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ORIGINAL RESEARCH ARTICLE

Geographic distribution and associated flora of native and introduced bumble bees (*Bombus* spp.) in Chile

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Summary

In the present work, we update floral associations and geographical distribution for four species of *Bombus* present in Chile, two native (*B. dahlbomii* and *B. funebris*) and two introduced species (*B. terrestris* and *B. ruderatus*). We also examine possible associations among native or introduced bees with native or introduced plant species. We found a significant non-random plant association among non-native bumble bee species and non-native plant species. Because of the distributional overlap between *B. dahlbomii* with the two non-native bee species, it is likely that *B. dahlbomii* interacts with these non-native bees.

Distribución geográfica y flora asociada de abejorros nativos (*Bombus* spp) e introducidos en Chile

Resumen

En este trabajo actualizamos las asociaciones florales y la distribución geográfica de las cuatro especies de *Bombus* presentes en Chile, dos especies nativas (*B. dahlbomii* y *B. funebris*) y dos especies introducidas (*B. terrestres* y *B. ruderatus*). Examinamos las posibles asociaciones entre abejas nativas o introducidas con las especies nativas o introducidas de plantas. Encontramos una asociación significativa no aleatoria entre especies de abejorros introducidos con especies de plantas introducidas. El solapamiento de la distribución de *B. dahlbomii* con los abejorros introducidos es probable que se produzca por la relación entre estas especies.

Keywords: *Bombus*, associated flora, distribution, Chile

Introduction

Bumble bees (*Bombus* spp.) are a genus of polylectic bees of the family Apidae, distributed worldwide, principally in temperate areas of North America and Eurasia (Michener, 2007). For the Neotropics, a total of 42 - 43 species have been recorded in a great variety of habitats, ranging in altitude from sea level to about 4400 m in the Andes (Williams, 1998; Abrahamovich and Díaz, 2002, Moure *et al.*, 2007). *Bombus* bees are important pollinators in natural and agricultural ecosystems, depending upon pollen and nectar from a great variety of plants (Traveset, 1999; Abrahamovich *et al.*, 2001; Aizen *et al.*, 2002; Morales and Aizen 2004; Smith-Ramírez *et al.*, 2005). Preliminary understanding of the relationship between *Bombus* species and the plants they exploit begins with simple observations of visitations and feeding behaviour (Abrahamovich *et al.*, 2001), which we attempt to summarize here for *Bombus* in Chile.

Bumble bees have also been introduced into many countries to provide a pollination service for commercial crops. In new environments, introduce *Bombus* may threaten populations of native pollinators by transporting diseases and competing with natives for food resources and nest sites (Free, 1993; Delaplane and Mayer, 2000; Stout and Goulson, 2002; Goulson and Hanley, 2004; Goulson, 2003; Goulson, 2004; Morales, 2007). In addition, deliberate introductions often turn into invasions with negative impacts on native

flora and fauna (Macfarlane and Gurr, 1995; Goulson, 2003). In Chile, several bees have been introduced for commercial purposes. Already reports have indicated naturalization, and in some areas large abundances (Ruz, 2002; Montalva *et al.*, 2008). This raises the concern about whether native and introduced species are interacting (Morales and Aizen, 2004; Madjidian *et al.*, 2008).

Here, we compile and update information about floral associations and geographic distribution of the species of *Bombus* present in Chile. Secondly, we address whether associations between native or introduced *Bombus* and native or introduced plant species are random or not. We specifically ask: 1) whether native and introduced *Bombus* species overlap in distribution; and 2) whether introduced *Bombus* and native *Bombus* are associated with similar plant groups (i.e. native or introduced)?

Materials and methods

Floral associations and geographical distribution of *Bombus* in Chile were gathered from personal collections (n = 48), field observations, specimens housed in entomological collections (n = 473): Pontificia Universidad Católica de Valparaíso (PUCV); American Museum of Natural History New York (A.M.N.H.); Museo Nacional de Historia Natural Chile (M.N.H.N); Instituto de Entomología de la Universidad Metropolitana de Ciencias de la Educación (U.M.C.E); Institute Miguel Lillo, Argentina (I.M.L); Museo Argentino de Ciencias Naturales Bernardino Rivadavia" (MACN); Instituto Patagónico de Ciencias Naturales San Martín Los Andes (I.P.C.N); Museo de La Plata, La Plata, Argentina (M.L.P); from the primary literature: (Spinola, 1851; Ruiz, 1923; Frison, 1925; Claude-Joseph, 1926; Montealegre, 1927; Ruiz 1941; Milliron, 1973; Arroyo *et al.*, 1982; Arretz and MacFarlane, 1986; Peña, 1986; Toro, 1986; Pérez and Petersen, 1989; Telleria, 1993; Toro and Chiappa, 1996; Abrahamovich and Díaz, 2001, Abrahamovich *et al.*, 2001; Ruz and Herrera, 2001; Abrahamovich and Díaz, 2002; Aizén *et al.*, 2002; Morales and Aizen, 2002; Ruz, 2002; Rasmussen, 2003; Abrahamovich *et al.*, 2004; Humaña and Valdivia, 2004; Rebolledo *et al.*, 2004; Abrahamovich *et al.*, 2005; Ruz and Vivallo, 2005; Smith-Ramírez *et al.*, 2005; Valdivia and Niemeyer, 2005; Muñoz *et al.*, 2006; Pérez *et al.*, 2006; Rovere *et al.*, 2006; Torreta *et al.*, 2006; Valdivia and González, 2006; Michener 2007; Morales, 2007; Montalva *et al.*, 2008; Montalva and Ruz, 2010) and congress proceedings (Retamales and Morales, 2006).

