BIOGEOGRAPHIC REGIONALIZATION OF CHILEAN ASTERACEAE: BRIDGING THE WALLACEAN SHORTFALL

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Introduction

A biogeographic regionalization comprises from the general to the particular several concepts beginning from the realm (=kingdom), thdfregion, the dominion, and the province. Each of the levels in the biogeographic hierarchy contends the following levels, on the base of the characteristics (taxa) they share; a realm contains various regions, a region contains several dominions, and so on. Since the beginnings of biogeography a crucial task has been the classification of biotas into these categories. Also since the very beginning, till today, researchers have to deal with the problem of inadequacies in taxonomic and distributional data. These two main problems are called the Linnean and Wallacean shortfalls respectively (cfr Whittaker et al. 2005). The first plant geographical map for Chile accompanied Reiche's analysis of the distribution of the Compositae (Asteraceae) family in the country (Reiche 1905). My attempt is to replicate this early work at the light of current taxonomic knowledge, generating a biogeographic regionalization of Chile by means of the analysis of distribution patterns of the genera of the family Asteraceae, the richest country's plant family. The Asteraceae, in spite of being one of the more diverse plant families in the world, is getting better known due to the effort of the botanical community (e.g. Funk et al. 2005, Anderberg et al. 2007, Katinas et al. 2008). This includes a constant increase in knowledge in Andean countries like Peru (Dillon and Sagástegui 2002) and Chile (Moreira-Muñoz and Muñoz-Schick 2007).

In this paper I analyze the patterns of distribution and endemism of the Chilean genera of the family Asteraceae, and propose a system of floristic units based on the distribution of the genera of Asteraceae.

Methods

The historical collections of the National Herbarium at the Museo Nacional de Historia Natural have been used for the study. The database comprises more than 25,000 records of the 116 Chilean native genera of Asteraceae. Some records have been already georreferenced, but this needed to be completed and checked. Finally, more than 15,000 unique localities were obtained, that were overlapped to a grid of quadrats of 1 degree latitude x 1 degree longitude covering Chile.

The optimality algorithm is a method especially created for identifying areas of endemism, by the software NDM/VNDM. It calculates an endemicity index for a set of areas based on the adjustment of the distributions of two or more species (Szumik et al. 2002, Szumik et al. 2004, Goloboff 2005). The program is actually widely used for biogeographic regionalization (e.g. Carine et al. 2009, Casagranda et al. 2009).
The program was run with the next options: save sets with two or more endemic species, save sets with score above 2.0, type of swapping of one cell at a time and discard, replace and precheck, and 0% of unique species in keep overlapping subsets option. The search was performed until the number of sets was showed stable with different random seeds, using edge proportions. The sets obtained were treated under consensus by a 10% of similarity in species and the option against any of the other areas in the consensus.

Results

NDM program obtained 16 areas of endemism in continental Chile. Table 1 and Fig 1 summarize the obtained areas or sets, the obtained score (a score above 2.0 is needed to support an area of endemism); the number of cells of the area; the latitudinal extent, the number of genera building the area of endemism, and the identity of the genera.

Table 1. Areas of endemism obtained by NDM/VNDM program

N° set	Score	N° cells	Latitudinal extension (°S)	N° genera	Scoring genera
Set 0	2.05	10	28-33	3	*Flourensia, Guynesomia, Pleocarphus*
Set 1	3.34	21	30-39	5	*Ageratina, Gochnatia, Micropsis, Podanthus, Psilocarphus*
Set 2	3.81	18	30-38	6	*Aristeguietia, Gochnatia, Micropsis, Moscharia, Podanthus, Psilocarphus*
Set 3	2.40	9	32-37	4	*Anaphalis, Blennosperma, Micropsis, Mikania*
Set 4	2.25	121	17-56	3	*Baccharis, Perezia, Senecio*
Set 5	2.36	22	32-42	5	*Belloa, Chevreulia, Dasyphyllum, Lucilia, Noticastrum*
Set 6	2.14	7	29-33	4	*Brachyclados, Flourensia, Guynesomia, Pleocarphus*
Set 7	2.02	5	32-35	3	*Anaphalis, Calopappus, Marticorenia*
Set 8	5.63	13	17-24	7	*Chersodoma, Cotula, Diplostephium, Helogyne, Luciliocline, Parastrephia, Xenophyllum*
Set 9	2.58	6	13-18	3	*Erechtites, Gypthamnium, Oxyphyllum*
Set 10	2.85	4	17-20	6	*Coreopsis, Heterosperma, Lophopappus, Mniodes, Pluchea,*

