

Article

Geographic Range vs. Occurrence Records in Plant Distribution Mapping: The Case of *Arbutus* in the Old World

Simone De Santis ¹ , Francesco Spada ² and Donatella Magri ^{1,*} 

¹ Department of Environmental Biology, Sapienza University of Rome, Piazzale Aldo Moro 5, 00185 Rome, Italy; simone.desantis@uniroma1.it

² Department of Ecology and Genetics, Uppsala University, Norbyvägen 18 D, SE-752 36 Uppsala, Sweden; francesco.spada@ebc.uu.se

* Correspondence: donatella.magri@uniroma1.it

Abstract: Species mapping methods play a central role in biogeographical questions, as they may generate a domino effect on further works based on species distribution. In light of the massive recent increase in the availability of online occurrence data, we highlight the strengths and limitations of the mapping methods most widely used to display the geographic distribution of plants, namely geographic range maps and occurrence record maps. We use the modern distribution of the genus *Arbutus* in western Eurasia, North Africa, and Macaronesia, for which no occurrence record map has been published yet, to discuss critical issues in data collection and representation. The occurrence record map of *A. unedo*, *A. andrachne*, *A. canariensis*, and *A. pavarii* shows how well this mapping method captures the details of peripheral and isolated stands as well as the variability of population density. A number of biogeographical issues are addressed by this approach, including the determination of the chorological centre of gravity in relation to historical dynamics, genetic patterns in relation to range porosity, and the autochthony status of marginal stands. These issues constitute the necessary foundation for additional palaeobotanical research and ecological modelling to investigate the past-to-future dynamics of *Arbutus* and other species of the Mediterranean–Atlantic area.

Keywords: tree distribution; *Arbutus unedo*; *Arbutus andrachne*; *Arbutus canariensis*; *Arbutus pavarii*; Lusitanian geoelement



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1. Introduction

Interpreting the geographic range of species is not a trifling matter. Species ranges have always been considered the basic research unit of biogeography by scholars [1–5]. Accordingly, mapping methods play a central role in biogeographical questions, increasing or decreasing the inner complexity of their interpretation. Apart from the general cognitive capacity of researchers to look at and search on maps [6–9], the interpretation of plant species ranges is strongly connected with other disciplines and depends on data quantity and quality, as well as on representation methods and techniques [10].

A comprehensive understanding of the quantitative features of the species ranges (e.g., size, shape, boundaries, and internal structure) has become available in recent times [11–14]. Species range maps provide a synthetic comparative basis in chorological, phylogeographic, and palaeoecological research, useful for detecting dynamic pictures of evolutionary and macroecological patterns. In conservation biology, the degree of reliability of distribution maps plays a fundamental role, since the International Union for Conservation of Nature (IUCN) established range-size variations as fundamental criteria to assess the vulnerability of threatened species for planning conservation actions at species, habitat, and ecosystem scales [15].

Among all the existing geographic and environmental datasets, species distribution data have been estimated to be the “coarser” ones in resolution [16], especially concerning

plant occurrence at a global scale, which may be affected by several biases and uncertainties [17]. Nevertheless, the relatively recent increase in the number of open access data repositories provides a substantial availability of georeferenced occurrences, widely used to predict species distribution and habitats [18–24], to edit species richness and abundance maps [25–29], and to plan conservation actions in relation to the ongoing global change [21,30,31].

Different mapping methods tend to overestimate or underestimate the real geographic range of species [25], affecting the further steps of analysis and complicating the ecological model of interpretation. They may generate a domino effect on further works requiring species sampling and collection [32,33] or predicting species ranges for conservation planning [34]. Sources of uncertainty include imprecise information concerning the area under survey, taxonomic and systematic identification, as well as limitations due to the biological complexity of species [35,36]. Being aware of these uncertainties may have a positive effect on research. The scientific community has extensively concentrated on how to accurately predict distribution ranges from a database with a small or biased number of occurrences or combining different types of occurrence data [37,38]. Currently, the massively increased number of georeferenced occurrence records, widely accessible online, prompts a rethinking of how to best use these data to investigate macroecological patterns and emerging biogeographic questions. This is an intricate matter that is seldom discussed in a structured way but requires accurate consideration.

As a simple representation of the actual occurrence of species, each type of distribution map can be considered a model. Many authors have investigated the reliability of different approaches in distribution mapping [39–41], in order to assess the quality and biases of data [17,40,42], and to determine which representation is best suited to answer different biogeographic questions [23,43–46].