We prepared the information for each *Bombus* species, recording the following features of each: location, date, and associated plant information. We pooled all data from the different sources, performed a χ^2 test to examine associations between native or introduced bees with plant species.

Results

Native taxa summaries

***Bombus (Fervidobombus) dahlbomii* Guérin-Méneville**

Species with yellowish brown wings, and orange hairs, (varying from orange ferruginous to very pale or whitish yellows) (Fig. 1) Queens start to build their nests early in growing season. They are usually located in irregular soil cavities. Colonies are small compared to other species of the same genus.

Distribution:

From regions IV to XII in Chile (Fig. 2), from the coast to the Andes, with individuals seen over 3200 m. This is one of few species of native bees presents on the Chiloé island. Recently, there have been reports indicating its declination in the IV, V and Metropolitan Regions.

Associated flora:

B. dahlbomii is associated with 84 plant species, 63 native and 21 introduced, belonging to 42 families (Table 1): Myrtaceae (9), Asteraceae (6), Fabaceae (6), Lamiaceae (5), Alstroemeriaceae (3), Berberidaceae (3), Elaeocarpaceae (3), Gesneriaceae (3), Loasaceae (3), Anacardiaceae (2), Bignoniaceae (2), Boraginaceae (2), Brassicaceae (2), Liliaceae (2), Mutisiaceae (2), Onagraceae (2), Philesiaceae (2), Proteaceae (2), Rosaceae (2), Scrophulariaceae (2), Tropaeolaceae (2), Apiaceae (1), Caryophyllaceae (1), Convolvulaceae (1), Cunoniaceae (1), Desfontaineaceae (1), Ericaceae (1), Escalloniaceae (1), Eucryphiaceae (1), Fumariaceae (1), Gentianaceae (1), Hydrangeaceae (1), Hydrophyllaceae (1), Lobeliaceae (1), Loranthaceae (1), Mimosaceae (1), Oxalidaceae (1), Sapotaceae (1), Saxifragaceae (1), Solanaceae (1), Thymelaeaceae (1), and Verbenaceae (1).

Fig. 1. Photo of *Bombus dahlbomii* on *Galega officinalis* L.

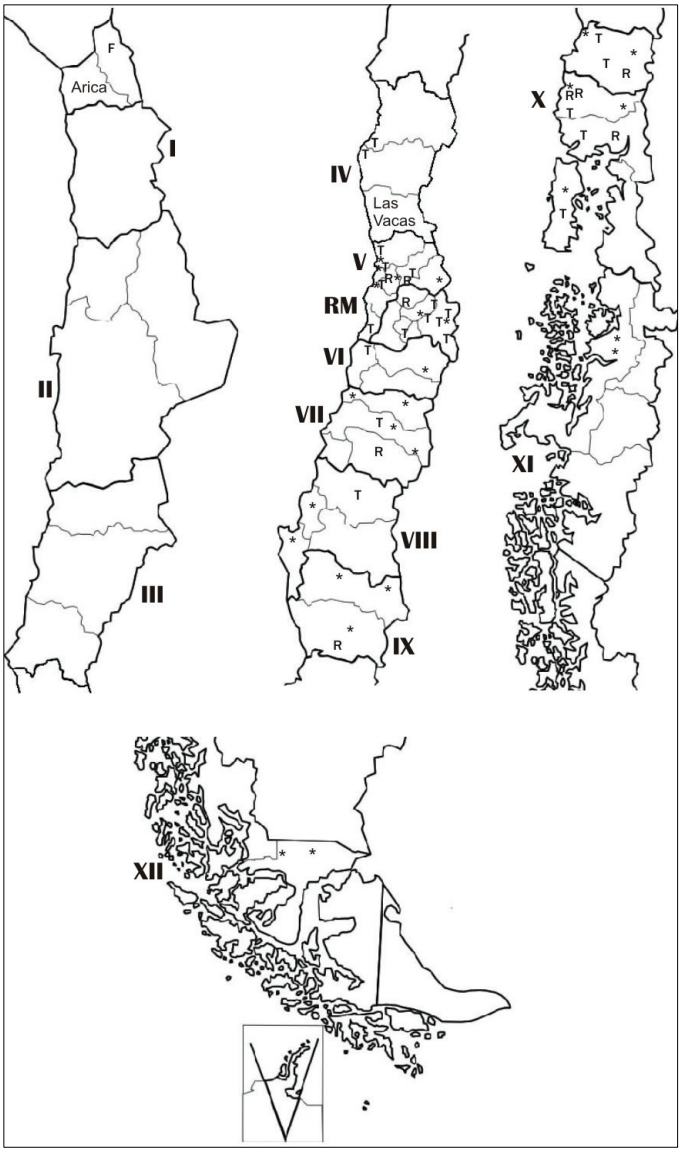

Fig. 2. Distribution according to museum labels examined here of the four *Bombus* species presents in Chile: *B. dahlbomii* (*); *B. funebris* (F); *B. terrestris* (T); *B. ruderatus* (R). Abbreviations: I-XII, regions of Chile; RM, región metropolitana.

***Bombus (Funebribombus) funebris* Smith**

Species with abundant black hairs, except a whitish circular or oval patch on the thoracic disc between wing bases, and the metasomal T4-5. Nesting or other biological characteristics remain unknown.

