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Track analysis of Oribatid mites (Acari: Oribatida) of the Subantarctic subregion of South America

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Abstract

We analysed distributional data of 30 species of Oribatid mites of the Subantarctic subregion of southern South America in order to contribute to elucidate their biotic evolution. We constructed individual tracks for the species analysed, based on published and unpublished records. After superposing them we obtained six generalized tracks and five nodes. Four generalized tracks (T2, T3, T4 and T6) extend along and near the Andean ranges, whereas two generalized tracks (T1 and T5) may be artefacts caused by the lack of information. The generalized tracks and nodes show the complex relationships of the austral biota, as hypothesized in previous contributions based on other plant and animal taxa.

Key words: Nodes, Oribatid mites, Subantarctic subregion, South America, Tracks

Introduction

Oribatid mites are small arachnids and one of the most diverse and abundant groups of arthropods, which are present in almost every environment of the Earth. Most of the species are strongly sclerotized and slow-moving as adults. They are primarily fungivorous, algivorous or saprophytic (Starý & Block 1998). Their dispersal abilities are limited because of their microscopic size.

It is usually assumed that mites are widely distributed around the world, and little attention has been paid so far to any patterns of distribution at a global scale and the processes that might have shaped them. Since oribatid mites are a group of very ancient arthropods, with an evolutionary history extending back several millions of years into geological time, we should consider the possibility that their global distribution has been influenced by changes in world climate and topography that have occurred during this time (Hammer & Wallwork 1979).

Different geological and climatic events have determined the structure and distribution of communities in the extreme south of South America, having a causal role in the extinction, differentiation and changes in the geographical distribution of the biota (Simpson 1983, Nores & Cerrana 1990, Crisci *et al.* 1991a, Hernández *et al.* 1992, Hinojosa & Villagrán 1997, Villagrán & Hinojosa 1997, Young *et al.* 2002). Some authors have associated the rise of the Andes with the expansion of the distribution of some taxa (Van Der Hammen & Cleef 1983, Ezcurra *et al.* 1997). For example, several sub-Antarctic taxa (e.g., *Colobanthus* Bartl., *Cotula* L., *Oreobolus* R. Br., *Uncinia* Pers. and many bryophytes) have reached the northern Andes, spreading throughout the Andean highlands (Van Der Hammen & Cleef 1983). Other authors have considered that the Andean uplift was a vicariant event that split the continent into a western area with taxa usually related phylogenetically to taxa from Australia and New Zealand; and an oriental area with taxa related to taxa from the Old World tropics (Katinas *et al.* 1999, Morrone 2001).

Distributional patterns of Cryptostigmatid genera on a global scale have been documented by Hammer &

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Wallwork (1979), who considered that the observed patterns could be interpreted in the light of continental drift theory. One-third of the genera belonging to the suborder Oribatei are cosmopolitan in distribution. Another third posses a wide distribution on land masses that can be identified with either the ancient Gondwanaland or Laurasia, which is consistent with the antiquity of the group (Hammer & Wallwork 1979). In addition, there seems to be very little evidence of any large-scale recent dispersal overseas. Many of the more 'recent' genera (i.e. Oribatei Superiors) have restricted or endemic distributions (Wallwork 1984).

The present study analyses the distributional patterns of 30 species of oribatid mites in the Subantarctic subregion of South America. It represents the first track analysis of its kind which uses new records of Oribatid mites in Argentina.