According to a large body of literature, there are two main categories into which mapping methodologies for species occurrence can be synthesized: geographic range maps and occurrence record maps. These two categories may be related to two distinct ecological concepts: the Extent of Occurrence (EOO), which is the area enclosing the locality where the species has been recorded, and the Area of Occupancy (AOO), which is the surface occupied by the species [12,47]. EOO and AOO do not necessarily match and may respectively bear errors of commission (false positive), overestimating the real extent of the species, and omission (false negatives), underestimating the occupancy area for the species. Any representation of the geographical distribution of species falls in between these two concepts.

Predicted ranges across space and/or time provided by species distribution models (SDMs) are in some way based on the information supplied by the two main categories above. It has been shown that SDMs based on occurrence records may be very different from expert-based range maps of the same taxon [48], although there may be no considerable discrepancies at large spatial and taxonomic scales [49].

Here, we first discuss the strengths and limitations of the geographic range maps and occurrence record maps, used to display the geographic distribution of plants. Secondly, we focus on the modern distribution of the genus *Arbutus* in the Old World, as a case study that may effectively illustrate critical issues in occurrence data collection and representation, potentially influencing the further interpretation of geographic, historical, and ecological patterns. Our aim is to produce a detailed occurrence record map and to discuss whether this provides useful additional biogeographical information to geographic range maps.

1.1. Geographic Range Maps

Geographic range maps display the areal extent of occurrence of a species and are commonly referred to as “expert-based range maps” or simply “range maps”. The range is represented as a polygon including a homogeneous area where the species is assumed to occur [47,50], and its edge is usually delimited on the basis of the knowledge of experts

about the species distribution. Geographic ranges, depicting the external limit of the distribution, better represent the EOO of species than point locality data [51].

One of the main advantages of geographic range maps is that they offer immediacy in the comprehension of the distribution limits of species especially at the continental scale, resulting in direct comparisons with other species and easier definition of chorological types. The comparison of range maps with environmental variables (e.g., climatic and topographic isolines) provides a simple way to infer the ecological requirements of species. Range maps are commonly available in the scientific and grey literature, including technical reports, manuals, and governmental documents. Frequently used online repositories include the IUCN expert maps [52], atlases and monographs [53–58].

The main limitation of geographic range maps is that they are subject to error of commission, since they may include areas where the presence of the species is not documented, thus overestimating the actual range [11,14,25,47]. In range maps, boundaries may fail to capture the irregular distribution of species at their range limits [59], leaving out areas of occupancy associated with peripheral or small disjunct populations [60]. Despite their accessibility, IUCN expert maps [15] are often available only for those species that need priority for conservation. Geographic range maps have the significant drawback of lacking any information about population density and fine fragmentation, or “porosity”, that may result from dynamics of colonization, range expansion, reduction, and thinning, reflecting biological processes or human activity, diseases, and climate changes. Moreover, this continuous and uniform style of representation, which does not necessarily correspond to a continuous and uniform distribution, may not adequately reflect the local physiographic factors that control the distribution of vegetation.

1.2. Occurrence Record Maps

Occurrence record maps show georeferenced locality points, mostly obtained from natural history collections [61–64] and surveys [65,66]. These data sources frequently serve as the starting point for further investigations on species distributions and macroecological patterns [29,33,67,68]. In principle, occurrence record maps bear no commission error, unless they consider records from non-native areas (e.g., gardens), included in non-filtered databases. Occurrence records tend to underestimate the AOO of a species, generating false negatives. Often, locality points are re-edited into grid-based maps, showing the occurrence of species in a matrix of cells with a defined areal extension. Grid range maps may bear errors of both commission and omission, depending on the resolution derived from the size of the cell.

One of the main advantages of occurrence records consists of their availability in online open-access repositories, thanks to increasingly common digitization and georeferencing processes [69,70]. The Global Biodiversity Information Facility (GBIF) [71] is one of the main online repositories for georeferenced records with global cover [72], widely used as a source of occurrence for macroecological prediction and analysis [21,73–75]. Occurrence record maps show the degree of density within the range, which is a very useful parameter to investigate demographic and environmental patterns in both present and past distributions, since it may represent discontinuities related to population dynamics and ecological constraints, especially at the edge of the geographic range.

One of the main limitations of occurrence record maps is that data repositories, although rapidly increasing, are still incomplete [76]. These maps cannot avoid biases due to sampling methods and techniques [77–80], so they require careful selection of the source of information as well as cross-checking against other scientific references. Many authors suggest preliminary filtering and correction of data [81–83], especially when they are used in macroecological analyses [46,74,84]. Even records from natural history collections and surveys are subject to errors related to sampling [42,85], species identification [86–88], spatial biases in remote and inaccessible areas [77,89,90], and digitization and georeferencing methods [91,92].

