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research article

Network-based global bioregionalization of terrestrial gastropods

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Abstract

Global bioregionalization provides a framework for assessing large-scale patterns of species distributions and biodiversity. Here, we delineated global bioregions for terrestrial gastropods using species occurrence data from GBIF and compared the resulting patterns with previous biogeographical schemes for terrestrial organisms. We compiled 1,414,131 georeferenced occurrence records representing 17,229 species from six major terrestrial gastropod clades and analysed their spatial distribution using the Infomaps Bioregions 2 algorithm. The analysis identified 14 biogeographical regions, broadly consistent with major bioregions previously proposed for terrestrial organisms. Most continental regions were recovered, including the Nearctic, Neotropical, Palearctic, Ethiopian, Oriental, and Australian regions. The main differences involved insular territories, with the Antillean, Malagasy, Tristanian, Sub-Antarctic, Neozelandic, Melanesian, and Micronesian-Polynesian regions recovered as distinct bioregions. This stronger differentiation of island faunas may reflect their geographic isolation and high levels of endemism. Our results provide a global biogeographical framework for terrestrial gastropods and highlight the importance of insular regions in shaping their distribution patterns.

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1. Introduction

Data on the geographic distribution of organisms and the processes that shape these patterns are fundamental to biogeography and ecology (Capinha et al. 2015; Sommeria-Klein et al. 2021). Knowledge of bioregions helps improve our understanding of evolutionary patterns and their underlying drivers (Mazel et al. 2017; He et al. 2020; Ficetola et al. 2021) and can also provide a basis for conservation planning (Whittaker et al. 2005; Dinerstein et al. 2017; Ennen et al. 2020). Different groups of organisms have been used to propose several global biogeographical regions, such as including vertebrates, arthropods, and vascular plants (e.g. Kreft & Jetz 2010; Procheş & Ramdhani 2012; Holt et al. 2013; Rueda et al. 2013; Morrone 2015; Shen et al. 2021; Carta et al. 2022; Morrone & Ebach 2022; Falaschi et al. 2023).

There are over 26,000 described species of terrestrial gastropods. These species have evolved through at least 30 independent colonization events of terrestrial environments, but only Cyclophoroidea, Helicinoidea, Hydrocenidae, Littorinoidea, Stylommatophora, and Veronicellidae have diversified into more than 100 extant species (Vermeij & Watson-Zink 2022). Terrestrial gastropods are widely distributed across a broad range of habitats, from deserts to rainforests and from tropical to subpolar environments (Barker 2001; Kano et al. 2002; Chapman 2009; Bouchet et al. 2017). They are also diverse in their ecological roles, contributing to nutrient cycling (Nicolai & Ansart 2017) and participating in the food webs as both prey and predators of many different species (Speiser 2001). Besides, many species of terrestrial gastropods have

medical, veterinary, and economic importance (Barker 2002; Lu et al. 2018). These animals also exhibit high levels of endemism and some of the highest extinction rates, particularly on islands (Chiba & Roy 2011; Chiba & Cowie 2016; Nicolai & Ansart 2017), with more than 188 extinct species and over 1,000 currently threatened (IUCN 2025). Understanding how terrestrial gastropods are distributed across bioregions could therefore provide valuable information for directing conservation efforts.

Hence, the goals of this study are to: (1) delineate global bioregions based on the distribution of terrestrial gastropods; and (2) compare the resulting bioregionalization with previous biogeographical scenarios proposed for other terrestrial organisms.

2. Material and Methods

Occurrence data for the six most diverse clades of terrestrial gastropods (Cyclophoroidea, Helicinoidea, Hydrocenidae, Littorinoidea, Stylommatophora, and Veronicellidae) were obtained from the GBIF website (GBIF.org 2025), retaining only records with exact geographic coordinates. Species names were updated according to their current taxonomic status in MolluscaBase (MolluscaBase eds 2025). Records were excluded if they were not identified to species level; referred to non-terrestrial species; represented the location of the museum or collection where the specimen is deposited; or belonged to any of 82 invasive species that have artificially expanded distributions and had over 10,000 occurrence records (invasive species excluded listed in Supplementary Material S1). The resulting dataset comprised 1,414,131 records of 17,229 species distributed worldwide (Supplementary Material S2).

