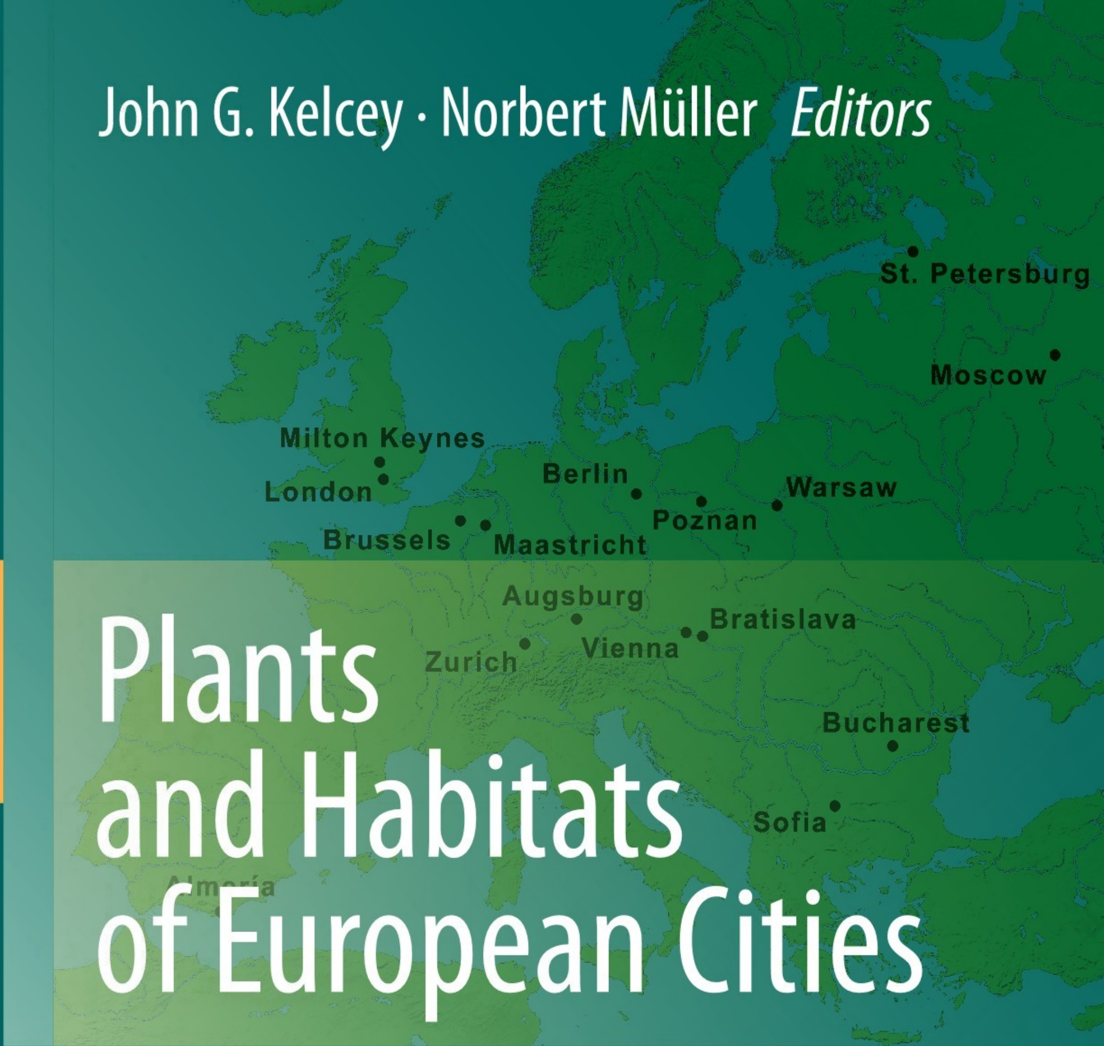
John G. Kelcey · Norbert Müller *Editors*



Plants and Habitats of European Cities

Springer

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John G. Kelcey · Norbert Müller
Editors

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Preface

John G. Kelcey

I wish to open this preface with an acknowledgement that would normally appear at the end, but the circumstances are exceptional, which is why it has to be done here. As newspaper editors know only too well most readers only read the first 1–2 column inches. And so it is that I wish to thank my partner Liz Colville for her sacrifices, tolerance and the immense effort she has applied in ensuring the completion of this book. Without Herbert Sukopp, Norbert Müller and Clive Stace, the book would not have been started, without Liz it would never have been finished – in reality a third editor.

This book and its companion volume on birds are two of many European seeds that were probably sown in my sub-conscious childish mind 50–60 years ago – they are the first two to bear fruit having been carefully nurtured and cultivated for the last 30 years or so by Herbert Sukopp. Whether the rest of the fruit matures or falls to the earth rotten remains to be seen. The journey from seed to fruit has been long and convoluted and subjected to many influences, a few are outlined in the following paragraphs – in no particular order.

The European peninsula is a fascinating natural unit to which, with the benefit of experience, the Middle East (the Fertile Triangle of the European homeland) should be added. The peninsula is divided into two opposing factions, human beings constrained by raging and desperate nationalism (despite the European Union) and plants and other animals that are not constrained by administrative/political boundaries. The former has had and continues to have a very serious effect on the understanding of the latter exacerbated by the failures in cultural understanding.

The issue is not one of federalism but of considering Europe as a single but diverse unit, the problem is the lack of understanding of the European condition, the solution is education and the provision of information. My early childhood interests in the cultures (a terrible word) of Europe in general but especially central and eastern Europe, in particular, were frustrated by the British attitude to Europe, the inability to travel and the lack of books. The former, which continues, raises the issue of why 50–100 million people died between 1914 and 1945; the freedom of movement has substantially improved since the early 1990s but the lack of information remains.

