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The shoemaker's son always goes barefoot: intercontinental dispersal of Ostracoda (Crustacea) by scientists attending an IBS excursion

Human activity is one of the main mechanisms through which alien species are dispersed, often unintentionally. Freshwater alien species commonly are transported between continents by vectors such as ballast water or ship transport of commercial stocks for aquaculture or agriculture (Amat et al. 2005, Escrivà et al. 2012, Strayer 2010). Recent studies conducted within the same biogeographic region on plant seed and aquatic invertebrate dispersal have shown that shoes, clothes and car wheels also can be important vectors (Lonsdale and Lane 1994, Mount and Pickering 2009, Waterkeyn et al. 2010, Wichmann et al. 2009).

Many scientists participate regularly in research meetings held in continents other than where they work, and these usually include excursions to natural areas. When the meeting is over and they return to their home region, the participants could act as vectors for long-distance dispersal (LDD). Here, we checked the dispersal potential of freshwater invertebrates through transcontinental traveling of practicing scientists attending an International Biogeography Society meeting.

The International Biogeography Society (IBS) organized its 6th Biennial Conference in Miami (Florida) in January 2013. Three researchers of the University of Valencia enrolled in fieldtrips to the Everglades on the 9th and to the Fakahatchee Strand on the 13th, organized as part of the meeting (Hortal et al. 2012). Both trips involved swamp tromp activities, where the attendants enjoyed walking in the shallow (c. 15–50 cm deep) wet prairies, sloughs and cypress swamps for several hours using their own footwear, which got wet and muddy. Upon arrival to the hotel one pair of hiking trainers was washed in tap water, (sample A) while two pairs of hiking boots (samples B and C) were kept dirty. Each pair, after being air-dried, was stored in a different plastic bag until arrival to the city of Valencia (Spain) the 16th of January. Researchers returned home by plane with the boots in their luggage.

In the laboratory, the three pairs of footwear were individually washed with de-ionized water in a plastic container on the 21st of January. Each wash sample (A, B and C) was homogenized and separated in three subsamples accounting for a total of nine 1-liter aquaria. All aquaria were placed in a culture chamber at a temperature of 15 ºC and 16 hours light : 8 hours dark photoperiod. Water levels were kept constant throughout the study by adding distilled water when required. During the 28 day experimental period each aquarium was checked for invertebrates on seven occasions (on days 1, 3, 7, 12, 16, 22 and 28). Limnological parameters were recorded on day 12. Each check consisted of filtering the water from each aquarium through a 100 µm mesh net and observing the retained material under a stereomicroscope (10–100x magnification). The invertebrates found (belonging to Ostracoda) were preserved in 70% ethanol. Ostracod specimens were identified according to Furtos (1936), Keyser (1977) and Teeter (1980).

The electrical conductivity (EC = 1.5 ± 0.4 mS/cm), water temperature (T = 17.3 ± 0.5 ºC) and pH (pH = 8.3 ± 0.05) in the cultures did not vary notably among aquaria. On day 12, one living ostracod and one right valve of the same species were collected from aquarium B2, all identified as females of *Candona furtosae* Teeter, 1980 (Fig. 1), a species only recorded previously in Florida (USA). The carapace lengths of these individuals measured 1.05 and 1.10 mm, similar to measures of adult females collected in Pleistocene sediments of Florida by Teeter (1980). This author remarks that *C. furtosae* was also found in wayside pools by Furtos (1936) and mangrove regions of the Everglades National Park (Keyser 1977) in Southern Florida (in both publications misidentified as *C. balatonica*). Karanovic (2006) checked the material of Furtos (1936) and reassigned her

C. balatonica specimens to *Candona acutula* Delorme, 1967. However, after checking SEM pictures of valves of *C. acutula* from Canada taken by Horne et al. (2011), we observed clear morphological differences with the pictures of *C. furtosae* described by Teeter (1980). Furtos (1936) drawings, Keyser (1977) SEM photos and our individuals (Figure 1) are all most similar to Teeter (1980) specimens. Therefore, taking into account these morphological differences, together with the strong climatic cline comparing the distribution of *C. acutula* (mostly distributed in Canada) with that of *C. furtosae*, we consider them as different species, needing further clarification of anatomical details described by Karanovic (2006).

