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Vertebrates and Invertebrates of European Cities

Selected Non-Avian Fauna

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Contents

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Vertebrates and Invertebrates of European Cities:Selected Non-Avian Fauna

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Preface

It is usual for acknowledgements to appear in the 'small print' at the end but this approach hides the contribution made by others because as newspaper editors say most people only read the first few centimetres of an article. As always I have received invaluable assistance from Herbert Sukopp. I shall be eternally indebted to Peter Werner for suggesting most of the main authors. Without the contributors the book would never have been written; it is theirs, I simply acted as an enzyme or a form of RNA. The book would never have been completed without the enormous help, tolerance and support of my partner Liz Colville (to whom this book is dedicated) who has done her best to keep me relatively sane in the face of many adversities. Finally, my grateful thanks go to Springer for agreeing to publish the book and especially Janet Slobodien, somewhat belatedly (with due apologies) to Melissa Higgs and Zach Romano for their tolerance as time after time I suffered the embarrassment of having to report yet another delay.

The book is the last in an ad hoc series of three about the plants and animals of European cities. The 'series' started life in my mind in the late 1970s out of curiosity—knowledge for its own sake, 'what do we know about the organisms in cities, the abiotic environment in which they live and their dynamics?' At that time the answer was 'very little' and that remains largely unchanged. It took 35 years for the first book to appear and another 10 years for this 'final' volume to be published.

A fourth volume remains to be written, namely 'The Protozoans, Bacteria (and related organisms) and Viruses' in European Cities. These organisms make a larger contribution to urban biodiversity than all the plants and animals added together and are far more important in relation to human existence, both positively and negatively. It is regretted that some of these issues were not discussed at all in *Birds in European Cities* whilst the effects of pollen on human health is considered briefly in *Plants and Habitats of European Cities*. The brief accounts of the Fungi in the latter are mainly confined to the macro-fungi (the large members of the Ascomycetes (cup and flask fungi) and Basidiomycetes (mushrooms and toadstools). The 'micro-fungi' such as the moulds and yeasts are virtually ignored, especially those that cause symptoms that human beings call 'diseases' such as *Aspergillus* spp., *Arthroderma* spp. and *Candida* spp., which appear to be restricted to medical mycology. These organisms cannot be put in a vase, do not flit colourfully around the

garden, are not furry and do not have forward-looking eyes, but they are extremely important to people, other animals and plants—many are deadly while others are essential to the making of bread and beer. The same principle applies to bacteria—in terms of human values there are 'good' ones and 'bad' ones.

There is no doubt that sufficient information is available to write the fourth volume, although a different approach and format is needed. Sadly as with aspects of mycology and entomology, the subject falls between two stools of disinterest—on the one hand, medical practitioners and biomedical scientists who have little (if any) interest in the natural history of the urban environment and botanists, zoologists and ecologists who have little (if any) interest in people and what artists and writers call the 'human condition'. The gap between them is huge.

Knowledge of and interest in urban natural history remains in its infancy and is at least 50 years behind studies of the species composition and associations of woodland, grassland, freshwater and other ecosystems in rural areas. A major inhibition to the understanding of urban ecosystems is that descriptive ecology is no longer fashionable; consequently very little is known about the structure of the urban ecosystem, let alone how it functions. What information there is, is disparate and 'un-coordinated' whilst research lacks direction and an overall objective. Politicians, the media and people at large consider urban ecology in terms of nature conservation and the 'curious' when the issues are infinitely more serious and go to the heart of the planning, design and management of cities, the use of natural resources and the creation of a high quality environment for the benefit of people as a whole.

The urban population is at serious risk in both geological and biological terms. There are disasters waiting to happen, it is simply a question of when because many cities have been built in inappropriate places such as on the banks of major rivers, low-lying coastal land, on the sides of volcanoes and in earthquake belts without regard to the dynamics of geological processes and the climate. Although it is probably fair to state that at the time the settlements originated such matters were either not understood or not appreciated. People did not learn from Pompeii and the Dutch have continued to drain land and build cities several feet below sea level. In some cases there is nothing that can be done while in others there is but the solutions depend upon a detailed knowledge of the structure and function of ecosystems involved.

Predicting the biological disasters that are waiting to happen is more intractable, mainly because of lack of detailed knowledge about the presence, distribution, relative abundance and dynamics of the populations of vertebrates and invertebrates and the 'pathogens', as well as the adverse effects of pollution of the air, water and soil. On the other hand, there are considerable psychological benefits derived from the proximity of vertebrates and invertebrates provided that people like them. In addition, fishing along the banks of rivers and lakes is a major recreational activity.

This is a highly unsatisfactory state of affairs because it is a sad fact that politicians do not anticipate environmental problems (*sensu lato*). As one of my client's commented, 'Politicians and their officials aim to catch the bus as it passes the door but they often miss it'. The political expediency is to react to disasters after the event when they tend to panic, overreact and fund short-term 'emergency' research

that would have helped prevent or reduce the impact of the disaster in the first place. On the other hand, physicists have managed to convince governments to spend huge sums pursuing the origins of the universe, which is of no consequence to anyone. The fact of the matter is that more is known about the universe and its origins than about the urban environment in which 70% (and growing) of the human population lives. No doubt physicists will disagree on the basis of the incidental benefits that emerge by chance, although I accept that pure research has its place. However, the cost of research to fully understand the structure and functioning of the urban ecosystem is likely to be infinitesimal compared with the cost of funding space exploration and, amongst others, the construction, maintenance and administration of the European Centre for Nuclear Research in Geneva—and the research needed to justify the investment.

Similarly, more is known about the marine ecosystem where no people live than that of the city where most of them live. Large sums of money are spent investigating global warming, more accurately climate change which has been a continuous process for millions of years and which we can do little, if anything, about; during the same period there has been relatively little funding of the urban ecosystem although we can do a lot to improve the quality of the lives of people and other organisms. Then there is the sacred cow of 'biodiversity' another scientific windmill that politicians have fallen for. The preparation of three volumes in this informal series and a general investigation for the fourth have demonstrated beyond all reasonable doubt that very little is known about the number and relative abundance of species that can be seen with the naked eye let alone those that occur below ground.

At the conference held in Curitiba in 2007 with the title 'Cities and Biodiversity; Engaging Local Authorities in the Implementation of the Convention on Biological Diversity', the Executive Secretary of the Convention stated '*The battle for life on earth will be won or lost in urban areas*'. That was 8 years ago; the quality of the urban environment in Europe was not on the political agenda then, it is still not and will not be until a major 'event' jolts politicians and biologists into action.

The contents of this book (and the previous two) will be of no direct assistance in winning the battle or preventing the inevitable disasters BUT they pave the way for fundamental and much-needed improvements in the understanding of the structure and function of the urban ecosystem and changes in the approach to planning, design and management of cities, which should be more firmly based in the biological sciences and the wise use of natural resources.

The book has been prepared and written for a wide audience comprising seven groups of potential readers. Some of my detractors will consider the audience to be too wide but the quality of the environment of cities is or should be a major concern to most of the world's population because they live in them or may soon do so. The groups are (in no particular order):

1. Natural scientists in universities and research institutions.
2. Zoologists, ecologists and other biologists in private practice.
3. Teachers, researchers and practitioners in other disciplines including architects, planners, engineers, landscape architects, anthropologists and the medical professionals.