Back to natural history, the component nations appear to have considered and continue to consider that interest in it should stop at the national boundaries and yet those boundaries have been changing continually since the "establishment" of the nation state 1,000 years ago or so. Parts of present France were once part of Britain. Then, there were countries such as Persia and Prussia and the "units" of the Habsburg Empire. Czechoslovakia did not exist until the early 1920s, the Czech and Slovak Republics not until 1993. Transylvania is now part of Romania, much to the annoyance of Hungary. Yugoslavia has been divided into seven or so States although Bulgaria lays claims to Montenegro. And so it goes on. In short, it is more appropriate to study the flora of Europe than that of its component countries. Whether a species is endemic or an archaeophyte is dependent upon the political boundaries of the time.

It is a sad reflection on European botanists that there is no current, reliable flora of Europe and no standardization of the nomenclature or, it appears, the spelling of some names. It should be possible for an academic botanist or even someone with a general interest in plants to read or buy a book in Lisbon and find that the same names are used in Moscow, Athens and Helsinki. It is also a sad fact that for the most part national floras are confined to angiosperms or vascular plants – algae and bryophytes are rarely considered. The same applies to fungi and lichenised fungi (lichens), which although no longer within the Plant Kingdom, for practical purposes, should be considered as "plants".

A botanist wishing to enjoy the plants of Europe (for serious study or general interest) will find it impossible to do so, not only for the reasons considered in the previous paragraph but because there are no national floras for some countries, for example France. Observations of the physical form of the European landscape and its vegetation suggests that probably only a small proportion of it has ever been explored by botanists, who may well have missed much of botanical interest. For example, consideration of the logistics of undertaking a botanical survey of the Carpathians between Sibiu and Cozia in Romania indicate the magnitude and impossibility of the task – and that is a small area compared with Romania, even smaller if Bulgaria is included and smaller still when the whole of Europe is considered. However, these issues have much more serious implications in relation to the assessment of the status of species and the need or otherwise for statutory protection and the inclusion of a species within European protection measures.

My appointment in 1972 as the ecologist with Milton Keynes Development Corporation (a Government Agency) was the first of it kind in Britain occurred well before I was able to travel throughout Europe as I wished to do. The appointment was a baptism of fire – continual cross examination by cynical engineers, architects, estate managers, lawyers and finance officers was only just less traumatic than the refusal of the Government's nature conservation agency and academics to show any interest on the grounds of the presence of people and the need for a 5-year research programme, respectively.

In the early 1970s, the Corporation developed a particular interest in the approach of the Dutch to the provision, design and management of existing and new green space in Amsterdam, Almere, Delft and Lelystadt. In addition, the Corporation bought virtually all (if not all) of its trees from The Netherlands. Consequently, attending ecological conferences and undertaking a few days of study were easily approved – in addition, the Corporation saw considerable opportunities for publicity, "Look, we have an ecologist." The Garden Festival projects in Germany and the

British Government's interest in them provided the opportunity to go east, even as far as Berlin – but no further.

And so it was that in the early 1970s, I was thrilled and relieved to meet Hebert Sukopp, Maciej Luniak, Tj Deelstra and many others who were previously unknown to me but understood the natural history of urban areas. It was a revelation that impressed my employers – here were ecologists who actually worked in cities and who could be turned to for advice and to whom people were just part and parcel of life. They were immensely helpful and influential – in those days moving 1% forward was a major step.

Working in an urban development project with the objective of transforming more or less 9,000 ha of rural land into a "city" for 250,000 in 20 years sharpens the mind. Ecological arguments were subject to stringent testing while the arguments of other disciplines were tested although less vigorously. In order to understand and argue a case, it was necessary to understand the other disciplines involved and to be ready, almost immediately, with a credible answer. A week is a long time in urban development – stopping a job will cost thousands of Euros per day, changing a contract or instructions may cost hundreds of thousands if not millions of Euros and then there is the small matter of who pays and professional liability. In short, it was a matter of "using best endeavours."

As a consequence, the mind was broadened to include an appreciation of architecture, landscape design and other applied arts and from there to the other arts. The debates raged from the intellectual to the elementary. Sadly, what emerged was disappointing – as a rule, democracy only results in the mediocre – it requires authoritarianism to produce the outstanding but often at a social cost.

With some exceptions, there was little published information (in English) about urban natural history, there were some notable exceptions such as Berlin and Warsaw, and therefore "being prepared" was difficult, often impossible. This stimulates the mind to identify what is needed to solve the problem. The answer, "technical information that is easily understood and available quickly." However, there was another equally important approach and one that I had frowned on for a decade or so, namely, 'curiosity' the pursuit of knowledge out of sheer pleasure and interest. For decades, botanists had been describing and analyzing the flora of countries and units of countries woodlands, grasslands, coasts, road verges and many other habitats but not cities. For some reason, cities were exempt as was former industrial land, which botanists were intent on re-grading and turning bright green using *Lolium* or multi-coloured using *Lupinus.*

We needed some books about the natural history of cities, especially European cities. "Why in English?" asked Herbert Sukopp – a good point. He also asked me why most ecological/botanical papers published in Britain did not contain references to German papers. The same principle applies to papers in Italian, French and Spanish. Of course, the answer was and is easy – the British do not understand other languages, which is different from France where the French do but prefer not to. This diversion turned out to be interesting because the comment ultimately led to my reaching the view that European-wide books should be published in German and/or French. The suggestion was unanimously rejected by the contributors to the book "Birds in European Cities," (edited by Goetz Rheinwald and myself and published by

Ginster-Verlag in 2005). I was told, very firmly, that it is inappropriate to publish a scientific book these days unless it is written in some form of English, which is why that and this book are in English.

My initial aspiration (which remains to be achieved) was to write a series of volumes about the natural history of specific cities, including the geology, geomorphology, soils, origin, evolution, architecture, landscape, engineering, human values and behaviour, public health and such design, planning and management as there may have been, climate, air and water quality, habitats and the organisms from viruses to vertebrates of some of the major cities of Europe. This assumed there were sufficient data and that it was in English or I could get it translated – both rather naïve, with the benefit of hindsight.

Even trying to write a book about the natural history of a city proved impossible, and so it was at 2 a.m. one morning the obvious dawned on me. If the aspiration was to make any progress, I would need to consider cities in terms of the major groups of organisms starting with plants (or more precisely vascular plants), followed by birds. Time to discuss these matters with Herbert and Maciej, for reasons that are not at all clear now, I decided to reverse the order and start with birds. May be it was because birds are more popular, there are less of them (in terms of species), there are more ornithologists and bird watchers, and therefore likely to be more data. Encouraged by my two mentors, a delightful joint editor and enormous support from those who agreed to contribute the book, which was published at the end of 2005.

