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Expansion in the selection of breeding sites by the European Roller (*Coracias garrulus*) in the Caserta area

Danila Mastronardi*, Bruno Dovere, Giuseppe Pesapane, Sergio Tanga, Elio Esse

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***Correspondence:** danila.mastronardi@gmail.com; https://orcid.org/0000-0003-4954-0588

Affiliation: Associazione Studi Ornitologici Italia Meridionale odv, Via Cavalli di Bronzo, 95 – 80046 S. Giorgio a Cremano

Running Title: Nesting from ruins to nest boxes and pylons

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Abstract

The Caserta population (Campania-Southern Italy) of the European Roller *Coracias garrulus* has been monitored since 2012, remaining relatively stable in numbers. From that year until 2023, it chose the ruins of the Opera Nazionale Combattenti (ONC) as breeding sites, highlighting the need to often change the breeding site due to mainly anthropogenic pressures. In 2021, in collaboration with TERNA S.p.a., 30 wooden nest boxes were installed, which were ignored by the species until 2023. In 2024, two of them were occupied, and in the same year, two pairs chose a breeding site different from the ONC ruins, occupying cavities in the electric pylons, and one inspected a third concrete nest box installed by the authors near one of the historically occupied ruins. This expansion in the choice of breeding sites raises hope for an increase in the Caserta population.

Key words: *Coracias garrulus*, South Italy, selection breeding site, nest-box.

Riassunto

La popolazione casertana (Campania-Sud Italia) di Ghiandaia marina *Coracias garrulus* viene monitorata dal 2012, mantenendosi piuttosto stabile numericamente. Da quell'anno fino al 2023 ha scelto come siti riproduttivi i ruderi dell'Opera Nazionale Combattenti (ONC), evidenziando la necessità di modificare spesso il sito riproduttivo a causa delle pressioni soprattutto antropiche. Nel 2021 sono state installate, in collaborazione con la società TERNA S.p.a., n. 30 cassette nido in legno che sono state ignorate dalla specie fino al 2023. Nel

2024 due di esse sono state occupate e, nello stesso anno, due coppie hanno scelto un sito riproduttivo diverso dai ruderi dell'ONC, occupando cavità nei tralicci elettrici e una ha ispezionato una terza cassetta nido in cemento installata dagli autori in prossimità di uno dei ruderi storicamente occupati. Questo ampliamento nella scelta dei siti riproduttivi fa sperare in un incremento numerico della popolazione casertana.

Parole chiave: *Coracias garrulus*, sud-Italia, selezione siti riproduttivi, cassette nido.

Introduction

The European Roller (*Coracias garrulus*) is a polytypic species with an Euro-Turanian-Mediterranean distribution, with two recognized subspecies: the nominal one, which occupies a vast area extending west from Morocco to central and southwestern Europe, and east from Asia Minor to Iran and southwestern Siberia; and the subspecies *C.g.semenowi*, which occupies a territory that includes Iraq, Kashmir, and up to western China (Keller *et al*. 2020). It primarily nests in plains or hilly areas, up to 600-700 meters above sea level. Its breeding habitat is characterized by mosaic-shaped vegetation, where it chooses old, abandoned ruins, electrical transformer boxes, artificial nest boxes, barns, and floodplain forests as breeding sites (Cramp 1985; Brichetti and Fracasso 2007). The breeding population in Italy is about 1000 pairs (Meschini 2015, 2022). The wintering range is in sub-Saharan Africa, from Senegal to Cameroon and from Ethiopia to South Africa (Del Hoyo *et al*. 2001). The species is SPEC 2, listed in Annex I of the Birds Directive, and considered 'endangered' in the national Red List (Gustin *et al.* 2019). In the regional Red List, it is classified as a species threatened with extinction (Fraissinet and Russo 2013). Nationally, it is considered to be increasing (Tokody *et al.* 2017), but the negative global trend and the importance of source populations require high attention to its conservation. In Campania region, it was not reported in the Atlas of Breeding Birds in Campania (Fraissinet and Kalby 1989), but was mentioned by Grimmett and Jones (1989) in the gorges of the Calore River in the province of Salerno, and by Scebba (1993), who reported its presence under highway viaducts in the Padula – Lagonegro (SA) section (Landolfo), and nesting in the 1960s along the Volturno River near Grazzanise, in the province of Caserta.

Currently, the European Roller is present during migratory transits and the breeding period, nesting mainly in the Caserta area and sporadically in the Salerno area (Mastronardi *et al*. 2015). The Caserta population, subject to systematic studies, has been estimated at about 18 pairs, including those with certain, probable, and possible nesting, and has remained fundamentally stable over the years (Mastronardi and Esse 2022).

Study Area

In the Caserta province, the occupied area lies within the alluvial plain of the Volturno and Garigliano rivers and currently does not enjoy any degree of protection. The area is mostly cultivated with crops that rotate between forage (especially for buffalo breeding), vegetables, and cereals. Cultivation is primarily traditional with the use of chemical products. The entire area is traversed by both irrigation and drainage canals, as well as tree-lined rows primarily of Eucalyptus trees (*Eucalyptus spp.*) and shrub rows mainly of Bramble (*Rubus ulmifolius*). A smaller area is dedicated to fruit trees. Throughout the investigation area, there are numerous abandoned ruins of the Opera Nazionale Combattenti (ONC). The area occupied by the species covers approximately 370 km² and extends from Falciano del

Massico in the north, Brezza of Grazzanise and San Tammaro in the east, Villa Literno in the south, and the Tyrrhenian coast in the west at a minimum distance from the latter of about 3 km. Isolated pairs at the margins of this area are not excluded.

Methods

The species has been systematically studied in Campania since 2012, following the adhesion of the Associazione Studi Ornitologici Italia Meridionale (ASOIM) to the national Coracias project (Meschini 2015), and investigations have continued uninterrupted to this day. Monitoring begins every year at the end of April and continues until the first decade of August. The entire reproductive range is surveyed, monitoring the pairs and collecting data on ecology and reproductive biology. In particular, the sites chosen for reproduction have been investigated and found to be, until the 2023 breeding season, 100% abandoned tuff ruins with a preference for those with at least part of the roof present. The species has occupied cavities at heights ranging from 4.5 to 6 meters, rarely lower (Mastronardi *et al.* 2014). A total of 96 ruins were checked; there is a high degree of turnover of occupied sites due to numerous abandonments (Mastronardi and Esse 2022). In 2021, thanks to cooperation with the electric company Terna S.p.A., 30 wooden nest boxes were mounted on high-voltage transmission towers, located in the most suitable sites. In the same year, a concrete nest box was built on a high pole next to a ruin occupied by the species in the municipality of Castel Volturno. The nest boxes were installed at heights of 6-7 meters and with SE or NE exposure. The nesting categories are referred to the following classification: possible reproduction (Ps) – sporadic observation of a pair during the breeding period with a suitable site nearby; probable (Pb) presence of the pair at the site throughout the breeding season – nest not identified; certain (C) active nest and/or presence of young of the year near the nest. For the numbering of the sites reported in tables 1 and 2, the same numbering used in the field was preferred, therefore the numbering of the sites does not follow the natural numerical order.

Results

Table 1 reports the known breeding sites of the species in the Caserta area over 13 years of monitoring (2012-2024) and some characteristics of the sites and cavities. Nest height, exposure, and cavity type data are reported only in cases where the nest was identified. The indicated year refers to the first occupation; multiple years are reported in case of different nest cavities in the same ruin were used in different years.

From the analysis of Table 1, it is evident that the breeding sites identified during the years of study are 22, of which 20 are certain nesting sites, one probable, and one possible. In two of these sites, different cavities were occupied in different years for a total of 24 occupied cavities. At site 4, successful nesting occurred in 2012 and 2013, while in 2014, in a different nest cavity, it remained only possible. In subsequent years, the pair was seen near the ruin, but nesting certainty was not achieved. The nest cavities with data on exposure and height are 17, including 12 ruins, 2 electrical poles, and 3 nest boxes.

The nest cavity height ranges between 3 and 6 meters, with 7 cases in the 3-4 meter range, 3 in the 4.1-5 meter range, and 7 cases in the 5.1-6 meter range.

Three nests were exposed to the NE, 3 to the SE, 2 to the NW, 4 to the SW, 3 to the W, 1 to the E, and one was not assessable because the entrance was located at the top, in the insulator of the electric pole.

Table 2 shows that only one site has experienced continuous nesting from 2012 to

Table 1. Occupied Sites. The data on nest height, exposure, and type of cavity are reported only in cases where it was possible to identify the nest. The year refers to the first occupation. Different years for the same site are reported if different cavities were occupied. C= certain nesting; Pb= probable nesting; Ps= possible nesting.

Breeding sites	Occupation year	Artefact	Nest height in meters	Nest exposure	Types of cavity	
Site 1	2012	Ruin	6	W	Piping hole	C
	2021	Ruin	3	SW	Hole in tuff bricks	C
Site 3	2012	Ruin	5	SW	Hole in tuff bricks	C
Site 4	2012	Ruin	6	SW	Hole in tuff bricks	C
Site 4	2014	Ruin	4,5	W	Hole in tuff bricks	Ps
Site 5	2013	Ruin	3,5	NW	Hole in tuff bricks	C
Site 6	2014	Ruin	/	/	/	C
Site 8	2014	Ruin	/	/	/	C
Site 9	2014	Ruin	6	NE	Hole in tuff bricks	C
Site 10	2014	Ruin	6	SW	Hole in tuff bricks	C
Site 14	2015	Ruin	3	SE	Hole in tuff bricks	C
Site 15	2015	Ruin	/	/	/	C
Site 19	2018	Ruin	/	/	/	C
Site 20	2018	Ruin	5	W	Lamp holder hole	C
Site 22	2019	Ruin	4	E	Hole in tuff bricks	C
Site 23	2020	Ruin	/	/	/	C
Site 26	2021	Ruin	/	/	/	C
Site 27	2021	Ruin	4	NW	Hole in tuff bricks	C
Site 29	2022	Ruin				Pb
Site 33	2024	Inactive electric pole	4	NE	Hole in tuff bricks	C
Site 34	2024	Medium voltage electric pole	6	Not valuable	Hole in insulator electric pole	C
Site 35	2024	Nest box	6	NE	Nest box n. 182	C
Site 36	2024	Nest box	6	SE	Nest-box n. 192	C
Site 37	2024	Concrete nest box	4	SE	Concrete nest box	Ps

the present, although it is not excluded that sites 6 and 15 were also occupied in 2017, the only year the pair was not found, but for entirely random reasons, the pairs were not seen that year. In other cases, the absence was confirmed by numerous visits to the nest, or abandonment was documented.

From the same table, it emerges that in 2024 there were 5 pairs that occupied sites different from the ruins, behavior not observed in previous years.

In 2024, specifically on June 10, a Roller was seen leaving nest box no. 179, mounted at 7 meters with NE orientation in the municipality of Castel Volturno, on the roof of which an Italian Sparrow male, *Passer italiae*, was calling. The Roller was still present on the roof of the nest box on June 17, while on June 24, it had moved to a box mounted on a transmission tower about a hundred meters away (nest box no. 182) and was seen several times until the end of the breeding season.

On the same day, a Roller was seen leaving the concrete box mounted near site 15. Subsequent checks did not confirm the occupancy of the nest box.

On June 30, 2024, a pair was seen repeatedly entering and leaving nest box no. 192, mounted at a height of 6 meters with SE orientation on a transmission tower in the

Table 2. site occupation over the years.

Breeding sites	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Site 1	x	x	x	x	x	x	x	x	x	x	x	x	x
Site 3	x	x	x	x									
Site 4	x	x	x		x			x		x			
Site 5		x	x	x	x								
Site 6			x	x	x		x	x	x	x	x	x	x
Site 8			x	x				x					
Site 9			x	x	x	x	x	x	x	x			
Site 10			x	x	x	x	x		x	x			
Site 14				x	x		x						
Site 15				x	x		x	x	x	x	x	x	x
Site 19							x	x					
Site 20					x	x	x	x	x	x	x	x	
Site 21					x			x	x	x		x	
Site 22									x		x		
Site 26										x			
Site 27										x		x	x
Site 29											x		
Site 33													x
Site 34													x
Site 35													x
Site 36													x
Site 37													x
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024

municipality of Cancello e Arnone, seen with food on July 4, and still in the area until the end of the breeding season.
In the same year, besides the nest boxes, holes in concrete electric poles were occupied. On June 20, 2024, the presence of a pair in a medium voltage pole a few kilometers from site 20 was confirmed. The individuals perched and used the structure at the level of the insulators. The pair was seen numerous times throughout the breeding season.
On the same day, the presence of another nesting pair in a light pole was confirmed; it was an inactive medium-voltage pole with holes in the concrete pole. In two holes at the same height but on different sides, an Italian Sparrow was seen entering one side, and a Roller with food on the other.
The light pole was located near a historic nesting ruin of the species (site 20), where competition with the Jackdaw is very strong. In this case too, the pair was seen several times during the breeding season, while site 20 in the ruin cavity was occupied by the Western Jackdaw.
It is very likely that the pair that used the hole in the disused electric pole was the same that previously occupied site 20. However, in the case of the pairs found in the nest boxes and on the active medium-voltage transmission tower, they were not pairs that moved from nearby ruins to these different structures, as the nearby ruins still hosted the species.