Material and methods

Records of mites were compiled from Ruiz *et al.* (2015) and Ruiz (unpubl. data). The oribatid mites selected for this work are not cosmopolitan and their occurrences were obtained from bibliography as well as from collected materials by the authors in the Subantarctic subregion of South America in *Nothofagus* forests. The selected species are: *Austrocarabodes (A.) travei* (Balogh & Csiszár 1963), *Austroppia crozetensis* (Richters 1907), *A. petrohuensis* (Hammer 1962), *Brachioppiella (Gressittoppia) pepitensis* (Hammer 1962), *B. periculosa* (Hammer 1962), *Gerloubia bicuspidata* (Hammer 1958), *Globoppia minor* (Hammer 1962), *Graptoppia (Stenoppia) angusta* (Hammer 1962), *Heminothrus (Platynothrus) quadristriatus* (Hammer 1958), *H. (P.) skoettsbergi* (Trägårdh 1931), *Lanceoppia (Bicristoppia) bicristata* (Hammer 1962), *L. (L.) kovacsi* (Balogh & Csiszár 1963), *Licnodamaeus granulatus* (Balogh y Csiszár 1963), *Liochthonius (L.) fimbriatissimus* (Hammer 1962), *Loftacarus longicaudatus* (Balogh & Csiszár 1963), *Maculobates longiporosus* (Hammer 1962), *Membranoppia (Pravoppia) argentinensis* (Balogh & Csiszár 1963), *Neoamerioppia (N.) longiclava* (Hammer 1962), *Oribatella (Oribatella) punctata* (Hammer 1958), *Paraphauloppia morenoi* (Hammer 1962), *Pheroliodes roblensis* (Covarrubias 1968), *Pletzenoppia inclinata* (Hammer 1962), *Pseudotocepheus hauseri* (Mahunka 1980), *Pseudoceratoppia horaki* (Mahunka 1980), *Sellnickochthonius elsosneadensis* (Hammer 1958), *Subiasella (Lalmoppia) arcuata* (Hammer 1958), *Suctobelbella (S.) variabilis* (Hammer 1962), *Suctobelbila pulchella* (Hammer 1962), *Trichthonius pulcherrimus* (Hammer 1958) and *Zetomimus (Z.) furcatus* (Warburton y Pearce 1905).

Track analysis is based on three main concepts: individual track, generalized or standard track and node (Morrone 2009). The 219 occurrences of the 30 oribatid mites species studied were georreferenced using Global Mapper v.16.2 (Blue Marble Geographics, www.bluemarblegeo.com). Species are represented by at least two occurrences, with a mean of seven occurrences per species. Once distribution points for each species were generated on a map, they were connected with a line representing the minimum distance between them, known as individual track. Individual tracks represent the spatial coordinates of a species or group of related species in space. When individual tracks from different taxa match, they reflect a generalized track, which allows to infer the existence of an ancestral biota widely distributed and fragmented by vicariance events, suggesting a shared history within a biota (Torres-Miranda & Luna-Vega 2006). When two or more generalized tracks overlap in an area, a biogeographic node is identified. It is considered a complex area, where different ancestral biotic and geological fragments interrelate in space-time as a consequence of terrane collision, docking or suturing (Morrone & Crisci 1995). Regarding the identification of nodes, it is important to note that not all species belonging to a generalized track are present in the nodes, since some individual tracks are not part of the entire extension of a generalized track. Nodes are represented by an "x" enclosed by a circle (Fortino & Morrone 1997).

Results

We constructed 30 individual tracks for the analyzed taxa (Fig. 1–4). Most of the individual tracks are distributed in south-western Argentinean Andes, along *Nothofagus pumilio* forests: *A. travei*, *A. crozetensis*, *A. petrohuensis, G. bicuspidate, G. minor*, *G. angusta*, *L. kovacsi*, *L. granulatus*, *L. fimbriatissimus*, *L. longicaudatus*, *M. longiporosus*, *N. longiclava, P. morenoi*, *P. roblensis*, *S. elsosneadensis*, *S. pulchella* and *S. variabilis*. The species *B. pepitensis, B. periculosa*, *L. bicristata, M. argentinensis, P. inclinata*, *P. horaki* and *P. hauseri* cross Santa Cruz province over the Patagonian steppe, probably due to lack of data. On the other hand, *H. skoettsbergi, O. punctata* and *S. arcuata* cross all the Patagonian province by the east and south of the Monte province, probably due to lack of data. One species, *T. pulcherrimus*, is distributed in the southern South American transition zone that includes the Monte and Prepuna provinces.

We obtained six generalized tracks (Fig. 5). Four of them are located in the Andean region and two in both the Andean region and the South American Transition zone. Individual tracks supporting each generalized track are indicated on table 1. Individual tracks of *Globoppia minor, Maculobates longiporosus, Neoameroppia longiclava, Oribatella punctate, Suctobelbella variabilis and Trichthonius pulcherrimus* did not contribute to any of the generalized tracks found.

TABLE 1. Contribution of Oribatid mites species to generalized tracks found.