Distribution:

It has only been found in Putre of the Parinacota Province, Arica Region (Fig. 2). *B. funebris*, seems well suited to high altitudinal ranges with individuals found up to 4400 m. This species was mistakenly catalogued for the IV Region, first by Milliron (1973) in his Monograph of the Western Hemisphere Bumble bees (Hymenoptera: Apidae, Bombinae) and later by Toro (1986) in the "Lista Preliminar de los Apidos Chilenos". This error was probably generated by Luis Peña who deposited a sample in the Collection of Kansas indicating Las Vacas (Cochabamba), Bolivia as the location instead of the true one, Las Vacas (Coquimbo), Chile (Fig. 2).

Associated flora:

B. funebris has been associated with eight plant species, five native and three introduced, belonging to seven families (Table 1): Solanaceae (2), Asteraceae (1), Brassicaceae (1), Caesalpinaceae (1), Fabaceae (1), Lamiaceae (1), and Loasaceae (1).

Introduced taxa summaries

***Bombus (Megabombus) ruderatus* (Fabricius)**

Species with yellow, black and white hairs, mesosoma typically golden -yellow with well-defined band on the inter-wing black, metasomal terga yellow, black, and ending in white hairs. This species has a rare, completely black colour morph. Queens start to build their nests early in the growing season. Nests are usually located in irregular soil cavities such as in abandoned rodent dens. Colonies may be large.

Distribution:

Region V to the south of Puerto Montt (Fig. 2). *B. ruderatus* was introduced to Chile in 1982-1983 from New Zealand (although its primary origin was England) with the purpose of pollinating red clover, *Trifolium pratense* L. The species was used in Cunco and Coipue, south of Temuco, in the IX region. In the last two decades, *B. ruderatus* has expanded from its area of introduction, and is currently considered naturalized from Regions V to X, possibly by spreading north from the VII region. This species was described as a new species by Asperen de Boer (1992) who assigned the name of *Bombus (Megabombus) villaricaensis*, by describing 74 queens, 36 workers and one male collected in Region IX, specifically near Lake Villarrica. Later, the same author realized that this species was *B. ruderatus*, and in 1993 published a clarification that identified *Bombus villaricaensis* as a synonym for *B. ruderatus*.

Associated flora:

B. ruderatus has been associated with 18 plant species of which four are native and 14 introduced belonging to the 10 families (Table 1): Fabaceae (7), Rosaceae (2), Alstroemeriaceae (1), Boraginaceae (1), Convolvulaceae (1), Lamiaceae (2), Mimosaceae (1), Proteaceae (1), Scrophulariaceae (1), and Violaceae (1).

***Bombus (Bombus) terrestris* (Linnaeus)**

Body typically a combination of yellow, black and white hair, anterior mesosoma with yellow dorsal hairs, and the rest black; the metasoma has black hair on terga 1,3, yellow on terga 2, and whitish hair on the posterior half of tergum 4 and all of tergum 5. The nests typically by mining in underground galleries mostly in abandoned rodent dens, but it has been observed nesting in wooden walls in strongly urbanized areas.

Table 1. *Bombus* species present in Chile (*Bombus dahlbomii,* B.d.; *Bombus funebris*, B.f.; *Bombus ruderatus*, B.r.; and *Bombus terrestris*, B.t.) and the associated flora grouped according to family.

Associated plant species	**Plant Type**	***Bombus* species**			
		B.d.	***B.f***	***B.r***	***B.t***
AGAPANTHACEAE					
Agapanthus africanus L.					+
ALSTROEMERIACEAE					
Alstroemeria cummingiana (Herb.) Ehr. Bayer	Native	+			
Alstroemeria aurea Graham	Native	+		+	
Alstroemeria umbellata Meyen	Native	+			
ANACARDIACEAE					
Lithraea caustica (MOL.) Hook. & Arn.	Native	+			+
Schinus latifolius (Gill. Ex Lindl.) Engler	Native	+			+
APIACEAE					
Eryngium paniculatum Cav. et Domb. ex Delar.	Native	+			+
ASTERACEAE					
Carduus pycnocephalus L	Introduced				+
Centaurea solstitialis L	Introduced				+
Cirsium vulgare Savi	Introduced	+		+	+
Cynara cardunculus L.	Introduced	+			+
Chrysanthemum sp.	Introduced				+
Chuquiraga oppositifolia D.	Native	+			
Nassauvia pungens Phil.	Native	+			
Senecio bustillosianus Remy.	Native	+			
Senecio erucaeformis Remy.	Native	+			
Senecio sp.	Native		+		
Taraxacum officinale Weber	Introduced	+			+
BERBERIDACEAE					
Berberis buxifolia	Native	+			
Berberis darwinii Hook.	Native	+			
Berberis microphylla G. Forst.	Nativa	+			
BIGNONIACEAE					
Campsidium valdivianum (Phil.) Skottsb	Native	+			
Jacaranda mimosifolia D. Don	Introduced	+			+
BORAGINACEAE					
Echium vulgare L.	Introduced	+		+	+
Borago officinalis	Introduced	+			+
BRASSICACEAE					
Brassica campestris L.	Introduced	+			+
Brassica sp	Introduced		+		
Raphanus sativus L.	Introduced	+			
CAESALPINACEAE					
Senna birostris (Vogel) H. S. Irwin & Barneby	Native		+		
CARYOPHYLLACEAE					
Cerastium arvense L.	Introduced	+			
CONVOLVULACEAE					
Lavatera arborea L.	Introduced	+			
Calystegia sepium (L.) R. Br.	Introduced			+	+
CUNONIACEAE					
Caldcluvia paniculata (Cav.) D. Don	Native	+			
DESFONTAINEACEAE					
Desfontainia spinosa Ruiz *&* Pavon.	Native	+			

Table 1. Cont.