Discussion

The European Roller in Campania is subject to numerous pressures, mainly of anthropic origin (Mastronardi *et al*. 2022), which cause continuous movements from one site to another within the same year or in different years. A natural cause is competition with the Western jackdaw, which in various sites has prevented the reproduction of the European Roller by occupying the cavities early (Mastronardi *et al*. 2022). This behavior has also been observed in other regions of Italy (Muscianese *et al*. 2014; Ianiro & Norante 2020). Competition with the Western Jackdaw has been considered one of the main causes of species decline in Europe (https://ec.europa.eu/environment/nature/conservation/wildbirds/threatened/c/coracias_garrulus_en.htm) and has been cited by numerous national and international authors (Kiss *et al*, 2014; Marini *et al*. 2015).

Many are the anthropogenic pressures in a socially and economically depressed territory and have been analyzed in detail in the recent work by Mastronardi *et al*. (2022), to which reference is made. Regarding the type of breeding sites chosen by the species, it is interesting to note that, until 2023, the European Roller had exclusively occupied cavities in the tuff ruins of the ONC, ignoring the various opportunities that the territory offered, in particular the 30 nest-boxes installed in 2021. This work aims to highlight the fact that for 13 years the European Roller in the Caserta area had only occupied the tuff ruins, while in 2024, without apparent environmental modifications, as many as 5 pairs occupied (in one case it was only a possible nesting) different structures. The causes that have determined this different behaviour can be varied and difficult to investigate. It is hoped that further information will be obtained in the coming years of research. The occupation of artificial nest boxes is encouraging, with a probable increase in the Campania population that will need to be verified with future monitoring. This method is efficient in the conservation of secondary-nesters and may contribute to the increase of population size in threatened species (Avilés and Parejo 2004; Kiss et al. 2017; Monti *et al.* 2019). These will also need to confirm the species' tendency to expand its choice of anthropogenic structures other than ruins. It is hoped that the installation of nest boxes and the expansion of site selection observed in 2024 will lead to an increase in the species in the Caserta area.

Author contributions

Conceptualisation: D.M.
Data Curation: D.M. & G.P.
Investigation: B.D. & S.T. & E.E & D.M.
Project Administration: D.M.
Methodology: D.M. & E.E.
Resources: D.M. & B.D. & E.E.
Writing: D.M. & G.P.

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Analysis and Comparison of Breeding Bird Chorological Categories in Urban Areas through a Meta-Analysis of Ornithological Atlases of the Western Palearctic.

Maurizio Fraissinet[1], Maurizio Zotti[2], Marcello Bruschini[1], Sabrina Maria Marsala[3]

DOI https://doi.org/10.6093/2724-4393/11765

***Correspondence:**
info@asoim.org

Affiliation:
[1] Associazione Studi Ornitologici Italia Meridionale, ASOIM, Via Cavalli di Bronzo 95, 80046 San Giorgio a Cremano (Napoli). Italy
[2] Department of Agricultural Sciences, University of Naples Federico II, Via Università 100, 80055 Portici (Naples), Italy
[3] Italian National Research Council (CNR) - Institute for Agriculture and Forestry Systems in the Mediterranean (ISAFoM), Piazzale E. Fermi, 1 - 80055 Portici, Italy

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Abstract

In the last decades of the 20th century and the early 21st century, significant research efforts have focused on urban bird species. As a result, a growing body of literature has emerged, including urban atlases, checklists, and comparative studies on urban and extra-urban bird communities.
This study examines the relative abundance of bird species categorized into different zoogeographical classes: Palearctic-Indomalayan, Palearctic-Paleotropical-Australasian, Holarctic, Palearctic-Paleotropical, Palearctic and Cosmopolitan breeding birds. We compared species frequency in 44 European cities, where ornithological atlases and checklists from urban areas are available, with the breeding avifauna of the surrounding Vast areas. The findings reveal an elevated frequency of species from the Palearctic-Indomalayan category in urban environments, whereas other zoogeographical groups do not exhibit this pattern. This increased presence persists over time, as confirmed by analyses of cities with repeated ornithological atlas assessments. A similar trend is also observed in North African and Middle Eastern cities where breeding bird checklists are available. This pattern is hypothesized to be linked to the extensive range characteristic of species within the Palearctic-Indomalayan category, which spans diverse biomes. This broad distribution may provide these species with a greater ability to colonize new environments, including urban landscapes.

Keywords: Urban birds**,** Palearctic-Indomalayan bird species, Urban Ornithological Atlases

Riassunto

Negli ultimi decenni del XX secolo e all'inizio del XXI secolo un notevole lavoro di ricerca è stato dedicato alle specie di uccelli urbani. Come conseguenza di ciò è stata prodotta anche una corposa letteratura in merito: atlanti urbani, check-list, ma anche studi che mettono a confronto le comunità di uccelli urbane ed extraurbane. In questo lavoro indaghiamo la frequenza delle specie di uccelli classificate in base alle categorie zoogeografiche. Abbiamo preso in considerazione gli uccelli nidificanti appartenenti alle categorie paleartico-indomalese, paleartico-paleotropicale-australasiatico, oloartica, paleartico-paleotropicale, paleartica e cosmopolita. Abbiamo confrontato la frequenza di ciascuna categoria in 44 città europee in cui sono stati pubblicati atlanti ornitologici e check-list, con la frequenza dell'avifauna nidificante delle aree vasti circostanti ciascuna città. È stata riscontrata una frequenza elevata della categoria paleartico-indomalesiano in contesti urbani, mentre le altre categorie zoogeografiche non mostrano questo fenomeno. Questa elevata frequenza persiste nel tempo, e ciò è stato convalidato attraverso le analisi ripetute degli atlanti ornitologici delle città coinvolte nello studio. Un fenomeno comparabile si è riscontrato anche nelle città nordafricane e mediorientali di cui sono disponibili check-list delle specie nidificanti. Si ipotizza che questa tendenza sia associata all'ampio areale che caratterizza le specie della categoria zoogeografica paleartico-indomalese, che è caratterizzata da molti biomi di origine conferendo ad esse una maggiore capacità di colonizzare nuovi ambienti, come quelli urbani.

Parole chiave: Uccelli urbani, specie ornitiche del Paleartico-Indomalesiano, o Atlanti Ornitologici Urbani

Introduction

At the end of the 20th century and the beginning of the 21st century, there has been a notable expansion in the literature on urban avian species (Hedblom & Murgui 2017). One key area of research focuses on identifying differences and similarities between urban avifauna and that of the vast areas surrounding cities. The objective is to determine whether urban environments exert a 'filtering' effect that favors certain species or groups while disadvantaging others, and to explore the mechanisms underlying this process (Clergeau et al. 2001; Bonier et al. 2007; Croci et al. 2008; Møller 2009; Fraissinet & Fulgione 2008; Møller et al. 2012; Ferenc et al. 2013; 2018; Filloy et al. 2018).
Ecological and biogeographical analyses were made possible by conducting research on a large geographical scale and examining urban avifauna across multiple cities. Moreover, the investigated cities are situated at different latitudes and exposed to varying environmental and climatic conditions (Bonier et al. 2007; Fraissinet & Fulgione 2008; Evans et al. 2009; Luck & Smallbone 2011; Ferenc et al. 2013; Jokimäki et al. 2016; Jokimäki & Suhonen 2017; Chen & Wang 2017; Ferenc et al. 2018; Fattorini et al. 2018).
Two main aspects emerge from the literature review: the homogenization of urban avifauna (Bellocq et al. 2017; Chen & Wang 2017; Ferenc et al. 2018) and biogeographical changes, particularly the loss of both latitudinal and peninsular gradient effects on species richness (Jokimäki & Suhonen 2017; Ferenc et al. 2013; Fraissinet & Fulgione 2008).
A previous study by Fraissinet & Fulgione (2008) analyzed breeding avifauna checklists from 29 Italian urban ornithological atlases. Their research focused on differences in bird communities between urban areas and adjacent natural habitats, further contributing to the evidence of bird homogenization in urban environments. The study found a higher richness of Palearctic-Indomalayan species in the regions surrounding the analyzed urban areas.
This finding encouraged the production of

new ornithological atlases and checklists on urban avifauna, particularly within Italy (Fraissinet 2023) and across Europe (Luniak 2017). Additionally, further research has highlighted how species with wide geographical distributions are more successful in colonizing urban environments (Bonier et al. 2007; Ferenc et al. 2018).

In the present study, we conduct a comprehensive investigation into the zoogeographical categories of breeding avifauna in Italian cities and selected cities within the western Palearctic region. Our aim is to determine whether certain groups of species have a greater ability to colonize urban environments. To achieve this, we performed a comparative analysis of the zoogeographical categories of breeding avifauna in urban areas and those in the surrounding vast areas. Furthermore, this study seeks to validate the observations made by Fraissinet & Fulgione (2008) by utilizing a more geographically extensive dataset.

Materials and Methods

Data Collection

A total of 44 cities with ornithological atlases and checklists were included in the present work. We analyzed the breeding avifauna lists from 25 Italian cities where ornithological atlases or comprehensive checklists of breeding species have been published. Some cities have multiple editions of ornithological atlases available, leading to a total of 37 datasets on Italian urban breeding avifauna. Additionally, we integrated the Italian dataset with records from 18 European cities, one North African city, and one Middle Eastern city where ornithological atlases or checklists have been published (see Figure 1). A complete list of works included in this study is available in Table 1.

Recognizing that multiple editions of ornithological atlases exist for certain European cities, our analysis includes a total of 23 urban bird datasets from outside Italy. All the cities included in the study are located within the Western Palearctic region. The collected data range from the publication by Adar (1982) for the city of Jerusalem to the most recent 2023 publication for the city of Caltanissetta (Nardo et al. 2023). The selection of ornithological atlases for bird lists was also driven by the need to focus on studies specifically centered on urban environments. Therefore, atlases encompassing both urban areas and regions of high naturalistic value were excluded, as the latter could influence the relative abundances of urban bird communities. Specific cases include the cities of Trento (LIPU 1998) in Italy and Bielefeld (Laske et al. 1991) in Germany. The only checklists used that were not derived from ornithological atlases were selected based on their alignment with urban fauna criteria established in ornithological atlases. Several cities – such as Udine, Cremona, Forlì, Florence, Pisa, Grosseto, Livorno, Naples, London, Brussels, Berlin, and Valencia – have had multiple editions of ornithological atlases published over time and were also included in the final dataset (Figure 1).

Urban and Extra-Urban Categorization

To categorize the data, we distinguished between urban and extra-urban areas. Urban areas (Level I) were identified according to the guidelines proposed by Dinetti et al. (1995). Briefly, urban areas are those where buildings and roads account for more than 50% of the land cover in a defined area. Extra-urban areas (Vast areas) were defined based on two levels of spatial extension: i) Level II: Areas extending up to 50,000 km² around each city; ii) Level III: Areas extending over 50,000 km² around each city.

The adoption of the ornithological atlas methodology facilitated comparisons with vast areas using consistent methodologies. For further details on the ornithological atlas method, refer to Keller et al. (2020) and Fraissinet (2023).

Zoogeographical Classification

Taxa were grouped according to a modified zoogeographical classification. The geographical distinctions regarding species origin were initially proposed by Newton (2003). Except for the Palearctic category, all other analyzed groups were derived from merging multiple regions, including Palearctic-Indomalayan, Afrotropical, Australasian, and Holarctic. The classification of individual species follows the fundamental Western Palearctic chorotypes defined by Brichetti & Gariboldi (1997) as:

Palearctic-Indomalayan: Species found in both the Palearctic and Indomalayan regions.

Palearctic-Paleotropical-Australasian: Species distributed across the Palearctic, Afrotropical, Eastern, and Australasian regions, typically restricted to southern areas of the Palearctic.

Holarctic: Species with distributions covering both the Nearctic and Palearctic regions, typically showing a Euro-Siberian distribution.

Palearctic: Species whose distribution aligns entirely with the Palearctic zoogeographical region.

Palearctic-Paleotropical: Species occurring in the Palearctic, Afrotropical, and Indomalayan regions, often restricted to southern areas of the Palearctic.

Cosmopolitan: Species found across all major zoogeographical regions, except for one (subcosmopolitan).

Detailed information regarding the global distribution of the chorotypes included in this study is presented in Figure 2.