Species	Generalized tracks					
	1	2	3	4	5	6
Austrocarabodes (A.) travei						X
Austropia crozetensis			X			
A. petrohuensis			X			
Brachioppiella (G.) pepitensis.	X					
B. periculosa	X					
Gerlubia bicuspidata				X		
Globoppia minor	None					
Graptoppia (S.) angusta			X			
Heminothrus (P) quadristreatus					X	
H. (P) skoettsbergi		X				
Lanceoppia (B) bicristata	X					
Lanceoppia (L.) kovacsi						X
Licnodemaeus granulatus						X
Liochthonius (L.) fimbriatissimus		X				
Loftacarus longicaudatus				X		
Maculobates longiporosus	None					
Membranoppia (P.) argentinensis	X					
Neoamerioppia (N.) longiclava	None					
Oribatella punctata	None					
Paraphauloppia morenoi		X				
Pheroliodes roblensis				X		
Pletzenoppia inclinata	X					
Pseudoceratoppia horaki	X					
Pseudotocepheus hauseri	X					
Sellnickochthonius elsosneadensis				X		
Subiasella (L.) arcuata	X					
Suctobelbella pulchella						X
S. variabilis	None					
Trichthonius pulcherrimus	None					
Zetomimus furcatus					X	

Generalized track 1 is located in the Subantartic subregion (Valdivian Forest and Magellanic Forest provinces) and the Patagonian subregion (Patagonian province). This track is distributed in south-western Argentina, and also crosses Santa Cruz province over the steppe.