The preparation of, and the enthusiastic response to the bird book encouraged me to discuss again with Herbert Sukopp the possibility of a companion volume on the plants and habitats of European cities. He suggested a collaborative venture with Norbert Müller. Herbert and Clive Stace kindly provided us with lists of first class contributors most of whom graciously and generously accepted our invitation to write a chapter about "their city." Sadly, some were too busy, some did not reply and one dropped out after two years stating that he knew nothing about the subject, and therefore he could not write the chapter.

Norbert and I have tried to ensure that the preparation of the book has been a democratic exercise in which we have acted as enzymes – simply trying to make something worthwhile happen. I shall be eternally grateful to all those who have given their time without any financial reward (so far) to assist me in my endeavours to spread the understanding of the natural history throughout Europe in general and European cities in particular.

Many other companion volumes about the plants, habitats and birds of one or more other European cities remain to be written, as they do about cities elsewhere in the world. It is evident that most of the chapters in this book could be expanded into whole books. There are volumes to be written about the vertebrates and the invertebrates – as a whole or in "groups" such as the insects as a whole or individually Lepidoptera, Odonata and Orthoptera and then the molluscs. And of course, the original aspiration still remains to be achieved.

John G. Kelcey
A restless itinerant of Europe
November 2009

Introduction

Herbert Sukopp, Norbert Müller, and John G. Kelcey

The flora and vegetation of some European cities (mainly in central Europe) have been described and mapped over several decades. As a result, it is now possible to draw conclusions about environmental changes that have occurred by comparing the historical data with present conditions. The investigations demonstrate that the recent spatial distribution of spontaneous plants in cities has different causes:

1. Land use, care and substrate play an important role as well as the climate. Thus, the distribution patterns mirror building, economic and social structures.
2. The distribution and dispersal of archaeophytes and neophytes in cities have changed during the last centuries resulting in the present higher percentage of species that are sensitive to frost and cold.
3. The meso- and macro climatic characteristics overlie the distribution patterns by forming a gradient from the centre to the periphery.
4. The spatial differences caused by the special temperature conditions are reflected in the systematic phenological investigations, which enable heat islands and cooler areas to be mapped easily.

In many cases, the phenological phases start several days earlier in the centre of the city than in the periphery or in large parks. In the urban core, the first flowers can be observed 8 days earlier than in the outskirts, where one day equates to 1°C, which correlates well with the distribution of phenological phases in Europe in general. In cool valleys and wetlands, the flowering may even start two days later than on the city margins. The steepest gradient is found at the boundary between forests and built up areas.

As the result of the long-term studies of the urban heat island and the related effects on the flora and vegetation in European cities since the middle of the nineteenth century, it is possible to use cities as models for the effects of climate change on flora and vegetation.

"Urban vegetation" in its narrowest sense is the vegetation of ruderal places, for example rubble, railway and port areas, ruins, walls and waste areas. The occurrence of new non-native species in areas that are subject to human influence has stimulated a large number of investigations of the adventive flora for many decades. The newcomers were recorded and categorized according to the time of introduction, the way of introduction and the degree of naturalization. The highlights of such studies were the rapid colonization of the bombed areas of cities in the 1940s (for example, London and Warsaw) and the climatic changes of the last decade. It is important to recognise that, as well as the typical urban habitats, many cities contain several pristine natural and semi-natural habitats.

A question frequently asked is, "whether or not the warmer city climate influences the flora and vegetation of cities?" However, as mentioned above there are not only climatic changes, but also other ecological and socio-economic factors that influence urban vegetation. Transport, trade and horticultural activities reasons are the main "vectors" for the introduction and subsequent dispersal of non-native thermophilous species. In many cases, this has resulted in the breakdown of biogeographical barriers. In cities, native species become associated with species that would never have reached them without human activities.

The presence of a large number of non-native species is a characteristic feature of urban areas. Urban areas not only show a decline in the number of native species and archaeophytes, they are and will continue to be the starting point and centre of dispersal of non-native species, especially from the warmer regions of Europe, Asia and America.

Many native species (called apophytes) are able to colonize new urban sites, which raises interesting questions about dispersal (especially over long distances), colonization and succession. In Berlin, 63% of the species established on urban sites are native; some botanists consider that all native plants could exist as apophytes in one form or another.

Non-native plant species in urban areas have a relatively slow rate of dispersal into the surroundings of cities; the colonization process can continue for several decades, centuries, or millennia. The dispersal and naturalization varies between species. Of all the introduced taxa, on average only 10% are able to colonise areas temporarily (casuals), 2–3% can exist in man-made habitats and become a permanent member of the flora whilst only 1% is able to survive in natural ecosystems (for example, forests).

This is the first book to describe, in one volume, the flora and habitats of European cities and the changes that have occurred in them as a consequence of urban development. The 16 cities were not selected but "chose" themselves based on two criteria; first, the availability of sufficient information and second, the willingness of an author with sufficient expertise to write the chapter. As will be discussed in the conclusions, there are some obvious omissions. The book is another step forward in the wider recognition of the long tradition of research on urban flora and vegetation of Europe that has been undertaken in central Europe since the 1960s. It is hoped that it will provide the basis for more extensive and intensive botanical research throughout Europe.

The chapters, which comprise a series of individual essays, are idiosyncratic in reflecting the similarities and differences in the approaches of the authors. Nevertheless, the chapters follow a general pattern starting with a description of the natural features of the city, including the geology, topography, soil and climate. Then follows a general account of the history of the physical, economic and political development of the city from the earliest human settlement to present and how urbanization has affected the environment (for example, pollution and the heat island effect) and how the environment has affected the city (for example, climate change).

The recorded botanical history of the city is followed by an account of the flora which is mainly concerned with flowering plants and ferns. The chapters go on to describe the most frequent spontaneous plants and the frequently planted trees along roads and in parks and gardens.