Data Analysis

For each avifauna atlas, we calculated the

Figure 1. Location of the cities included in the study, arranged according to latitude

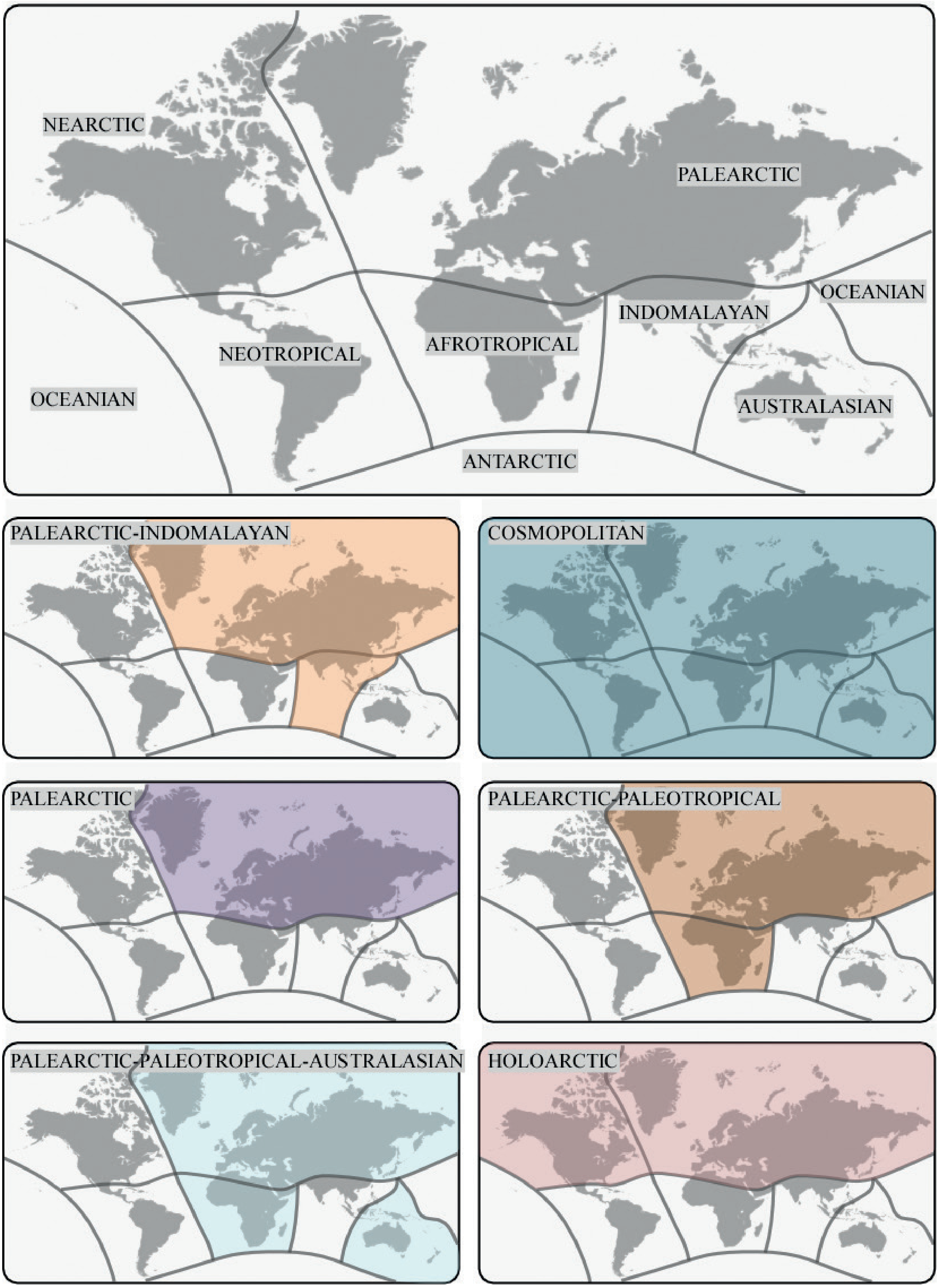

Figure 2. Maps of chorotypes included in the study according to Vigna Taglianti et al. (1992).

relative abundance of species categorized within the following chorological groups: Palearctic-Indomalayan, Palearctic-Paleotropical-Australasian, Holarctic, Palearctic-Paleotropical, Palearctic, and Cosmopolitan. To assess intrinsic variations in bird communities classified by zoogeographical origin, we conducted a Principal Component Analysis (PCA), using the relative abundance of each zoogeographical class as variables and cities and levels of extension as cases (Table 1). To confirm the exploratory analysis provided by PCA and to identify the factors most influencing changes in bird communities, we performed a PERMANOVA analysis, using zoogeographical origin as a variable and city and level of extension (Level I, II, and III) as fixed factors. Based on the results, we further analyzed the dataset at a multivariate level by conducting an additional PERMANOVA analysis with pairwise comparisons across different levels of extension. Multivariate data analysis was performed using Primer7. Percentage data were log-transformed prior to each analysis to mitigate heteroskedasticity issues.

Results

Table 1 presents the frequencies of species for each zoogeographical category in each city, compared with larger areas. Notably, only the Palearctic-Indomalayan category exhibits higher percentages in cities compared to vast areas.

The Principal Component Analysis (PCA) revealed that the relative abundance of birds from different zoogeographic categories varies according to the level of extension considered. Specifically, Palearctic (Pal), Palearctic-Indomalayan (PalIn), and Palearctic-Paleotropical (PalPal) species are more closely associated with cities that belong to Level I and Level II, which represent smaller extensions

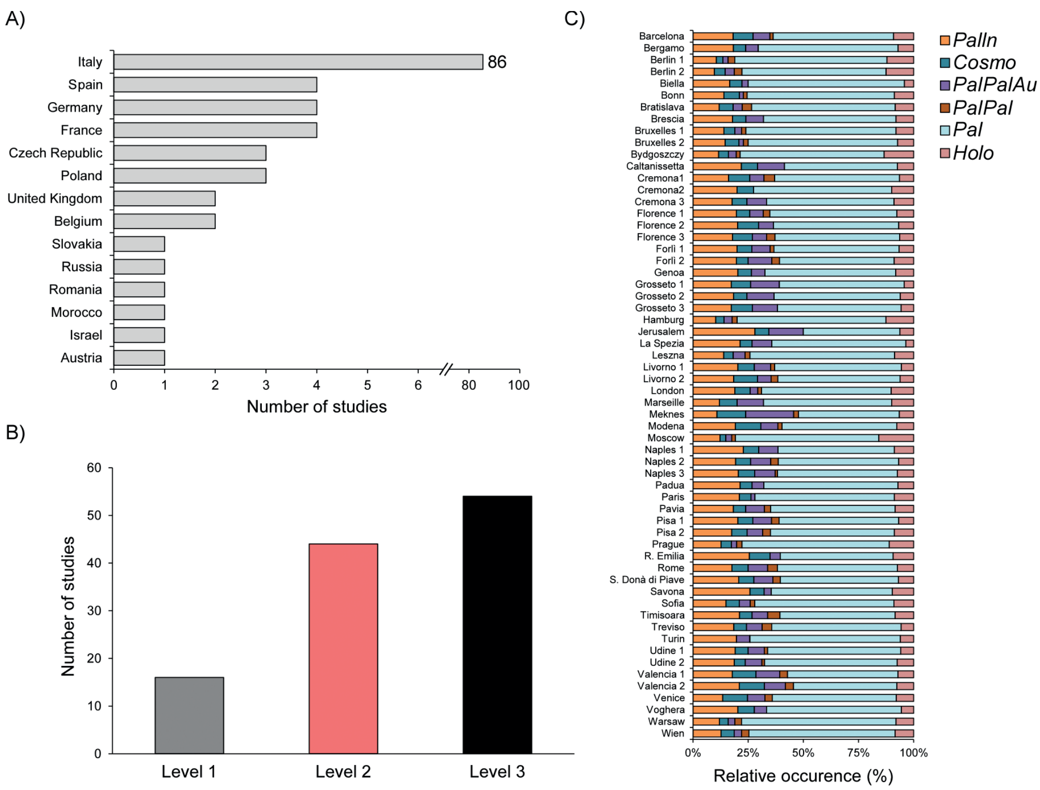

Figure 3. A) number of studies divided by country. B) number of studies divided by levels. C) Stacked bar plots on relative occurrence of PalIn, Cosmo, Pal, PalPal, PalPalAu, and Holo groups in each city included in the study.

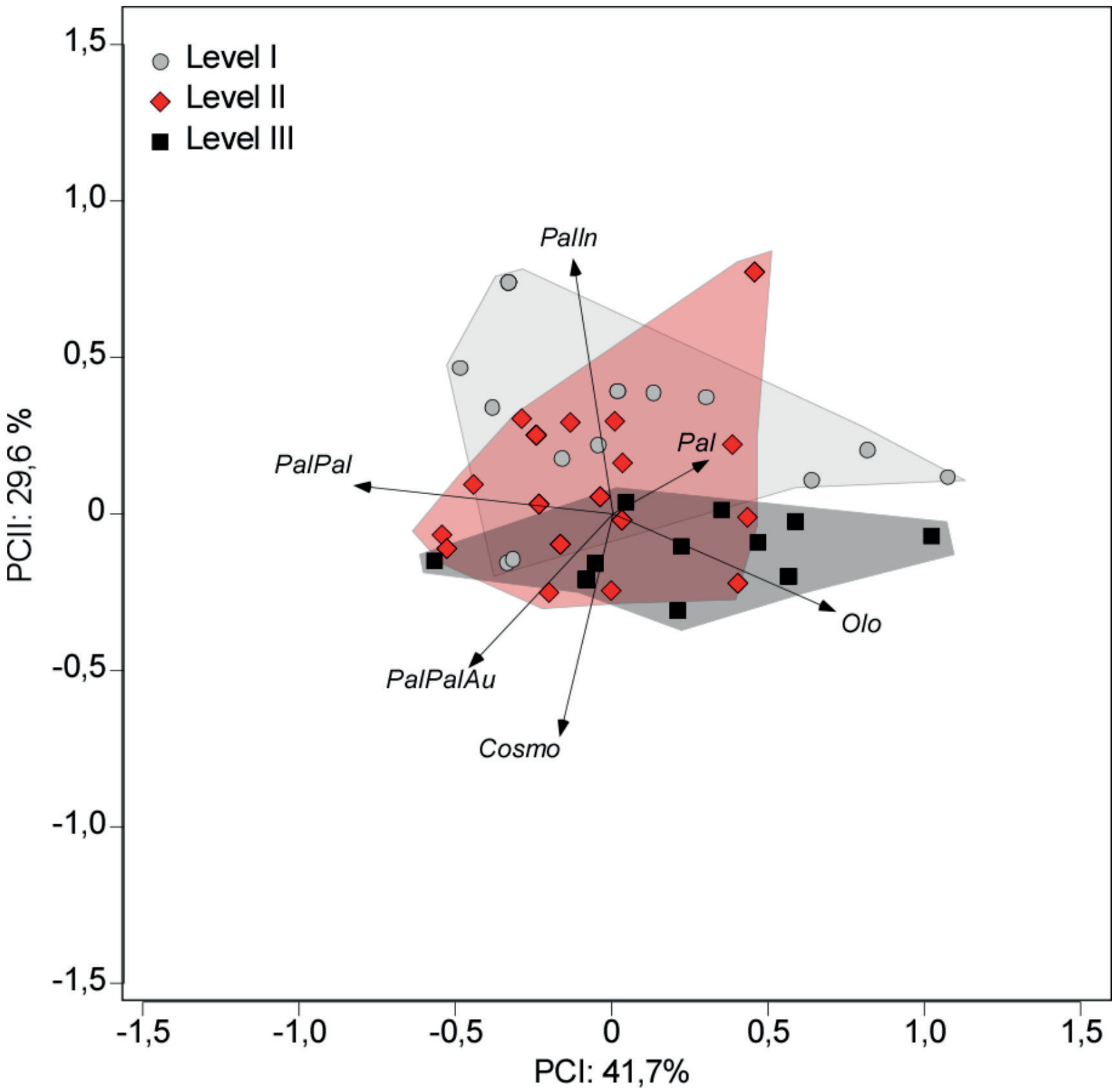

Figure 4. Principal component analysis of birds belonging to different zoogeographic categories in Europe. Different colors in legends refer to different extension of cities. Level I: urbanized areas, level II < 50,000 km², and level III > 50,000 km².

of vast areas. Conversely, the ordination in multidimensional space demonstrated that the segregation of Level III cities is primarily driven by the increased abundance of Cosmopolitan (Cosmo), Holarctic (Olo), and Palearctic-Paleotropical-Australasian (PalPalAu) species.

The findings from the PCA are further supported by the PERMANOVA analysis (Table 2 and Table 3), which confirms that the level of extension is the primary factor influencing changes in bird community composition based on zoogeographic origin (Pseudo-F: 16.6; P=0.001). However, city identity also plays a significant role in shaping bird community variations, albeit to a lesser extent (Pseudo-F: 1.82; P=0.003).

The analysis comparing different levels of extension revealed that bird communities in Level I cities show a greater differentiation from those in Level III compared to Level II.

Table 1. Frequencies of species for each zoogeographical category in individual cities and Vast areas. Bold font indicates the highest frequency value within each chorological category, level I reported as the name of the city. Refer to the text for the significance of the levels.