The occurrence dataset was analysed with the Infomap Bioregions 2 algorithm (Edler et al. 2017, 2023; https://mapequation.org/bioregions/). This interactive web application uses an adaptive spatial grid to group occurrence data into assemblages through an automated algorithm optimization. In other words, grid cells sharing similar species assemblages are assigned to the same bioregion and an indicative species score is calculated. The indicative score represents the degree of exclusive association of a species to a single bioregion. This means that higher scores indicate species that are strongly restricted to that region. The algorithm was parameterized to allow for cell sizes ranging from 1 to 4 degrees and prioritize a number of occurrence records ranging from 10 to 700.

The resulting bioregions were compared to the consensus terrestrial bioregions based on multiple studies of terrestrial organisms, such as mammals, reptiles, amphibians, beetles, moths, butterflies, flies, and vascular plants (Sclater & Sclater 1899; Good 1963; Takhtajan 1986; Daniels & Veblen 2000; Procheş & Ramdhani 2012; Ribeiro et al. 2014; Klassa & Santos 2015; Carta et al. 2022; Morrone & Ebach 2022; Santos & Ribeiro 2022; Falaschi et al. 2023; Gross et al. 2025). Through this comparison, we identified and named our bioregions based on previously named areas (Morrone & Ebach 2022). We used the term "bioregion" for our results to avoid directly associating them with any particular hierarchy level previously proposed (e.g. Kingdom, Subkingdom, Region, Subregion/Transition Zone in Morrone & Ebach 2022).

3. Results

Our bioregionalization analysis revealed a total of 14 biogeographical regions (Figure 1). The Nearctic bioregion (1) is characterized by species such as *Arionimax dolichophallus*, *Megapallifera mutabilis*, *Triodopsis tridentata*, *Helminthoglypta nickliniana*, and *Webbhelix multilineata* (score = 6.52). The Antillean bioregion (2) is characterized by species such as *Eutrochatella pulchella*, *Parthena acutangula*, *Pleurodonte josephinae*, *Coryda alauda*, and *Lucidella adamsiana* (score = 28.71). The Neotropical bioregion (3) is characterized by species such as *Drymaeus papyraceus*, *Phyllocaulis soleiformis*, *Naesiotus quitensis*, *Porphyrobaphe iostoma*, and *Drymaeus poecilus* (score = 83.22). The Palearctic bioregion (4) is characterized by species such as *Vertigo ronnebyensis*, *Ena montana*, *Clausilia cruciata*, *Clausilia pumila*, and *Vertigo geyeri* (score = 1.58). The Ethiopian bioregion (5) is characterized by species such as *Nata vernicosa*, *Psichion inclara*, *Afrocyclus isipingoensis*, *Hypolysia florentiae*, and *Coeliaxis blandi* (score = 96.35). The Tristanian bioregion (6) is characterized by the species *Balea tristensis*, *Balea ventricosa*, and *Balea goughensis* (score = 52,375.22). The Arabian bioregion (7) is characterized by species such as *Achatinelloides socotorensis*, *Lithidion lithidion*, *Achatinelloides hadibuensis*, *Achatinelloides longiformis*, and *Soqena microsculptata* (score = 3,074.2). The Malagasy bioregion (8) is characterized by species such as *Tropidophora vallorzi*, *Embertoniphanta oviformis*, *Tropidophora bicarinata*, *Edentulina minor*, and *Tropidophora semidecussata* (score = 113.18). The Oriental bioregion (9) is characterized by species such as *Nesiohelix swinhoei*, *Sarika siamensis*, *Stereophaedusa japonica*, *Satsuma japonica*, and *Georissa similis* (score = 22.95). The Sub-Antarctic bioregion (10) is characterized by the species *Notodiscus hookeri* (score = 5,179.97). The Australian bioregion (11) is characterized by species such as *Triboniophorus graeffei*, *Sauroconcha corneovirens*, *Caryodes dufresnii*, *Cystopelta purpurea*, and *Ubiquitarion iridis* (score = 13.37). The Melanesian bioregion (12) is characterized by species such as *Placostylus fibratus*, *Placostylus porphyrostomus*, *Aspastus miltocheilus*, *Pararhytida dictyodes*, and *Sturanya sublaevigata* (score = 230.95). The Micronesian-Polynesian bioregion (13) is characterized by species such as *Achatinella apexfulva*, *Achatinella bulimoides*, *Leptachatina gummea*, *Achati-*