1.3. *Arbutus* in the Western Palearctic Region

The current distribution of the genus *Arbutus* in western Eurasia, North Africa, and Macaronesia may be a case study useful for highlighting critical issues in mapping species distribution. While several geographic range maps of different species of *Arbutus* have been produced during the last 80 years [2,51,93–97], no occurrence record map has been published yet.

Arbutus is a genus belonging to Ericaceae. It was spread throughout Central Europe in the Oligocene and was still common during the Miocene and Pliocene, at a time when it was already present around the Black Sea [98] and in the Canary Islands [99]. In the Old World, four species are known, according to the present-day outputs of phylogeny and taxonomy [52,100,101].

The most widespread species is *A. unedo* L., centred in the Western Mediterranean Basin and Atlantic coast of Europe, followed by *A. andrachne* L., centred in the Eastern Mediterranean Basin and the coasts of the Black Sea. The species *A. canariensis* Veill. is known only from the Canary Island, and *A. pavarii* Pamp. has been described only from Cyrenaica in north-eastern Libya.

Arbutus spp. is an evergreen, often polychormic small tree, characterized by a nearly continuous blooming across the year, occurring simultaneously with the ripening of the fruits of the previous year. Most fruits fall to the ground uneaten, although thrushes, blackbirds, and wood pigeons are the principal means of dispersal [102]. Larcher [103] demonstrated a high winter photosynthetic rate compared to other sclerophylls, while exceedingly high temperatures are unfavourable to its growth. Adult trees tolerate moderate frost without damage, but temperatures around $-10\text{ }^{\circ}\text{C}$ can eventually kill them [102]. In Ireland, *Arbutus* frequently exhibits dormancy, and even when it appears healthy, it does not produce any fruit [103]. In Libya, it does not produce flowers and seeds in case of extreme summer drought [104]. *Arbutus* is distinguished from other sclerophylls by its ability to emit sprouts from a swollen stem base, called a lignotuber [105–107], that is sufficiently deep to escape fire. This explains the tenacious persistence and longevity of some populations even after long-lasting coppice and fire events. However, *Arbutus* is not completely fire-adapted, since it does not propagate by seeds after fires and tends to disappear when repeated fires affect deep soil layers [108].

Most of the stands of *Arbutus* physiognomically conform to the so-called ‘maquis’, a thicket where *Arbutus* and *Erica* spp., *Rhamnus alaternus*, *Pistacia lentiscus*, *Myrtus communis*, and *Phillyrea* spp. dominate, sometimes with shrubby individuals of evergreen *Quercus* spp. and other sclerophyllous taxa. *A. unedo* tends to dominate in these communities when originated from a pristine evergreen forest especially rich in *Q. suber* on crystalline bedrock and leached soils [95,109]. Nevertheless, the stands of *A. unedo* along the Atlantic coast of France and Ireland stretch markedly outside the area of Mediterranean-type ecosystems, being hosted within coastal temperate deciduous forests, dominated by *Quercus petraea*, *Carpinus betulus*, *Ilex aquifolium*, and *Betula pendula*, as successional species. However, *Q. ilex* reaches Noirmoutier in Brittany on the Atlantic coast at almost 47° N . In this district, *A. unedo* occurs in coastal enclaves with a “para-Mediterranean” climatic regime, relatively humid and warm, nearly frost-free, with low seasonal fluctuations. A similar climatic regime is detected in Northern Anatolia, where *A. andrachne* reaches its easternmost outpost (42° E) stretching into the Euxino-Hyrcanian domain [3].

2. Materials and Methods

The occurrence record map for the genus *Arbutus* (Figure 1) has been produced by collecting records from different sources and excluding stands known to have been historically introduced, as follows (Table S1).

- GBIF: records were selected from countries where *Arbutus* is known to be native, considering only georeferenced point occurrence data from selected institutions and datasets of specimen collections (Herbaria) and vegetation surveys [110–118]. Citizen

science datasets were excluded. A complete list of the selected institutions and datasets, along with the DOI download reference, is listed in Table S1.

- IUCN Red List: the geographic ranges of *A. andrachne*, *A. canariensis*, and *A. pavarii* were retrieved from the respective online assessments [119–121] (Table S1).
- Other databases and online repositories that are not donated to GBIF include: Botanical Society of Britain and Ireland [122], Nationwide Vegetation Plot Database–Sapienza University of Rome [123], Flora Ionica [124]; FAO Map Catalog [125]; EU-Forest [126]; Flora Croatica Database [127]; Lebanon Flora [128]; TÜBİVES–Turkish Plants Data Service [129]. Since many occurrences in these databases were only depicted on maps, it was often required to georeference this information. In some cases (e.g., Flora Croatica Database) the mapped occurrences were clearly representing the centroid of a cell of a grid map.
- Literature: an extensive bibliographic survey was carried out on regional floristic checklist, vegetation surveys, conservation reports, scientific papers, and National Floras [94,95,102,105,130–168]. When geographic coordinates were not available, records from the literature were georeferenced based on the toponyms and the description of the recorded sites. The literature search was especially devoted to those regions that are underrepresented in the above-listed databases. A complete list of references is available in Table S1.

