dry periods (temporary streams). We observe moreover that the terrestrial component of flooded areas is discriminated against, in favour of the aquatic component.

The intertidal zone of the Ijzer estuary is a single species springtail community. *Archisotoma pulchella* is the only species trapped in our pitfall on the clay flats of the salt marsh, but in very high numbers. This species belongs to the family Isotomidae (order Entomobryomorpha, class Collembola; Syn.: *Isotoma pulchella* Moniez, 1890). It is a new species for the Belgian fauna.

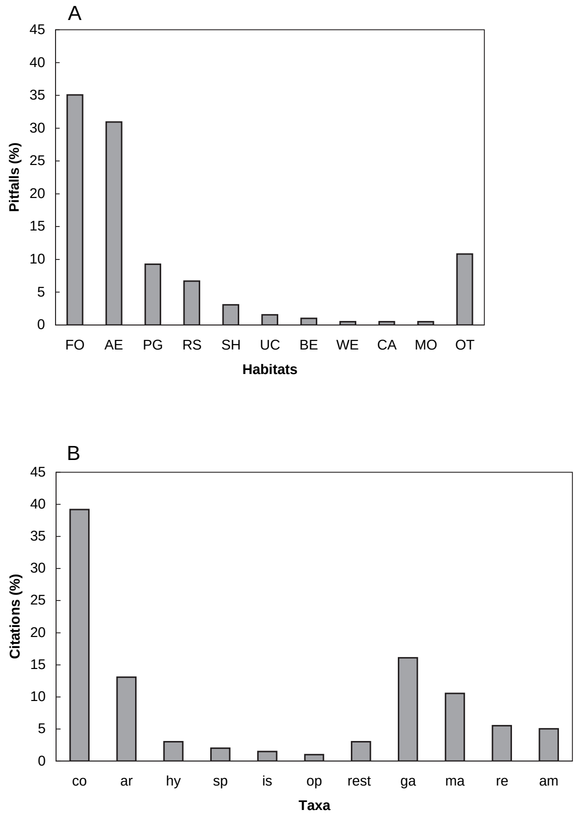

Fig. 3. – The results of a literature search of pitfall trapping in different habitats (A), and of the animal taxa collected in flooding areas (B) for five recent years. Habitat classes (key words): FO: forests, AE: agricultural ecosystems, PG: pastures, RS: riparian habitats, SH: shrub habitats, UC: urban areas, cities, BE: beaches, WE: wetlands (including marshes, fen and bog habitats), CA: caves, MO: moor lands, fell fields, grassland, river banks, shore lines of lakes, OT: others (glacier foreland, open ruins, desert, and/or undefined habitats).-The taxa are: co: Coleoptera (beetles), ar: Araneae (spiders), hy: Hymenoptera (ants), sp: Collembola (springtails), is: Isopoda, op: Opiliones, rest (Acari, Annelida, Aves, Bacteria, Chironomidae, Copepoda, Decapoda, Diplopoda, Ephemeroptera, Hemiptera Isopoda, Mollusca, Myriapoda, Nematoda, Odonata, Orthoptera, Pisces, Plecoptera, Porifera, Rotatoria, Trichoptera), ga: arthropods (general), ma: Mammalia, re: Reptilia, am: Amphibia.

The species is known from the coasts of France, Germany, The Netherlands and England. When it occurs at the sea shores of all these surrounding countries, it is evident that the Belgian gap is filled now. Known as a moderately common, widespread, littoral species, it prefers muddy or sandy surfaces on low sea shores. As a stenohaline species, it is abundant on the water surface of saline pools and under stones. The distribution pattern of *Archisotoma* communities in the soils of intertidal salt marshes is described by STERZYNSKA & EHRNSBERGER (2000). These authors found that the springtails colonize intertidal 'mud' soils to a depth of 30cm and at a distance of 10m towards the sea from the coastal edge. Our results confirm these data. Gut contents show transparent empty shells of digested diatoms (Fig. 5). Using our sampling technique, we found not only the species, but moreover we are able to reconstruct some characteristics of the population dynamics of the springtail, even though only one trap was used over a short period of time (Table 2 and Fig. 4). The numbers increase during the sampling campaign, starting from the transit of the dry hot summer period (4th of August), arriving at the high numbers in the second half of August, to a maximum at the end of the sampling period in October. In contrast, *Archisotoma* was not trapped in pitfalls at the nearby flood line, nor were common species among the amphipods, spiders, beetles and other taxa of the pitfalls on the flood line of the same sampling site found in the submersible pitfall (HOFFMANN et al., 2004). Only some individuals among the Diptera were trapped in the submersible pitfall, belonging to the families Anthomyidae (6 specimens), Chloropidae (1), Dolichopodidae (23), Ephydridae (7), Sphaeroceridae (2), and one Staphylinid beetle. Spiders and isopods were not captured by this type of trap. One could conclude that they don't walk on such mud flats.