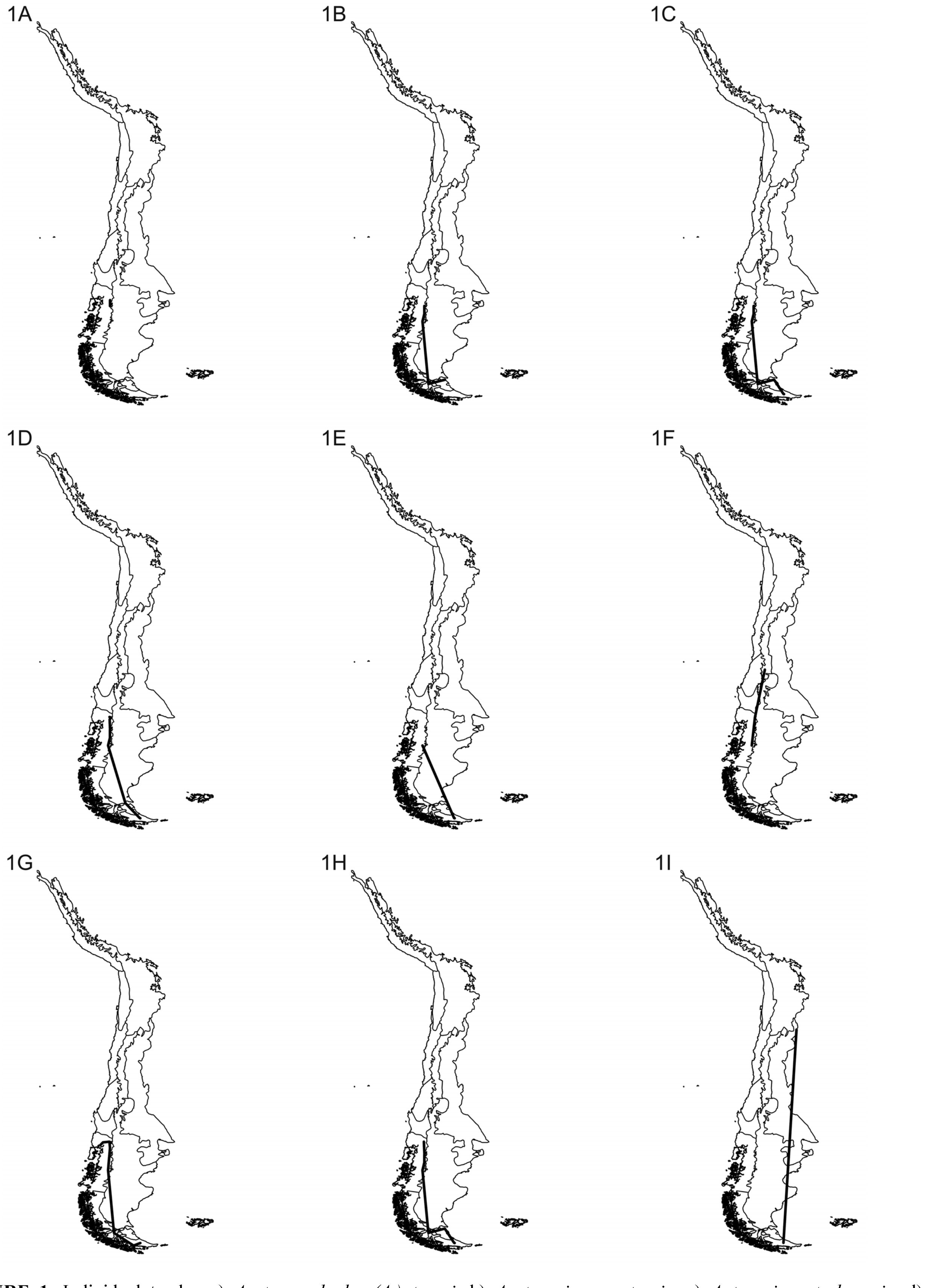

FIGURE 1. Individual tracks. a) *Austrocarabodes (A.) travei*, b) *Austroppia crozetensis*, c) *Autroppia petrohuensis*, d) *Brachioppiella (G.) pepitensis*, e) *Brachioppiella periculosa*, f) *Gerlubia bicuspidata*, g) *Globoppia minor*, h) *Graptoppia (S.) angusta*, i) *Heminothrus (P.) quadristriatus.*