					Trixis
Set 11	3.33	24	29-39	4	*Ageratina, Gochnatia, Podanthus, Psilocarphus*
Set 12	4.06	4	18-21	5	*Coreopsis, Heterosperma, Lophopappus, Pluchea, Trixis*
Set 13	3.76	20	29-38	5	*Aristeguietia, Gochnatia, Moscharia, Popdanthus, Psilocarphus*
Set 14	3.04	15	32-39	4	*Blennosperma, Chaptalia, Micropsis, Mikania*
Set 15	4.52	6	18-22	6	*Coreopsis, Cotula, Diplostephium, Heterosperma, Lophopappus, Trixis*

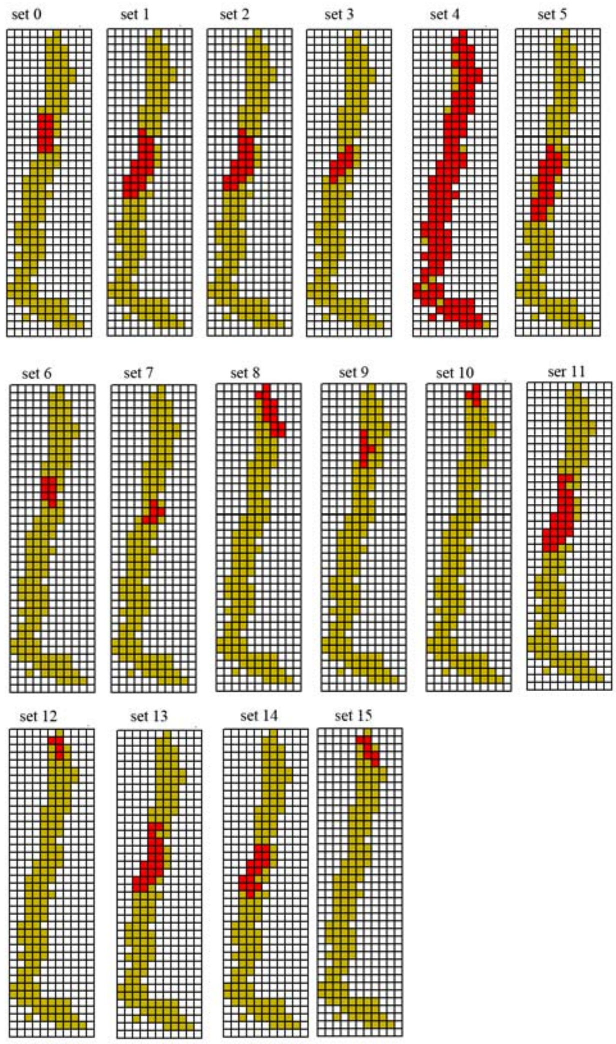

Figure 1. Areas of Endemism obtained by NDM/VNDM.

These results were further integrated as consensus areas, described hereafter and showed in Fig. 2. In spite of consensus areas search for a limited overlap, the 6 consensus areas obtained still showed some degree of overlapping.

The consensus Area 0 was obtained from two sets (0, 6), showed four endemic genera and a score of 2.3. It is between 28°-33°S. Genera endemic to this area are *Brachyclados, Flourensia*, *Guynesomia* and *Pleocarphus*.

The consensus Area 1 was obtained from seven sets (1, 2, 3, 7, 11, 13, 14), built by the distribution of 13 endemic genera and having a score of 3.81. It extends from 29°-40°S. Its endemic genera are *Ageratina, Anaphalis, Aristeguietia, Blennosperma, Calopappus, Chaptalia, Gochnatia, Marticorenia, Micropsis, Mikania, Moscharia, Podanthus* and *Psilocarphus*.

The consensus Area 2 is built by one set (4), made by 3 genera and a getting a score of 2.5. It encompasses the whole country's latitudinal extent (17°-56°S). The widespread genera supporting this area are *Baccharis, Perezia* and *Senecio*.