Cities	PalInd	Cosmo	PalPal	PalPalAu	Pal+Eur	Olo	Reference
Biella	**16.22**	5.41	2.7	0	**68.92**	4.05	Bordignon, 1999
Level II	9.52	5.29	**5.29**	3.17	59.79	**10.05**	Mingozzi et al. 1988
Level III	7.2	**7.5**	5	**3.57**	50.74	9	Baccetti et al. 2021
Torino	**16.89**	5.19%	5.19	**5.19%**	58.44	5.19	Maffei et al. 2001
Level II	9.52	5.29	**5.29**	3.17	**59.79**	**5.29**	Mingozzi et al. 1988
Level III	7.2	**7.5**	5	3.57	50.74	**9**	Baccetti et al. 2021
Savona	**22.86**	5.71	2.86	0	48.57	8.57	Galli e Spanò 2001
Level II	11.72	4.14	4.14	0.69	**60.69**	8.96	AA.VV. 1989
Level III	7.2	**7.5**	**5**	**3.57**	50.74	**9**	Baccetti et al. 2021
Genova	**17.24**	5.17	5.17	0	50	6.9	Borgo *et al.*, 2005
Level II	11.72	4.14	4.14	0.69	**60.69**	8.96	AA.VV. 1989
Level III	7.2	**7.5**	5	**3.57**	50.74	**9**	Baccetti et al. 2021
La Spezia	**20**	5	**8.33**	0	56.67	3.33	Dinetti 1996
Level II	11.72	4.14	4.14	0.69	**60.69**	8.96	AA.VV. 1989
Level III	7.2	**7.5**	5	**3.57**	50.74	**9**	Baccetti et al. 2021
Cremona1	**19.51**	7.32	0	0	**60.98**	**9.76**	Groppali 1994
Level II	9.44	6.67	**5**	3.33	60	8.89	Brichetti & Fasola, 1990
Level III	7.2	**7.5**	**5**	**3.57**	50.74	**9**	Baccetti et al. 2021
Cremona2	**16.67**	6.25	**8.33**	0	54.17	8.33	Groppali, 2004
Level II	9.44	6.67	5	3.33	**60**	8.89	Brichetti & Fasola, 1990
Level III	7.2	**7.5**	5	**3.57**	50.74	**9**	Baccetti et al. 2021
Cremona 3	**15.1**	**9**	**6**	**4.5**	52.9	6	Groppali 2015
Level II	9.44	6.67	5	3.33	**60**	8.89	Brichetti & Fasola, 1990
Level III	7.2	7.5	5	**3.57**	50.74	**9**	Baccetti et al. 2021
Voghera	**19.3**	**7.02**	**5.26**	0	57.89	5.26	Gatti 2011
Level II	9.44	6.67	5	3.33	**60**	8.89	Brichetti & Fasola, 1990
Level III	7.2	**7.5**	5	**3.57**	50.74	**9**	Baccetti et al. 2021

Pavia	**17.81**	5.48	**8.22**	2.74	54.79	8.22	Bernini et al. 1998
Level II	9.44	6.67	5	3.33	**60**	8.89	Brichetti & Fasola, 1990
Level III	7.2	**7.5**	5	**3.57**	50.74	**9**	Baccetti et al. 2021
Brescia	**17.31**	5.77	**7.69**	0	57.69	7.69	Ballerio & Brichetti 2003
Level II	9.44	6.67	5	3.33	**60**	**8.89**	Brichetti & Fasola, 1990
Level III	7.2	**7.5**	5	**3.57**	50.74	9	Baccetti et al. 2021
Bergamo	**16.88**	**5.19**	5.19	0	58.44	6.49	Cairo e Facoetti 2006
Level II	9.44	6.67	5	3.33	**60**	**8.89**	Brichetti & Fasola, 1990
Level III	7.2	**7.5**	5	**3.57**	50.74	9	Baccetti et al. 2021
Padua	**20.69**	**5.17**	5.17	0	**58.62**	6.9	Bottazzo & Giacomini 2010
Level II	10	**8**	5	3	55.5	**10.5**	Fracasso et al, 2011
Level III	7.2	**7.5**	5	**3.57**	50.74	9	Baccetti et al. 2021
Treviso	**17.81**	5.48	**6.85**	**4.11**	**56.34**	5.48	Nardo & Mezzavilla 2017
Level II	10	**8**	5	3	55.5	**10.5**	Fracasso et al. 2011
Level III	7.2	**7.5**	5	3.57	50.74	9	Baccetti et al. 2021
S. Donà di Piave 1	**20.34**	6.78	**8.47**	3.39	52.54	6.78	Nardo 2003
Level II	10	**8**	5	3	**55.5**	**10.5**	Fracasso et al. 2011
Level III	7.2	7.5	5	**3.57**	50.74	9	Baccetti et al. 2021
S. Donà di Piave 2	**18.6**	**9.3**	2.3	2.3	**58.1**	6.9	Nardo et al. 2019
Level II	10	8	5	3	**55.5**	**10.5**	Fracasso et al. 2011
Level III	7.2	7.5	5	**3.57**	50.74	9	Baccetti et al. 2021
Venice	**12.77**	**10.64**	**7.45**	3.19	53.19	7.45	Bon & Stival 2013
Level II	10	8	5	3	**55.5**	**10.5**	Fracasso et al. 2011
Level III	7.2	7.5	5	**3.57**	50.74	9	Baccetti et al. 2021
Udine 1	**18.57**	5.71	**7.14**	1.43	**58.57**	5.71	Parodi 2008
Level II							
Level III	7.2	**7.5**	5	**3.57**	50.74	**9**	Baccetti et al. 2021

Udine 2	**18**	4.8	**7.2**	1.2	**57.7**	7.2	Tringa FVG 2022
Level II							
Level III	7.2	**7.5**	5	**3.57**	50.74	**9**	Baccetti et al. 2021
Forlì 1	**19.35**	6.45	**8.06**	1.61	54.84	6.45	Ceccarelli et al. 2006
Level II	9.64	**8.12**	5.08	**4.06**	**55.33**	8.63	Bagni et al, 2003
Level III	7.2	7.5	5	3.57	50.74	**9**	Baccetti et al. 2021
Forlì 2	**16.9**	4.6	**9.2**	3	44.6	7.6	Ceccarelli et al. 2020
Level II	9.64	**8.12**	5.08	**4.06**	**55.33**	8.63	Bagni et al. 2003
Level III	7.2	7.5	5	3.57	50.74	**9**	Baccetti et al. 2021
Reggio Emilia	**24.44**	**8.89**	4.44	0	48.89	8.89	Gustin 2002
Level II	9.64	8.12	**5.08**	**4.06**	**55.33**	8.63	Bagni et al. 2003
Level III	7.2	7.5	5	3.57	50.74	**9**	Baccetti et al. 2021
Modena	**18.87**	**11.32**	**7.55**	1.89	50.94	7.55	Fangarezzi et al. 1999
Level II	9.64	8.12	5.08	**4.06**	**55.33**	8.63	Bagni et al.2003
Level III	7.2	7.5	5	3.57	50.74	**9**	Baccetti et al. 2021
Florence 1	**17.81**	5.48	5.48	2.74	52.05	6.85	Dinetti & Ascani 1990
Level II	10.43	4.91	**6.13**	**3.68**	**52.76**	7.97	Tellini et al., 1997
Level III	7.2	**7.5**	5	3.57	50.74	**9**	Baccetti et al. 2021
Florence 2	**18.29**	**8.54**	6.1	3.66	51.22	6.1	Dinetti &Romano 2002
Level II	10.43	4.91	**6.13**	**3.68**	**52.76**	7.97	Tellini et al. 1997
Level III	7.2	7.5	5	3.57	50.74	**9**	Baccetti et al. 2021
Florence 3	**16.28**	**8.14**	5.81	3.49	51.16	5.81	Dinetti 2009
Level II	10.43	**4.91**	**6.13**	**3.68**	**52.76**	7.97	Tellini et al. 1997
Level III	7.2	7.5	5	3.57	50.74	**9**	Baccetti et al., 2021
Livorno 1	**18.97**	**6.9**	6.9	1.72	**53.45**	5.17	Dinetti 1994
Level II	10.43	4.91	**6.13**	**3.68**	52.76	7.97	Tellini et al. 1997
Level III	7.2	**7.5**	5	3.57	50.74	**9**	Baccetti et al. 2021

Livorno 2	**16.44**	**9.59**	5.48	2.74	49.32	5.48	Dinetti et al… 2013
Level II	10.43	4.91	**6.13**	**3.68**	**52.76**	7.97	Tellini et al. 1997
Level III	7.2	7.5	5	3.57	50.74	**9**	Baccetti et al. 2021
Pisa 1	**19.05**	6.35	**7.94**	3.17	50.79	6.35	Dinetti 2003
Level II	10.43	4.91	6.13	**3.68**	**52.76**	7.97	Tellini et al. 1997
Level III	7.2	**7.5**	5	3.57	50.74	**9**	Baccetti et al. 2021
Pisa 2	**14.71%**	5.88%	5.88%	2.94%	47.06%	7.35%	Dinetti 2018
Level II	10.43	4.91	6.13	**3.68**	**52.76**	7.97	Tellini et al. 1997
Level III	7.2	**7.5**	5	3.57	50.74	**9**	Baccetti et al. 2021
Grosseto 1	**15.69**	**7.84**	**11.76**	0	50.98	3.92	Giovacchini 2001
Level II	10.43	4.91	6.13	**3.68**	**52.76**	7.97	Tellini et al. 1997
Level III	7.2	7.5	5	3.57	50.74	**9**	Baccetti et al. 2021
Grosseto 2	**16.67**	**5.56**	**11.11**	0	51.86	5.56	Diaz 2011
Level II	10.43	4.91	6.13	**3.68**	**52.76**	7.97	Tellini et al. 1997
Level III	7.2	**7.5**	5	3.57	50.74	**9**	Baccetti et al. 2021
Grosseto 3	**15.2**	**8.4**	**10**	0	49	5	Giovacchini et al. 2021
Level II	10.43	4.91	6.13	**3.68**	**52.76**	7.97	Tellini et al. 1997
Level III	7.2	**7.5**	5	3.57	50.74	**9**	Baccetti et al. 2021
Rome	**15.19**	6.33	**7.59**	**3.8**	46.84	6.33	Cignini & Zapparoli 1996
Level II	10.29	5.14	5.71	2.86	**52.57**	8	Brunelli et al, 2011
Level III	7.2	**7.5**	5	3.57	50.74	**9**	Baccetti et al. 2021
Naples 1	**20.63**	6.3	**7.9**	0	47.62	7.9	Fraissinet 1995
Level II	10.32	**7.74**	6.45	3.22	50.32	**9.03**	Fraissinet & Usai 2021
Level III	7.2	**7.5**	5	**3.57**	**50.74**	9	Baccetti et al. 2021
Naples2	**17**	6	**8**	3	48	6	Fraissinet 2006
Level II	10.32	**7.74**	6.45	3.22	50.32	**9.03**	Fraissinet & Usai, 2021
Level III	7.2	**7.5**	5	**3.57**	**50.74**	9	Baccetti et al. 2021

Naples 3	**18**	6.5	**8.1**	1	47.5	6.5	Fraissinet & Capasso 2020
Level II	10.32	**7.74**	6.45	3.22	50.32	**9.03**	Fraissinet & Usai 2021
Level III	7.2	**7.5**	5	**3.57**	**50.74**	9	Baccetti et al. 2021
Caltanissetta 1	**18.75**	6.25	**10.42**	0	43.75	6.25	Falci, pers. com.
Level II	10.38	**7.14**	8.44	3.2	44.8	8.44	AA.VV. 2008
Level III	7.2	**7.5**	5	**3.57**	**50.74**	**9**	Baccetti et al. 2021
Caltanissetta 2	**17.3**	7	7	0	48	7	Nardo et al. 2023
Level II	10.38	**7.14**	8.44	3.2	44.8	8.44	AA.VV. 2008
Level III	7.2	**7.5**	5	**3.57**	**50.74**	**9**	Baccetti et al. 2021
Warsaw	**12**	4	3	3	**70**	8	Luniak et al. 2001
Level II							
Level III	8.56	**5.86**	**3.15**	2.7	62.61	**15.32**	Tomialojc 1990
Leszna	**13.83**	4.26	**5.32**	2.13	**64.89**	8.51	Kuzniak 1996
Level II							
Level III	8.56	**5.86**	3.15	**2.7**	62.61	**15.32**	Tomialojc 1990
Bydgoszczy	**11.61**	4.46	**3.57**	1.79	**65.18**	13.39	Indykiewicz et al, 1997
Level II							
Level III	8.56	**5.86**	3.15	**2.7**	62.61	**15.32**	Tomialojc 1990
Berlin 1	**10.53**	3.01	2.26	**3.01**	**68.42**	12.03	Witt, 1985; Degen & Otto 1988
Level II							
Level III	7.05	**6.64**	**3.73**	2.49	58.51	**17.01**	Hagemeijer & Blair 1997
Berlin 2	**9.4**	4.7	**4.03**	**3.36**	**63.09**	12.08	Otto & Witt 2002
Level II							
Level III	7.05	**6.64**	3.73	2.49	58.51	**17.01**	Hagemeijer & Blair 1997
Hamburg	**10.22**	3.65	3.65	2.19	**66.42**	12.41	Mitschke & Baumung, 2001
Level II							
Level III	7.05	**6.64**	**3.73**	**2.49**	58.51	**17.01**	Hagemeijer & Blair 1997
Bonn	**13.45**	**6.72**	1.68	1.68	**63.87**	8.4	Kelcey & Rheinwald 2005
Level II							
Level III	7.05	6.64	**3.73**	**2.49**	58.51	**17.01**	Hagemeijer & Blair 1997