Associated plant species	**Plant Type**	***Bombus* species**			
		B.d.	***B.f***	***B.r***	***B.t***
ELAEOCARPACEAE					
Aristotelia chilensis (Mol.) Stunz.	Native	+			
Crinodendron patagua Mol.	Native	+			+
Crinodendron hookerianum Gay.	Native	+			+
ERICACEAE					
Gaultheria phillyreafolia (Pers.) Sleumer	Native	+			
ESCALLONIACEAE					
Escallonia pulverulenta (R *et* P) Pers.	Native	+			+
EUCRYPHIACEAE					
Eucryphia cordifolia Cav.	Native	+			
FABACEAE					
Cytisus striatus (Hill) Rothm.	Introduced			+	
Galega officinalis L.	Introduced	+			+
Lotus uliginosus (Schkuhr)	Native			+	
Lupinus arboreus Sims	Introduced				+
Lupinus luteus L.	Introduced			+	
Otholobium glandulosum L.	Native	+			+
Parkinsonia aculeata L.	Introduced				+
Senna candolleana (Vogel) Irw. & Barn	Native				+
Sophora microphylla Aito	Native	+		+	
Teline monspessulana (L.) K. Koch	Introduced				+
Trifolium pratense L.	Introduced	+	+	+	
Trifolium striatum L.	Introduced	+			
Ulex europaeus L.	Introduced			+	
Vicia faba L.	Introduced			+	
Vicia nigricans Hook. & Arn.	Native	+			
FUMARIACEAE					
Fumaria capreolata L.	Introduced	+			+
GENTIANACEAE					
Gentianella ottonis (Phil.) Muñoz	Native	+			+
GERANIACEAE					
Geranium sp	Introduced				+
GESNERIACEAE					
Asteranthera ovata (Cav.) Hanst.	Native	+			
Mitraria coccinea Cav.	Native	+			
Sarmienta repens Ruiz & Pavón.	Native	+			
HYDRANGEACEAE					
Hydrangea serratifolia (H. & A.) F. Phil.	Native	+			
HYDROPHYLLACEAE					
Phacelia secunda J. F. Gmel.	Native	+			
LAMIACEAE					
Lavandula sp.	Introduced	+			+
Lavandula officinalis L.	Introduced			+	
Mentha aquatica Ehrh	Introduced	+			+
Mentha pulegium L.	Introduced	+			
Salvia leucantha cav	Introduced				+
Stachys albicaulis Lindl.	Native	+			
Stachys arvensis L.	Introduced		+		

Table 1. Cont.

Associated plant species	**Plant Type**	***Bombus* species**			
		B.d.	***B.f***	***B.r***	***B.t***
LILIACEAE					
Luzuriaga radicans Ruiz & Pav.	Native	+			
Luzuriaga polyphylla (Hook.) J.F. Macbr.	Native	+			
LOASACEAE					
Caiphora coronata (Gillies ex Arn.) Hook. & Arn	Native	+			
Caiophora pedunculariss (K.Presl) Weigend & M.Ack.	Native		+		
Loasa caespitosa Phil.	Native	+			
Loasa heterophylla Hook. *&* Arn.	Native	+			
LOBELIACEAE					
Lobelia bridgesii Hook. *&* Arn.	Native	+			
LORANTHACEAE					
Desmaria mutabilis (P. *et* E.) Van Tiegh. ex Jacks	Native	+			
MIMOSACEAE					
Acacia dealbata Link	Introduced	+		+	
MUTISIACEAE					
Mutisia decurrens Cav.	Native	+			
Mutisia sinuata Cav.	Native	+			
MYRTACEAE					
Amomyrtus luma (Mol.) Legr. *&* Kaus.	Native	+			
Amomyrtus meli Legr. & Kaus.	Native	+			
Eucalyptus globulus Labill	Introduced				+
Luma apiculata (DC.) Burret	Native	+			
Myrceugenia ovata (Hook. & Arn.) Berg.	Native	+			
Myrceugenia parvifolia (DC.) Kausel	Native	+			
Myrceugenia planipes.(Hook. & Arn.) Berg.	Native	+			
Tepualia stipularis (Hook. & Arn.) Griseb.	Native	+			
Ugni candollei (Barnéoud) O. Berg	Native	+			
Ugni molinae Turcz.	Native	+			
ONAGRACEAE					
Fuchsia lycioides Andrews	Native	+			+
Fuchsia magellanica Lam.	Native	+			
OXALIDACEAE					
Oxalis compacta Gillies ex Hook. *&* Arn.	Native	+			
PHILESIACEAE					
Lapageria rosea Ruiz & Pav.	Native	+			
Philesia magellanica Gmel.	Native	+			
POLIGONACEAE					
Polygonum persicaria L.	Introduced				+
PROTEACEAE					
Embothrium coccineum J.R. & G. Foster	Native	+		+	
Gevuina avellana Mol.	Native	+			
RHAMNACEAE					
Colletia spinosissima Gmel	Native				+
Retanilla trinervia Miers	Native				+
ROSACEAE					
Quillaja saponaria Mol.	Native	+			+
Rubus ulmifolius Schott	Introduced	+		+	+
Rosa rubiginosa L.	Introduced			+	

Table 1. Cont.