4. Post-graduates, undergraduates and other students in a wide range of disciplines who wish to know more about the life in cities.
5. People who are simply curious about and wish to know about the natural history of cities.
6. Politicians and administrators in central and local government and other public bodies concerned with the planning, design and management of cities.
7. Not least, the book is aimed at every man who should know more about the environment in which he or she lives.

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Porto

Filipa Guilherme, Miguel A. Carretero and Paulo Farinha-Marques

Abstract The city of Porto (42 km^2 and 237,000 inhabitants) is located in the coastal area of northern Portugal at the convergence of the Mediterranean and Atlantic climates. There are signs of human settlements since prehistoric times but until the nineteenth century, Porto was still a small and compact urban centre surrounded by a large belt of agricultural and forest landscapes. Since the mid-twentieth century, the city has spread throughout the rural fringes to its administrative limits creating an urban continuum with the adjoining municipalities while agricultural land also suffered major changes (intensification and Eucalyptus plantations, *Eucalyptus* sp.). Consequently, the urban green structure is highly fragmented, comprising mainly small and highly altered spaces interspersed in the urban matrix, except in the peripheral areas where agricultural and forest (either of native or alien species) patches still occur. The biodiversity of Porto is still largely unknown, since urban ecology is a nontraditional subject in Portugal. To our knowledge, the urban territory supports 50 species of vertebrates (birds not included): 23 fishes, 7 amphibians, 7 reptiles, 11 small mammals and 2 large mammals. The species occur in the remnants of natural or semi-natural habitats existing in the city and also in the public parks and gardens that act as refuge areas in the artificial matrix.

Natural Environment of the City

AQ1

The city of Porto is located in the northern region of Portugal, facing the Atlantic Ocean and the Douro River, roughly between 8°33′W and 8°41′W longitude and 41°8′N and 41°11′N latitude. Despite its limited area (about 42 km^2), it is the heart

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Fig. 1 View of the city facing Douro River, as seen from Serra do Pilar

of the greater metropolitan area of Porto that is formed by 16 municipalities, housing more than 2 million residents (of which only around 10% live in Porto nowadays), Fig. 1, 2.

Consequently, the territory is heavily urbanized up to its municipal boundaries (Fig. 3), whereas most of the natural habitats, large forest and agricultural areas are located on the outskirts of the metropolitan area.

The city centre, which is orientated to the south–southeast, is densely built and characterized by low-rise buildings, mostly from the turn of the twentieth century, usually developed in blocks or ribbons with mixed occupancy of housing, retail and office. The centre corresponds to the ancient medieval city; consequently, there are many historic monuments, most of them being of religious or defensive function. In an intermediate area, high-density housing takes the form of multi-storey buildings; moving towards the periphery, they are replaced with low-density buildings and some larger green spaces. The suburban area is characterized by a scattered and poorly planned land use. Large industrial areas and a reasonable amount of undeveloped land occur on the city limits. Regarding the latter, while until the 1950s, the land was a mixture of small agricultural fields and remnants of natural habitats, both habitat types have been partially replaced by intensive agriculture orientated towards producing feed for dairy cattle (corn fields) and plantations of *Eucalyptus* spp. and *Pinus* spp. (pines) for the paper industry.

Although the area is dominated by artificial surfaces, green spaces are present throughout the city. The urban green structure of Porto (Fig. 4) is highly fragmented, comprising mainly small patches interspaced in the urban matrix, especially in the city core.

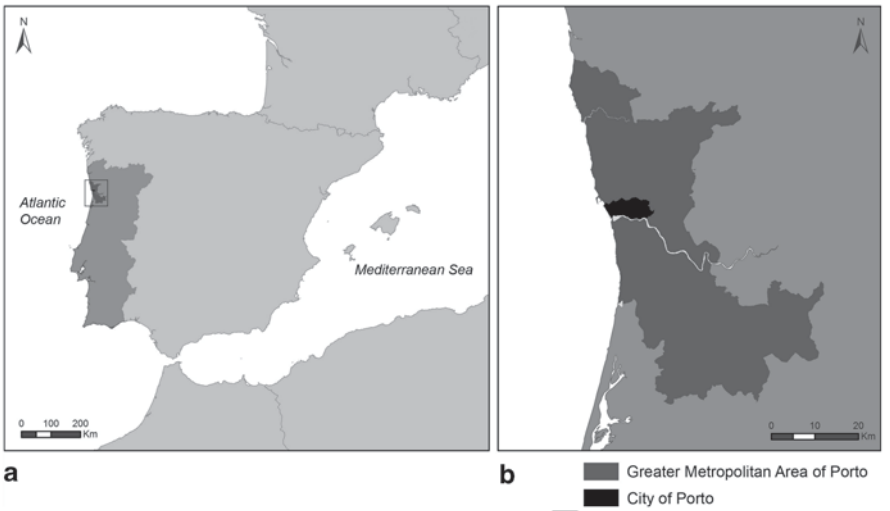

Fig. 2 Location of the city of Porto: **a** in the Iberian Peninsula; and **b** in the greater metropolitan area of Porto

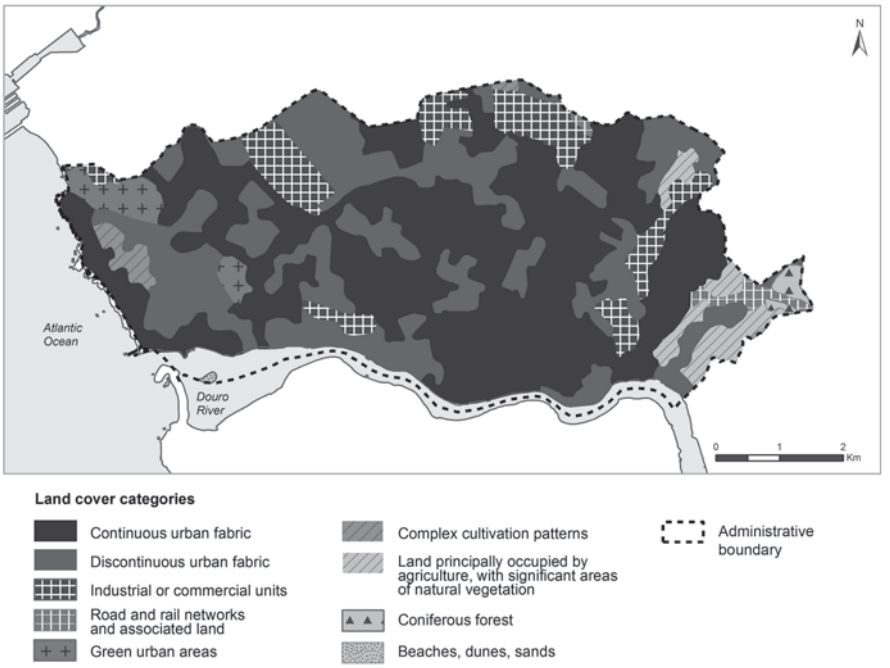

Fig. 3 Land cover categories in Porto, based on CORINE Land Cover 2006. (Caetano et al. 2009)

Fig. 4 Urban green structure of Porto

Small urban yards play an important role in assuring the presence of vegetation in the dense urban fabric in the centre, as they are virtually the only existing typology of green space. In the outer core, high- and low-density housing areas (multi-storey buildings and detached housing) are also complemented with green open space and private gardens, respectively. In this transitional area, public parks and gardens become more significant: They provide larger habitats for urban biodiversity and are easily accessible; they play an important role in human health and well-being. In the periphery, the green structure is ordinarily represented by small agricultural patches, wastelands and vacant lots. Large civic infrastructures, like schools, colleges, hospitals and sports facilities, are more frequent in the suburbs and they are often integrated into the urban green spaces. The city of Porto is linked to key ecological systems, with the Atlantic Ocean to the west and the Douro River, with its rocky steep banks to the south, which strongly affects the urban environment and can also act as habitats and dispersion corridors connecting Porto to the adjoining municipalities, particularly those situated upstream in the Douro valley. More detailed information on the green structure of Porto and its typologies can be found in Farinha-Marques et al. 2011 and Farinha-Marques et al. 2013.