The occurrence records of *Arbutus* were mapped using the open-source software QGIS [QGIS 3.28.4], with the EPSG:32632–WGS 84/UTM zone 32 N coordinate system and represented in Figures 1 and 2, for visual comparison with published geographic range maps (Figure 3).

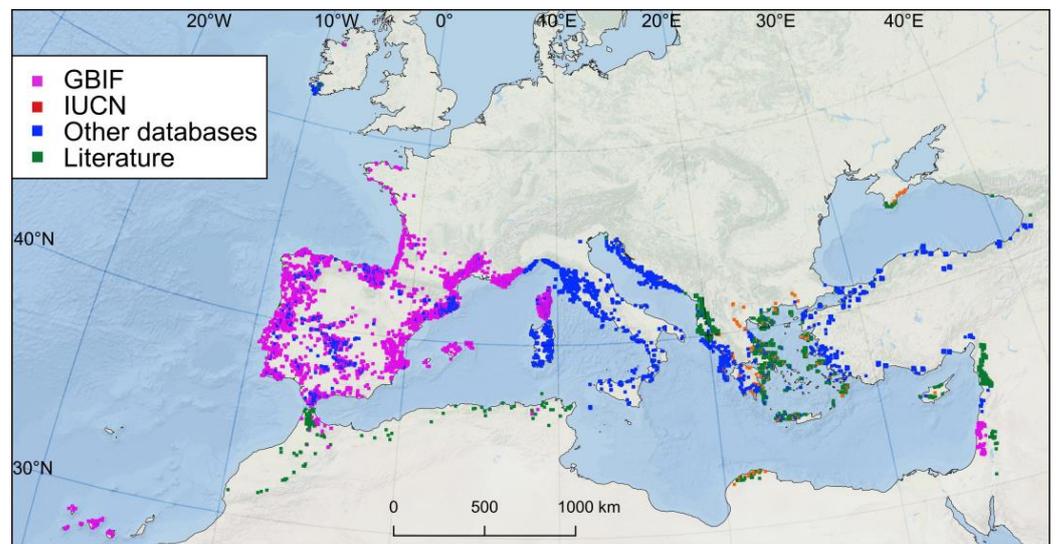


Figure 1. Occurrence record map for the genus *Arbutus* showing the different sources of data. Pink dots: GBIF; orange dots: IUCN; blue dots: other databases and online repositories; green dots: literature (Table S1). The size of the dots is arbitrary.

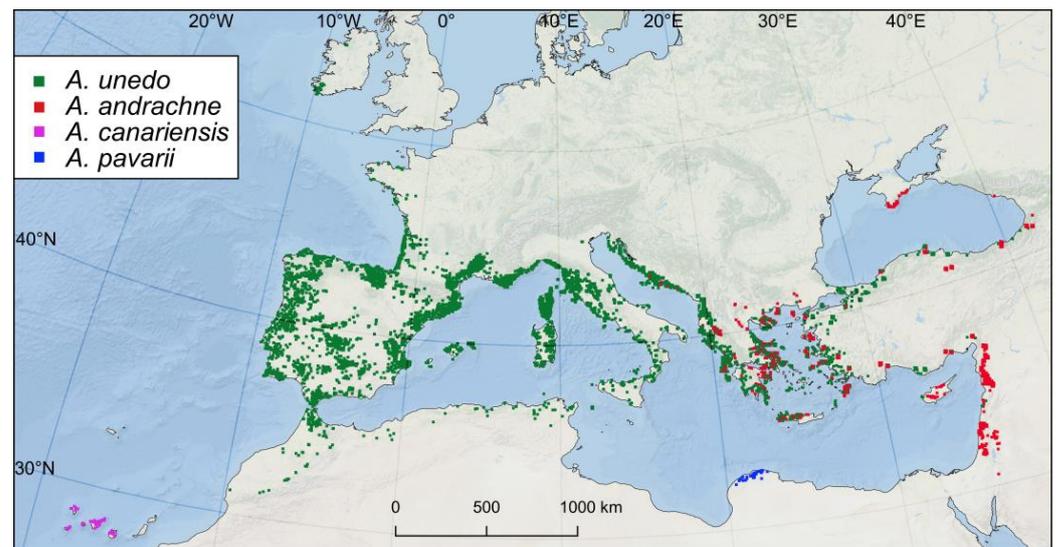


Figure 2. Occurrence record map for the genus *Arbutus* showing the distribution of *A. unedo* (green dots), *A. andrachne* (red dots), *A. canariensis* (violet dots), and *A. pavarii* (blue dots). The size of the dots is arbitrary.