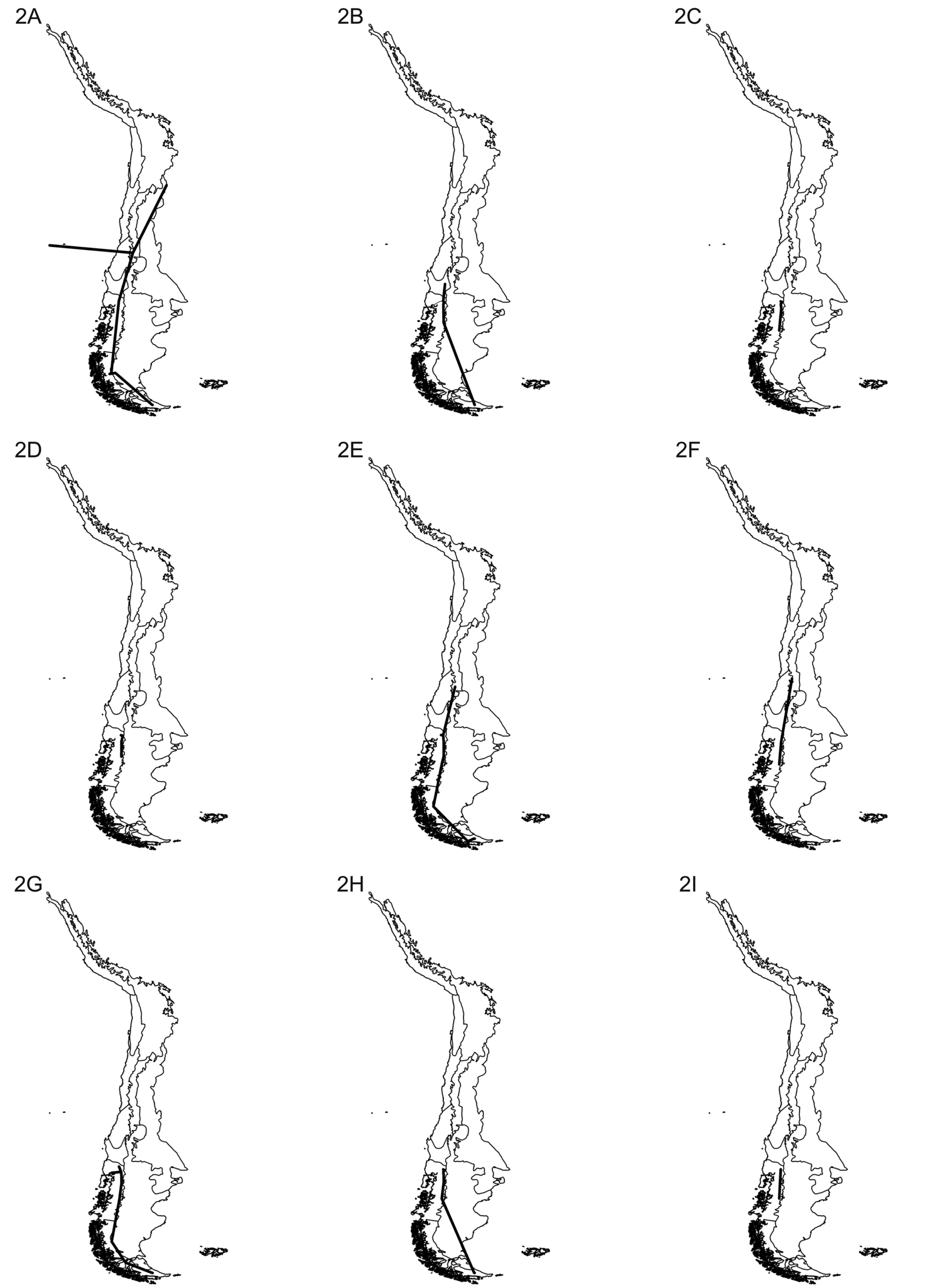

FIGURE 2. Individual tracks. a) *Heminothrus (P.) skottsbergi,* b) *Lanceoppia (B.) bicristata,* c) *Lanceoppia (L.) kovacsi,* d) *Licnodemaeus granulates,* e) *Liochthonius (L.) fimbriatissimus,* f) *Loftacarus longicaudatus,* g) *Maculobates longiporosus,* h) *Membranoppia (P.) argentinensis,* i) *Neoameroppia (N.) longiclava.*