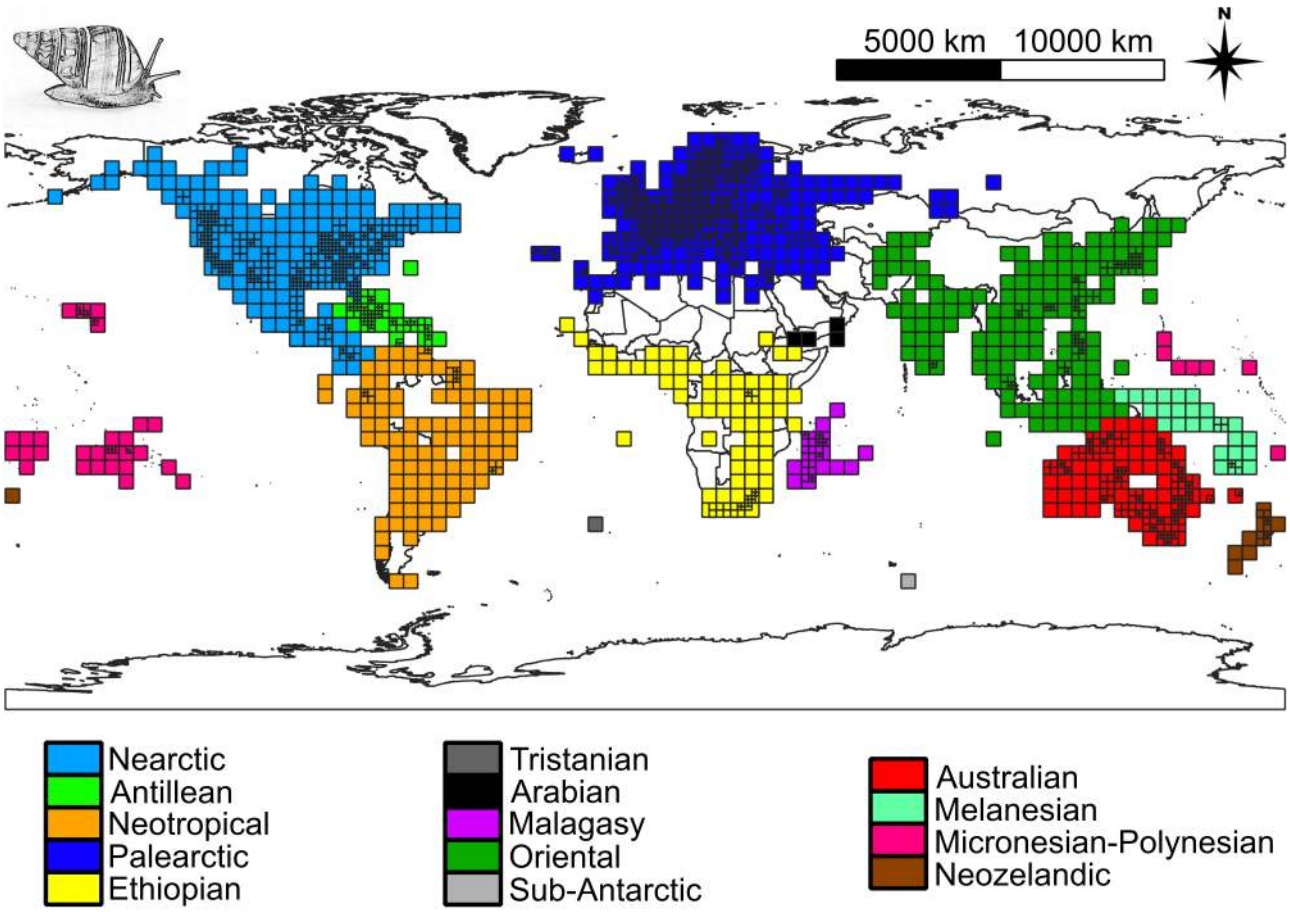


Figure 1. Network-based global bioregions for terrestrial gastropods.

nella viridans, and *Achatinella curta* (score = 56.54). Lastly, the Neozelandic bioregion (14) is characterized by species such as *Powelliphanta hochstetteri*, *Rhytida greenwoodi*, *Tornatellides subperforatus*, *Amborhytida dunniae*, and *Powelliphanta superba* (score = 331.18). Most abundant and indicative species for each bioregion are summarized in Table 1 and further descriptions of each bioregion are summarized in Table 2.