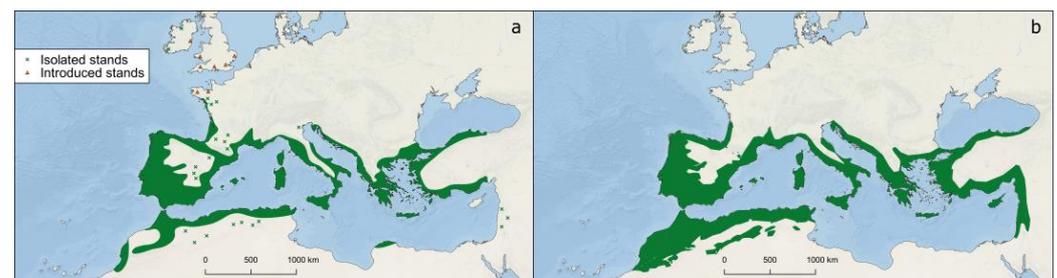


Figure 3. Geographic range maps for *A. unedo* adapted from (a) [53]; (b) [97].

3. Results

A high-resolution map made up of 12,644 occurrence records was produced (Figure 2), including *A. unedo* (11,474 records), *A. andrachne* (1010 records), *A. canariensis* (129 records), and *A. pavarii* (41 records). *A. unedo* and *A. andrachne* share part of their ranges in the Eastern Mediterranean region, where *Arbutus* × *andrachnoides*, the natural hybrid between the two species, poorly discussed in the literature, is also possible to find [169].

A. unedo naturally grows within a wide latitudinal and longitudinal range, from W Ireland, including both the northernmost (Counties of Killarney and Sligo, >54° N) and westernmost (Counties of Cork, <10° W) outposts, to the Souss-Massa region of Morocco (<32° N), and the Eastern Black Sea districts of Turkey (>41° E). On the Atlantic coasts of Europe, dense populations occur from the French Aquitaine through the Spanish Basque Country, Asturias, Cantabria, and Galicia, to the entire coast of Portugal, the Algarve region, and the Strait of Gibraltar. Scattered coastal populations extend northward along Brittany and western Ireland and southward to the region of Marrakesh. In the Western Mediterranean Basin, rather sparse stands of *A. unedo* occupy a large part of the central-southern Iberian Peninsula, the Pyrenees, and inland Aquitaine. In eastern Spain, *A. unedo* shows a continuous range from the region of Valencia through Catalonia to Occitania in France. Following a small distribution gap in Camargue, it is abundantly represented in Provence and continuously occurring along the Tyrrhenian coast of the Italian Peninsula. It is very abundant in Corsica and frequent in Sardinia and the Balearic Islands. It is scattered in the Atlas Mountains, throughout the regions of North Africa (Morocco, Algeria, and Tunisia) facing the Mediterranean Sea, Sicily, and the Eastern regions of the Italian Peninsula along the Ionian and Adriatic coasts, with a single outpost in the Euganean Hills.

It is very common along the Balkan coast, from Slovenia (the northernmost stands along the Mediterranean Sea) to southern Greece, occurring in almost all the Ionian and Aegean islands, with a very restricted enclave in Cyprus and Lebanon, and scanty populations along the Mediterranean coast of Turkey and the southern coast of the Black Sea.

A. andrachne is found in the Eastern Mediterranean Basin, with sparse populations from the Croatian region of Istria, throughout Dalmatia to western Greece and the Ionian Islands. It is more abundant in eastern Greece, Crete, and the Aegean Islands, where it shares a large part of its geographic range with *A. unedo*. It shows dense stands in Cyprus and a large part of the Levant. *A. andrachne* is one of the main components of the evergreen oak forests dominated by *Quercus calliprinos*, the semi-deciduous oak forests of *Quercus aegilops*, as well as the coniferous forests dominated by *Pinus brutia* and *P. halepensis* in south-western Anatolia, Syria, Lebanon, and Jordan [162]. It is scattered in the Mediterranean and Eastern Black Sea districts of Turkey and some isolated locations on the coasts of Georgia. A separate rich population is located along the shores of southern Crimea, where it forms pure stands.

A. canariensis, morphologically similar to *A. andrachne*, is the southernmost species of the Old-World genus *Arbutus*. It is confined to the Canary Islands, more precisely the north faces of La Palma, El Hierro, La Gomera, Tenerife, and Gran Canaria. It is missing from Lanzarote, Fuerteventura, as well as from Madeira and the archipelago of the Azores.