Each of the chapters considers the evolution of the urban flora from the earliest agricultural period to the introduction of a very large number of ornamental species from the sixteenth century onwards. The past, present and future implications of the mixing of non-native with native plants, which would not otherwise occur naturally, are discussed.

Where sufficient information is available, the chapters include summary descriptions of the algae and bryophytes and because of their general visual affinity with plants the lichens (lichenized fungi) and fungi are also included. Because of the imbalance in knowledge and information, the accounts of the non-vascular plants and fungi are not as comprehensive as they should be; this deficiency has been compensated for by the provision of references to other literature.

The plant communities and species composition of the major natural and semi-natural habitats within the municipal area are described followed by accounts of the species found in more typical urban habitats, including housing areas of different types and densities, industrial zones, unused and previously developed land, parks, cemeteries, allotments and similar habitats, transport routes (for example, railway land and road verges) and various aquatic habitats, including rivers and flooded mineral workings.

The chapters end with an account of the environmental planning, protection and education aspects of the particular city, including Red Data List species, statutory habitat and species protection with special emphasize on the European Union Habitats Directive. Educational programmes such as nature trails are also described.

Finally, it is necessary to explain some inconsistencies in the number of references quoted and listed. Originally, the contributors were asked to provide only about eight publications for further reading. Some contributors did their best to comply whilst others were unhappy because they considered that the absence of references and/or a short reference list would indicate to their academic colleagues/potential readers that they were not familiar with the literature and that this would adversely affect their academic credibility. The difficulty was resolved by the editors succumbing to contributor pressure, and the writing this “health warning.”

Almería

Elias D. Dana, Juan García-de-Lomas, and Manuel A. Guerrero

Fig. 1 Fishing port of Almería, with La Alcazaba in the background (Photograph by Maria del Mar Bayo)

Abstract The Province and city of Almería are important areas of the Mediterranean basin with respect to their cultural heritage and environmental values. However, unfortunately, the recent and dramatic landscape transformation has resulted in the destruction of natural habitats and their component species – in the last 50 years,

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the area of the city has increased from about 2.5 km^2 to about 10 km^2. The present population is 190,000. The predominant traditional agricultural system of family farms has been replaced by intensive agriculture, greenhouse and built development. The urban area of the city supports about 200 vascular plant species, most of which are associated with ruderal or weed communities. The overall proportion of non-native taxa is 5% but in densely urbanised areas it increases to 12%. The non-native taxa include several genotypes and undescribed varieties of *Phoenix dactylifera* from North Africa and the highly invasive ornamental species *Pennisetum setaceum*. Most of the non-native taxa develop during the late spring and autumn, whereas the native taxa develop between the winter and early spring. In addition, the typical urban habitats in the city contain ten important natural or semi-natural coastal, scrub and grassland habitats of plant communities.

Natural Environment of the City

The continental areas of Spain are divided into Regional Governments (Comunidades Autónomas) and Provinces, which contain municipalities (101 in the Almería Province). Each province has an administrative city of the same name; hence, "Almería" is the name of the Province and the capital city, which are within the Regional Government of Andalusia (Comunidad Autónoma of Andalucía). More information on the political, administrative and social aspects can be found at http://en.wikipedia.org/wiki/Almeria and http://en.wikipedia.org/wiki/Provinces_of_Spain.

Unless otherwise stated, "Almería" refers to the city, which is located in south-eastern Spain (Latitude 36°50′ north, Longitude 2°28′ west). The locations of the Province and the city are shown in Fig. 2.

Most of the city is only a few meters above sea level. The geology of Almería comprises mainly calcareous and sedimentary deposits of marine and freshwater (river) origin (Aguirre 1998). These materials have determined the features of the main soil classes, which are characterised by small particle sizes, with a relatively high content of sodium (Na) and potassium (K) and in the inner parts of the city, calcium (Ca) derived from clay and limestone. The basal mountain areas on the western side of the city have poorly developed soils with calcareous outcrops. Sandy soils are generally restricted to the sea fringe (Fig. 2).

The general climate of the area is Mediterranean, semi-arid xeric, characterised by strong aridity and mild winters with high relative humidity. The annual mean rainfall is about 145 mm and the annual mean air temperature is 18°C. Meteorological data for the period 1929–2009 show mean maximum and minimum daytime temperatures of 23°C and 15°C, respectively, with a maximum of 44°C and a minimum of −1°C. These conditions, together with a high level of evapo-transpiration, impede the development of coastal forests, which are replaced by tall shrub communities, including *Maytenus senegalensis* ssp. *europaeus, Ziziphus lotus, Pistacia lentiscus* and *Olea europaea* ssp. *sylvestris*. Figure 2 shows that the landscape is dominated by perennial grasslands and medium to low scrub.

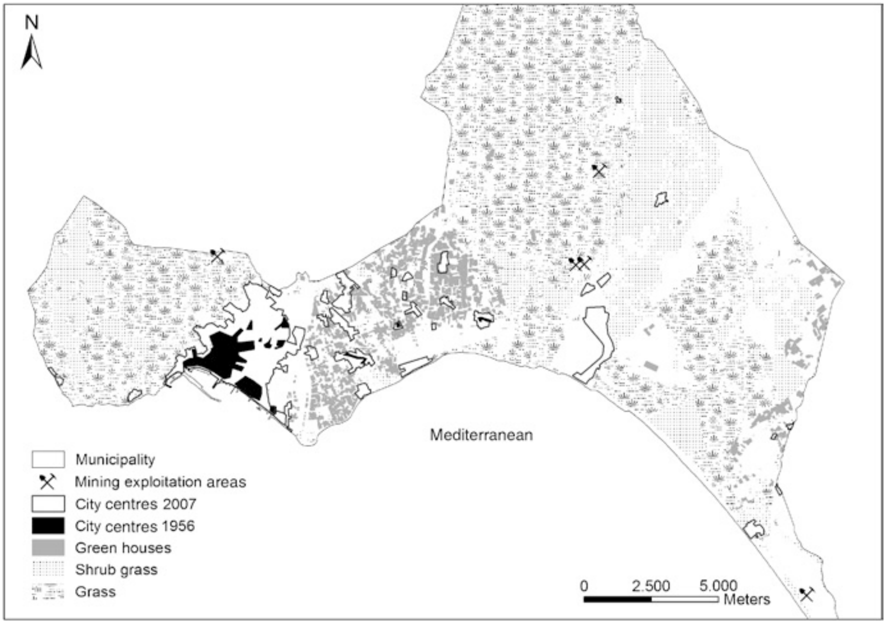

Fig. 2 Main landscape features and vegetation types of Almería city and administrative areas