4. Discussion

The bioregions identified for terrestrial gastropods were broadly consistent with those proposed for other terrestrial groups (Morrone & Ebach 2022). Despite some differences, six of the eight regions proposed by Morrone & Ebach (2022) were recovered: the Nearctic, Neotropical, Palearctic, Ethiopian, Oriental,

Table 1. Most abundant and indicative species of global bioregions for terrestrial gastropods.

	Five most abundant species	n	score	Five most indicative species	n	score
Nearctic	*Ariolimax columbianus*	32,293	6.51	*Ariolimax dolichophallus*	2,684	6.52
	Liguus fasciatus	8,420	5.45	*Megapallifera mutabilis*	2,289	6.52
	Monadenia fidelis	7,998	6.51	*Triodopsis tridentata*	1,234	6.52
	Ariolimax buttoni	7,391	6.52	*Helminthoglypta nickliniana*	961	6.52
	Helicina orbiculata	5,648	6.51	*Webbhelix multilineata*	881	6.52
Antillean	*Liguus fasciatus*	1,641	4.68	*Eutrochatella pulchella*	470	28.71
	Caracolus carocolla	1,333	28.61	*Parthena acutangula*	309	28.71
	Polymita picta	1,101	28.69	*Pleurodonte josephinae*	290	28.71
	Zachrysia provisoria	837	6.72	*Coryda alauda*	268	28.71
	Caracolus marginella	817	28.54	*Lucidella adamsiana*	256	28.71
Neotropical	*Megalobulimus oblongus*	640	76.75	*Drymaeus papyraceus*	368	83.22
	Drymaeus papyraceus	368	83.22	*Phyllocaulis soleiformis*	271	83.22
	Bulimulus tenuissimus	321	80.95	*Naesiotus quitensis*	219	83.22
	Beckianum beckianum	278	23.44	*Porphyrobaphe iostoma*	161	83.22
	Phyllocaulis soleiformis	271	83.22	*Drymaeus poecilus*	156	83.22
Palearctic	*Arianta arbustorum*	39,617	1.57	*Vertigo ronnebyensis*	8,325	1.58
	Perpolita hammonis	36,685	1.57	*Ena montana*	3,201	1.58