Moscow	**12.28**	2.63	**2.63**	1.75	**64.91**	15.79	Kalyakin & Voltzit 2006
Level II	9.6	**4.24**	2.42	**2.42**	64.85	**16.36**	Kalyakin & Voltzit 2006
Level III							
Prague	**12.7**	4.76	2.38	2.38	66.67	11.11	Fuchs et al. 2002
Level II	9.67	5.1	**3.8**	2.5	**67.05**	11.61	Ferenc, pers. com.
Level III	7.96	**6.19**	3.1	**3.1**	63.72	**12.83**	Ferenc, pers. com.
Bruxelles 1	**13.59**	4.85	2.91	1.94	**66.02**	7.77	Rabosée et al. 1995
Level II	6.81	**6.82**	**3.98**	**2.84**	59.66	**14.2**	Devillers et al. 1988
Level III							
Bruxelles 2	**13.59**	5.83	1.94	1.94	**63.11**	6.8	Weiserbs & Jacob 2007
Level II	6.81	**6.82**	**3.98**	**2.84**	59.66	**14.2**	Devillers et al.1988
Level III							
Paris	**19.67**	4.92	1.64	0	59.02	8.2	Malher 2010
Level II	16	6.7	**4.88**	**3.6**	**59.15**	10.98	Le Marechal & Lesaffre 2000
Level III	6.47	**7.19**	4.67	3.23	52.12	**13.3**	Yeatman-Berthelot, 1994
Marseille	**10**	6.67	10	0	48.33	8.33	Marchetti & Gallner 1976
Level II	7.82	8.69	**4.78**	**3.47**	**54.35**	10	Flitti et al. 2009
Level III	6.47	**7.19**	4.67	3.23	52.12	**13.3**	Yeatman-Berthelot 1994
Barcelona	**14.45**	7.22	**6.02**	1.2	43.34	7.22	Anton et al. 2017
Level II	7.48	**7.48**	5.28	**4.4**	48	8.81	Estrada et al. 2004
Level III	7.6	6.8	5.2	3.6	**48.8**	**10**	Purroy 1997
Valencia 1	**15.15**	**9.09**	**9.09**	3.03	42.42	6.06	Murgui, pers. Com.
Level II	9.04	7.97	6.91	**4.25**	41.48	6.91	Polo & Polo 2005
Level III	7.6	6.8	5.2	3.6	**48.8**	**10**	Purroy, 1997
Valencia 2	**16.9**	**9.2**	**7.6**	3	37.7	6.1	Murgui 2021
Level II	9.04	7.97	6.91	**4.25**	41.48	6.91	Polo & Polo 2005
Level III	7.6	6.8	5.2	3.6	**48.8**	**10**	Purroy 1997
Sofia	**14.15**	5.66	4.72	1.89	**59.43**	8.49	Iankov 1992
Level II							
Level III	7.6	**6.08**	**4.94**	**2.66**	57.79	**8.75**	Iankov 2007

Timisoara	**20.83**	5.56	**6.94**	**5.56**	51.39	8.33	Stanescu & Parvulescu 2008
Level II							
Level III	8.54	**7.32**	3.66	3.26	**59.34**	**10.57**	Hagemeijer & Blair 1997
London	**18.64**	**6.78**	**3.39**	**1.69**	**57.62**	10	Oliver 1997
Level II							
Level III	7.93	6.34	2.11	1.58	53.97	**20.1**	Gibbons et al.1993
Bratislava	**11.41**	**6.04**	**4.03**	**4.03**	62.42	8.05	Kelcey & Rheinwald 2005
Level II	8.22	5.48	3.2	3.2	**63.93**	**12.33**	Hagemeijer & Blair 1997
Level III							
Wien	**12.5**	5.8	3.3	**3.3**	**65**	8.3	Wichmann et al. 2009
Level II							
Level III	8.3	**6**	**3.7**	2.8	63.7	**11.6**	Craig 1994
Jerusalem	**18.75**	4.17	**10.42**	0	**29.17**	4.17	Adar 1982
Level II	8.85	**7.96**	7.08	**2.65**	22.12	**7.08**	The Israeli Birding Web Site
Level III							
Meknes	**9.09**	**10.91**	**18.18**	1.82	**38.18**	5.45	Franchimont pers.com.
Level II							
Level III	8.29	7.37	6.91	**4.15**	31.8	**6.91**	Thévenot et al. 2003

Table 2. Result of PERMANOVA (Perm. 999) analysis showing the significant difference according to zoogeographical categories of birds in Europe according to City and levels of extension. Significant differences for values of P < 0.01

	df	SS	MS	Pseudo-F	P(perm)
City	66	67.25	1.01	1.82	***0.003***
Levels	2	18.58	9.29	16.6	***0.001***
Residuals	45	25.19	0.56		
Total	113	116.37			

Table 3. Result of PERMANOVA (Perm. 999) analysis showing the significant difference for pairwise comparison between levels of extension according to changes in bird zoogeographical classification. Significant differences for values of P < 0.01

Pairwise comparison	t	P(perm)	perms
Level I vs Level II	2.26	***0.007***	999
Level I vs Level III	3.42	***0.001***	998
Level II vs Level III	5.24	***0.001***	999

Discussion:

Species belonging to the Palearctic-Indomalayan zoogeographical region show a higher frequency in urban areas compared to the vast areas they inhabit. This pattern persists despite biogeographical constraints such as latitude and longitude, encompassing species from mixed deciduous forests in temperate or cold climates as well as those from Mediterranean vegetation zones with a xeric climate. This finding aligns with existing literature highlighting the homogenizing effect of urban ecosystems on biodiversity, particularly within ornithological communities (Clergeau et al. 2006; Møller 2009; Fraissinet & Fulgione 2008; Ferenc et al. 2013; Ferenc et al. 2018).

Moreover, the frequency of Palearctic-Indomalayan species decreases as the surface area of vast areas increases (see Table 1). This suggests that the urban environment's influence weakens as the spatial scale expands, reducing its impact on bird communities in the surrounding regions. Additionally, this phenomenon appears to be temporally stable, as indicated by the consistently higher frequency of Palearctic-Indomalayan species in cities compared to vast areas, even when urban ornithological atlases have been updated over time (see Table 1).

The broad distribution of many Palearctic-Indomalayan species may be explained by their evolutionary adaptation to expansive geographic ranges, allowing them to thrive in diverse environmental conditions, withstand disturbances, and exploit new trophic niches. Urban environments often pose significant challenges for bird species, yet the plasticity of species in this zoogeographical category may have facilitated their successful colonization, unlike species with more restricted distributions or specialized ecological requirements (Møller 2009; Ferenc et al. 2013; Ferenc et al. 2018).

Interestingly, this adaptability contrasts with Cosmopolitan species, which, despite their widespread distribution, do not demonstrate the same success in urban colonization. It is well established that specialist species tend to decline along an urbanization gradient (Clergeau et al. 2006). However, some exceptions exist, such as the Peregrine falcon, a species specialized in rocky environments, which has successfully adapted to urban settings by using buildings as hunting grounds and nesting sites. This exception is largely due to the presence and high abundance of its primary prey, the Feral pigeon, a species that behaves as a generalist in trophic strategies.

The patterns observed in this study warrant further investigation, particularly by expanding the dataset to fill gaps in current observations. For example, it would be valuable to extend studies to Asian cities and regions outside the Palearctic to determine whether similar trends occur in other zoogeographical categories. Unfortunately, these regions remain underrepresented in research on this topic (Hedblom & Murgui 2017; Ferlini 2022). However, some studies from South America and China, despite not explicitly addressing zoogeographical categories, have reported similar homogenization trends (Belloq et al. 2017; Chen & Wang 2017).

Future research should also integrate geographical composition data, considering the types and number of habitats present in each city and how these factors influence different chorological species groups. Additionally, studies should assess the availability of resources and the presence of allochthonous species, both of which may significantly shape urban bird communities.

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Author contributions

Conceptualization: M.F.
Data curation: M.F., M.B.
Formal analysis: M.Z., S.M.M.
Investigation: M.F., M.B.
Project administration: M.F.
Writing - original and final draft preparation: M.F., M.Z., M.B., S.M.M.

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Phytotherapy in the management of African healthcare: Our experience in Benin (West Africa)

Gianmaria Fabrizio Ferrazzano[1,2,3], Francesca D'Ambrosio[4,*], Silvia Caruso[5], Sara Caruso[5], Roberto Gatto[5], Nunzia Pepe[6], Virinder Goyal[7] and Antonino Pollio[6]

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***Correspondence:**
francescadambrosio4@gmail.com

Affiliation:
[1] UNESCO Chair in Health Education and Sustainable Development, Paediatric Dentistry Section, University of Naples "Federico II", 80138 Naples, Italy
[2] Paediatric Dentistry Section, East-Asian-Pacific International Academic Consortium, Tokyo 113-0033, Japan
[3] U.N.-E.U. International Research Project on Human Health-Oral Health Section, 1200 Geneve, Switzerland
[4] Department of Laboratory and Infectious Diseases Sciences, Fondazione Policlinico Universitario A. Gemelli IRCCS, 00168 Rome, Italy
[5] Department of Life, Health and Environmental Sciences, University of L'Aquila, 67100 L'Aquila, Italy
[6] Department of Biology, University of Naples "Federico II", Naples, Italy
[7] Department of Pediatric and Preventive Dentistry, Gurunanak Dev Dental College, Patiala 148028, Punjab, India

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Abstract

Africa, renowned for its vast plant biodiversity, remains the largest reservoir of infectious diseases globally, with high morbidity and mortality rates due to conditions like tuberculosis, malaria, and AIDS. Despite the limited availability of modern medical facilities, traditional medicine, particularly herbal remedies, is pivotal, serving approximately 90% of the population. The Republic of Benin, a small West African nation, exemplifies this reliance on phytotherapy. This review delves into how traditional medicine is integrated into Benin's healthcare system, emphasizing the extensive use of medicinal plants for various local diseases. Through our personal experience at Ziniviè "La Croix" Hospital, we recorded the use of 41 medicinal plants. Comparing these findings with other African countries reveals both unique and common phytotherapeutic practices. Despite the advantages, the unregulated use of herbal medicines presents safety risks, highlighting the need for careful regulation and standardization. The study emphasizes the importance of combining traditional knowledge with modern scientific research to ensure the safe and effective use of medicinal plants.

Keywords: Ethnobotany, Phytotherapy; Traditional medicine; Africa; Benin

Riassunto

L'Africa, nota per la sua ampia biodiversità vegetale, rimane il più grande serbatoio di malattie infettive a livello globale, con alti tassi di morbilità e mortalità dovuti a patologie come la tubercolosi, la malaria e l'AIDS. Nonostante la limitata disponibilità di strutture mediche moderne, la medicina tradizionale, in particolare i rimedi erboristici, è fondamentale e serve circa il 90% della popolazione. La Repubblica del Benin, una piccola Nazione dell'Africa occidentale, è un esempio di questo affidamento alla fitoterapia. Questa rassegna analizza come la medicina tradizionale sia integrata nel sistema sanitario del Benin, sottolineando l'ampio uso di piante medicinali per varie malattie locali. Attraverso la nostra esperienza personale presso l'ospedale di Ziniviè "La Croix", abbiamo registrato l'uso di 41 piante medicinali. Il confronto con altri Paesi africani rivela pratiche fitoterapiche uniche e comuni. Nonostante i vantaggi, l'uso non regolamentato dei farmaci vegetali presenta rischi per la sicurezza, evidenziando la necessità di un'attenta regolamentazione e standardizzazione. Lo studio sottolinea l'importanza di combinare le conoscenze tradizionali con la moderna ricerca scientifica per garantire un uso sicuro ed efficace delle piante medicinali.

Parole chiave: Etnobotanica, Fitoterapia, Medicina tradizionale, Africa, Benin

1. Introduction

Africa is the largest reservoir of infectious diseases in the world. Indeed severe pathologies such as tuberculosis, malaria and AIDS, represent a substantial burden in African healthcare systems, leading to high morbidity and mortality rates across the continent (Mbele et al., 2017). It is estimated that 90% of the African population are still dependent on traditional medicine (Wachtel-Galor & Benzie, 2011). This reliance is often due to the limited availability of modern medical facilities and the high cost of conventional treatments, which many people cannot afford. As a result, traditional medicine, comprising insects (Ferrazzano et al., 2023) and medical herbs, remains an integral part of the healthcare landscape in Africa (Okaiyeto & Oguntibeju, 2021). Moreover, Africa is characterized by an impressive floristic richness and biodiversity. The continent's diverse ecosystems host a wide variety of plant species, many of which have been used for centuries in traditional medicine. Suffice it to say that more than 5400 African medical plants are documented, although only the 8% of the medical herbs used worldwide origin from Africa (Wink, 2011; Brendler & van Wyk 2008).

The affordability and the ease of finding and preparing botanical extracts make phytotherapy attractive for developing countries and, in some cases, may be the only resource. African traditional medicine is in the hands of so-called healers, who pass down their knowledge from generation to generation. These healers are often highly respected members of their communities, serving as both medical practitioners and keepers of cultural heritage. However, healers wouldn't necessarily get appropriate training and education required to prescript and administer herbal products. This lack of formal education can lead to inconsistent practices and potential health risks. In fact, even though the beneficial role of plant extracts is acknowledged worldwide, the indiscriminate use of herbal medicines may cause adverse effects, like kidney failure, live damage, diarrhea, and so on (Gurib-Fakim, 2006). Such adverse effects highlight the need for careful regulation and standardization of herbal medicine practices. Eventually, incorrect dosages may turn out to be toxic, so safety issues must always be considered (Fennel et al., 2004).