The Andarax river has the hydrological characteristics of North African wadies and has superficial freatic layers. In former times, this river was associated with the development of riverine tree plant communities dominated by *Tamarix* spp. and occasionally by *Populus alba*. Currently, most of the non-riparian and riparian communities have disappeared or their extent has been drastically reduced. As described below, the latter are of considerable conservation importance.

Historical Development of the City

Until AD 1200

Almería and its surroundings have been inhabited since the Neolithic period, when the area was colonised from the east. During these times, the main settlements were located close to the current city boundaries and the Andarax river. Typical riparian forest communities dominated by *Salix* spp. and *Populus* spp. and the associated riparian fauna have been found in nearby archaeological sites. Although Roman culture left some heritage, the most important legacy came from the Moors civilisation, which made Almería the administrative capital and political centre of the area in AD 955. A fortress with watch towers was built to defend the previous administrative capital of Pechina (formerly called Bayyana), which is about 10 km from Almería. At that time, Almería was called Al Mariyyat Bayyana (meaning "the watchtower of Bayyana"). A series of infrastructure and commercial activities took place at the fortress and its surroundings, including the creation of the Medina, the establishment of markets and the construction of ports.

The golden era of Almería was the tenth to twelfth centuries. In that period, it became one of the largest and most important commercial cities for Mediterranean maritime traffic. The Arab influence resulted in many important philosophers being born in or attracted to the city, such as important thinkers of Al-Andalus and the Mediterranean areas. The area became a centre of excellence for contributors to the development of geography, agronomy (for example, Al Idrisi), theology and poetry (for example, Al Mutasim, the poet Emir) and for important leaders of Sufism (a mystic branch of Islam) such as Ibn Al Arif and Ruayni of Córdoba who were disciples of Ibn Masarra.

In 1147, the by now rich city of Almería was conquered by the troops of the Catholic king Alfonso VII and his allied kingdoms and the state-cities of Catalonia, Pisa, Geneva and France. Although it was soon re-conquered by the Almoravids, Almería never recovered its previous importance because the trading routes were diverted to other coastal cities of the Mediterranean.

AD 120–1900

Soon after the occupation (in 1489) by the Catholic monarchs Isabel and Fernando, the city and its inhabitants were plunged into a period of considerable poverty (both material and cultural) until the mid-nineteenth century, when iron and silver mines were discovered by British and French companies. This resulted in a rapid population increase and a temporary reduction in poverty in the city and the province. However, it was accompanied by extreme environmental degradation, which is a typical consequence of sudden population growth. The degradation included deforestation, soil erosion and lack of food (mainly proteins), which ultimately resulted in a general poverty vortex that reached its maximum during and just after the civil war of 1936–1939. Figure 3 shows the demographic trend since the existence of reliable census data.

The architectural development of Almería is as complex as its history. After the conquest by the Catholic monarchs, the city was almost completely destroyed at different times by earthquakes. It was not until the nineteenth century that the city really emerged from the influence of the ancient Medina and expanded to the size it is today (see Dana et al. (2002)).

1950s to the Present

Between 1950 and 1960, the landscape surrounding the city was typical of the Mediterranean irrigated agricultural system, comprising small pieces of land, each (or a few of them) maintained by families. Figures 4 and 5 show the intense and rapid transformation of the urban nucleus into the surrounding areas during the last 60 years or so.