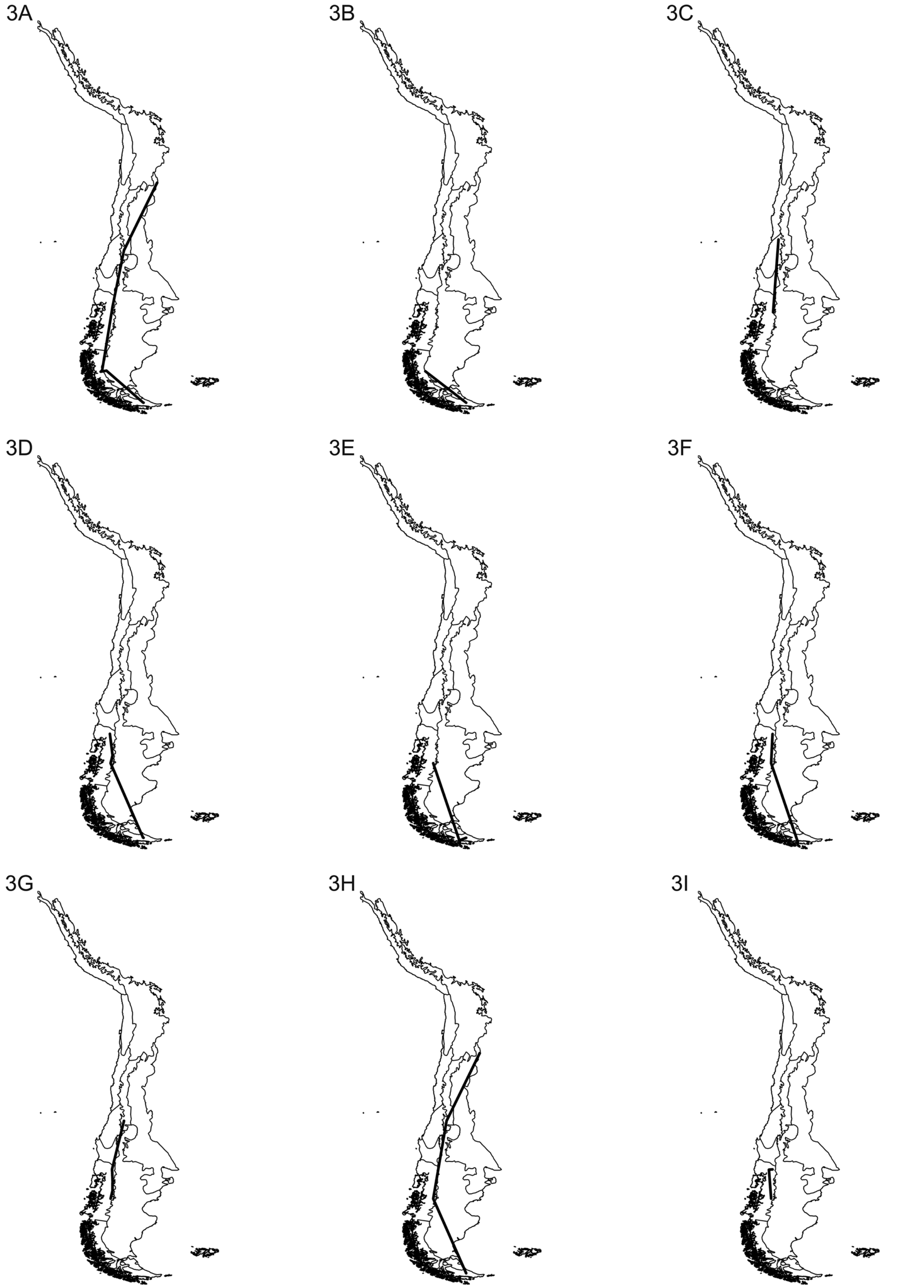

FIGURE 3. Individual tracks. *a*) *Oribatella (O.) punctata. b*). *Paraphauloppia morenoi*, c) *Pheroliodes roblensis*, d) *Pletzenoppia inclinata*, e) *Pseudoceratoppia horaki, f) Pseudotocepheus hauseri, g*) *Sellnickochthonius elsosneadensis, h*) *Subiasella (Lalmoppia) arcuata* i). *Suctobelbila pulchella*.

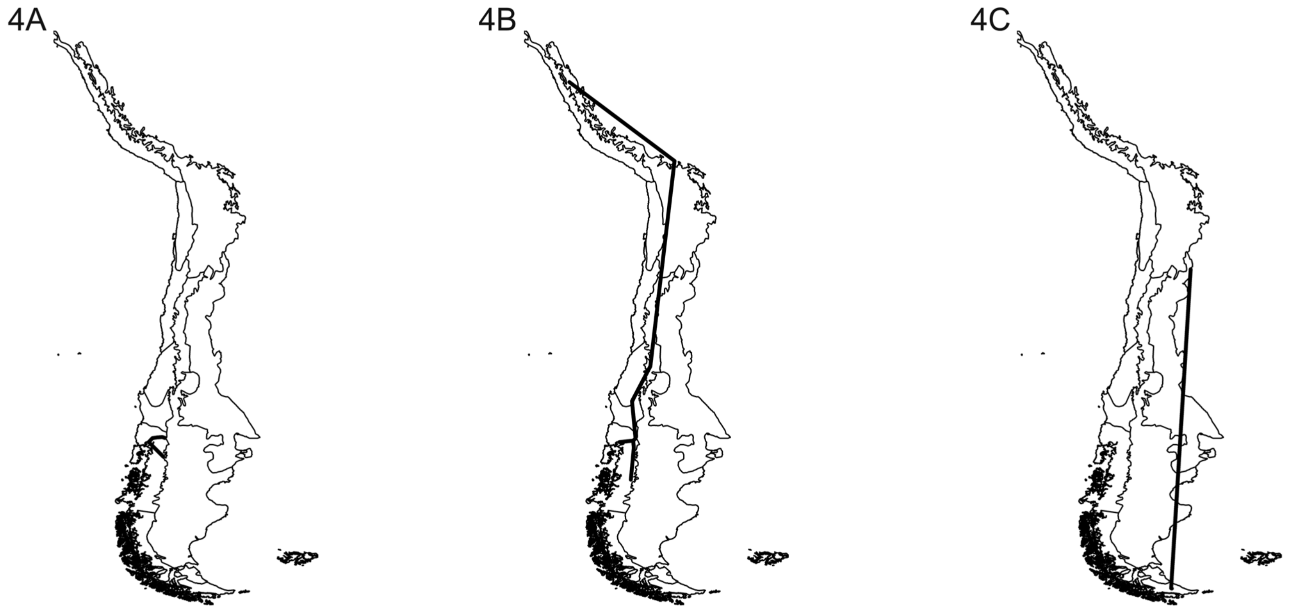

FIGURE 4. Individual tracks. a) *Suctobelbella (S.) variabilis*, b), *Trichthonius pulcherrimus, c*) *Zetomimus (Z.) furcatus.*