Historical Development of the City

First Settlement to 1143 AD

Archaeological evidence confirms the presence of humans in the Porto region for at least 100,000 years. In northern Portugal, from the Minho district down to the left bank of the Douro River, there are several records of prehistoric artefacts from the Palaeolithic and Neolithic periods.

In the first half of the first millennium BC, new human settlements were built in northern Portugal, generally in areas at high or medium altitudes, near rivers and streams, where the soils were suitable for agriculture and with access to mineral resources. These settlements, which are called *Castros,* were the typical built settlements in northwest Iberia in the Bronze and Iron Ages—they were fortified refuges protected by stone walls and earthworks. In Porto, the first settlement took place, in a south–southeastern position, in *Morro da Sé*.

Following the Cantabrian Wars (29–19 BC), the northwestern Iberian Peninsula was occupied by the Romans, who reorganized the territory, developed a vast road network and focused on economic exploitation of the natural resources. From the Upper Middle Ages, the Porto area was occupied by Germanic peoples (Vandals and Suevi, around 400 AD), Muslims (in 716 AD) and re-conquered by the Catholics (Kingdom of Asturias, León and Navarra) in 868. The names given to places within the city include Germanic, Roman and protohistoric designations, suggesting a continuous occupation since the original settlement in *Morro da Sé*.

1143 to 1763

In 1143, the country of Portugal was recognized as independent from the empire of *León*. Until the end of the twelfth century, the urban area of Porto (3.5 ha) was isolated and confined by its walls. It was only after the Portuguese border extension to the south of the Tagus River that the city experienced a period of peace and security and some economic growth boosted by international trade. At this time, the municipality area encompassed the walled city core and the adjoining periphery occupied by fields and groves. Beginning in the thirteenth century, the urban area started to expand outside the city walls, occupying previous agricultural fields and expanding to the north-west and to the south. In the fourteenth century, there was already more urban areas outside than inside the walls and the need to protect the newly constructed range became evident. The construction of new walls, enclosing around 44.5 ha began in 1355 and it was concluded in 1370.

As a result of previous developments, during the next few centuries, the city was divided into three distinct areas: the walled city centre (new wall), the suburban ring and the rural ring. Regarding urban green space, the walled city was meagrely vegetated with the exception of some domestic backyards and orchards, the yards of monasteries (that frequently included productive gardens and also orchards) and the steep banks of the Douro River. Outside the city walls, despite the increasing urbanization, the area kept much of its rural aspect. The agricultural fields provided food for the city with some tree-covered market places close to the city gates. In the sixteenth century, the new urban ideals started to demand the creation of green areas for collective recreational use**.** The first public green area stemmed from the landscaping of an old market place (*Jardim da Cordoaria*), which still survives today although greatly altered. Responding to the new urban living habits, new public open areas, mainly squares, were created; some of them were also vegetated.

1763 AD to 1900 AD

The second half of the eighteenth century marked the beginning of one of the most important periods of the urban transformation of Porto. In 1763, *Junta das Obras Públicas* (Public Works Commission) was created to perform urban interventions as a response to the economic development and the demands of rapid population growth. The *Junta,* which was headed by *João de Almada,* derived its financial strength from the port wine trade; taxes were allocated to improve the urban environment. One of the main objectives of *Junta das Obras Públicas* was to plan the urban growth outside the walls, which was already taking place in a rapid and unorganized way. The opening of new streets defined the main axis for extra-mural expansion and facilitated the connection between the city centre and the periphery. After 1792, long sections of the wall began to be demolished, many public buildings were erected in its place.

At the beginning of the nineteenth century, social instability, instigated by the Peninsular War, the establishment of Liberalism and cholera outbreaks caused demographic stagnation, which stopped the urban improvement operations. The city centre deteriorated and became unsanitary, whereas the recently urbanized areas outside the walls became more valuable—the upper classes leaving the centre to enjoy the peacefulness and purity of their mansions surrounded by luxurious green areas. Nevertheless, the city centre remained active through the establishment of commercial and financial institutions.

In the 1830s and 1840s, the city went through a new urbanistic momentum. New markets were built and new streets opened. A new garden, *São Lázaro,* which was created in an old market place, was opened to the public. A new suspension bridge was erected to connect the two sides of the Douro River. There was also an urban expansion as many of the surrounding parishes were included within the city limits. These parishes were already fairly urbanized, but they kept some of the rural features, especially in the farms interspersed in the urban matrix. Many farms had been built since the eighteenth century, and around the 1800s, most of them adopted a recreational function for the enjoyment of their bourgeois landowners (e.g., *Quinta do Campo Alegre* and *Quinta de Serralves*). In the second half of the nineteenth century, the demographic growth increased (Fig. 5) and the economic activities flourished, especially industry. They stimulated a major transformation in the urban fabric.

The city centre was vastly improved in its street and road network and unsanitized areas were destroyed but the progress was more noticeable in the periphery. New buildings were created, more streets were open, bridges were built and many watercourses were culverted**.** The railway was inaugurated in 1875, when the train station in Campanhã was opened.

The newly created urban public transportation network—street cars and trams—stimulated urbanization in the periphery. The city underwent a tremendous increase in urban green space. First and mainly for aesthetic purposes, the main streets were planted with avenues of trees. Second, public gardens were created to improve social and health conditions in the city after the Industrial Revolution, as happened in other European cities. The notable urban park *Jardins do Palácio de Cristal* was created at this time, Fig. 6.

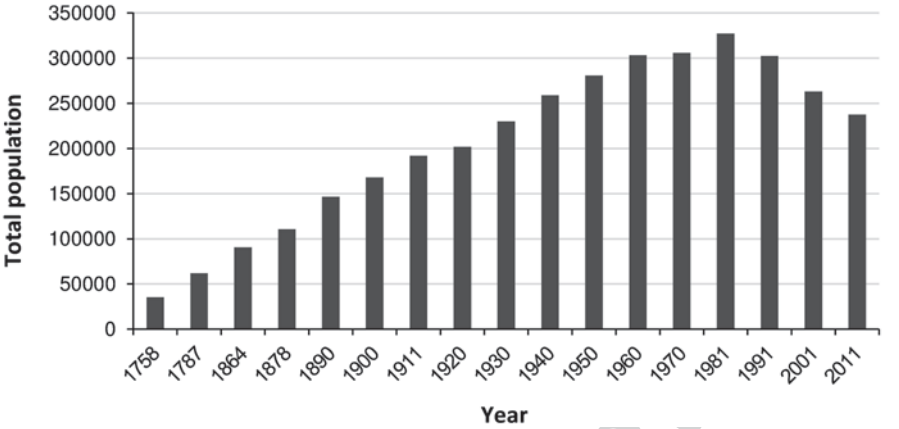

Fig. 5 Evolution of the urban population of Porto. (From 1758 –2011 census data)

Fig. 6 View towards the Douro River from Jardins do Palácio de Cristal, the oldest urban park in Porto

The park has been significantly altered over time but it is still one of the most important green areas in the city, especially by being relatively close to the centre. Additionally, the new urbanization models unintentionally altered the urban green structure. By designating new buildings to be developed in large and open blocks, it allowed the vegetation to be present in greater proportions.