The consensus Area 3 was obtained from 1 set (5), with a score of 2.6. The area is located between 32°-42°S, and the genera are *Belloa, Chevreulia, Dasyphyllum, Lucilia* and *Noticastrum*.

The consensus Area 4 was obtained from 4 sets (8, 10, 12, 15), had 13 genera and a score of 5.63 encompassing the northernmost Chilean Altiplano between at 17° and 24°S. This area has the higher score. Its endemic genera are *Chersodoma*, *Cotula, Coreopsis, Diplostephium, Helogyne, Heterosperma, Lophopappus, Luciliocline, Mniodes, Parastrephia, Pluchea, Trixis* and *Xenophyllum.*

The consensus Area 5, obtained from one set (9), had three endemic genera. It shows a score of 2.83 and encompasses the latitude 23°-28°S. Its endemic genera are *Erechtites*, *Gypothamnium* and *Oxyphyllum*.

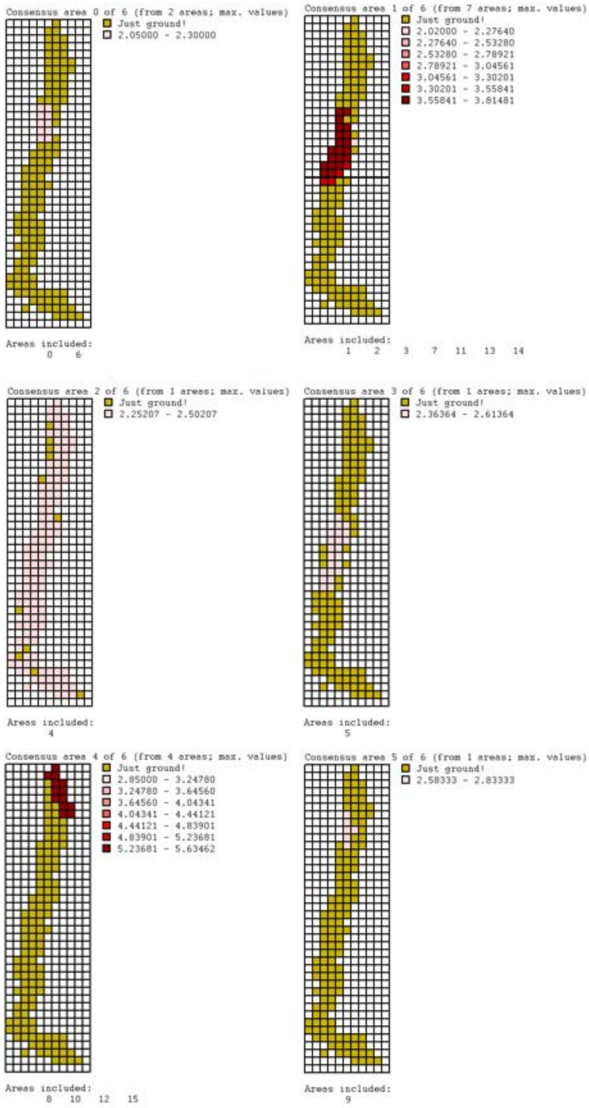

Figure 2. Consensus Areas obtained by NDM/VNDM.

The PAE method so far did not yield satisfactory solutions, due to the presence of many collection gaps. These gaps should be filled in the course of the present investigation due to the intensive field work extending to 2011.

Discussion and Conclusions

The first biogeographic regionalization for Chile was proposed by Reiche more than 100 years ago (Reiche 1905). Due to the accumulation of knowledge in this period, areas of endemism obtained by NDM logically differentiate from Reiche's proposal. Nevertheless, there are several remarkable similarities: the consensus area 5 is highly coherent with the North coastal floristic region (Fig. 3), encompassing the genera *Oxyphyllum* and *Gypothamnium*. Also Area 4 was recognized by Reiche as a 'North Andean' region, although not so strictly limited as in the present results (Fig. 2). Reiche's 'Central and Southern Andes' and 'Central Coastal' regions are partly consistent with Areas 0 and 1. Reiche proposed a sharp limit between coastal and Andean units, which are not retrieved by NDM. This can be an effect of the scale and origin of the grid that can only be surpassed with better distribution data. The low richness from the Magallanes regions does not allow the recognition of a specific floristic region, as proposed by Reiche.