Associated plant species	Plant Type	*Bombus* species			
		B.d.	***B.f***	***B.r***	***B.t***
SAPOTACEAE					
Pouteria splendens (A. DC.) O.K.	Native	+			
SAXIFRAGACEAE					
Francoa appendiculata Cav.	Native	+			
SCROPHULARIACEAE					
Alonsoa meridionalis L.F	Native				+
Digitalis purpurea L.	Introduced	+		+	+
Mimulus luteus L.	Native	+			+
Verbascum virgatum Stockes	Introduced				+
SOLANACEAE					
Datura sp.	Native		+		
Schizanthus hookeri Gillies ex gram.	Native	+			+
Solanum sp	Native		+		
THYMELAEACEAE					
Ovidia pillopillo (Gay) Meisn.	Native	+			
TROPAEOLACEAE					
Lonicera japonica Thunb.	Introduced	+			+
Tropaeolum azureum Bert. ex Colla	Native				+
Tropaeolum majus L.	Introduced	+			+
Tropaeolum tricolor Sweet	Native				+
VERBENACEAE					
Rhaphithamnus spinosus (Juss.) Moldenke	Native	+			
VIOLACEAE					
Viola arvensis Murria	Introduced			+	
Viola portalesia Gay	Native				+
Winteraceae					
Drimys winteri J.R. et Forster	Native				+

Distribution:

Regions IV to X including Chiloé island (Fig. 2). *B. terrestris* was introduced to Chile during 1997-1998, from colonies reared in Belgium and Israel, as a pollinator for greenhouse tomatoes. They were introduced in several localities: Arica, Copiapó, Ovalle, San Felipe, Quillota, Limache, Santiago y Los Ángeles. Currently, this species is naturalized from the IV to IX Regions (Fig. 2). All known populations appear to have high frequency of individuals and range across habitat types, including urban situations. In 2006, specimens of this species were collected in the province of Neuquén, Argentina. This finding represents a first evidence that *B. terrestris* has emigrated from Chile to Argentina.

Associated flora:

B. terrestris is associated with 48 plant species, 20 native, and 28 introduced species, which belong to 24 families (Table 1):Asteraceae (6), Fabaceae (6), Scrophulariaceae (4), Tropaeolaceae (4), Lamiaceae (3), Anacardiaceae (2), Boraginaceae (2),Elaeocarpaceae (2), Rhamnaceae (2), Rosaceae (2), Agapanthaceae (1), Apiaceae (1), Bignoniaceae (1), Brassicaceae (1), Convolvulaceae (1), Escalloniaceae (1), Fumariaceae (1), Gentianaceae (1), Geraniaceae (1), Myrtaceae (1), Onagraceae (1), Poligonaceae (1), Solanaceae (1), Violaceae (1), and Winteraceae (1).

Collective summary

Description:

The four species are generally of similar size and morphology. *B. terrestris* has a shorter tongue compared to the other three species. Colour patterns are quite varied across species, ranging from black to orange-yellows tones.

Nesting:

Three species build their nests early in the growing season with queens overwintering. Nest construction is also similar with the three using abandoned rodent galleries. Information is lacking for *B. funebris*.

Table 2. Contingency table for the association between *Bombus* species and type of plant, native or non-native. Values obtained from Table 1.

Contingency Table
BEE By Flower

	Native bumble bee	**Introduced bumble bee**	**Total**
Native plant			
Count	69	25	94
Total %	43.13	15.63	58.75
Col %	74.19	37.31	
Row %	73.40	26.60	
Introduced plant			
Count	24	42	66
Total %	15.00	26.25	41.25
Col %	25.81	62.69	
Row %	36.36	63.64	
Total			
Count	93	67	160
Total %	58.13	41.88	

Tests

N	**DF**	**-LogLike**	**RSquare (U)**
160	1	11.075390	0.1018

Test	**ChiSquare**	**Prob>ChiSq**
Likelihood Ratio	22.151	<.0001
Pearson	21.857	<.0001

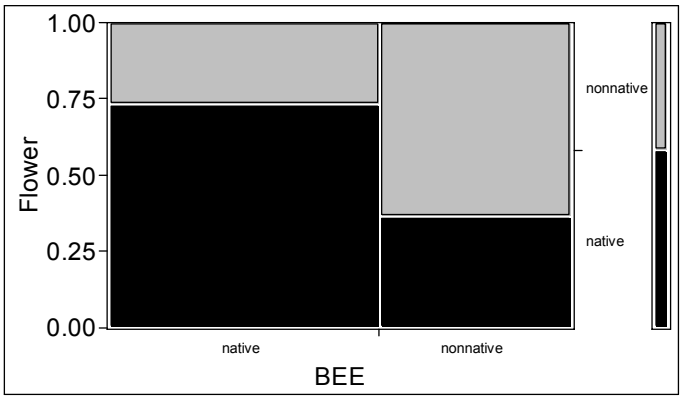

Fig. 3. Mosaic plot of the proportion of occurrences for which introduced and native bees are associated with introduced and native plants. Grey tiles indicate introduced status and black tiles native status

Distribution:

Only one species has a limited, non-overlapping distribution, *B. funebris*; whereas, the other three have overlapping distributions in central Chile.