In 1895, the *Circunvalação* (external ring road) was opened and more parishes were incorporated into the city. The road defines the current limits of the city. In the peripheral areas, the industrial progress coexisted with the rural areas. The outskirts

of the city were still dominated by agricultural activities. However, the economic growth of the nineteenth century demanded the use of peripheral spaces to construct railways and new industrial units, destroying many of the agricultural fields. To accommodate factory workers, new neighbourhoods were constructed, connected to the industrial units.

1900 AD to Present

In the twentieth century, the city limits began to 'dilute', as some important institutions were no longer centralized in Porto but transferred to adjoining municipalities (e.g., the commercial port)—the region showed signs of becoming a metropolitan area. The transportation network developed, especially the urban and suburban road infrastructure, which facilitated communications and exchanges between the municipalities. The peripheral cities gained new large infrastructure for trade and industry and the generalized use of the motor vehicles after the 1960s promoted an exodus from Porto to the contiguous municipalities, where the population began to settle.

Until the end of the twentieth century, the urban growth of Porto was mostly unplanned and depended on chance, individual choice and real estate speculation. This caused high levels of urban dispersion throughout the territory, which raised urbanization costs. Until the end of the nineteenth century, urban planning acted mainly on the construction of individual streets and public landscaping procedures. From the 1930s to the 1950s, there were a few attempts on urban planning but the results were never implemented. In 1962, Robert Auzelle synthesised the previous plans and presented the first *Plano Director da Cidade do Porto* (Master Plan for the City of Porto). The plan, which was reviewed in 1978, was the first to be applied effectively, although some of its directives were only implemented a generation later, as occurred with *Via de Cintura Interna* (Internal Ringway of Porto) and *Parque da Cidade* (the City Park, Fig. 7).

Auzelle's plan was the first to show any concern about environmental conservation and heritage preservation, proposing renovation instead of demolition. The struggle to implement urban planning shows a city that has always favoured private initiatives. Speculation still continues to alienate people from the city, hence promoting urban deterioration and the population decline is seen over the last 30 years (Fig. 5). The metropolitan area of Porto was created in 1991 (although planned since 1936); however, the metropolitan area concept has been reviewed and updated in recent years; the metropolitan area of Porto adopting its present position in 2008.

At the beginning of the twentieth century, green, vegetated areas occupied about 75 % of the city. However, throughout the twentieth century, the urban green structure has been reduced to less than half. The urban population increase (Fig. 5) caused a higher demand for construction and consequently more and more land became occupied by buildings. Urbanization has reached the administrative boundaries of the municipality, the peripheral rural ring was massively fragmented and most of the

Fig. 7 Parque da Cidade, one of the most recent green areas in Porto, is considered to be the largest urban park in Portugal. (Photograph by Isabel Leal)

cultivated fields were abandoned, converted to *Eucalyptus* or *Pinus* monocultures, or devoted to intensive cereal production. Some larger green areas were preserved and included in the green structure. Most of the recreational farms were acquired by private or public institutions and transformed into public or semi-public parks or gardens (e.g., *Parque de Serralves* and *Quinta da Bonjóia*). Some forest patches were also integrated into the new and modern public parks created in the last half of the twentieth century (e.g., *Parque da Cidade,* in Fig. 7, and *Parque da Pasteleira*).

Abiotic Environment of the City

Climate

According to the Köppen Climate Classification System, the city of Porto is included in the *Csb* category—dry and hot summers. The Porto region has a Mediterranean climate but it is influenced by the Atlantic Ocean, which causes a decrease in the annual temperature amplitude (usually around 10 °). The average lowest temperature is 8.7 ° in January; July is the hottest month with an average of 19.7 °. Average precipitation always exceeds 1200 mm/year but the annual precipitation pattern can vary immensely (lowest record was around 600 mm/year in 1953; the highest was 2000 mm/year in 1960). The heaviest rain periods are concentrated in the autumn and winter months. Precipitation occurs for 150 days/year. Besides rain,

the climate is characterized by the common occurrence of fog (120 days/year, on average), triggered by the proximity to the ocean and the river.

Geology and Geomorphology

The geomorphological evolution of Porto was especially influenced by two major agents, hydrodynamics (particularly the Douro River and the Atlantic Ocean) and tectonics. The lithological substrate comprises mainly granite and schist from the Palaeozoic and also some Quaternary deposits caused by the fluvial–oceanic dynamics. The granitic rock (early Herzinian) occupies most of the urban territory. In the western part of the city, and to a lesser extent also in the east, the dominant substrate is a schist–greywacke complex from the early Ordovician. The oldest rocks, thought to be Precambrian, are located on the western limits, bordering the ocean.

The platform where the city is based is composed of successive terraces leading down to the Atlantic Ocean. The western part of Porto lies between 0 and 100 m above sea level (a.s.l.), whereas the eastern section lies mostly between 100 and 160 m a.s.l (with the exception of the Tinto River valley which is highly eroded and at a lower altitude). The last glaciation caused the sea level to drop 100–120 metres below its current level, which led to the regression of the coast line by almost 40 km. This event influenced the shape of the mouth of the Douro River, by producing a deep thalweg and consequently very steep margins. In fact, most of the city has shallow slopes (0–10°), except for the steep (>30°) rocky cliffs adjacent to the Douro River. The geomorphology of Porto is undoubtedly shaped by the watersheds. The city is dominated by the Douro watershed, most of the streams flow into the Douro River while others flow into the Leça River (to the north) and also to the Atlantic Ocean. Nowadays, the majority of the watercourses are culverted for most of their lengths, which alters their hydrological and ecological dynamics. Furthermore, the main watercourses in the Douro watershed are heavily polluted—they show increased levels of nutrients and faecal matter.

Air Quality

Regarding air quality, the metropolitan area of Porto is considered to be one of the most polluted regions in Portugal. In the last decade, excessive concentrations of pollutants have been recorded in the area, especially nitrogen dioxides, sulphur dioxides, ozone and particulate matter (Monteiro et al. 2007). The main source of atmospheric pollution in the city is road traffic, especially due to commuter movements along the various highways that enter and cross the urban perimeter. Besides traffic pollution, the adjoining municipalities contain several sources that also contribute to the high levels of pollutants present in the city: an oil refinery, a petrochemical plant, a thermo-electric power station, an incineration unit and an international shipping port.