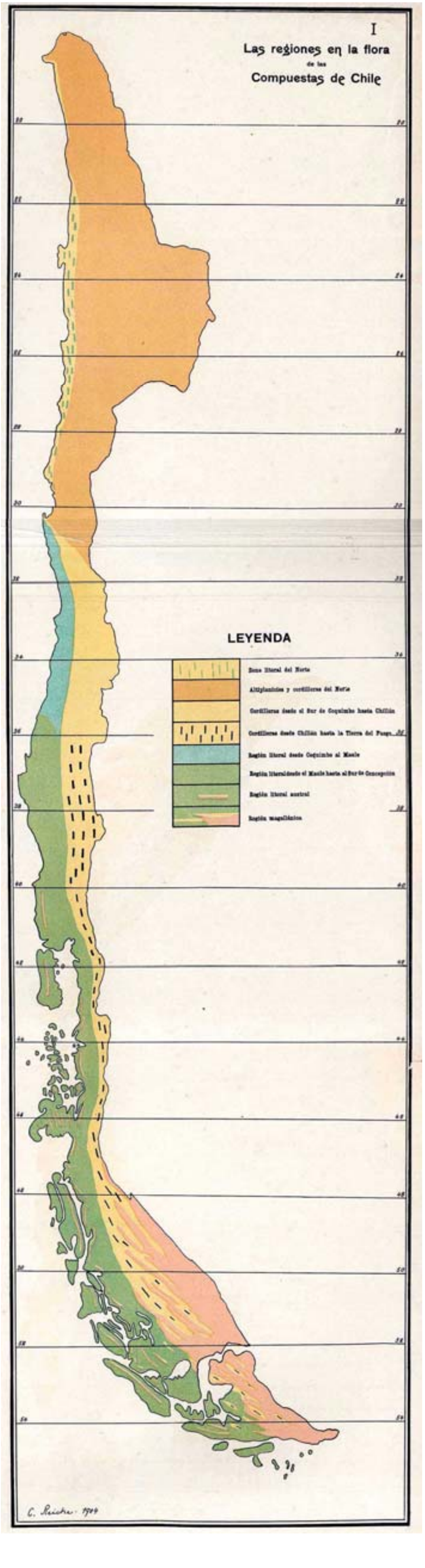
I
Las regiones en la flora
de las
Compuestas de Chile
LEYENDA
Zona litoral del Norte
Altiplanicies y cordilleras del Norte
Cordilleras desde el Sur de Coquimbo hasta Chillán
Cordilleras desde Chillán hasta la Tierra del Fuego
Región litoral desde Coquimbo al Maule
Región litoral desde el Maule hasta al Sur de Concepción
Región litoral austral
Región magallánica

Figure 3. Regionalization proposed by Reiche (1905) by means of the analysis of Asteraceae genera.

Future analyses will have to include not only genera but species, and especial attention has to be paid to the adequate taxonomy of the taxa and the further increase in the distributional knowledge.

These results show the importance of systematic approaches applying new technologies to old questions like the problem of floristic regionalization. This is a promissory approach that should gain much more attention for analyzing other groups from the Chilean flora. Herbarium records are proving to be a powerfull tool in biodiversity research, and there is a global tendency to put this information globally available through the internet (e.g. Muñoz-Schick and Moreira-Muñoz 2008). As the research project continues, it will be allow to gain a better knowledge on the distribution of the taxa, shortening the "Wallaceaen shortfall" and helping also to win knowledge useful for an adequate systematic treatment of these taxa (Linnean shortfall), and also to propose better actions for the conservation of these taxa in the long term, under scenarios of global change and increasing uncertainty (cfr Moreira-Muñoz 2005).

Acknowledgements

Claudia Szumik and Tania Escalante helped with the appropriate use of the program NDM/VNDM, thanks to a kind invitation for the author to participate at the XXVII International Meeting of the Willi Hennig Society, held in Tucumán in October 2008. Vanezza Morales helped with the analysis and confection of the figures. Mélica Muñoz-Schick, Curator of the National Herbarium, kindly provided access to data bases and botanical information. Project sponsored by Fondecyt Iniciación (2008) 11085016.

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