The Republic of Benin, one of the smallest countries of West Africa, located in the tropical zone between the Equator and the Tropic of Cancer, has a rich cultural heritage and a diverse ecosystem that supports a wide variety of medicinal plants. Indeed, this country boasts a wide use of medical herbs, considered as the primary source of healthcare.

In this review we'll discuss the role of phytotherapy in Benin and the application of several plant species in the treatment of local pathologies, according to our personal experience in Ziniviè "La Croix" Hospital. We will explore how these traditional practices are integrated into the local healthcare system and their effectiveness in treating various ailments. Eventually, we will compare the clinical application of medicinal plants in Benin, with other African countries. By drawing these comparisons, we aim to highlight both the commonalities and unique aspects of phytotherapy practices across the continent.

2. Benin Healthcare

Benin is one of the poorest countries in the world, with a critical health condition. The economic challenges faced by the country severely impact its healthcare system, creating numerous obstacles to providing adequate medical care for its citizens.

The demographic structure is comparable to the situation of backward sub-Saharan regions (May, 1989). According to the World Health Organization report of 2016, life expectancy is 60 years for men and 62 years for women. This relatively low life expectancy is a stark indicator of the health challenges faced by the population, reflecting widespread issues such as infectious diseases, malnutrition, and inadequate medical care. The probability of dying between birth and age 1 per 1000 live births is 62.04, although this value rises to 95.6 within 5 years old. These alarming statistics highlight the urgent need for improved maternal and child health services, as well as better prenatal and postnatal care. Moreover, it is estimated that about a third of children under 5 suffer from malnutrition. Malnutrition is a significant problem that affects physical and cognitive development in children, leading to long-term health issues and perpetuating the cycle of poverty.

The public health system in Benin is organized in a three-tiered pyramid structure. At the base, there are peripheral health facilities, such as medical dispensaries, which are the most decentralized and accessible. These facilities refer patients to area hospitals, which are designed to serve populations ranging from 100,000 to 200,000 people. At the top of the pyramid are the national hospitals, which are expected to offer specialized and advanced medical care. However, their accessibility is often limited to urban areas, resulting in a lack of services for rural populations.

The situation of public health infrastructure has certainly improved in recent years, but the availability of medicines, both public and private, remains inadequate and limited. This shortage of medicines leads to significant treatment gaps and forces patients to seek alternative, often less effective, remedies.

Moreover, there has been no fair distribution at the national level and therefore there are areas where it is difficult to have even basic assistance. Rural and remote areas are particularly disadvantaged, lacking the most fundamental healthcare services and infrastructure.

One of the major problems of the health system in Benin is the human resources available for health, in terms of quantity, quality and distribution. It has been estimated that per 10.000 inhabitants there are about 1.6 doctors, leading to long waiting times and inadequate care for many patients.

Another critical point of the socio-sanitary situation, in Benin, is the private health system. While private healthcare facilities may offer higher quality services, their costs are relatively high. For this reason, most treatments and surgical interventions are unaffordable for most of the population, forced to survive with incomes below the poverty line.

3. The relationship between patients and the traditional medicine in Benin

In the cultural context of the Beninese tradition, the state of disease is often considered as misfortune, divine punishment, or curse. As a result, the cultural interpretation of sickness significantly influences the healthcare-seeking behavior of the population. Patients prefer to rely on traditional healers, rather than go to hospitals. Healers are often the first point of contact for individuals seeking medical help and are believed to possess spiritual and medicinal knowledge, that is passed down through generations. It is a fact that the first reference health for the Beninese population is that of traditional care: first as self-medication and then benefiting from therapists related to the so-called "folk health care system". With the term "traditional medicine" or "folk health care system", the World Health Organization (WHO) indicated in 1976: "the collection of all knowledge, the use of substances, measures and practices that can be explained or not, based on the socio-cultural and religious foundations of a specific community, which rely exclusively on experiences and observations transmitted from generation to generation, orally and in writing, and used to diagnose, prevent or eliminate an imbalance in physical, mental and social well-being". This definition underscores the holistic nature of traditional medicine, integrating physical, mental, and social aspects of health. In 2000, the WHO further clarified the definition of traditional medicine: "the sum of knowledge, skills and practices based on indigenous theories, beliefs, and experiences of different cultures, whether or not they can be explained, used in maintaining health, as well as in prevention, diagnosis, improvement or treatment of physical and mental diseases. In some countries, the terms complementary/alternative/unconventional medicine are used interchangeably with "traditional medicine". Eventually, in Benin, the therapeutic form of self-medication is extremely widespread: traditional medicines or modern drugs are sold at low cost on the streets or in markets, and this situation, of course, demonstrates a total lack of control over the prescription and use of drugs.

4. Source of data

All the plants described in this review and their clinical applications derive from our personal experience in the hospital "La Croix", in the region of Ziniviè. This hospital was founded in 1980 by priests belonging to the Camillian Order, who still manage it. The integrative approach combining modern medicine with phytotherapy offers patients a choice of different treatment options, that can help improve their overall well-being and customize the treatment to their needs and preferences. Our 6 months experience in "La Croix" hospital and the interaction with patients allowed us to collect information about 41 medicinal plants and their application in the treatment of different diseases.

As mentioned above, Africa is characterized by an impressive biodiversity, that supports a wide variety of plant species, many of which have unique medicinal properties.

In the following paragraphs, we'll report the most frequently employed plants in in the hospital "La Croix", of Benin, detailing their specific use, compared with the use of these plants in other African regions (Table 1).

4.1. Plants used in the management of microbial diseases

Africa has always been one of the largest reservoirs of viral infections, and this explains the wide use of medicinal plants to face these diseases (Ndhlala et al., 2013). Based on the data we collected, most plants are used in Benin local medicine to treat hepatitis B (HBV). The natural history of this pathology in Africa is poorly understood, although approximately 80 million people struggle with HBV (Riches et al., 2023). Despite the significant impact of HBV, there is still a lack of comprehensive epidemiological data and a need for more research to understand the progression and management of the disease in the African context. Leaves and roots of *Annona muricata*, a tropical plant of the Annonaceae Family, is widely used in Benin to treat HBV, while

Table 1. Plants used in the traditional medicine of Benin, compared with their use in other African Sates (N/A: Not Available)

Name	Family	Medical use in Benin	Part(s) used	Medical use in Africa	Part(s) used	Reference
Abrus precatorius L.	Leguminosae	Asthenia, cough, asthma, jaundice	Leaves	Antimicrobial and cytotoxic activity; Tuberculosis; bronchitis; whooping cough; chest complaints; asthma.	Leaves, stem, seeds, roots, fruits	Madikizela et al., 2013; Jiofack et al., 2010
Aframomum melegueta K. Schum.	Zingiberaceae	Kidney pain	Seeds	Antimicrobial and antiviral activity; Typhus; Amoebiasis; Skin diseases.	Seeds, leaves, rhizome, fruit, roots	Doherty & Olaniran, 2010; Alo et al., 2012; Oladunmoy, 2011; Egharevba & Ikhatua, 2008.
Allium cepa L.		Hernia	Bulb	N/A	N/A	N/A
Amorphophallus dracontioides (Engl.) N.E.Br.	Araceae	Hernia	Roots	N/A	N/A	N/A
Anacardium occidentale L.	Anacardiaceae	hyperglycemia, hypertension	Leaves, bark	Antiviral and antimicrobial; Skin diseases; Diabetes; Dental Caries; Peptic ulcer.	Seeds, leaves, stem, bark extract	Onawunmi et al., 1984; Shah et al., 2011; Jeruto et al., 2011; Lawal et al., 2010; Akinjogunla et al., 2012
Annona senegalensis Pers.	Annonaceae	Anorexia	Leaves	Stomach problems; Infertility; improved sexual performance; Diarrhea; Antimalarial; Antibacterial; Antioxidant; Anti-inflammatory, Anticonvulsant; Antinociceptive; Analgesic.	Bark; root; leaves	Mahwasane et al., 2013; Suleiman et al., 2008; Ajaiyeoba et al., 2006; Lino & Deogracious, 2006; Okhale et al., 2016.
Annona muricata L.	Annonaceae	Hepatitis B	Leaves, seeds	Hypoglycemic effects; Anti-hypertensive; Antitumoral; Antimicrobial; antioxidant.	Leaves, bark root seed, fruit, bark, stem	Adewole & Caxton, 2009; Zubaidi et al. 2023; Gavamukulya et al. 2014; Nwokocha et al., 2012
Anthocleista vogelii Planch.	Loganiaceae	Hernia	Roots	Antidiabetic; Antibacterial; Urinary tract infections; typhus; diarrhea; skin diseases and food poisoning; antimalarial; anti-inflammatory; venereal diseases.	Stem bark, leaves, root bark, root	Jiofack et al., 2010; Anyanwu et al., 2015; Eta Okon et al., 2014.
Boerhaavia diffusa L.	Nyctaginaceae	Threat of abortion	Leaves	Anticonvulsant; antioxidant; Antibacterial; Anti-tumor; anti-inflammatory; immunomodulatory.	Leaves, roots	Kaur & Goel, 2011; Kouakou-Siransy et al., 2010; Girish &, Satish 2007; Patil KS, Bhalsing, 2016

Bosquiea angolensis Ficalho	Moraceae	Dysentery	Leaves	N/A	N/A	N/A
Citrus aurantium L.	Rutaceae	Hepatitis B, sickle cell anemia	Leaves and fruits	Anticancer, antianxiety, antiobesity, antibacterial, antioxidant, pesticidal, and antidiabetic.	Fruits, seeds, leaves, flowers	Suryawanshi, 2011; Suntar et al., 2018
Citrus limon L.	Rutaceae	Rheumatisms	Fruits	Antibacterial; antioxidant; Cough; Influence; Analgesic; Protector of the intestinal mucosa.	Fruits	Otang &, Afolayan, 2016; Maroyi, 2013
Clausena anisata (Willd.) Hook.f. ex Benth.	Rutaceae	Sinusitis	Whole plant	Hypoglycemic effects; Antioxidant; Anti-inflammatory.	Whole plant	Ojewole, 2002; Amoo et al., 2012; Adebayo et al., 2015
Crateva religiosa G. Forst.	Capparaceae	Migraine, antibiotic	Leaves	Antibacterial properties; anti-inflammatory; antifungal.	Whole plant	Patil, 2012; Sharma et al., 2013
Cymbopogon citratus (Ness) Stapf.	Gramineae	Hepatitis B	Leaves	Antibacterial; anti-amoebic; antibacterial; antidiarrheal; antifilarial; antifungal; anti-inflammatory; antimalarial; antimutagenicity; antimycobacterial; antioxidants; hypoglycemic; neurobehavioral.	Leaves and whole plant	Onawunmi et al., 1984; Sha et al., 2011
Diospyros mespiliformis Hochst.	Ebenaceae	Hernia	Roots	Stomach disorders; Vomiting; Diarrhea; Abdominal pain; Antimicrobial effects.	Bark, roots	Mahwasane et al., 2013; Maroyi, 2013; Mabona et al., 2013
Ehretia cymosa Thonn.	Boraginaceae	Sickle cell anemia	Whole plant	Venereal diseases, pneumonia, epilepsy, dry cough, malaria, ECF, tonsils, mental problems, asthma, typhoid, wounds, aphrodisiac Venereal illnesses; Pneumonia; Epilepsy; Dry cough; Malaria;Tonsils; Mental Problems; Asthma; Typhus; Wounds; Aphrodisiac.	Leaves, roots	Jeruto et al., 2011
Elaeis guineensis Jacq.	Arecaceae	Kidney pain, Licken Plaw	Oil	Menstrual cramps	Dry leaves	Lawal et al., 2010
Euphorbia hirta L.	Euphorbiaceae	Asthma	Whole plant	Diarrhoea; Gastritis; diabetes; dysentery; rheumatisms; amoebiasis; antibacterial.	Whole plant	Jiofack, 2010
Gardenia spellis J. Ellis	Rubiaceae	Hypertension	Leaves, stem	N/A	N/A	N/A
Jatropha gossypiifolia L.	Euphorbiaceae	Anemia	Roots, leaves	Antimalarial; antimicrobial, anti-inflammatory, antidiarrheal, antihypertensive; anticancer.	leaves	Gbeassor et al., 1989; Félix-Silva, 2014
Momordica charantia L.	Cucurbitaceae	Licken Plaw	Fruits	Peptic Ulcer; Yellow Fever; Jaundice; Diabetes; Infertility; Dysmenorrhea	Fruits, whole plant	Jiofack, 2010; Oladunmoye, 2011; Tsabang et al, 2017; Sharaibi et al., 2017