After traveling thousands of kilometers, a minimum of two diapausing ostracod eggs or juveniles tolerant to desiccation (as observed in other Candoninae; Horne, 1993) were transported in mud attached to footwear and hatched under laboratory conditions. Ostracod LDD can be related to natural dispersal vectors such as migrating birds (Proctor 1964, Frisch et al. 2007) but, to our knowledge, this is the first time that unintentional LDD by researcher-related activities has been demonstrated in ostracods, although previous studies already suggested that it might happen more commonly than thought (Nathan et al. 2008, Waterkeyn et al. 2010). Waterkeyn et al. (2010) found that muddy boots of field biologists can be a significant vector of invertebrate eggs in natural parks, and suggested that if carried in a secondary transport between different wetlands also could result in LDD. Our study, although just a proof of principle, demonstrates this type of LDD, warning that mud adhered to clothes and footwear might be an important transcontinental dispersal vector of aquatic invertebrates. Most probably many small freshwater organisms are being dispersed long distances at higher rates than previously thought (Strayer 2010), and mostly via trading activities (i.e. *Artemia franciscana* (Kellog 1906) (Amat et al. 2005) and *Daphnia lumholtzi* G.O. Sars, 1885 (Havel et al. 2005)). Wildlife tourists and scientists alike, who are usually concerned about the threats posed by invasive species, should be aware and take special cautions when visiting natural (protected) environments in foreign countries to avoid becoming themselves LDD vectors of potential invaders. In this regard, not only tourists and scientists, but also trip organizers and field guides and agencies must consider prevention measures. Control protocols by the Australian Custom Services are a good example of this (Pheloung, 2003).

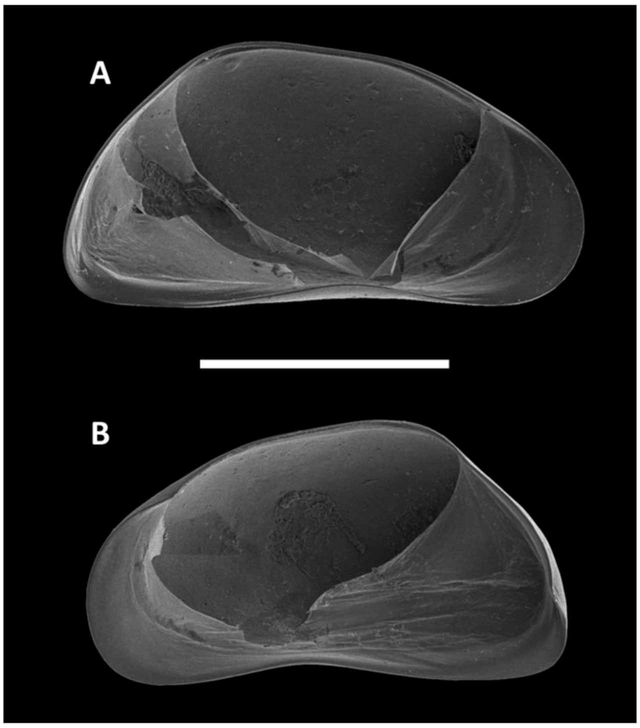

Figure 1. Scanning electron microscope (SEM) picture of female *Candona furtosae* Teeter, 1980. A: Left valve, inner view; B: Right valve, inner view. Scale bar: 447 µm.

In this study we only examined the footwear of three researchers and found one transcontinental dispersal event. How many of us might have contributed to LDD from/to natural areas elsewhere? Devising and promoting measures to prevent these dispersal events at science meetings is imperative. To start controlling them, IBS organizers could provide resources for field trip attendees to clean their clothes and boots after finishing the trip to reduce dispersal risk, and field guides should provide advice on this issue. Otherwise we would resemble the shoemaker's son that went home barefoot: discussing in one continent the problems of human-mediated dispersal of alien species and then returning home loaded with an unnoticed charge of potential invaders.

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