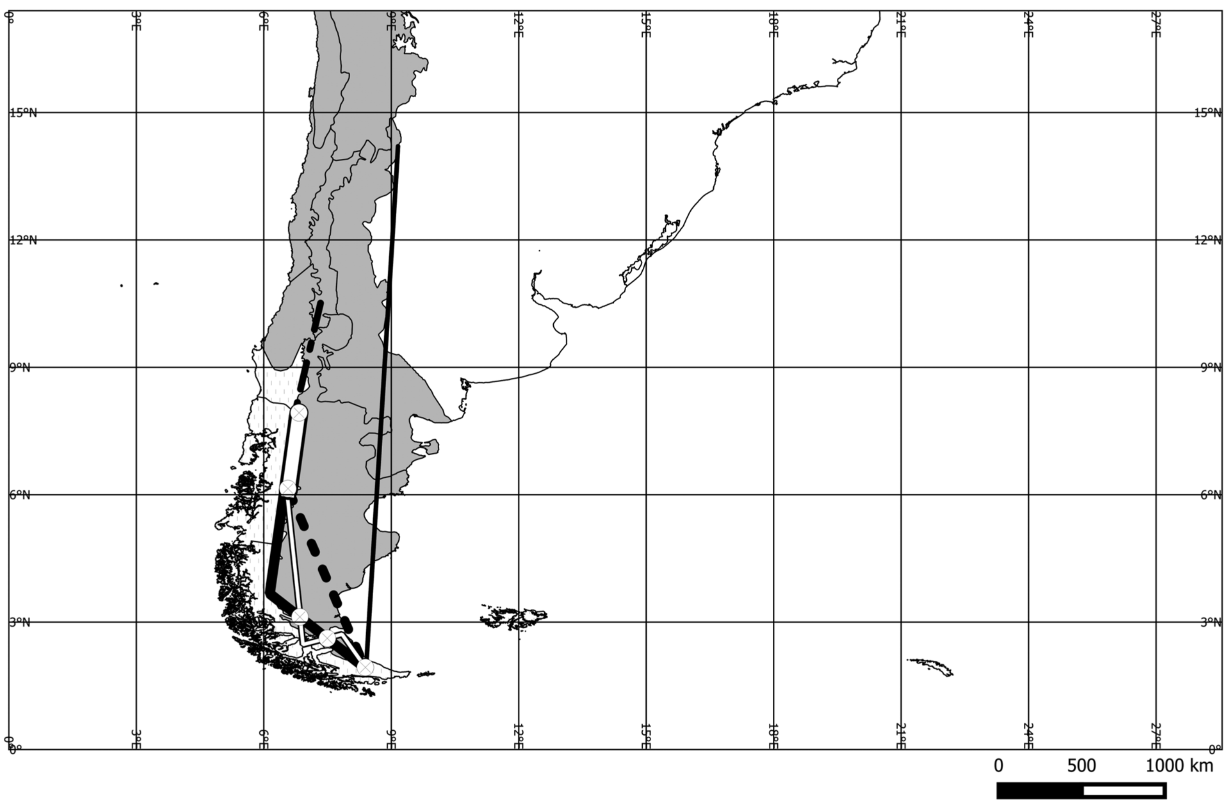

FIGURE 5. Generalized tracks (1–6) and nodes (A–E). Generalized track 1, dotted black line. Generalized track 2, thick black line. Generalized track 3, thin white line with black border. Generalized track 4, dot-line black line. Generalized track 5, thin black line. Generalized track 6, thick white line with black border.

Generalized track 2 is located in the Patagonian subregion (Patagonian province) and Subantartic subregion (Valdivian Forest and Magellanic Forest provinces).

Generalized track 3 is distributed in Argentina and Chile, in the Patagonian subregion (northern Patagonian province) and Subantartic subregion (Valdivian Forest and Magellanic Forest provinces).

Generalized track 4 is located in the South American transition zone (southern Prepuna province), Central Chilean subregion (Santiagan province), Subantartic subregion (Maule and Valdivian forest provinces) and Patagonian subregion (Patagonian province).

Generalized track 5 is located in the Subantartic subregion (Magellanic Forest province), Patagonian subregion (Patagonian province) and the South American transition zone (Monte province).

Generalized track 6 is located in the Subantartic subregion (Valdivian Forest province) and Patagonian subregion (Patagonian province).

We identified five nodes (A–E; Fig. 5) at the overlap of the generalized tracks obtained. Node A is located at the intersection of tracks 1, 2, 3, 4 and 6; it corresponds to the boundary between the Subantartic subregion (Maule and Valdivian Forest provinces) and the Patagonian subregion (Patagonian province). Node B is based on the superposition of tracks 1, 2, 3 and 6; it is located south of node A, between the Subantartic subregion (Valdivian Forest province) and Patagonian subregion (Patagonian province). Nodes C and D are based on the superposition of tracks 2 and 3, located in the Patagonian province, at both sides of the Strait of Magellan. Node E, formed by the superposition the generalized track 1, 2 and 5, is the node with the southernmost location, in the Magellanic Forest province.