	Five most abundant species	n	score	Five most indicative species	n	score
	Euconulus fulvus	34,012	1.51	*Clausilia cruciata*	2,764	1.58
	Clausilia bidentata	31,520	1.57	*Clausilia pumila*	2,662	1.58
	Punctum pygmaeum	31,042	1.57	*Vertigo geyeri*	2,623	1.58
Ethiopian	*Cochlitoma zebra*	589	96.19	*Nata vernicosa*	188	96.35
	Elisolimax flavescens	535	95.46	*Psichion inclara*	168	96.35
	Tropidophora ligata	224	95.46	*Afrocyclus isipingoensis*	139	96.35
	Archachatina marginata	196	89.93	*Hypolysia florentiae*	138	96.35
	Nata vernicosa	188	96.35	*Coeliaxis blandi*	121	96.35
Tristanian	*Balea tristensis*	15	52,375.22	*Balea tristensis*	15	52,375.22
	Balea ventricosa	10	52,375.22	*Balea ventricosa*	10	52,375.22
	Balea goughensis	2	52,375.22	*Balea goughensis*	2	52,375.22
Arabian	*Achatinelloides socotorensis*	49	3,074.2	*Achatinelloides socotorensis*	49	3,074.2
	Lithidion lithidion	38	3,074.2	*Lithidion lithidion*	38	3,074.2
	Achatinelloides hadibuensis	21	3,074.2	*Achatinelloides hadibuensis*	21	3,074.2
	Achatinelloides longiformis	18	3,074.2	*Achatinelloides longiformis*	18	3,074.2
	Soqena microsculptata	18	3,074.2	*Soqena microsculptata*	18	3,074.2
Malagasy	*Tropidophora vallorzi*	258	113.18	*Tropidophora vallorzi*	258	113.18
	Tropidophora consocia	195	112.6	*Embertoniphanta oviformis*	135	113.18
	Ampelita lamarei	143	112.39	*Tropidophora bicarinata*	122	113.18
	Embertoniphanta oviformis	135	113.18	*Edentulina minor*	119	113.18
	Tropidophora bicarinata	122	113.18	*Tropidophora semidecussata*	113	113.18
Oriental	*Meghimatium bilineatum*	2,492	22.5	*Nesiohelix swinhoei*	1,333	22.95
	Laevicaulis alte	2,224	16.71	*Sarika siamensis*	1,214	22.95
	Nesiohelix swinhoei	1,333	22.95	*Stereophaedusa japonica*	1,005	22.95
	Leptopoma perlucidum	1,327	16.62	*Satsuma japonica*	752	22.95
	Megaustenia imperator	1,324	22.86	*Georissa similis*	638	22.95
Sub-Antarctic	*Notodiscus hookeri*	268	5,179.97	*Notodiscus hookeri*	268	5,179.97
Australian	*Triboniophorus graeffei*	3,259	13.37	*Triboniophorus graeffei*	3,259	13.37
	Helicarion cuvieri	2,248	13.36	*Sauroconcha corneovirens*	2,181	13.37
	Sauroconcha corneovirens	2,181	13.37	*Caryodes dufresnii*	1,389	13.37
	Sphaerospira fraseri	1,674	13.36	*Cystopelta purpurea*	941	13.37
	Austrorhytida capillacea	1,483	13.36	*Ubiquitarion iridis*	854	13.37
Melanesian	*Placostylus fibratus*	351	230.95	*Placostylus fibratus*	351	230.95
	Placostylus porphyrostomus	179	230.95	*Placostylus porphyrostomus*	179	230.95
	Aspastus miltocheilus	92	230.95	*Aspastus miltocheilus*	92	230.95
	Sturanya macgillivrayi	88	223.34	*Pararhytida dictyodes*	81	230.95
	Pararhytida dictyodes	81	230.95	*Sturanya sublaevigata*	78	230.95
Micronesian-Polynesian	*Achatinella apexfulva*	881	56.54	*Achatinella apexfulva*	881	56.54
	Achatinella vulpina	760	56.39	*Achatinella bulimoides*	738	56.54
	Achatinella bulimoides	738	56.54	*Leptachatina gummea*	736	56.54
	Leptachatina gummea	736	56.54	*Achatinella viridans*	325	56.54
	Achatinella mustelina	571	56.44	*Achatinella curta*	309	56.54
Neozelandic	*Paryphanta busbyi*	479	330.49	*Powelliphanta hochstetteri*	303	331.18
	Powelliphanta hochstetteri	303	331.18	*Rhytida greenwoodi*	192	331.18
	Rhytida greenwoodi	192	331.18	*Tornatellides subperforatus*	115	331.18
	Powelliphanta traversi	186	327.66	*Amborhytida dunniae*	86	331.18
	Wainuia urnula	163	327.16	*Powelliphanta superba*	80	331.18

and Australian regions. The exceptions were the Andean and the Antarctic regions, for which there were no records. Among the transition zones, only the Saharo-Arabian transition zone was recovered as a separate bioregion. Here, we refer to this area as the Arabian bioregion given the absence of available records from the Sahara region. The remaining four transition zones were found as part of other bioregions. Other differences included the separation of the Antillean and Malagasy bioregions from the corresponding mainland regions, the fragmentation of the Australian region, and the recovery of the Tristanian and Sub-Antarctic bioregions.

The Nearctic region is usually defined as including Greenland but excluding Central America (Ribeiro et al. 2014; Escalante et al. 2021; Carta et al. 2022; Morrone & Ebach 2022; Gross et al. 2025). However, we had no records from Greenland and therefore could not include it in our analysis. Central America also represents a transitional area between the Nearctic and Ne-

Table 2. General information of global bioregions for terrestrial gastropods.