Floral associations:

Bombus spp. were found to visit a total of 160 plant species 94 of which were native and 66 of which were introduced (Table 1). We found a significant non-random plant association among introduced bumble bee species and introduced plant species (χ^2 22.151 $p < 0.0001$) (Table 2, Fig. 3).

Further notes:

Two additional species mentioned for Chile, *Bombus* (*Fervidobombus*) *opifex* and *B.* (*Pyrobombus*) *impatiens* (Ruz, 2002; Milliron, 1973; Toro, 1986) bear mentioning here. Similarly to the early example of *B. funebris*, *B. opifex* was mistakenly cited for Coquimbo. In this case, seven workers were deposited in the collection of Kansas with labels indicating the locality of Las Vacas, but unlike *B. funebris*, the species was never present in Chile (Peña, 1986). *Bombus impatiens* is native along the Atlantic coast of North America and during the late nineties some queens were imported to Chile to pollinate greenhouse tomatoes; however, its current status in the country is unknown.

Discussion

The four *Bombus* species belong to four different subgenera: *B. dahlbomii* to *Fervidobombus*, *B. Funebris* to *Funebribombus*, *B. ruderatus* to *Megabombus* and *B. terrestris* to *Bombus* s. str. (Williams, 1998). Coloration patterns are distinct between native species, making them easily distinguishable. In contrast, the introduced species have similar patterns and colours. The small tongue of *B. terrestris* distinguishes it from the other three species. Due to this feature, it may have a more restricted nectar resource base, being blocked from ingesting tubular flower nectar unless 'robbing' it by biting the corollas for access (Montalva *et al.*, 2008).

Bombus spp behave similarly with respect to nest construction. In Japan, *B. terrestris* competes with native bumble bees for nest sites (Inoue and Yokoyama, 2010). Little work has been done in Chile, investigating possible competition for nest sites. Some information is known in regards to *B. terrestris*, which indicates no specific requirements in source of material or location of sites for nest building. There are examples of the species using abandoned rodents burrows, building walls, house attics, and leaf litter cavities (Arroyo, *pers. comm.*; Morales, 2007; Montalva *et al.*, 2008). Three of the four species have similar phenologies; *B. funebris* is unknown.

Of the four species only the native *B. funebris* was found to have a unique distribution restricted to one locality in northern Chile (Fig. 2). The two introduced species overlap extensively with the native *B. dahlbomii* in several regions of the country. Because of the distributional overlap between *B. dahlbomii* with the two introduced bee species, it is likely that *B. dahlbomii* interacts with these introduced bees.

We found that native bumble bees preferred to visit native plants while introduced bumble bees preferred to visit introduced plants similar to other studies (Fig. 3) (Telleria, 1993; Morales and Aizen, 2002; Goulson, 2003; Goulson and Hanley, 2004). Our data suggest that introduced bees may facilitate the invasion potential of

introduced plants through pollination service (Stout and Goulson, 2002; Hingston, 2006). Potential negative affects of sympatry among bees such as resource competition may be partially ameliorated due to the association between introduced bees with introduced plant species. Nevertheless, Hingston (2005) found introduced bumble bees foraging indiscriminately on native and introduced plant species. Additionally, although we found a strong association between introduced bumble bee and introduced plants, it is important to mention that it was also common for introduced bees to be associated with native plants (25 out of 67 plant associations).

We recommend monitoring introduced species in Chile, mainly their dispersal, settlement and competition with native species to provide baseline information for planning of future conservation strategies for native Chilean *Bombus*. This is particularly vital given the global decline in bumble bee abundance and diversity (Colla and Packer, 2008; Williams *et al.*, 2009; Williams and Osborne, 2009).

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References

ABRAHAMOVICH, A H; DÍAZ, N (2001) Distribución geográfica de las especies del género *Bombus* Latreille (Hymenoptera, Apidae) en Argentina. *Revista Brasileira de Entomologia* 45(1): 23-26.

ABRAHAMOVICH, A H; TELLERÍA, M C; DÍAZ, N B (2001) *Bombus* species and their associated flora in Argentina. *Bee World* 82: 76-87.

ABRAHAMOVICH, A H; DÍAZ, N B (2002) Bumble bees of the neotropical region (Hymenoptera: Apidae). *Biota Colombiana* 3: 199-214.

ABRAHAMOVICH, A H; DIAZ, N B; MORRONE, J J (2004) Distributional patterns of Neotropical and Andean species of the genus *Bombus* (Hymenoptera: Apidae). *Acta Zoologica Mexicana* 20: 99-117.

ABRAHAMOVICH, A H; DIAZ, N B; LUCIA, M (2005) Las especies del género *Bombus* Latreille en Argentina (Hymenoptera: Apidae). Estudio Taxonómico y Claves Para su Identificación. *Neotropical Entomology* 34: 235-250.

AIZEN, M; VÁZQUEZ, D; SMITH-RAMÍREZ, C (2002) Historia natural y conservación de los mutualismos planta-animal del bosque templado de Sudamérica austral. *Revista Chilena de Historia Natural* 75: 79-97.

ARRETZ, P; MACFARLANE, R (1986) The introduction of *Bombus ruderatus* to Chile for red clover pollination. *Bee World* 67: 15-22.

ARROYO, M T K; PRIMACK, R; ARMESTO, J (1982) Community studies in pollination ecology in the high temperate Andes of Central Chile. I. Pollination mechanisms and altitudinal variation. *American Journal Botany* 69: 82-97.