Table 1 Fish species recorded in Porto

Order	Scientific name	Common English name
Anguilliformes	*Anguilla anguilla*	European eel
Atheriniformes	*Atherina presbyter*	Sand smelt
Cypriniformes	*Squalius carolitertii*	Northern Iberian chub
Mugiliformes	*Chelon labrosus*	Thick-lipped grey mullet
Mugiliformes	*Mullus barbatus*	Red mullet
Mugiliformes	*Mullus surmuletus*	Surmullet
Mugiliformes	*Liza aurata*	Golden grey mullet
Mugiliformes	*Liza ramada*	Thin-lipped grey mullet
Mugiliformes	*Mugil cephalus*	Flathead mullet
Perciformes	*Dicentrarchus labrax*	European seabass
Perciformes	*Diplodus sargus*	White seabream
Perciformes	*Echiichthys vipera*	Lesser weever
Perciformes	*Gobius niger*	Black goby
Perciformes	*Labrus bergylta*	Ballan wrasse
Perciformes	*Pomatoschistus microps*	Common goby
Perciformes	*Pomatoschistus minutus*	Sand goby
Perciformes	*Trachurus trachurus*	Atlantic horse mackerel
Pleuronectiformes	*Solea senegalensis*	Senegalese sole
Pleuronectiformes	*Solea solea*	Common sole
Pleuronectiformes	*Platichthys flesus*	European flounder
Scorpaeniformes	*Chelidonichthys lucernus*	Tub gurnard
Syngnathiformes	*Sygnathus acus*	Greater pipefish
Syngnathiformes	*Syngnathus typhle*	Broad-nosed pipefish
Total 23		

Fauna

Fish

Twenty-three fish species have been recorded in Porto, see Table 1; only six occur in freshwater habitats (either resident or catadromous species), which represents only 10% of the species that occur within Portugal.

Anguilla anguilla (European eel) is a benthic species found in most European rivers where it lives during most part of its life cycle, before migrating to oceanic waters to spawn (in the central and western Atlantic). It is classified as 'Critically Endangered' on a global level ('Endangered' in Portugal) due to a sharp decline in its population, caused mainly by over-fishing, parasites, pollution and barriers to migration (hydroelectric dams).

Atherina presbyter (sand smelt) is a pelagic species that is found in coastal areas and estuaries in the eastern Atlantic (from the British Isles to the Canary Islands, Mauritania and Cape Verde) and the western Mediterranean. *Squalius carolitertii* (Northern Iberian chub) is a freshwater species that is endemic to the Iberian Peninsula, where it occurs in major river basins.

The most abundant fish species in the city belong to the Order Mugiliformes (mullets). There are six species. *Chelon labrosus* (thick-lipped grey mullet) occurs in shallow coastal areas and estuaries and it is distributed in the Mediterranean and eastern Atlantic, from Scandinavia to Cape Verde. *Mullus barbatus* (red mullet) is a marine species that dwells on gravel, sand and mud bottoms of the continental shelf; it is found in the eastern Atlantic (from the British Isles to Senegal), in the Mediterranean and in the Black Sea. *Mullus surmuletus* (surmullet) has a similar distribution to *M. barbatus* and can be found on rough or soft substrates at low depths in coastal areas. *Liza aurata* (golden grey mullet) is a neritic marine species which occurs in brackish waters in estuaries and lagoons. It is present in the eastern Atlantic (Scotland to Cape Verde), in the Mediterranean and the Black Sea. *Liza ramada* (thin-lipped grey mullet) is a coastal species occurring in shallow waters in the eastern Atlantic (Norway to Morocco), the Mediterranean and the Black Sea. *Mugil cephalus* (flathead mullet) is a widespread species, being present in tropical, subtropical and warm temperate regions. It is a pelagic species occurring near shores, occasionally foraging in lagoons, estuaries and lower reaches of rivers.

Order Perciformes has the highest species diversity in the city, although their abundance does not exceed that of the Mugiliformes. *Dicentrarchus labrax* (European seabass) is present in the northeastern Atlantic and the Mediterranean and the Black Seas, where it inhabits coastal areas, lagoons and estuaries. *Diplodus sargus* (White seabream) occurs in rocky coastal areas of the eastern Atlantic, the Mediterranean and the Black Sea. *Echiichthys vipera* (lesser weaver) is a coastal benthic species that is found along the European shores of the Atlantic and the Mediterranean. *Gobius niger* (black goby) is distributed over estuaries, lagoons and inshore waters around the eastern Atlantic, Mediterranean and Black Sea. *Labrus bergylta* (ballan wrasse) is a coastal species that occurs in rocky areas, reefs and seaweeds; it is present along the Atlantic shores of Europe. *Pomatoschistus microps* (common goby) prefers inshore habitats of the eastern Atlantic and western Mediterranean. *Pomatoschistus minutus* (sand goby) occurs in inshore areas and in estuaries along the shores of the eastern Atlantic, the Mediterranean and the Black Sea. *Trachurus trachurus* (Atlantic horse mackerel) is a pelagic-neritic species that is present in sandy coastal areas in the eastern Atlantic, from Norway to South Africa and in the Mediterranean.

Solea senegalensis (Senegalese sole) inhabits mainly marine areas with sand or sand-mud bottoms; it is present in the eastern Atlantic, from the Gulf of Biscay to the coasts of Senegal. *Solea solea* (common sole) can be found in the eastern Atlantic and the Mediterranean in sandy and muddy substrates in coastal areas; juveniles are usually found in estuaries. *Platichthys flesus* (European flounder) is native to the northeastern Atlantic and the Mediterranean—it is a migratory species (spawning takes place in the ocean, and larvae and early juveniles migrate along rivers, upstream), but the species spends most of its life cycle in the shallow waters of estuaries that have sand or mud substrates.

Chelidonichthys lucernus (tub gurnard) occurs in sand, mud or gravel bottoms in the eastern Atlantic and the Mediterranean and Black Seas. *Syngnathus acus* (greater pipefish) is found in coastal and estuarine waters along the shore of the eastern

Table 2 Amphibian species recorded in Porto

Order	Scientific name	Common English name
Anura	*Alytes obstetricans*	Common midwife toad
Anura	*Discoglossus galganoi*	West Iberian painted frog
Anura	*Pelophylax perezi*	Perez's frog
Caudata	*Salamandra salamandra*	Fire salamander
Caudata	*Lissotriton boscai*	Bosca's newt
Caudata	*Lissotriton helveticus*	Palmate newt
Caudata	*Triturus marmoratus*	Marbled newt
Total 7		

Atlantic Ocean, from Norway to South Africa, Western Indian Ocean, and Mediterranean and Black Seas**.** *Syngnathus typhle* (broad-nosed pipefish) is present around the European Atlantic and the Mediterranean and Black Seas, where it is usually found along the coasts and estuaries.

Amphibians

Seven species of amphibians have been recorded within the city boundaries of Porto (three anurans and four caudates; Table 2), which corresponds to more than 40 % of the Portuguese amphibian diversity.

The Anura is represented by two Alytidae: *Alytes obstetricans* (common midwife toad) and *Discoglossus galganoi* (West Iberian painted frog) and one Ranidae: *Pelophylax perezi* (Perez's frog).

A. obstetricans is a western European species that occurs in the northern half of Portugal. It is associated with a large variety of habitats, as long as they are linked to permanent water bodies. The climbing ability of the adult toads and the ability of males to carry eggs allow this species to use artificial water bodies. *D. galganoi* is endemic to the Iberian Peninsula, where it prefers the granite and schist regions. It needs small temporary water bodies for reproduction, such as puddles and small ponds, waterlogged grasslands and shallow creeks. *P. perezi* has a southwestern European distribution and is a highly resilient species even under regimes of eutrophication, pollution, salinity or high thermal amplitudes; it can occur in every kind of aquatic environment, regardless of the surrounding conditions.