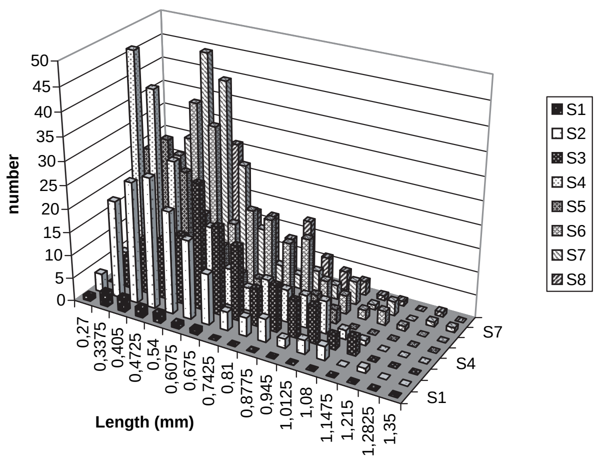

Fig. 4. – Distribution (numbers) of body length (mm) for the different sampling periods, arranged in time according to Table 2.

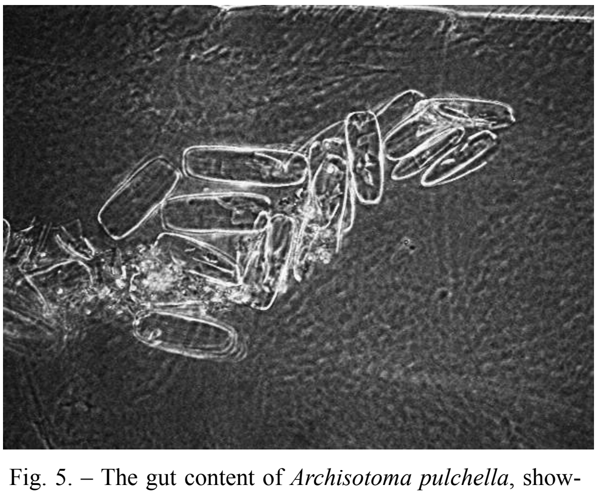

Fig. 5. – The gut content of *Archisotoma pulchella*, showing digested empty shells of diatoms.

TABLE 1

The literature search (1998-2003) on animals in submersible habitats, subdivided according to their components (water column, benthos, pedofauna and arborel); the numbers correspond to the amount of records (between brackets all cited taxa; the abbreviations are: ac: Acari, an: Annelida, ar: Araneae, av: Aves, ba: Bacteria, ch: Chironomidae, co: Coleoptera, cp: Copepoda, de: Decapoda, ep: Ephemeroptera, ga: general, arthropods, he: Hemiptera, hy: Hymenoptera, ma: Mammalia, mo: Mollusca, ne: Nematoda, od: Odonata, pi: Pisces, pl: Plecoptera, po: Porifera, re: Reptilia, ro: Rotatoria, tr: Trichoptera, un: unicellular.

aquatic		terrestrial	
mangrove: 40			
water column: 13 (pi 10; he 1; cp 1)	benthos: 23 (mo 5; de 5; ga 5; an 4; ne 2; ba 2; ac 1; po 1; un 1)	pedofauna: 0	arboreal: 7 (hy 4, ac 1, re 1, ga 1)
floodplain: 36			
water column: 18 (pi 8; ga 5; ro 2; cp 1; od 1)	benthos: 9 (ch 5; an 2; ga 2; mo 1; pl 1; ep 1)	pedofauna: 7 (ma 3; co 2; ar 2; mo 2; ac 1)	arboreal: 0
salt marsh: 27			
water column: 14 (pi 10; de 4; ga 3; cp 1; un 1)	benthos: 7 (ga 6; de 3; ne 2; an 2; mo 2; av 1)	pedofauna: 1 (co 1; ar 1)	arboreal: 0
temporary / desert / intermittent stream: 10			
water column: 0	benthos: 7 (ga 6; pl 1)	pedofauna: 2 (ga 2)	arboreal: 1 (tr 1)
creek: 6			
water column: 2 (pi 2)	benthos: 4 (ga 3; mo 1)	pedofauna: 0	arboreal: 0

TABLE 2

Number and capture rate (springtails/day) of *Archisotoma* collected in the submersible trap over a continuous sampling period, divided in 8 intervals (sampling time: day/month).

sampling time	04/08	12/08	18/08	25/08	01/09	08/09	15/09	06/10
number	2	810	2610	1700	4680	2640	1290	5540
capture rate	0.3	101.3	435.0	242.9	668.6	377.1	184.3	26.3

CONCLUSION

Although pitfall trapping is a widely used technique for studying pedofauna communities, this sampling method is not used for habitats subjected to flooding, due to the lack of a well adapted trap. Here we present a device enveloping the pitfall trap in an air bell during the whole period of inundation, leaving the trap functional when the water retreats. This type of sampling generates new information, adding to the knowledge on biodiversity and ecology of terrestrial wetland species, as we proved for the springtail *Archisotoma pulchella*.

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