A. pavarii is confined to the region of Cyrenaica (Libya), where the most abundant populations are found in the Al-Akhdar and Al-Jabal mountains, as a dominant element of the maquis, associated with other woody plants such as *Ceratonia*, *Rhamnus*, *Pistacia*, *Olea*, *Cupressus*, *Smilax*, *Phillyrea*, and *Juniperus* [164].

4. Discussion

The critical interpretation of the available sources for the geographical distribution of *Arbutus* has been a major challenge in the compilation and mapping of the occurrence record map (Figure 2). A large number of ambiguous or inaccurate sources, as well as the heterogeneity and incompleteness of the data from literature and databases, required a substantial effort to standardise and synthesise the available data into a comprehensive graphical output. Another complication was the variety of stand toponyms, observation scales, and local and regional distribution map types in surveys from different countries. Moreover, the interpretation of different authors concerning native versus introduced stands was often contradictory. The outliers of the core areas, which are crucial for outlining the limit of the range and providing elements to reconstruct past dynamics and range fluctuations, required particular attention and lengthy searches.

This entire process was quite time-consuming, and it is reasonable to question whether it was worthwhile. A comparison with published geographic range maps may answer this question and help to define the differences in the outcome and the potential use of the two mapping methods. In this comparison, it should be considered that the most recent geographic range maps for *A. unedo* (Figure 3) were produced with the aim of representing the general limit of its distribution and providing readily available information for scientific research and management planning, rather than for fine usability [53,97].

In general, the occurrence record map appears to be more precise in depicting the territories occupied by the different species of *Arbutus*. For example, the map by Caudullo et al. [53] (Figure 3a) entirely omits the isolated stands of *A. unedo* in western Cyprus, while Wazen et al. [97] (Figure 3b) extend the range of the species to the whole island. The range map by Wazen et al. [97], based on the administrative map of The Euro+ Med PlantBase [170] considers *A. unedo* native in Syria and Israel, where Caudullo et al. [53] place some isolated populations (Figure 3). However, only *A. andrachne* is found in Syria and Israel (Figure 2). These discrepancies likely derive from the replication of previous range maps [2,93,94], which however clearly reported the distinction between *A. unedo* and *A. andrachne* in the region. Furthermore, the occurrence record map better displays the areas where the two species occur together, giving back an accurate detail of how they

overlap. Isolated stands in Algeria and the westernmost distribution area in Morocco also replicate previous maps but are not confirmed by our in-depth search on North African checklists and surveys. It is also to be noticed that [53] follows [2] in displaying *A. unedo* in Cyrenaica, where only *A. pavarii* is found.

The scattered stands of *A. unedo* along the Atlantic coast of Brittany are another contentious topic. Caudullo et al. [53] (Figure 3a) represent these stands as isolated and consider them to be introduced and naturalised, while Wazen et al. [97] completely ignore them (Figure 3b). However, in this region, *Arbutus* is consistently reported in the literature as native, e.g., [93,163]. On the cliffs of Trieux near Paimpol, it grows to form a scrub, successfully competing with other members of the flora of north-western Europe. Southward, it is represented by scattered populations following the coast and the Loire River, establishing range continuity from La Rochelle to the border of Atlantic Spain, where it enters into contact with the Basque populations (Figure 2). Those stands form the so-called Lusitanian geoelement [171], a Mediterranean-like floristic stock extending along the Atlantic coast of continental Europe, missing in Great Britain and appearing again in Ireland, where *Arbutus* is the main constituent of open-shrub vegetation on limestone cliffs and rocky sites associated with *Ilex aquifolium*, *Taxus baccata*, *Corylus avellana*, *Sorbus aucuparia*, *Rubia peregrina*, *Calluna vulgaris*, *Ulex gallii*, *Hedera helix*, and *Betula pubescens*. The Irish disjunct outposts have no demographic connections with the continental populations and belong to a different genetic cluster [172]. Anthropogenic import in Ireland cannot be excluded [173], although this distribution perfectly fits the natural “Lusitanian element” of Western Eurasia.

Another fundamental difference between the two mapping methods concerns the wide-scale representation of the density of populations. In the geographical range maps of *Arbutus* (Figure 3), the homogeneous shading of the distribution area does not provide any information about the variability of population density, whereas our occurrence record map (Figure 2) focuses on a variety of situations, from isolated or scattered occurrences to rich abundance. The number of records plotted against longitude intervals (Figure 4) indicates that a high number of sites, pointing to high density, are found in specific intervals of longitude (10° W to 20° E for *A. unedo* and 20° – 40° E for *A. andrachne*), corresponding to centres of gravity. East and west of these high-density distributions, there are tails of sparse presence. *A. canariensis* and *A. pavarii* are so reduced in number of occurrences that their whole distribution lies within a limited longitude range (Figure 4).