From the Order Caudata, there are four Salamandridae species: one salamander and three newts. *Salamandra salamandra* (fire salamander) is common throughout central and western Europe. The species requires damp and shaded environments, which it can find in deciduous forests and other areas with plentiful tree cover, near clear running waters. *Lissotriton boscai* (Bosca's newt) is found only in the Iberian Peninsula, in a multitude of habitat types, from woods to grasslands, close to still water such as ponds, wells and tanks. In western Europe, *Lissotriton helveticus* (palmate newt) occurs in many habitat types close to still water bodies. In Portugal, it is much more restricted than *L. boscai,* occupying only a narrow coastal strip in

Table 3 Reptile species recorded in Porto

Group	Scientific name	Common English name
Sauria	*Timon lepidus*	Ocellated lizard
Sauria	*Podarcis bocagei*	Bocage's wall lizard
Sauria	*Podarcis hispanica*	Iberian wall lizard
Sauria	*Tarentola mauritanica*	Moorish gecko
Sauria	*Anguis fragilis*	Slow worm
Amphisbaenia	*Blanus cinereus*	Blind snake
Serpentes	*Hemorrhois hippocrepis*	Horseshoe whip snake
Total 7		

the northern region, where the influence of the oceanic climate is stronger (high levels of precipitation). *Triturus marmoratus* (marbled newt) is distributed in Portugal, Spain and France, where it lives in the proximity of still water bodies, which it needs for successful reproduction.

At the international level, none of the species is considered to be threatened. In Portugal, *Discoglossus galganoi* is considered to be 'Near Threatened' mainly due to habitat loss and fragmentation and *T. helveticus* has 'Vulnerable' status since its distribution is rather restricted and fragmented.

Reptiles

Regarding reptile diversity, seven species have been recorded in Porto (more than 20 % of Portuguese reptile species), see Table 3.

The Lacertidae is the most represented Family of reptiles in Porto, with three species present in the city. *Timon lepidus* (ocellated lizard) is present in the Iberian Peninsula, southern France and northern Italy. It is the biggest lizard in Portugal, where it occurs in dry and open habitats with abundant refuge sites. *Podarcis bocagei* (Bocage's wall lizard) which is endemic to the Iberian Peninsula is associated with wet climatic regions, influenced by the Atlantic. It typically occurs in deciduous woodland, scrub and agricultural land, where it can find shelter in crevices in walls and rocks or under vegetation. '*Podarcis hispanica*' (Iberian wall lizard), which is distributed throughout the Iberian Peninsula and adjacent southeastern France, is now considered a 'species complex'. In Portugal, there seems to be two distinct morphological types, the individuals found in Porto match *P. hispanica* morphotype 1. *P. hispanica* inhabits open habitats associated with rocky surfaces where it displays better climbing abilities than *P. bocagei*. Nevertheless, contrary to natural environments in northern Portugal, both species have never been found in strict syntopy within the city.

The only representative of the Phyllodactylydae Family in Portugal, *Tarentola mauritanica* (Moorish gecko), has recently been recorded in Porto. Although widespread across the western Mediterranean and in Portugal, this gecko specialises in vertical surfaces becoming more associated with buildings in the humid, northernmost limits of its range.

Table 4 Small mammal species recorded in Porto

Order	Scientific name	Common English name
Chiroptera	*Eptesicus serotinus*	Serotine bat
Chiroptera	*Myotis daubentonii*	Daubenton's bat
Chiroptera	*Pipistrellus pipistrellus*	Common pipistrelle
Lagomorpha	*Oryctolagus cuniculus*	European rabbit
Rodentia	*Apodemus sylvaticus*	Wood mouse
Rodentia	*Mus musculus*	House mouse
Rodentia	*Mus spretus*	Western mediterranean Mouse
Rodentia	*Rattus norvegicus*	Brown rat
Eulipotyphla (Insectivora)	*Crocidura russula*	Greater white-toothed shrew
Eulipotyphla (Insectivora)	*Erinaceus europaeus*	Western European hedgehog
Eulipotyphla (Insectivora)	*Talpa occidentalis*	Iberian mole
Total 11		

In Portugal, there is only one species from the Anguidae Family—*Anguis fragilis* (slow worm) is a Eurasian species that can be found in Porto. This semi-fossorial species prefers areas with a more humid and colder climate, in deciduous woodlands with high herbaceous cover.

Being one of the two representatives of the Amphisbaenians of the Blanidae Family, *Blanus cinereus* (blind snake) is a fossorial reptile that resembles an earthworm and is usually found in soils with well-developed Mediterranean vegetation. Porto is at the northern limit of its range.

Hemorrhois hippocrepis (horseshoe whip snake) is the only member of the Colubridae Family that has been recorded in the city. It is a species from the western Mediterranean Basin that exists in a variety of open and arid habitats, such as scrub. It also reaches the limit of its distribution in Porto.

All of the reptile species that occur in the city have the conservation status 'Of Least Concern'.

In addition to the inventory of native species, mention should be made of the presence of the non-native *Trachemys scripta elegans* (red-eared slider turtle), a species that has become or is becoming invasive in many areas of the world including the Iberian Peninsula; it has been reported from some park and garden ponds in Porto, e.g., *Serralves* and *Parque da Cidade*. Future monitoring should determine if this species and other alien freshwater turtles are successfully breeding in the city and consequently have become naturalized.

Small Mammals

Eleven species of small mammals occur in Porto (Table 4): three bats (27 in Portugal) one Lagomorph species (2 in Portugal); four rodent species (14 in Portugal) and three insectivores (9 in Portugal).

Three Vespertilionidae bat species have been recorded within the limits of the city (H. Rebelo 2013, *pers. comm.*). *Eptesicus serotinus* (serotin bat) is widespread

through Europe where it occurs in a wide range of habitats, such as woodland, scrub, farmland and urban areas. *Myotis daubentonii* (Daubenton's bat) has a European and Asian distribution and it is highly dependent on water bodies. It feeds exclusively on aquatic insects in woodland or scrub habitats. *Pipistrellus pipistrellus* (common pipistrelle) is one of the most common and abundant species in Europe. It forages in woodland, scrub, farmland and urban areas.

Oryctolagus cuniculus (European rabbit) is native to the western Mediterranean region, but it is currently present in large part of western and central Europe as an introduced species. It prefers typical Mediterranean habitats, whether woodland or scrub, being in suboptimal conditions in Porto. The species is native in the Iberian Peninsula and introduced elsewhere.

All of the four rodent species are from the Muridae Family. *Apodemus sylvaticus* (wood mouse) is an adaptable species found in woodland, scrub, farmland, dunes and gardens, across Europe. *Mus musculus* (house mouse) has a global distribution and is highly associated with human settlements, preferring urban habitats in residential, industrial or commercial areas. The species can also be found in rural areas but always in the vicinity of farm buildings**,** being replaced by other mouse species in more natural habitats. *Mus spretus* (Western Mediterranean mouse) on the other hand, tends to avoid human habitation, being found in arable land and open woodland, around the western Mediterranean Basin. *Rattus norvegicus* (brown rat), an introduced species from the Far East, is nowadays common throughout Europe. It is very abundant in man-made habitats (warehouses, sewers, refuse tips), especially close to water.