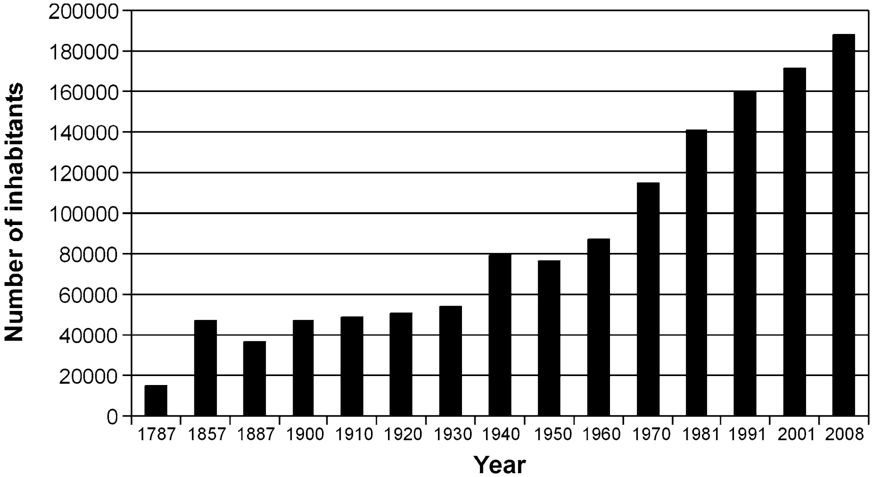

Fig. 3 Census data 1787–2008 for Almería city

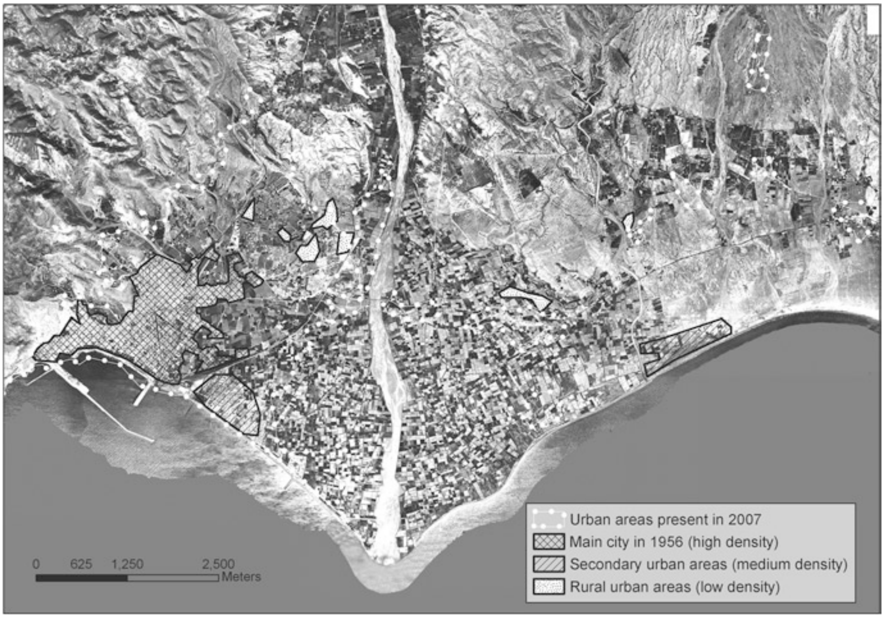

Fig. 4 Aerial image of the area in 1956 showing the evolution of urbanised areas. USA National Cartographic Service

In the 1950s, there were only minor extensions of the urban area into the adjacent agricultural land, which contained only two relatively important villages. Since that time, the cultivated lands have been gradually urbanised and the traditional farm systems converted into agricultural structures based on intensive food production,

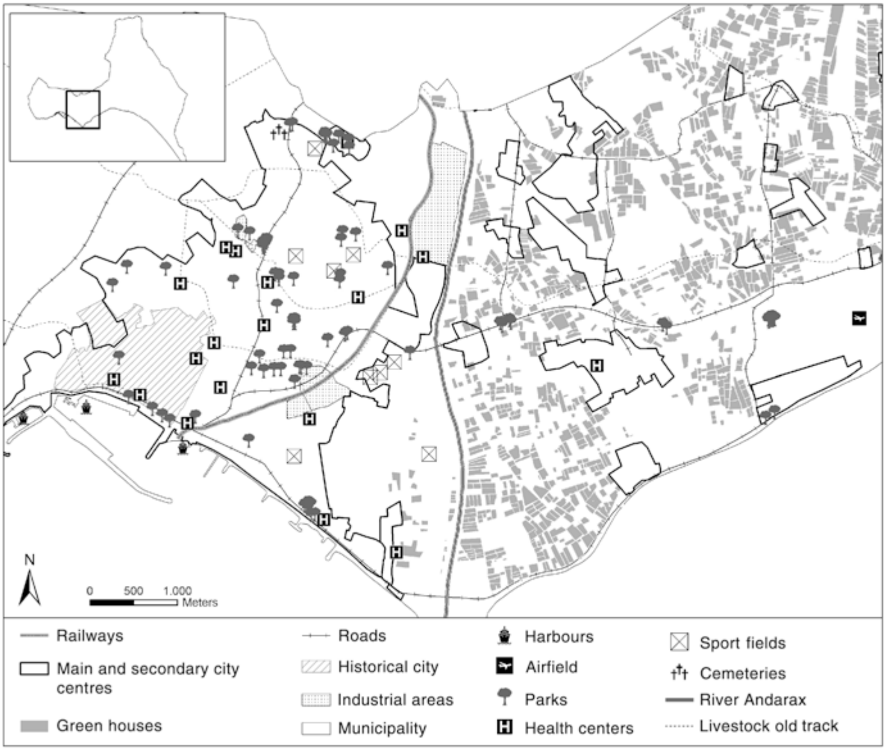

Fig. 5 Urban habitat and services. Note the scarce number of services in the secondary urbanised areas

mainly greenhouses. The analysis of aerial photographs indicates that the city occupied about 9.95 km^2 in 2007, almost a 300–400% increase since 1956, when the main urban area occupied 2.26 km^2 (the total urbanised land occupied 3.5 km^2). The images show the gradual appearance of new densely populated areas that were absent in 1956. It is important to note the gradual urbanisation of coastal habitats and the growth of existing settlements, especially since 2000.

Changes of the Environment Due to City Growth

Unfortunately, there are no published studies relating specifically to the environmental changes caused by the growth of the city. The most complete and interesting study investigated the socio-economic changes of the province and their effects on environmental and natural values (see García-Latorre and García-Latorre 2007). Among other sources, the authors used historical documents, archaeological evidence, place names, interviews with older farmers and field studies to gather information about how the landscape has probably been modified by people and their values. In the administrative area of Almería, most of the land has been occupied by irrigated land and pasture. Some of the irrigation systems were inherited from previous Arab cultures, while others were created during the nineteenth century as an answer to the increasing demand for food due to the expanding population. The greatest environmental change took place during the twentieth century when most of the cultivated land around the city became occupied by dense urban development, particularly since 1970. The most recent changes and their environmental implications can be assessed by comparing aerial images of 1950 with those of the present day (see Figs. 4 and 5). They can be summarised as the typical destruction of agricultural and grazing habitats and the associated species (in the former case, many of the taxa were linked to water availability), changes in traditional agricultural practices and the increase in urbanisation.

Agriculture has changed from "family farms" with *Lycopersicon esculentum, Capsicum* spp., *Solanum tuberosum* varieties, *Medicago sativa* spp. *sativa,* cereals, and fruits such as citric orchards, *Olea europaea, Armeniaca vulgaris, Prunus dulcis, Punica granatum, Eriobotrya japonica, Mespilus germanica* and *Ficus carica* were cultivated to intensive agricultural production (greenhouses with few modern varieties of *Lycopersicon esculentum* and *Capsicum* spp.). This change has involved large inputs of agrochemicals and has resulted in the homogenisation and impoverishment of landscape features and the associated biocoenosis. The traditional agricultural habitats that supported many typical animal species, especially birds (for example, *Upupa epops, Athene noctua, Tyto alba, Hirundo rustica* and *Erinaceus europaeus*), have declined dramatically, causing a local decrease in their populations (Manrique and De Juana 1991).