ASPEREN DE BOER, J (1992) *Bombus villarricaensis*, a new garden bumble bee from southern Chile (Hymenoptera: Apidae). *Entomologische Berichte* 52: 133-136.

CLAUDE-JOSEPH, F (1926) Recherches biologiques sur les hyménoptères du Chile (Melliferes). *Annales des Science Naturelles, Zoologie* 10: 114-268.

COLLA, S R; PACKER, L (2008) Evidence for decline in eastern North American bumble bees (Hymenoptera:Apidae), with special focus on *Bombus affinis* Cresson. *Biodiversity and Conservation* 17: 1379-1391.

DELAPLANE, K S; MAYER, D F (2000) *Crop pollination by bees*. CAB International; Wallingford, UK.

FREE, J B (1993) *Insect pollination of crops*. Academic Press; London, UK.

FRISON, T H (1925) Contribution to the classification of the Bremidae (bumble bees) of Central and South America. *Transactions of the American Entomological Society* 51: 137-165.

GOULSON, D (2003) Effects of introduced bees on native ecosystems. *Annual Review of Ecology and Systematics* 34: 1-26.

GOULSON, D (2004) Keeping bees in their place; impacts of bees outside their native range. *Bee World* 85: 25-26.

GOULSON, D; HANLEY, M (2004) Distribution and forage use of exotic bumble bees in South Island, New Zealand. *New Zealand Journal of Ecology* 28: 225-232.

HINGSTON, A (2005) Does the introduced bumble bee, *Bombus terrestris* (Apidae), prefer flowers of introduced or native plants in Australia? *Australian Journal of Zoology* 53: 29-34.

HINGSTON, A (2006) Is the introduced Bumble bee (*Bombus terrestris*) assisting the naturalization of *Agapanthus praecox* ssp. *orientalis* in Tasmania? *Ecological Management and Restoration* 7: 236-238.

HUMAÑA, A; VALDIVIA, C (2004) Sistema Reproductivo en *Crinodendron patagua* Mol. (Elaeocarpaceae), un Árbol Endémico de Chile Central. *Gayana Botánica* 61: 55-59.

INOUE, M; YOKOYAMA, J (2010) Competition for flower resources and nest sites between *Bombus terrestris* (L.) and Japanese native bumble bees. *Applied Entomology and Zoology* 45: 29-35.

MACFARLANE, R P; GURR, L (1995) Distribution of bumblebees in New Zealand. *New Zealand Entomologist* 18: 29-36.

MADJIDIAN, J; MORALES, C; SMITH, H (2008) Displacement of a native by an alien bumble bee: lower pollinator efficiency overcome by overwhelmingly higher visitation frequency. *Oecologia* 156: 835-845.

MICHENER, C D (2007) *The Bees of the World (2nd Ed.).* The Johns Hopkins University Press; Baltimore, USA. 953 pp.

MILLIRON, H E (1973) A monograph of the western hemisphere bumble bees (Hymenoptera: Apidae; Bombinae). II. The genus *Megabombus* subgenus *Megabombus*. *Memoirs of the Entomological Society of Canada* 89: 81-237.

MONTALVA, J; RUZ, L; ARROYO, M T K (2008) *Bombus terrestris* Linnaeus (Hymenoptera: Apidae) causas y consecuencias de su introducción. *Revista Chagual* 6: 13-20.

MONTALVA, J; RUZ, L (2010) Actualización a la lista sistemática de abejas Chilenas (Hymenoptera: Apidae). *Revista Chilena de Entomología* 35: 15-52.

MONTEALEGRE, R A (1927) Biología de insectos chilenos. IV. El moscardón (*Bombus Dahlbomi*, UER.) *Revista Chilena de Historia Natural* 31: 165-172.

MORALES, C; AIZEN, M A (2002) Does invasion of exotic plants promote invasion of exotic flower visitors? A case study from the temperate forests of southern Andes. *Biological Invasions* 4: 87-100.

MORALES, C L; AIZEN, M A (2004) "Potential displacement of the native bumble bee *Bombus dahlbomii* by the invasive *Bombus ruderatus* in NW Patagonia". In K Hartfelder, D De Jong *et al.*, (Eds). *Proceedings of the 8th International Conference on Tropical Bees and VI encontro sobre abelhas* pp. 7-76). International Bee Research Association.

MORALES, C L (2007) Introduction of non native bumble bees (*Bombus*): causes, ecological consequences and perspectives. *Ecologia Austral* 17(1): 51-65.

MOURE, J S; MELO, G A R; URBAN, D (2007) *Catalogue of bees (Hymenoptera, Apoidea) in the neotropical region*. Sociedade Brasileira de Entomologia; Curitiba, Brazil. 1058 pp.

MUÑOZ, A; ARROYO, M T K (2006) Pollen limitation and spatial variation of reproductive success in the insect-pollinated shrub *Chuquiraga oppositifolia* (Asteraceae) in the Chilean Andes. *Arctic, Antarctic and Alpine Research* 38: 608-613.

PEÑA, L E (1986) Presencia de *Megabombus (M.) opifex* (Smith) en Chile (Hymenoptera: Apidae). *Revista Chilena de Entomologia* 14: 103.

PÉREZ, D; PETERSEN, J (1989) Notas Sobre Abejas de la Región Magallánica, Chile (Hymenoptera: Apoidea). *Acta Entomologica Chilena* 15: 257-260.