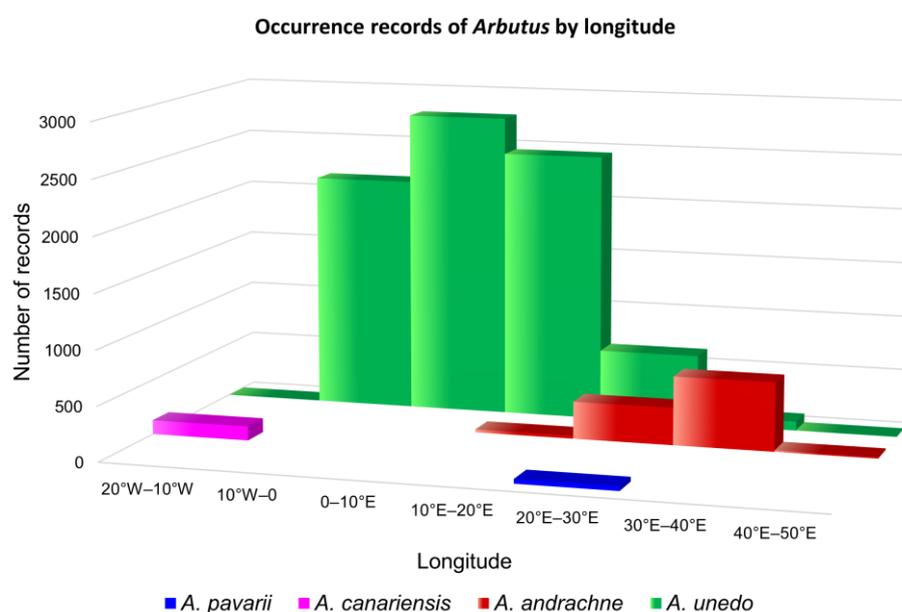


Figure 4. Number of occurrence records for the Palearctic species of *Arbutus* according to their longitude.

Geographic range maps do not allow a simple numerical representation of the centre of gravity of distribution. For example, in the range maps (Figure 3), the continuous filling of the distribution of *A. unedo* in Anatolia, in North Africa, and in some of the most important Mediterranean islands (e.g., Sicily and Crete) does not represent the natural thinning at the southern edge of the geographical range. The sparse occurrences of *Arbutus* in these areas are displayed as densely as in coastal Catalonia in the Iberian Peninsula, where populations are prevalent. Geographic range maps (Figure 3) would suggest southwest Iberia as the centre of gravity for *A. unedo*, because of its extensive distribution represented by a continuous filling. In contrast, the occurrence range map, supported by a large number of detailed data in this region, indicates sparse populations rather than a centre of gravity. The densest populations are found in the Basque Province, along the coasts of Portugal, Catalonia, Provence, and Tuscany, as well as in Corsica (Figure 2). In these regions, *Arbutus* is expected to have the highest potential resilience.

These observations about the variability of population density may have a direct implication in the understanding of genetic diversity. It has been shown that there is a genetic divide for *Arbutus* populations in Iberia, with separate populations located along the eastern and western coasts, respectively [96,172]. Separate eastern and western populations of *A. unedo* in Iberia are visible in our occurrence record map (Figure 2), which shows a significant thinning in the south-central sector of the peninsula, completely undetectable in the geographic range map.

The occurrence records of sparse marginal populations may be particularly useful in interpreting the genetic diversity at the edge of the distribution and in informing a sampling strategy targeted to the identification of expansion or contraction processes through genetic analysis. For example, the different genetic clusters of the Irish population from Killarney, compared to other Atlantic stands [172], might suggest a long-term persistence in the area rather than a long-jump dispersal or anthropogenic introduction. Additional genetic analysis from the northernmost isolated population of Lough Gill (Sligo) may provide new elements to disentangle this question.

Marginal range areas with scattered stands are expected to be especially vulnerable to climate change. It has been demonstrated that European *Buxus*, for which an occurrence record map is available, underwent a dramatic contraction of its sparse populations at the southern margin of the range (southeast Spain, Sicily, southern Greece), as a result of aridification of the Mediterranean regions in the last few millennia [174]. A similar threat can be reasonably feared for the North African populations of *Arbutus*, which appear extremely reduced in the occurrence record map, while the geographic range map does not show any evidence of risks.