Monodora myristica (Gaertn.) Dunal	Annonaceae	Rheumatisms	Seeds	Hypercholesterolemia; Antimicrobial; Skin diseases; Anti-inflammatory; Anthelmintic; Antioxidant	Seeds, bark	Egharebva et al., 2008 Lino & Deogracious, 2006; Adewole et al., 2013; Akinwunmi K & Oyedapo, 2015; Ekeanyanwu, 2012; Moukette et al., 2015; Onyenibe et al., 2015
Moringa oleifera Lam.	Moringaceae	Hepatitis B	Leaves	Cardiac and circulatory stimulant; Antitumor; antipyretic; antiepileptic; anti-inflammatory; antiulcer; antispasmodic; diuretic; antihypertensive; cholesterol lowering; antioxidant; antidiabetic; hepatoprotective; antibacterial; antifungal; Vitamin supplement; Acute rheumatism	Leaves, roots, seeds, bark, fruit, flowers and immature pods	Lawal et al., 2010; Anwar et al., 2007; Moyo et al., 2012
Newbouldia laevis (P.Bea.) Seen. Ex Bureau	Bignoniaceae	rheumatism, jaundice	roots	Antibacterial activity; Diarrhea; Dysentery; Sexually transmitted diseases, Jaundice; Antifungal; Anti-inflammatory; Antioxidant; Anti-arthritic; Menstrual disorders; Infertility	Leaves, roots, stem	Sharaibi et al., 2017; Akinpelu et al., 2009; Hoffman et al., 2004; Chukwujekwu et al., 2005; Woode et al., 2008
Ocimum gratissimum L.	Lamiaceae	Sinusitis, antibacterial effects	Leaves	Peptic Ulcer; Skin diseases; Antimicrobial	;	Egharevba & Ikhatua, 2008; Alebiosu et al., 2012; Ngassoum et al., 2003
Ocimum americanum L.	Lamiaceae	Sickle cell anemia	Leaves	N/A	N/A	N/A
Phyllanthus amarus Schum. Et Thonn.	Euphorbiaceae	Hepatoprotective effects	Leaves	Antidiabetic	Whole plant	Tsabang et al., 2017
Piper guineense Schumach.	Piperaceae	Rheumatism	Fruits	Hypertension	Seeds, leaves	Mensah et al., 2009
Remirea maritima Aubl.	Cyperaceae	Hypocalcemia	Leaves	N/A	N/A	N/A
Rhaphiostylis beninensis (H. ex P.) Pl. Ex. Ben.	Icacinaceae	Sickle cell anemia	Leaves	Anti-inflammatory; antimicrobial; antitumoral	Roots, leaves	Ofeimun et al. 2014; Ofeimun & Mbionwu, 2014; Adebayo-Tayo et al., 2011
Securinega virosa Roxb. Ex Willd.	Euphorbiaceae	Fever	Leaves	Antiviral; Antidiarrheal; antioxidant	Leaves, root bark extracts	Oladunmoye, 2011; Uzama et al., 2013; Magaji et al., 2007
Senna occidentalis (L.) Link.	Fabaceae	Hepatitis B	Leaves	Diabetes; Jaundice	Leaves, seeds	Etuk & Mohammed, 2008; Musa et al., 2011

Spondias mombin L.	Anacardiaceae	Hepatitis B	Leaves	Antiviral; Antibacterial; child birth aid; cough; sore throat; antimalarial; stomachache	leaves, fruits, root, bark, flowers	Okigbo et al., 2009; Adedokun et al., 2010; Aromolaran & Badejo, 2014
Triplochiton scleroxylon K. Schum.	Sterculiaceae	Threats of abortion	Leaves	Backache	N/A	Lawal et al., 2010
Verbena officinalis L.	Verbenaceae	Nervous tension, stress, gastritis, antitussives, rheumatism	Leaves	Antimicrobial; anti-inflammatory; analgesic; neuroprotective; hypnotic/ sedative; gastroprotective; hepatoprotective; anticancer; wound healing; antioxidant	stem, shoots	Lai et al., 2006; Turker et al., 2010
Vernonia amygdalina Delila	Asteraceae	Hemorroids, Licken Plaw	Leaves	Digestive; Poisoning; Diabetes; Laxative; Malaria; Wounds; Antispasmodic; Antibacterial; Whooping cough; Hemorrhoids, Measles, Jaundice, Chickenpox, antihypertensive	Leaves, juice	Jiofack et al., 2010; Oladunmoye, 2011; Lawal et al., 2010; Mensah et al., 2009
Vitellaria paradoxa C. F. Gaertn	Sapotaceae	Ulcer, cough	Seeds	Worms; Ulcers; Diarrhea	Bark, whole plant, seeds	Jiofack et al., 2010
Vitex doniana Sweet	Lamiaceae	Asthenia	Leaves	Gastroenteritis; HIV	Leaves, bark, root bark	Tietjen et al., 2016; Agunu et al., 2005
Xylopia aethiopica (Dunal) A. Rich	Anonaceae	Diabetes, hernia, cough	Seeds	Anthelmintic; Analgesic; Lactation inducer	Leaves, fruits, seeds, bark	Oladunmoye, 2011; Lawal et al., 2010; Sharaibi et al., 2017; Ekeanyanwu, 2012
Zanthoxylum zanthoxyloides Zepern. et Timler	Rutaceae	Toothache, ulcer	Fresh root bark	Antimicrobial; asthma	Dried fruits, bark, roots and leaves	Lawal et al., 2010; Ngassoum et al., 2003

in the rest of Africa, this plant is employed in a plethora of different illnesses, showing hypoglycemic, anti-hypertensive, antitumoral, antimicrobic and antioxidant effects (Adewole & Caxton-Martins, 2009; Zubaidi et al., 2023). The versatility of *Annona muricata* is remarkable, as it has been traditionally used to combat a wide range of health issues, reflecting its broad spectrum of biological activities. In Benin, the use of this plant for HBV treatment is particularly significant given the high prevalence of the disease. The traditional knowledge surrounding *A. muricata* highlights the potential for discovering new therapeutic agents from this plant, warranting further scientific investigation.

Citrus aurantium (Rutaceae), commonly called bitter orange, is also employed in the treatment of HBV. In particular, leaves extracts and fruits are helpful in HBV cases and are also administered to patients with sickle cell anemia. Conversely, evidence shows a different use of this plant in Africa, where is considered healing because of its antitumor, antimicrobic and antidiabetic properties (Suryawanshi, 2011). This wide range of applications illustrates the plant's diverse pharmacological properties and its importance in traditional African medicine. The use of *C. aurantium* in treating such a broad array of ailments signifies the plant's potential as a source of multiple therapeutic agents. Among other plants used against HBV in "La Croix" Hospital, we appoint: *Cymbopogon citratus* (Gramineae), *Moringa oleifera* (Moringaceae), *Senna occidentalis* (Fabaceae) and *Spondias mombin* (Anacardiaceae). Each of these plants has unique medicinal properties that contribute to their use in African traditional medicine in various diseases. For instance, *Cymbopogon citratus*, commonly known as lemongrass, is renowned for its antipyretic effects and potential antibacterial properties), while *Spondias mombin*, commonly known as hog plum, is used for its anti-inflammatory and antimicrobial effects (Okigbo et al. 2009; Adedokun et al., 2010; Aromolaran & Badejo, 2014).

Dysentery is another widespread burden in Africa, primarily caused to Shigella dysenteriae infection. This condition is characterized by a state of infection of the intestine, especially the colon, which is manifested by abundant diarrheal discharges, presence of blood, mucus and/or pus in the stool. Moreover, loss of fluids and minerals can lead to dehydration and electrolyte imbalances. Interestingly, dysentery, regardless of bacterial or amebic etiology, is treated with leaves of *Bosquiea angolensis* (Moraceae).

Eventually, *Securinega virosa* (Euphorbiaceae) is commonly used in Africa to treat various diseases, i.e. diarrhea and viral diseases. Indeed, a study of Uzama et al. (2013), showed that leaf extracts of this plant display very good antioxidant activities, which may be due to the presence of phenols and flavonoids. However, in Benin traditional medicine, *Securinega virosa* is exclusively used in cases of flu. Moreover, leaves of *Crateva religiosa* (Capparaceae) are considered powerful antibiotics, and are mostly employed in "La Croix" Hospital to cure different diseases with microbial etiology. Furthermore, this plant is also administered to patients with migraine, and herbal teas made from this plant are curative in cases of Lichen planus, an autoimmune disease affecting the skin, nails, hair, and mucous membranes (Mansouri, 2022).

The diverse applications of these plants underscore their significance in traditional medicine and the potential benefits of integrating traditional knowledge with modern scientific research to discover new treatments for various diseases.

4.2. Plants used in the management of diseases with other etiologies

In Benin, the utilization of medicinal herbs is not only used in the treatment of pathologies with microbial etiology. Rheumatism, a multifaceted condition encompassing a spectrum of discomforts or pains associated with the locomotor system, is not often precisely diagnosed, due to its diverse manifestations. However, despite the diagnostic challenge, several herbs are used to alleviate joint pain. Healers generally use massages on the part of the body affected by pain with a mixture of extracts from different plants. Among the most common plants used in these treatments, notable mentions include *Citrus limon* (Rutaceae), *Monodora myristica* (Annonaceae), *Newbouldia laevis* (Bignoniaceae) and *Piper guineense* (Piperaceae). *Citrus limon* is well known for its antimicrobial and antioxidant efficacy and stands out as a particularly versatile remedy. While it is commonly employed across Africa for alleviating symptoms of fever and sore throat, its extracts have also been found to offer relief in cases of arthritis, showing the adaptability of this plant in a broad spectrum of diseases (Otang & Afolayan 2016; Maroyi, 2013).

Another pathological condition that is normally treated with the help of medicinal herbs is hernia. This condition finds remedies in extracts derived from the roots of *Amorphophallus dracontioides* (Araceae) and *Anthocleista vogelii* (Loganiaceae). While the use of *Amorphophallus dracontioides* is quite unpopular in the rest of Africa, the beneficial effects of *Anthocleista vogelii* are well recognized, due to its richness in phytochemicals. Indeed, the plant is rich in secoiridoids and alkaloids, making it a potential remedy in a variety of clinical conditions, such as diabetes, malaria and other microbial infections, hypertension and inflammation (Anyanwu et al., 2015, Eta Okon et al., 2014).

Additionally, *Diospyros mespiliformis* ~~Hochst~~. belonging to the Ebenaceae Family, emerges as another noteworthy ally in the treatment of hernia. Despite its limited usage compared to other South African regions, *Diospyros mespiliformis* finds application not only as a pain reliever, but also as an antimicrobial agent and in digestive disorders (Mahwasane et al., 2013; Maroyi, 2013; Mabona et al., 2013).

Hematological diseases, particularly sickle cell anemia (SCA), represent a burden in Benin, affecting predominantly children. SCA is a life-threatening or chronically debilitating disease. 75% of children with sickle cell disease worldwide were born in sub-Saharan Africa, and 50-90% of affected children die before five years old (Esoh et al., 2021). Transfusion is an essential component in the management of patients with SCA, but the transfusion system is far from adequate (Diop & Pirenne 2021). For this reason, it is local opinion that medical herbs may be supportive for this disease. Leaves and fruits of *Citrus aurantium* are used in cases of anemia, as well as HBV as previously described. To give further examples, *Ehretia cymosa* (Boraginaceae) and leaves of *Ocimum americanum* (Lamiaceae) and *Rhaphiostylis beninensis* (Icacinaceae) are also thought curative for SCA.

To conclude, it is necessary to mention the management of diabetes in Benin, since this chronic disease has increased rapidly over the last years in sub-Saharan Africa. Despite the alarming trend, patients rarely self-monitor their glucose levels and not often adhere to medical recommendations, posing significant challenges to effective diabetes management. In response to these challenges, healthcare practitioners at "La Croix" Hospital have integrated various medicinal plants into diabetes management protocols, leveraging the therapeutic properties inherent in these botanical resources. *Anacardium occidentale* (Anacardiaceae) renowned for its antimicrobial and hypoglycemic properties, is employed in the treatment of diabetes both in Benin and other Southern states of Africa (Oyedemi et al. 2017). Similarly, *Xylopia aethiopica* (Anonaceae) is typically used for the preparation of herbal teas and has found favor among healthcare practitioners as a therapy for diabetes or cough. Interestingly, despite the well documented hypoglycemic effects of certain plants in other African regions, their utilization in Benin refers to a range of pathologies different from diabetes. For instance, *Clausena anisata* (Rutaceae), acknowledged for its hypoglycemic effects (Ojewole, 2002), finds application in Benin primarily in the treatment of sinusitis through nasal insufflation along with other plant extracts. Similarly, *Senna occidentalis* (Fabaceae) is one of the best characterized plants in Nigeria to treat diabetes (Etuk & Mohammed, 2008) nonetheless the same plant assumes a different therapeutic role in Benin, mostly serving as a treatment for HBV.

5. Safety of traditional herbal drugs

The safety of medicinal plants in Africa is a topic of significant importance due to the widespread reliance on traditional medicine across the continent. While many plants harbor proven therapeutic benefits, concerns regarding their consistency, purity, and potential toxicity remain. The absence of stringent regulatory frameworks in many African countries means that the quality control of these medicinal plants can be inadequate, leading to risks such as contamination, incorrect dosage, and interactions with conventional drugs.