	Formed by	Number of Species	Number of Records	Number of cells	Total area (Km²)	Records per species	Species per cell	Records per cell
Nearctic	Canada, the mainland United States and Central America	1,994	217,006	518	23,161,383.81	108.83	3.85	418.93
Antillean	Antilles or West Indies (Greater and Lesser Antilles) and the Bahamas. The Greater Antilles comprise Cuba, Jamaica, Hispaniola and Puerto Rico, and the Lesser Antilles include Grenada, The Grenadines, St. Vincent, Barbados, St. Lucia, Martinique, Dominica, Marie Galante, Guadeloupe, La Desirade, Montserrat, Antigua, Nevis, St. Kitts, Barbuda, St. Eustatius, Saba, St. Barthélemy, St. Martin and Anguilla (Morrone 2017)	2,095	49,251	89	4,044,857.82	23.51	23.54	553.38
Neotropical	South America	1,511	16,992	130	19,210,884.34	11.25	11.62	130.71
Palearctic	Eurasia and Africa north of the Sahara	2,795	898,151	852	22,679,207.64	321.34	3.28	1,054.17
Ethiopian	Central and southern Africa	1,316	14,677	99	13,379,151.76	11.15	1.32	148.25
Tristanian	Saint Helena, Ascension Island, and the Tristan da Cunha archipelago, including Gough Island	3	27	1	155,953.39	9	3	27
Arabian	Arabian Peninsula	68	460	4	761,128.72	6.76	17	115
Malagasy	Madagascar and surrounding islands of Seychelles, Comoros, Mayotte and Mascarene	938	12,495	44	3,059,546.73	13.32	21.32	283.98
Oriental	All areas south of the Tibetan Plateau and the Yellow River and west of Weber's Line	3,831	61,618	243	27,672,237.95	16.08	15.77	253.57
Sub-Antarctic	Crozet Islands, Kerguelen Islands and Heard Island	1	268	1	116,757.85	268	1	268
Australian	Australia	1,465	105,792	250	13,628,609.71	72.21	5.86	423.17
Melanesian	Melanesian islands of New Guinea, Bismarck, Solomon, Santa Cruz, Vanuatu, Fiji and New Caledonia	686	6,123	34	5,100,495.36	8.93	20.18	180.09
Micronesian-Polynesian	Micronesian and Polynesian islands of Palau, Mariana, Caroline, Marshall, Kiribati; Tuvalu, Samoa, Tonga, Hawaii, Tokelau, Cook, Society, Austral, Marquesas, Tuamotu, Mangareva and Easter	1,168	25,012	56	6,854,294.83	21.41	20.86	446.64
Neozelandic	New Zealand and the surrounding islands of Stewart, Lord Howe, Norfolk, Chathams, Campbell and Kermadeck	291	4,270	22	1,642,314.38	14.67	13.23	194.09

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otropical regions. Northern Mexico is widely considered to be part of this transition zone, whereas the remainder of Central America, excluding the Antilles, is typically included in the Neotropical region (Espinosa et al. 2008; Morrone 2020; Hermogenes de Mendonça & Ebach 2020; Morrone & Ebach 2022). However, our analysis indicated a stronger association in the terrestrial gastropod fauna between Central America, excluding the Antilles, and North America, thus recovering it within the Nearctic bioregion.

The Antilles are sometimes included within the Neotropical region and treated as a subregion closely related to continental Central America (Echeverry & Morrone 2013; Morrone 2014; Klassa & Santos 2015; Morrone & Ebach 2022). In contrast, we recovered the Antillean bioregion at the same hierarchical level as the Neotropical bioregion, aligning with previous biogeographical schemes (Cabrera & Willink 1973; Falaschi et al. 2023; Gross et al. 2025). This result may reflect the distinct distributional patterns of terrestrial gastropods in the Antilles, which can be influenced by their geographic isolation from the mainland.

South America is generally divided into the Neotropical and Andean regions (Daniels & Veblen 2000; Carta et al. 2022; Morrone & Ebach 2022; Falaschi et al. 2023). We instead recovered a single bioregion encompassing the entire continent. This difference may partly result from low sampling effort, with only 16,992 records in 130 cells resulting in 130.71 records per cell (see Table 2). This sampling bias could be even greater in areas corresponding to the potential Andean region. Therefore, the bioregionalization of South American terrestrial gastropods should be reassessed as additional distributional data become available, including data from other databases.

The Palearctic region was broadly consistent with the bioregionalizations proposed for other terrestrial organisms (Schilder 1956; Cox 2001; Hermogenes de Mendonça & Ebach 2020; Morrone & Ebach 2022). However, the lack of records from the Siberian subregion limited direct comparison of its boundaries.