Apart from North Africa, other populations of *A. unedo* that appear to be threatened and may deserve attention in planning conservation actions include the marginal and isolated stands in Brittany, southern Sicily, and the Levant, as well as the southern and northern coasts of Turkey, especially at the easternmost margin of the range (Figure 2). These areas are not included in the IUCN Red List assessment, which reports the conservation status for *A. unedo* as of least concern, based on stable population trends [175]. In contrast, *A. andrachne* is included in the Jordan Red List as vulnerable, due to intensive grazing and urban expansion mainly for tourism development and agricultural intensification. Although this species meets the criteria of the endangered category, it was downgraded to vulnerable due to its wide global distribution [147] and classified in the IUCN Red List as of least concern [119]. *A. canariensis* is assessed as near threatened by the IUCN Red List because of its restricted extent of occurrence and area of occupancy, although there are no current threats to this species and no continuing decline in habitat area and extent [120]. *A. pavarii* has been experiencing a decreasing trend as a result of habitat degradation in the El-Jabal and El-Akhdar regions, due to urban expansion and agriculture, for which reason it has been assessed as near threatened [121]. Improvement in the accuracy of occurrence records, coupled with an increase in the quality of chronological and taxonomical details of fossil records, as well as routine inclusion of genetic analyses of both present and past plant

populations, may provide a more complete and synthetic view of the long-term trends of these scanty and marginal stands, so suggesting informed conservation actions in response to changing climate and increasing human pressure [176].

Another possible application in which occurrence record maps may be preferred to range maps is the combined use of present and past occurrence data with climate and environmental modelling. For example, a recently published predicted scenario (MaxEnt model) for the distribution of *A. unedo* [177] shows that during the Last Glacial Maximum (LGM) the species was located in Mediterranean islands (Sicily, Sardinia, and Balearics), eastern Spain, southern Italy, and North Africa. However, the palaeobotanical records presented in the same paper [177] show that *Arbutus* expanded only a few thousand years ago at its southern margin (North Africa and Sicily) and in the central Iberian Peninsula. These fossil data confirm that areas currently sparsely populated and far from the centres of gravity of distribution of the species (Figure 2) had a low potential for survival in the LGM, as they have at present. The discrepancy between the predicted distribution of the LGM and the palaeobotanical data may depend on the fact that the environmental requirements of the species were modelled on the basis of range maps showing an extensive distribution in North Africa and Sicily [53,172], completely ignoring that the species is extremely scanty in those regions (Figure 2). This example points to the importance of using detailed datasets of occurrence records when predicting past-to-future geographic ranges and of taking into account the density of distribution in order to weight the environmental niche modelling.

5. Conclusions

The case study of *Arbutus*, which resulted in a detailed occurrence record map for *A. unedo* and the other species of the Old World, clearly provides useful additional biogeographical information to the published geographic range maps. This information includes the importance of and details on peripheral stands, variability of population density, continuity vs gaps in distribution, plausible centres of gravity of the species, vulnerability, and potential resilience of populations.

The interconnection of occurrence records with the results from other biogeographical fields of research, such as palaeobotany, genetics, and ecological modelling, holds great scientific promise. When detailed palaeodistribution maps, phylogeographical analyses, and density-weighted ecological models are available, they may help to clarify at least some of the questions that the occurrence record map of *Arbutus* has brought up. These questions include the relation between current centres of gravity and glacial refugia, modern demography and postglacial population dynamics, patterns of genetic diversity and range fragmentation, and nativeness of marginal populations versus human introduction.

A significant challenge has been the critical interpretation of the many existing data sources for the geographical distribution of *Arbutus*. The entire procedure was quite lengthy, both for literature searching and the factual interpretation of the data from many different countries, authors, languages, scales, and mapping systems, for which reliability had to be assessed. However, this approach has shown that occurrence record maps have the advantage of being easily handled and updated by reviewing geographical and taxonomic issues and progressively incorporating new incoming data.

Our results show that this effort was worthwhile and beneficial, as in the case of North Africa and the northern Levant, where databases are missing, and the available information can only be derived from geobotanical surveys. Such regions are indeed especially important since they are at the edge of the ranges and therefore provide fundamental elements to reconstruct genetic diversity and range history. Moreover, they are extremely sensitive to climate change and human impact and deserve particular attention in conservation strategies.

In conclusion, despite the fact that occurrence record maps inevitably contain omission errors, the case of *Arbutus* shows that the advantages of a thorough and double-checked occurrence record map far outweigh the drawbacks. Extending this mapping method to

additional plant taxa will undoubtedly offer insightful hints that could have a beneficial cumulative effect on subsequent ecological and evolutionary studies.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/f14051010/s1>, Table S1: List of occurrence records of *Arbutus* spp.

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