The city has extended eastwards; so far, both sides of the Andarax river have been totally developed. During the last 2 decades, several adjacent rural villages and towns have been incorporated into the city as it has expanded. Since 2000, a large area of semi-natural dunes on the outer edge of the Natural Park "Cabo de Gata" has been replaced by greenhouses and the associated infrastructure, including roads, car parks and recreational areas. The dunes were characterised by psammophilous communities (dominated by species such as *Ammophila arenaria* or *Pancratium maritimum*) and by tall thorny shrub communities dominated by *Ziziphus lotus*. The latter communities act as a refuge for several mammal and steppe bird species of avian taxa (Heath and Evans 2000).

In addition to increasing urbanisation, erection of greenhouses is the other cause of environmental change. The impacts of these intensive agricultural systems are mainly habitat loss, pollution (generation of large quantities of plastic sheeting and agricultural waste, and contamination of aquifers), groundwater imbalances (including marine intrusion) and severe landscape modification. Also, large pits have been created by the extraction of gravel and clay for use as a substrate for cultivation (Pulido-Leboeuf et al. 2003; Downward and Taylor 2007). It has been recently proposed that because of their greater albedo, these areas may be an important factor contributing to climate change, especially in territories where most of the available land is covered by greenhouses (Campra et al. 2008). However, their effect on the municipality of Almería has not been investigated.

It can be concluded that substantial environmental changes have occurred since the 1950s as a response to changes in socio-economic values; that is to say, the transition of a rural local society based on the exploitation of land by family members to an economic model based on the provision of homes, services (banks, commerce and trade) and recreational facilities. These changes have led to the increase in (i) population (the current population of Almería city is ca.190,000, see Fig. 3), (ii) urbanised area and consequently (iii) landscape fragmentation and edge effects.

Flora

Vascular Plants

The city and its immediate fringes support about 200 angiosperm species, and most of them are ruderal and weed species (more information on the species found and the ruderal/weed communities is provided in Dana and Rodríguez-Tamayo (1999) and Dana et al. (2002). Most of the native taxa develop in the late winter–early spring, while the development of most of the alien species occurs mainly from late spring to autumn. The 50 most common species in the city are given in Table 1.

The percentage of alien taxa found in the whole of the administrative territory is low (5%), probably due to climatic and historic reasons. However, the percentage

Table 1 The 50 most frequent species found in Almería (no neophytes)

Bromus diandrus	*Plantago coronopus*
Bromus rubens	*Plantago lagopus*
Atriplex halimus	*Parietaria judaica*
Avena barbata	*Phalaris minor*
Beta vulgaris	*Oryzopsis miliacea*
Calendula arvensis	*Plantago ovata*
Carrichtera annua	*Poa annua*
Chenopodium album	*Polycarpon tetraphyllum*
Chenopodium murale	*Polygonum aviculare* agg.
Chrysanthemum coronarium	*Polypogon monspeliensis*
Convolvulus arvensis	*Portulaca oleracea*
Catapodium rigidum	*Reichardia tingitana*
Dittrichia viscosa	*Salsola vermiculata*
Echium creticum	*Salsola oppositifolia*
Erodium chium	*Schismus barbatus*
Eruca vesicaria	*Setaria verticillata*
Fagonia cretica	*Sisymbrium irio*
Hedypnois rhagadioloides	*Solanum nigrum*
Herniaria hirsuta	*Sonchus oleraceus*
Hordeum murinum	*Sonchus tenerrimus*
Hymenolobus procumbens	*Spergularia bocconnii*
Lamarckia aurea	*Spergularia. diandra*
Malva parviflora	*Urospermum picroides*
Mercurialis annua	*Urtica urens*
Papaver hybridum	*Volutaria lippii*

is higher in the more densely urbanised parts of the city, where the average value is about 12%. Some of the most frequent alien species found in the territory are mainly neophytes such as *Amaranthus muricatus, Aster squamatus, Mesembryanthemum crystallinum, Atriplex semibaccata, Nicotiana glauca, Conyza sumatrensis, Conyza bonariensis, Coronopus didymus, Chamaesyce serpens, Heliotropium curassavicum* and *Zygophyllum fabago*. The archaeophytes present include *Arundo donax* (which is abundant in the administrative area and a casual in the main city) and *Oxalis pes-caprae*.

Some taxa that were frequently found on the fringes of the main city up to the early 1990s have gradually become infrequent or have suffered a reduction either in frequency or patch size as a consequence of urbanisation. This has resulted in a decrease in the availability of areas that provided a source of propagules for the species that are more associated with agricultural land, either cultivated or abandoned. Some examples are *Bassia hyssopifolia, Coyncia tournefourtii, Hyoscyamus albus, Anagallis arvensis, Asphodelus* spp., *Atriplex glauca, A. semibaccata, Chondrilla juncea* and *Hammada articulata*. The analysis conducted by Dana et al. (2002) showed some interesting species that can be considered as "relicts" of the traditional agricultural landscape such as *Linum ussitatissimum,* and are almost absent now.

Planted Trees and Shrubs

Taxa planted in urban public spaces are mostly low-maintenance species adapted to the aridity and salinity influences of the coast. The most common tree species used in roadside plantings are *Ficus retusa, Acacia saligna* and *Washingtonia* spp. More recently and because of the lax sanitary procedures, several genotypes and unknown varieties of *Phoenix dactylifera* have been imported from North Africa to satisfy, as quickly as possible, the aesthetic demands of people living in the recently urbanised areas. This has led to an increase in the occurrence of insect *Rhynchophorus ferrugineus* and the consequential loss of a large number of *Phoenix canariensis* and *P. dactylifera,* some of which were more than 150 years old. This organism is also destroying large numbers of ancient palm trees outside the city in typical agricultural areas and so adversely affecting the historic landscape of the Province's lowlands. It is also essential to stop the recent use of highly invasive ornamental species such as *Pennisetum setaceum*. This species, which has recently colonised open habitats, has the potential to colonise wadies and a number of habitats of conservation interest such as coastal habitats and permanent grassland to the detriment of the native flora.

There is no information about the non-vascular plants and the fungi of Almería.