The Saharo-Arabian transition zone lies between the Palearctic and Ethiopian regions (Procheş & Ramdhani 2012; Hermogenes de Mendonça & Ebach 2020; Morrone & Ebach 2022). Because no data were available from the Sahara, only the Arabian Peninsula was represented in our analysis. This area was recovered as a separate bioregion, consistent with previous biogeographical schemes (as in Carta et al. 2022; Santos & Ribeiro 2022).

The Ethiopian region was also broadly consistent with previous studies (Escalante 2017; Hermogenes de Mendonça & Ebach 2020; Morrone & Ebach 2022). However, Madagascar was recovered as a separate bioregion at the same hierarchical level as the Ethiopian region, as in several previous classifications (Good 1963; Carta et al. 2022; Falaschi et al. 2023; Gross et al. 2025). This separation is consistent with the marked geographical isolation and high degree of endemism of the Malagasy terrestrial fauna.

The Oriental region was similarly recovered in our analysis, although the Chinese and Indo-Malayan transition zones were included within it. This pattern has also been found in some previous bioregionalizations (Ribeiro et al. 2014; Escalante 2017; Hermogenes de Mendonça & Ebach 2020; Morrone & Ebach 2022; Falaschi et al. 2023).

The Australian region has been treated differently among previous bioregionalizations. Some schemes include New Zealand and the Pacific Islands as subregions (Escalante 2017; Hermogenes de Mendonça & Ebach 2020; Carta et al. 2022; Morrone & Ebach 2022), whereas others recognize these areas at the same hierarchical level as the other major bioregions, as in our analysis (Sclater & Sclater 1899; Good 1963; Takhtajan 1986; Fleming 1987; Falaschi et al. 2023; Gross et al. 2025). The Pacific Islands, including Micronesia, Melanesia, and Polynesia, with the exception of New Zealand, are generally treated as a single bioregion (Good 1963; Takhtajan 1986; Morrone & Ebach 2022; Gross et al. 2025). In contrast, our analysis separated the Melanesian island from the remaining Pacific islands.

The Tristanian and Sub-Antarctic regions are not commonly recognized as separate major bioregions, but both comprise geographically isolated territories with high levels of endemism in several taxonomic groups (Holgate 1960; Barnes et al. 2009; Moon et al. 2017; Bridges et al. 2021; Marshall et al. 2025). Their recovery as distinct bioregions in our analysis therefore highlights the importance of these isolated regions in shaping the distribution patterns of terrestrial gastropods.

Overall, excluding regions for which data were lacking, the main differences between our results and previous bioregionalizations involved insular territories. The recognition of the Antillean, Malagasy, Tristanian, Sub-Antarctic, Neozelandic, Melanesian and Micronesian-Polynesian bioregions at a relatively high hierarchical level may be related to the high levels of endemism characteristic of insular terrestrial malacofaunas (Chiba & Roy 2011; Chiba & Cowie 2016; Proios et al. 2021), also shown by the considerably high scores of the most indicative species of these regions (see Table 1). This pattern suggests that geographic isolation and the resulting diversification of island lineages may play an important role in shaping the global biogeography of terrestrial gastropods. From a conservation perspective, the recognition of distinct bioregions may help identify areas with unique terrestrial gastropod assemblages and high conservation value, particularly in insular territories where endemism is high and extinction risk is often elevated.

5. Conclusion

The global bioregionalization of terrestrial gastropods was broadly consistent with bioregionalizations proposed for other terrestrial organisms, with most major continental regions being recovered. Intriguingly, however, insular territories showed a stronger biogeographical differentiation, with several island groups being recovered as distinct bioregions. This pattern may reflect the high levels of endemism and geographic isolation characteristic of terrestrial gastropod faunas and highlights the particular importance of island regions for understanding their global distribution. From a conservation perspective, the bioregions identified herein provide a complementary spatial framework for identifying areas with distinct terrestrial gastropod assemblages and potentially high conservation value. Finally, the lack of data from several regions, particularly the Andean region and other poorly sampled areas of South America, highlights the need for more comprehensive occurrence data to improve the resolution and robustness of global bioregionalizations including additional databases.

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