Discussion

According to the biogeographical regionalisation of the Andean region (Morrone 2015), most individual tracks have similar distribution along the Patagonian and Subantartic subregions. Some species extend to the southern portion of the South American transition zone (Monte province). Four out of the six generalized tracks obtained (2, 3, 4 and 6) extend along and near the Andean ranges, although a part of track 1 crosses the Patagonian steppe of Santa Cruz, away from the Andes, and reaches the province of Tierra del Fuego. Track 5 has a more distant distribution than track 1 to the Andes. Track 5 extends from the province of Tierra del Fuego to the province of Salta, crossing three subregions. Generalized tracks 1 and 5 may be artefacts, probably due to lack of records of species in the Andean mountains or pre-mountainous areas. Frequently the absence of data in certain areas (cities, inaccessible sites, etc.) responds to lack of sampling. Sample bias is a factor that should be considered when defining strategies of appropriate analysis and for the interpretation of the patterns found (Casagranda *et al.* 2009).

Based on the recent catalog of Subías (2004), the taxonomic studies of the oribatid fauna in Argentina are limited compared with studies in other parts of the world. The intensity of the research carried out in our region is not substantial considering the highest number of taxa known from the Palearctic region, even at the generic level (Schatz 2004). The most intensive studies were made mainly by Hammer (1958, 1962b) during her journeys to the Andean region of South America, when she described more than 100 new species. Balogh and Csiszár (1963) described 26 new species from Topal's collection, based on specimens collected near El Bolsón (Río Negro, Argentina). Apart from the above mentioned works, and those of Niedbala (1984) and Baranek (1986), no other taxonomic work on Oribatid mites was done in the Subantarctic subregion.

Generalized track 4 runs across some provinces of the Andean region and the South American transition zone. Previous contributions (Morrone 2001, 2006) have noted the presence of plants, insects and vertebrate common to both areas. According to several authors (Rapoport 1968, Kuschel 1969, Morrone, 1994, 2006), an important part of the Andean biota originally evolved in Patagonia and then dispersed gradually northward to the South American transition zone.

The nodes obtained show possible contact between biotic biogeographic provinces of the Andean region. Node A is located at the intersection of the Maule, Valdivian Forest and Patagonian provinces, representing a complex area related to both the Central Chilean and Subantarctic subregions. In a previous track analysis based on weevil taxa (Coleoptera: Curculionidae), Morrone (1996) also identified this area as a node. Moreira-Muñoz and Muñoz-Schick (2007) suggested the existence of a node in this area, based on species of Asteraceae, Rovito *et al.* (2004) identified a floristic boundary and Kutschker and Morrone (2011) suggested the existence of a node based on species of *Valeriana* (Valerianaceae). The complex relationships between the northern Subantarctic and Central Chilean subregions could be due to dispersal events, specially related to the ability of the biota of the Maule to disperse and colonize other areas. Node B, located between the Patagonian and the Valdivia Forest provinces (Subantarctic subregion), was also found in previous studies (Solervicens 1987). Nodes C and D are situated at both sides of the Strait of Magellan, in the Patagonian province, area that seems to provide optimal conditions for dispersal. Node E is located in Tierra del Fuego island (Magellan Forest province), near the city of Tolhuin. In a previous track analysis based on plants, insects, crustaceans, molluscs and oligochaetes (Morrone 1992), the southern portion of Tierra del Fuego (Magellan Forest and Magellanic Moorland provinces) is a node where generalized tracks connecting the Falklands and Campbell islands (New Zealand) overlap.

The large number of nodes obtained shows that the study area has a complex biogeographic history. The biogeographic patterns exhibited by the species of Oribatida, which are also distributed in Australia and New Zealand, reflect the existence of an ancient Austral biota, with Gondwanaland events likely playing a major role in their evolution, and with species extending to the Neotropics probably linked to a more recent history. These patterns confirm the complex origin of the Andean biota, evidenced in previous studies (Crisci *et al.* 1991b; Posadas *et al.* 1997). The results of this analysis are a preliminary contribution to understanding the distributional patterns of the southern species of mites in the context of evolutionary biogeography. Future analyses should handle a larger number of taxa, to achieve a deeper understanding of the evolution of the biota of the Subantarctic subregion.

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