The insectivores are represented by three families: Soricidae (shrews), Erinaceidae (hedgehogs) and Talpidae (moles). *Crocidura russula* (greater white-toothed shrew) is a western European species that inhabits grasslands, woodland fringes and gardens and is able to occupy Eucalyptus plantations. *Erinaceus europeus* (Western European hedgehog) is present throughout Europe; it occurs in a wide range of habitats from woodland to grassland, although it seems to prefer man-made habitats such as orchards, vineyards, farmland, parks and gardens, including those in urban areas. *Talpa occidentalis* (Iberian mole) is found only in Portugal and Spain. It is a burrowing species that is found in grassland, woodland and arable land where the soil has a good structure and composition.

Of the small mammal species present in Porto, only *Oryctolagus cuniculus* has an unfavourable conservation status—it is considered to be 'Near Threatened' (both in Portugal and globally), mainly due to the decreasing population trends caused by *Myxomatosis* (caused by the Myxoma virus) and rabbit haemorrhagic disease (caused by the rabbit Calicivirus).

Large Mammals

The records of the presence of large or medium-sized mammals have been rather scarce in recent years. Their requirement for large areas in which to live makes it difficult for them to find adequate conditions to survive in the small and fragmented

Table 5 Large mammal species recorded in Porto

Order	Scientific name	Common English name
Carnivora	*Vulpes vulpes*	Red fox
Carnivora	*Lutra lutra*	Eurasian otter
Total 2		

habitat patches of Porto. However, there are records of sporadic sightings of two species (Table 5): *Vulpes vulpes* (red fox) and *Lutra lutra* (Eurasian otter; P. Santos 2013, *pers. comm*)—which accounts for about 15% of the Carnivore species that occur in Portugal.

Vulpes vulpes from the Canidae Family is widely distributed across the Northern Hemisphere. It is a highly resilient species, found in a large variety of habitats from woodland and scrub to highly urbanized areas. Representing the Mustelidae, *Lutra lutra* is widespread throughout Europe and parts of Asia. The species, which is dependent on aquatic environments, occurs in a variety of habitats from mountain streams to brackish waters. *L. lutra,* although not threatened in Portugal, is considered to be 'Near Threatened' on an international level.

Vertebrate Fauna of Different Habitats

Natural and Semi-natural Habitats

River Banks and Cliffs The Douro River has eroded through the granitic plateau on which the city is built resulting in some sections of the river being contained within steep, exposed rock faces that are free or relatively free of human pressure and disturbance and form a unique habitat within the city. The steep banks shelter mainly rupicolous species, such as *Podarcis hispanica* that seems to have an advantage over *Podarcis bocagei* in these areas. In fact, *P. hispanica* was only found in close proximity to these particular habitats, within the city limits. In addition, the sandy, shallow margins are associated with the occurrence of *Rattus norvegicus,* maybe due to the fact that some of the streams that flow into the river were used for wastewater discharge in the past. Occasionally, there are also sightings of *Lutra lutra* incursions in the municipality along the river banks.

Forest Remnants Some patches of woody vegetation can be found in the city, which helps to explain the past distribution of woodland habitats (old woods of *Pinus* or *Quercus* and more recently *Eucalyptus* plantations). Some of these patches have been incorporated into the larger urban parks (e.g., *Parque da Cidade* and *Parque da Pasteleira*) and other public green spaces. A variety of vertebrate species are found in these habitats, with larger incidence of amphibians and small mammals when the appropriate conditions occur. The species include *Lissotriton helveticus, L. boscai* and *Salamandra salamandra,* representing the amphibians; the reptile species, *Hemorrhois hippocrepis* and the small mammals *Apodemus sylvaticus,*

Fig. 8 View of the city centre, densely built and with sparse greenery; Torre dos Clérigos in the background. (Photograph by Isabel Leal)

Mus spretus and *Crocidura russula*. In the past, the forest remnants sheltered a few *Vulpes vulpes,* but with the increasing habitat destruction and fragmentation, the presence of this species has not been recorded recently. We cannot, however, rule out the possibility of sporadic movements of some individuals from more suitable habitats in neighbouring municipalities, where it is seen more often.

Urban Habitats

Settlement Areas

City centre The city centre, as described City centre previously, is densely developed (Fig. 8); the green areas are sparse and of small size. Most vertebrate species find it difficult to thrive in these harsh conditions, with the exception of some commensal small mammal species, particularly *Mus musculus*. This species can satisfy all of its requirements in the area, as its food sources and shelter preferences are abundant in the older parts of the city. *Rattus norvegicus* can also be found in the city centre, especially in the areas that are contiguous with the river.

High-Density Housing Areas High-density housing extends from the city centre to the inner suburbs, where it is progressively replaced by low-density housing. In the inner areas, the dominant buildings are block and ribbon developments, with, traditionally, small yards or patios at the back of the properties. In the outer areas, more

multi-storey buildings start to appear usually surrounded by narrow strips of green space. These typologies of green space are thus highly fragmented and dispersed, and in some cases, biologically impoverished to such an extent that most vertebrate species are unable survive in them. Yet again, *Mus musculus* seems to be the most successful species in these areas. *Podarcis hispanica* also occurs on walls and roofs in the older buildings.

Low-Density Housing Areas In the low-density housing areas, found mainly in the inner suburbs, privately owned green spaces become larger due to the lower proportion of built surfaces. In addition, the extensive areas of green space, including parks and gardens, are more apparent. For these reasons, habitat availability and quality are much higher when compared with the inner areas of the city and several species become more frequent. In addition to the common *Mus musculus,* which is found throughout the city, the small mammals include *Mus spretus* and *Crocidura russula. Pipistrellus pipistrellus* is also found in these areas when there is a high tree cover. Small lizards, like *Podarcis hispanica* and *P. bocagei,* occur. The resilient *Pelophylax perezi* persists in suitable habitats while other amphibians such as *Salamandra salamandra, Triturus marmoratus, Lissotriton boscai* and *Alytes obstetricans* are present in small niches but to a far lesser extent.

Industrial Areas Large industrial areas, positioned near the periphery, tend to be poorly and simply vegetated or even completely deprived of vegetation. Despite this, some of these areas are in close proximity to more natural or semi-natural habitats; the species that thrive in these areas are usually commensal species, e.g., *Mus musculus* and *Rattus norvegicus*. Nevertheless, *Podarcis bocagei* also seems to succeed by occupying debris and ruderal vegetation.

Transport Routes and Areas Within the city, only roads and railways and associated areas fall into this category, since the harbour and the airport are situated in adjacent municipalities. Although there is no official information about the species that may occur in these areas in Porto, they are deemed as highly artificial habitats, with no suitable conditions for the survival of most species, except for *Mus musculus* and *Rattus norvegicus*. There may be a few exceptions: Some roads or railways are surrounded by vegetated slopes, frequently comprising canopy, shrub and field layers that are connected to nearby habitats to a limited extent. Additionally, the gravel associated with railway lines provides excellent micro-habitats and corridors for small lizards, such as *Podarcis bocagei*. On the other hand, most roads are 'challenging' barriers for terrestrial species, preventing or restricting dispersal and fragmenting the pre-existing habitats.