PÉREZ, F; ARROYO, M T K; MEDEL, R; HERSHKOVITZ, M A (2006) Ancestral reconstruction of flower morphology and pollination systems in *Schizanthus* (Solanaceae). *American Journal of Botany* 93(7): 1029-1038.

RASMUSSEN, C (2003) Clave de identificación para las especies peruanas de *Bombus* Latreille, 1809 (Hymenoptera, Apidae), con notas sobre su biología y distribución. *Revista Peruana de Entomologia* 43: 31-45.

REBOLLEDO, R; MARTÍNEZ, H; PALMA, R; AGUILERA, A; KLEIN, C (2004) Actividad de visita de *Bombus dahlbomi* (Guérin) y *Bombus ruderatus* (F.) (Hymenoptera:Apidae) sobre trébol rosado (*Trifolium pratense* L.) en la IX Región de la La Araucanía, Chile. *Agricultura Técnica* 64: 245-250.

RETAMALES, H; MORALES, N (2006) Espectro geográfico polinizador del insecto nativo *Bombus dahlbomii* Guer. (Hymenoptera: Apidae), dada la actual fragmentación del bosque nativo de Chile. *XXVIII Congreso Nacional de Entomología Universidad de la Frontera, Temuco. 29-30 November 2007.* p58

ROVERE, A; SMITH-RAMIREZ, C; ARMESTO, J; PREMOLI, A (2006) Sistema reproductivo de *Embothrium coccineum* (Proteaceae) en dos poblaciones ubicadas en diferentes laderas de los Andes. *Revista Chilena de Historia Natural* 79: 225-232.

RUIZ, P (1923) Los Himenópteros del Cerro San Cristóbal. *Revista Chilena de Historia Natural* 27: 99-106.

RUIZ, P (1941) Apidología Chilena. *Revista Chilena de Historia Natural* 44: 282-377.

RUZ, L; HERRERA, R (2001) Preliminary observations on foraging activities of *Bombus dahlbomii* and *Bombus terrestris* (Hym: Apidae) on native and non native vegetation in Chile. *Acta Horticola* 561: 165-169.

RUZ, L (2002) Bee pollinators introduced to Chile: a review. In P Kevan and F Imperatriz (Eds). *Pollinating bees - the conservation link between agriculture and nature.* Ministry of Environment; Brazil. pp. 297.

RUZ, L; VIVALLO, F (2005) Las abejas de Nahuelbuta. In C Smith and J Armesto (Eds) *Historia, biodiversidad y ecología de los bosques costeros de Chile.* Editorial Universitaria; Chile. pp. 165-180.

SMITH-RAMÍREZ, C; MARTÍNEZ, P; NUÑEZ, M; GONZÁLEZ, C; ARMESTO, J (2005) Diversity, flower visitation frequency and generalism of pollinators in temperate rain forests of Chiloé Island, Chile. *Botanical Journal of the Linnean Society* 147: 399-416.

SPINOLA, M (1851) Himenópteros. In Gay C , (Ed.) *Historia física y política de Chile. Zoologia 6.* Maulde and Renon; Paris, France. pp. 153-166.

STOUT, J C; KELLS, A R; GOULSON, D (2002) Pollination of a sleeper weed, *Lupinus arboreaus*, by introduced bumble bees in Tasmania. *Biological Conservation* 106(3): 425-434.

TORO, H (1986) Lista preliminar de los ápidos chilenos (Hymenoptera: Apoidea). *Acta Entomológica Chilena* 13:121-132.

TELLERIA, M C (1993) Flowering and pollen collection by the honey bee (*Apis mellifera* L var. *ligustica*) in the Pampas region of Argentina. *Apidologie* 24: 109-120.

TORO, H; CHIAPPA, E (1996) Order Hymenoptera (Apoidea). In J Cepeda (Ed.) *Insectos de la Alta Montaña del Valle del Elqui.* Dirección de Investigación y desarrollo, Universidad de La Serena; La Serena, Chile. pp. 120-146

TORRETA, J P; MEDAN, D; ABRAHAMOVICH, A H (2006) First record of the invasive bumble bee *Bombus terrestris* (L.) (Hymenoptera, Apidae) in Argentina. *Transactions of the American Entomological Society* 132(3): 285-289.

TRAVESET, A (1999) La importancia de los mutualismos para la conservación de la biodiversidad en ecosistemas insulares. *Revista Chilena de Historia Natural* 72: 527-538.

VALDIVIA, C; NIEMEYER, H (2005). Reduced maternal fecundity of the high Andean perennial herb *Alstroemeria umbellata* (Alstroemeriaceae) by aphid herbivory. *New Zealand Journal of Ecology* 29: 321-324.

VALDIVIA, C; GONZÁLEZ, P (2006) A trade-off between the amount and distance of pollen dispersal triggered by the mixed foraging behaviour of *Sephanoides sephaniodes* (Trochilidae) on *Lapageria rosea* (Philesiaceae). *Acta Oecologica* 29: 324-327.

WILLIAMS, P H (1998) An annotated checklist of bumble bees with an analysis of patterns of description (Hymenoptera: Apidae, Bombini). *Bulletin of the Natural History Museum, London (Entomology)* 67: 79-152.

WILLIAMS, P H; COLLA, S; XIE, Z (2009) Bumble bee vulnerability: common correlates of winners and losers across three continents. *Conservation Biology* 23: 931-940.

WILLIAMS, P H; OSBORNE, J L (2009) Bumble bee vulnerability and conservation world-wide. *Apidologie* 40: 367-387.