Habitats

The administrative area still supports important plant communities as defined by the "Habitats Directive" (Directive 92/43/CEE as amended by Council Directive 97/62/EC of 27 October 1997, Regulation No 1882/2003 of the European

Parliament and of the Council of 29 September 2003 and Council Directive 2006/105/EC of 20 November 2006 modifications). Nine communities that occur in Almería municipality are listed in Annex 1 (of the Directive), of which three are "Priority Communities". These communities and their EC and Corine codes (* indicates a priority habitat type) are described below. However, not all the species and other aspects of the community as described in the Directive necessarily apply to Almería city or its municipality.

1. Southern riparian galleries and thickets belonging to *Nerio-Tamaricetea* and *Securinegion tinctoriae* (EUH code 92D0; Corine code 44.81).

   Tamarisk, Oleander and *Chaste* tree galleries, which are thickets and similar low-growing woody habitats associated with permanent and temporary streams and wetlands of the thermo-Mediterranean zone and south-western Iberia. The plant species commonly found are *Nerium oleander, Vitex agnus-castus, Tamarix* spp., *Securinega tinctoria, Prunus lusitanica* and *Viburnum tinus*.

2. *Crucianellion maritima* fixed beach dunes (EUH code 2210; Corine code 16.223).

   Coastal dune communities of the eastern Mediterranean of the alliances *Crucianellion maritima, Medicagini marinae-Triplachnion nitensis* and *Ammophilion arenaria*. The plant communities are rich in species of the genus *Silene,* together with *Euphorbia terracina* and *Pancratium maritimum* among others.

3. *Malcolmietalia* dune grasslands (EUH code 2230; Corine code 16.228).

   Therophyte communities of the coasts of the Mediterranean basin and the subtropical Atlantic that colonise deep sands in clearings of permanent communities of fixed or semi-fixed dune systems, and sometimes depressions of white dunes with several *Malcolmia* spp.

4. *Arborescent scrub with *Ziziphus lotus* (EUH code 5220; Corine code 32.251).

   Pre-desert deciduous brush of *Periploca laevigata, Lycium intricatum, Asparagus stipularis, Asparagus albus* and *Withania frutescens* with tall *Ziziphus lotus,* confined to the arid Iberian south-west under a xerophytic thermo-Mediterranean bio-climate; corresponds to the mature phase or climax of climatophile and edapho-xero-psammophile vegetation series: *Periplocion angustifoliae, Ziziphetum loti, Zizipho-Maytenetum europaei, Mayteno-Periplocetum*. Other species present include: *Lycium intricatum, Asparagus stipularis, A. albus, Calicotome intermedia, Chamaerops humilis, Maytenus senegalensis* ssp. *europaeus, Periploca laevigata* ssp. *angustifolia, Phlomis purpurea* ssp. *almeriensis* and *Rhamnus oleoides* ssp. *angustifolia*.

5. Mediterranean and thermo-Atlantic halophilous scrub (*Sarcocornetea fruticosi*) (EUH code 1420; Corine code 15.61).

   This scrubby, halophilous vegetation develops in the uppermost levels of salt marshes, often where there is a transition from saltmarsh to dunes or in some cases where dunes overlie shingle. The permanent vegetation is mainly composed of scrub species that have an essentially Mediterranean–Atlantic distribution, for example, *Salicornia, Limonium vulgare, Suaeda* and *Atriplex* communities belonging to the *Sarcocornetea fruticosi Class.* The associated species are *Atriplex portulacoides, Inula crithmoides* and *Suaeda vera.* The lower topographical level supports species such as *Sarcocornia perennis, S. perennis* ssp. *alpini, S. fruticosa* and *Arthrocnemum macrostachyum,* whereas the higher topographical level is dominated by *Limoniastrum monopetalum, Aster tripolium* and *Limonium* spp.

6. Halo-nitrophilous scrub (*Pegano-Salsoletea*) (EUH code 1430; Corine code 15.17).

   Halo-nitrophilous scrub belonging to the *Pegano-Salsoletea* class, typical of dry soils in arid climates, sometimes including tall, dense shrubs. The species fo*und are Peganum harmala, Artemisia herba-alba, Lycium intricatum, Capparis ovata, Salsola vermiculata, S. genistoides, S. oppositifolia, Suaeda pruinosa, Atriplex halimus, A. glauca, Camphorosma monspeliaca* and *Haloxylum articulatum.*

7. Annual vegetation of drift lines (EUH code 1210; Corine code 17.2).

   Formations of annuals or representatives of annuals and perennials, occupying accumulations of drift material and gravel that are rich in nitrogenous organic matter lying at or above mean high-water spring tides. These shingle deposits occur as fringing beaches that are subject to periodic displacement or overtopping by high tides and storms. The distinctive vegetation, which may form only sparse cover, is therefore ephemeral and composed of annual or short-lived perennial species such as *Cakile maritima, Salsola kali, Atriplex spp., Polygonum spp., Euphorbia peplis, E. paralias, Glaucium flavum, Matthiola sinuata, M. tricuspidata,* and *Eryngium maritimum.*

8. *Iberian gypsum vegetation (EUH code 1520; Corine code 15.912).

   Low, open *Thymus, Teucrium* and *Helianthemum* garrigues (= Mediterranean scrub), which colonise the poorly developed gypsiferous soils of the arid south-east of the Iberian Peninsula. The characteristic herbaceous elements comprise *Teucrium libanitis, T. polium, T. pumilum, T. carthaginense, Thymus longiflorus, T. antoninae, Helianthemum lavandulifolium, H. squamatum, Gypsophila hispanica, G. struthium* and *Astragalus alopecuroides.* The grass species present include *Lygeum spartum, Stipa tenacissima,* and *Brachypodium retusum. Artemisia barrelieri* and taxa in the Chenopodiaceae may be locally abundant.

9. *Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea* (EUH code 6220; Corine code 34.5).

   Includes a variety of xeric, thermophilic and mostly open permanent and annual Mediterranean grasslands usually growing on eutrophic soils but also found on oligotrophic soils. There are three major sub-types: (i) permanent