Recreation Areas

Parks Urban parks are designed 'undeveloped' spaces, dominated by vegetation and created for public use. The human influence on biodiversity is extremely relevant in these spaces—the various options of spatial planning and design, maintenance

operations and the added pressure due to human use for recreation, influence the local fauna and flora. The larger parks are located mainly in the peripheral parts of the city; they are almost completely absent from the centre.

When it comes to urban biodiversity, urban parks are the most investigated areas in Porto. They have been shown to be ecologically significant by harbouring a high number of species. The small mammals, *Crocidura russula, Mus spretus, Erinaceus europaeus* and *Talpa occidentalis* occur in the parks as do all three of the bat species that are known to occur in the city, namely *Pipistrellus pipistrellus, Eptesicus serotinus* and *Myotis daubentonii*. These days, *Oryctolagus cuniculus* is abundant in the largest of the urban parks, following recent re-introduction campaigns. The reptiles *Podarcis bocagei, P. hispanica, Timon lepidus, Anguis fragilis* and *Hemorrhois hippocrepis* are also present. Amphibian species, which are so sensitive to urbanization, seem to prosper in these areas, mainly due to the prevalence of open water bodies that are rarely found within the urban matrix, e.g., *Salamandra salamandra, Triturus marmoratus, Lissotriton boscai, L. helveticus, Pelophylax perezi, Discoglossus galganoi* and *Alytes obstetricans* have been found in urban parks. In fact, for urban amphibians in this area, the availability of water and suitable habitats appears to be more limiting than fragmentation and patch size.

Allotments Currently, small areas of allotments, which are managed by individuals or families, are restricted to the urban periphery. Most of the old farms have been converted into public gardens, and some still maintain part of the fruit and vegetable plots for educational purposes (e.g., *Parque de Serralves* and *Quinta do Covelo*). These habitat types support small mammals, especially *Mus spretus* and *Crocidura russula*. Amphibians, such as *Triturus marmoratus, Salamandra salamandra, Alytes obstetricans* and *Discoglossus galganoi* are attracted by the abundance of freshwater and humidity. The reptiles *Anguis fragilis* and *Hemorrhois hippocrepis* are also present in these areas.

Sports Fields Sport fields and other intensively managed recreational areas are extremely simplified ecosystems, especially regarding vegetation diversity. Therefore, these areas cannot accommodate a wide range of vertebrate species.

Open Land

Waste Grounds Waste grounds and vacant lots represent almost 20 % of the urban green structure of Porto. This kind of green space may originate from several urbanization processes: areas set aside for designed green spaces are not yet implemented, lots awaiting building construction, and abandoned agricultural and industrial areas. This condition of temporarily undefined land use, allows the spontaneous colonization of pioneer vegetation that usually occupies all of the available space and the initial phases of ecological succession. These processes create complex habitat structures in between the urban matrix, which can make these areas rich in

biodiversity. However, the vertebrates of waste grounds have not been thoroughly surveyed and analysed, consequently, there are only records of *Crocidura russula, Podarcis bocagei, Anguis fragilis* and *Hemorrhois hippocrepis* occurring in these areas. The low species-richness, compared to the expected, can be the result of unfavourable disturbance dynamics and exotic species dominating the vegetation communities.

Water

Running Water The Porto environment is strongly influenced by the presence of the Douro River and all of the watercourses that cross through the urban perimeter. However, the vast majority of the watercourses do not offer adequate habitat conditions for the survivability of most vertebrate species (aquatic or terrestrial). In addition to the culverted watercourses, the water contains high levels of sewage contamination. The Douro estuary is no exception, although having reasonable oxygen levels, it is highly eutrophic and heavily polluted, consequently the diversity of the fish species is low.

All of the 23 fish species records in the city of Porto are derived from the Douro estuary. Regarding the estuarine fish community, it should be noted that it includes mostly marine species that can use these habitats at different life stages, depending on the species. Some species enter the estuary as larvae (e.g., *Platichtys flesus*) or at juvenile stage (e.g., *Liza aurata, Chelon labrosus* and *Mugil cephalus*), while others use the estuary only during their juvenile development or enter the estuary only occasionally (e.g., *Diplodus sargus* and *Mullus barbatus*). Additionally, there are also a few resident species that breed in the brackish waters of the estuary and spend most of their life cycle in a close range, such as *Pomatoschistus microps, Atherina presbyter* and *Syngnathus typhle*. The estuary is used both as a spawning and nursery area, even though it does not provide optimal conditions for the early stages in the life-cycle of individuals because of the hydro-dynamics of the river and the highly urbanized profile of the river mouth, which lacks aquatic vegetation and therefore breeding and feeding grounds and cover.

The most abundant fish species are, without a doubt, the Mugiliformes, especially *Liza* spp. This group is characterized by omnivorous and detritivorous species that are highly resistant to organic and even chemical pollution, which make them favoured by the current environmental conditions in the river.

Still Water (Ponds, Reservoirs) There are not many natural still water elements in the city, the largest exception being the *Salgueiros Pond,* located in a vacant lot in the northern part of the city. Most still water bodies are man-made and occur mostly in parks and gardens. These features, usually in the shape of ponds, can be more or less naturalized and seem to attract certain vertebrate species, especially amphibians such as *Triturus marmoratus, Lissotriton boscai, L. helveticus* and *Discoglossus galganoi*.

Comments and Discussion

The study of urban biodiversity is still a neglected subject in Portugal, being ignored and undervalued by most researchers and conservationists and the Government. Only recently have a few ecologists been taking small steps to open the issues to academic and public discussion. Portugal, being connected to the 'Mediterranean Basin biodiversity hotspot', has a high potential for harbouring important levels of urban biodiversity. Additionally, the city of Porto is located in the transition zone between typical Mediterranean and Atlantic climates, where species associated with both regions can occur.

In the last few years, the biggest Portuguese cities and metropolitan areas have been under the spotlight of some multi-disciplinary research teams, including nature conservationists and urban planners. Porto urban biodiversity has only just begun to be included in ecological research, mainly in relation to terrestrial vertebrates. A lot remains to be studied, analysed and understood.

The urban green structure of Porto, which provides the main habitat resources for vertebrate species, is highly altered and fragmented. While some urban planning concerns arose in the nineteenth century, most of the urban growth occurred without any official development strategy. This is particularly reflected in the present form of the urban green space, which is characterized by small spaces or spaces with structurally simplified habitats with low connectivity. It is crucial to integrate conservation actions in the urban management processes at local and regional levels.

Parks and gardens seem to have an augmented relevance in the urban green structure of Porto. With the modification of most natural habitats and the increasing habitat destruction and fragmentation caused by the ever expanding urbanization processes, these green areas act as refuges for many vertebrate species, even when the connectivity seems to be quite low. Here, they can find larger areas of suitable habitats with a diverse vegetation structure and species composition that provides good food, shelter and breeding conditions.

On the other hand, the river systems are in need of urgent management to improve the quality of the water. As opposed to what should be expected, the watercourses are not currently helping to improve urban biodiversity levels because they are virtually devoid of life. A long-term conservation plan should be considered in order to promote de-contamination operations, opening of culverted watercourses (where possible) and the re-construction of riparian galleries (which could also function as corridors and improve habitat connectivity on a city-scale). Recently, similar watercourse restoration measures were undertaken in nearby municipalities, with promising results—vertebrate species responded positively and rapidly colonized the previously impoverished streams and water bodies.

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