The potential hazards associated with the consumption of herbal medicines are often underestimated, with contaminations posing one of the most significant risks. These contaminations include microorganisms, i.e. *Staphylococcus aureus*, *Escherichia coli*, *Salmonella* spp., *Shigella* spp., *Pseudomonas aeruginosa*, as well as toxins (Aflatoxin, bacterial endotoxins). Moreover, the presence of pesticides (Chlorinated pesticides, Organic phosphates, Carbamate insecticides and herbicides, Dithiocarbamate fungicide, Triazin herbicides) and toxic metals (Lead, Cadmium, Mercury, Arsenic), further increase the risk associated to herbal plants administration (Parle & Bansap 2006).

Another important aspect is ensuring the correct dosage of herbal plants. Understanding the pharmacokinetic profile of phytochemicals is mandatory to ensure their safe and effective prescription, thereby minimizing the potential for adverse interactions with other drugs and herbs (Barnes et al., 2003). However, there is a lack of knowledge about pharmacokinetics linked to poor scientific studies and inadequate reporting, exacerbating the challenge of ensuring safe herbs usage (Muhammad & Awaisu, 2008).

Therefore, considering these complexities and risks, it is crucial to establish comprehensive safety assessments. This necessitates conducting rigorous toxicological studies to ascertain the safety profiles of medicinal plants and developing standardized guidelines for their cultivation, harvesting, processing, and administration. By instituting robust regulatory mechanisms and fostering scientific research endeavors, African nations can safeguard public health while harnessing the therapeutic potential of their rich botanical heritage.

6. Conclusions

In this review, we described the health conditions of Benin and the use of medicinal plants in the treatment of various diseases, according to data collected in the hospital "La Croix". Certainly, Benin fully represents the socio-health condition of Africa and has allowed us to investigate the concept of phytotherapy in depth. The use of medicinal plants in Africa is a deeply rooted tradition, integral to the continent's cultural and healthcare practices. Traditional healers, often referred to as herbalists, play a crucial role in this practice, possessing extensive knowledge of the medicinal properties of local flora. These natural remedies are not only accessible and affordable but also provide a sustainable alternative to conventional pharmaceuticals. Considering the local use of medicinal plants, it appears that there is a more restricted and limited use of herbs, which are used more extensively in the rest of Africa, probably due to lesser knowledge of their potential. However, the major concerns regarding the safety of medicinal plants are common with other African states. The use of African medicinal plants also requires that investors and researchers establish the cytotoxicity of these compounds to ensure their safety and efficacy. Eventually, as interest in natural and holistic medicine grows globally, African medicinal plants are gaining recognition for their potential in contributing to global health and wellness.

Author contributions

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Marine mammals in the Gulf of Gaeta: an updated checklist with historical data

Nicola Maio[1]*, Francesco Pollaro[2], Adriano Madonna[3,4], Luigi Valerio[3], Agnese Petraccioli[1], Valerio Manfrini[5]

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***Correspondence:**
nicomaio@unina.it

Affiliation:
[1] Dipartimento di Biologia, Università degli Studi di Napoli Federico II, Napoli, Italia
[2] Centro Studi Ecosistemi Mediterranei, Perdifumo (Salerno), Italia
[3] Associazione Internazionale Progetti Ulisse, Sperlonga - Minturno (Latina), Italia
[4] Scuola Superiore di Tecnologia per il Mare – ITS Academy "G. Caboto" (Gaeta, Latina), Italia
[5] Associazione Zoönomia, 40100 Bologna, Italia

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Abstract

This work contains historical and modern records of marine mammals observed in the Gulf of Gaeta (Italy, Central Tyrrhenian). Eleven species of cetaceans were sighted, representing about 58% of the Italian and about 46% of the Mediterranean cetofauna. Four species are regularly sighted: *Balaenoptera physalus*, *Physeter macrocephalus*, *Stenella coeruleoalba*, and *Tursiops truncatus*. *Ziphius cavirostris, Orcinus orca,* and *Grampus griseus* are rare. Two species – *Eschrichtius robustus* and *Megaptera novaeangliae* – are occasional, while sightings of *Globicephala melas* and *Delphinus delphis* seem to have decreased dramatically based on recent surveys. The *Monachus monachus* presence, recorded with certainty in the past, is now to be ruled out. Recent sightings without photos that confirm the correct identification are to be considered doubtful.

Keywords: marine mammals, cetaceans, Mediterranean monk seal, gulf, checklist.

Riassunto

Nel presente lavoro sono riportate le segnalazioni, storiche e moderne, dei mammiferi marini osservati nel Golfo di Gaeta (Lazio). È stata documentata la presenza di undici specie di cetacei che rappresentano circa il 58% della cetofauna italiana e circa il 46% di quella mediterranea. Quattro specie sono avvistate regolarmente: *Balaenoptera physalus*, *Physeter macrocephalus*, *Stenella coeruleoalba* e *Tursiops truncatus*; *Ziphius cavirostris, Orcinus orca* e *Grampus griseus* sono specie rare. Due specie, invece, sono occasionali ovvero *Eschrichtius* *robustus* e *Megaptera novaeangliae*, mentre gli avvistamenti di *Globicephala melas* e *Delphinus delphis* pare siano diminuiti drasticamente sulla base di recenti survey. La presenza attuale di *Monachus monachus,* documentata con certezza in tempi storici, è ormai da escludere. Avvistamenti recenti, privi di documentazione fotografica che ne confermino la corretta determinazione, sono da considerarsi dubbi.

Parole chiave: mammiferi marini, cetacei, foca monaca, golfo, checklist.

Introduction

The Gulf of Gaeta is located in the central part of the Tyrrhenian Sea (Italy), the deepest basin of the western Mediterranean Sea (Astraldi and Gasparini, 1994). The gulf takes its name by the city of Gaeta (Lazio region). The waters of the gulf are affected by various threats such as urbanization, agriculture, animal husbandry, mussel and fish farming, shipyards, and tourist facilities (Aguzzi et al., 2012, Orlandi et al., 2014). This water body has always been interested by the presence of cetaceans, as evidenced by many documents, sightings, and beachings. In the past, there was also the *Monachus monachus* that has currently disappeared in Italy, except for a few sporadic sightings (Fioravanti et al., 2020).

As reported in Manfrini et al. (2022), in Italy, the first attempts to systematically collect data on cetacean mortality and beachings were made by the World Wildlife Fund through the "Cetacean Project" at the end of the 1970s, followed by the efforts of the Centro Studi Cetacei (CSC), the first Italian national stranding network, which was established in 1985 and started its nationwide activities in 1986 (Cagnolaro, 1985; Borri, 1995; Borri, 1997). To date, the activities of CSC are concentrated in central Adriatic Sea. Since 2006, the Interdisciplinary Center for Bioacoustics and Environmental Research (Centro Interdisciplinare di Bioacustica e Ricerche Ambientali, CIBRA) of the University of Pavia and the Museum of Natural History of Milan have added to the fundamental role played by the CSC. They were appointed by the Italian Ministry of the Environment and the Protection of the Territory and the Sea (Ministero dell'Ambiente e della Tutela del Territorio e del Mare) to collect cetacean stranding data. As part of this assignment, the Italian stranding network database (Banca Dati Spiaggiamenti, 2025) was created. In 2014, the National Center For Diagnostic Investigations Of Stranded Marine Mammals (Centro di referenza nazionale per le indagini diagnostiche sui mammiferi marini spiaggiati, C.Re.Di.Ma.) was established. This institute cooperates with other entities of the national strandings network that includes the Cetacean stranding emergency response team (CERT), the Mediterranean marine mammals tissue bank of the University of Padua, and the BDS.

Currently, in the Gulf of Gaeta, the International Association Ulysses Projects (Associazione Internazionale Progetti Ulisse, AIPU) contributes to the conservation and dissemination of the good practices for cetaceans and marine life in general. These efforts follow those by the Italian Naval League, Sperlonga Section (Latina).

Nowadays, researchers who want to study the fauna or flora in a specific area have to look for photos and videos posted on social networks by citizens. Indeed, the massive presence of citizens/tourists in almost every geographical region around the world represents a workforce that researchers cannot match. With their posts, they contribute significantly to the knowledge of the species present in a specific area, and this is particularly true with cetaceans, which have always attracted the attention of the general public. However, all data posted on social media must be carefully

screened and validated by researchers and experts (Pace et al., 2019).
The work aims to provide a review of marine mammals data in the Gulf of Gaeta (Middle Age to present), from beachings, social media, and museums, to contribute to the knowledge of local species and prepare potential conservation programs.

Materials and Methods

The checklist we propose includes marine mammal species that, based on historical and modern data collected up to 2023, are observed regularly, rarely, and occasionally in the Gulf of Gaeta. Regular cetaceans are the species regularly present in the Italian seas – according to the biogeographical sectors adopted by the Italian Society of Marine Biology (Società Italiana di Biologia Marina, SIBM) – and in the Mediterranean Sea (Cagnolaro et al., 2015). Occasional (vagrant) is a species represented by individuals found outside their native range, appearing in a given region with high or extreme rarity (Notarbartolo di Sciara and Tonay, 2021).
For taxonomy, we have referred to the List of Marine Mammal Species and Subspecies of the Society for Marine Mammalogy (last updated June 2024; List of Marine Mammal Species and Subspecies, 2025). For the taxonomic names discussed, we adopted the most conservative option provided by Loy et al. (2019). Regarding the English common names and conservation status of each species, we referred to the IUCN Red List (IUCN Red List, 2025). For Italian names, we referred to Loy et al. (2019).
We collected data from three sources: 1) photos/videos uploaded on the Web by citizens 2) national databases of past and recent cetacean strandings 3) historical archives of all national museums of natural history and zoology. For the first source, we identified photos and videos of cetacean sightings in the Gulf of Gaeta uploaded to social networks. Then, we contacted the authors to obtain more information and verify the reliability of the data. For the second source, we relied on the two national databases, BDS and GeoCetus database of the Centro Studi Cetacei (Di Lorenzo et al., 2013; GeoCetus, 2025).
Finally, we consulted the archives of all Italian museums of natural history and zoology, in particular the Municipal Museum of Zoology and Museum of Comparative Anatomy "Battista Grassi" in Rome, and Zoological Museum in Naples (Podestà et al., 2008; Cagnolaro et al., 2012, 2014, 2015; Maio et al., 2014; Manfrini et al., 2022).

Study area

The borders of the Gulf of Gaeta are the Cape Circeo, Aurunci Mountains, and Roccamonfina Volcano in the northern sector; the Apennine fold and thrust belt in the eastern sector; the Neapolitan volcanic complex (Ischia and Procica Islands and the Gulf of Naples) in the southern sector; the Pontine Islands to the west (Figure 1). The geomorphological and geophysical features of the Gulf are related to the Volturno River and its flow rate. The last sector of the Volturno River crosses the Campanian plain, flowing into the town of Castel Volturno, where its mouth is. The bottom of the Gulf of Gaeta is a typical continental shelf. Quaternary clastic and volcanic deposits gradually slope westward, deepening abruptly to a depth of 120 m. In the Gulf of Gaeta, water circulation, similar to that of the Tyrrhenian Sea, is characterized by two seasonal currents that influence coastal circulation, such as coastal morphology and submerged morphostructures (Cavaliere et al., 2023). Within the Gulf is the Canyon of Cuma, a deep and wide underwater valley that starts from areas near the Campi Flegrei and reaches a maximum depth of 800 m between the islands of Ischia and Ventotene. This canyon represents a big sedimentary basin for the materials transported along the coast by the Volturno and Garigliano Rivers, and most importantly, it increases the upwelling velocity. Also, it acts as a conveyance channel to the sea. Sedimentation and hydrodynamic phenomena characteristic of canyons create a peculiar habitat characterized by a high local density and diversity of benthic and pelagic fauna (De Pippo et al., 2000).

Figure 1. Study area.
(Basic cartographic layer ESRI Ocean URL https://services.arcgisonline.com/ArcGIS/rest/services/Ocean/World_Ocean_Base/MapServer/tile/%7Bz%7D/%7By%7D/%7Bx%7D; Map by S. Viglietti).

Results

Historical Data

Archaeological findings dating back to the Middle Age and linked to the maritime culture of the cities in the Gulf of Gaeta showed the presence of large cetaceans in the study area. In the churches and cathedrals of Gaeta (Figures 2a-b) and Minturno (Latina), and those of Sessa Aurunca (Caserta), bas-reliefs on white marble slabs outside and inside, dating back to the 12th-13th centuries, are still preserved, depicting episodes from the biblical book of the prophet Jonah being swallowed and spat out by the "Pistrice-Leviathan" identified with the "Whale" whose tradition derives from the classical Greco-Roman Age. Fin whales (*Balaenoptera physalus*) and sperm whales (*Physeter macrocephalus*) have inhabited the

Gulf since the 19th century. Oronzio [= Oronzo] Gabriele Costa (1787-1867), Professor of Zoology at the University of Naples, was the first zoologist to provide a preliminary description of cetofauna of the Southern Italy seas in a monograph on the Mammals of the Kingdom of Naples. In particular, Costa (1839) described the presence, as mementos and relics, of "bones religiously preserved in the Church of Gaeta (ossami che religiosamente conservasi nella Chiesa di Gaeta)" (Maio & De Stasio, 2014; Maio et al., 2023a, 2024).

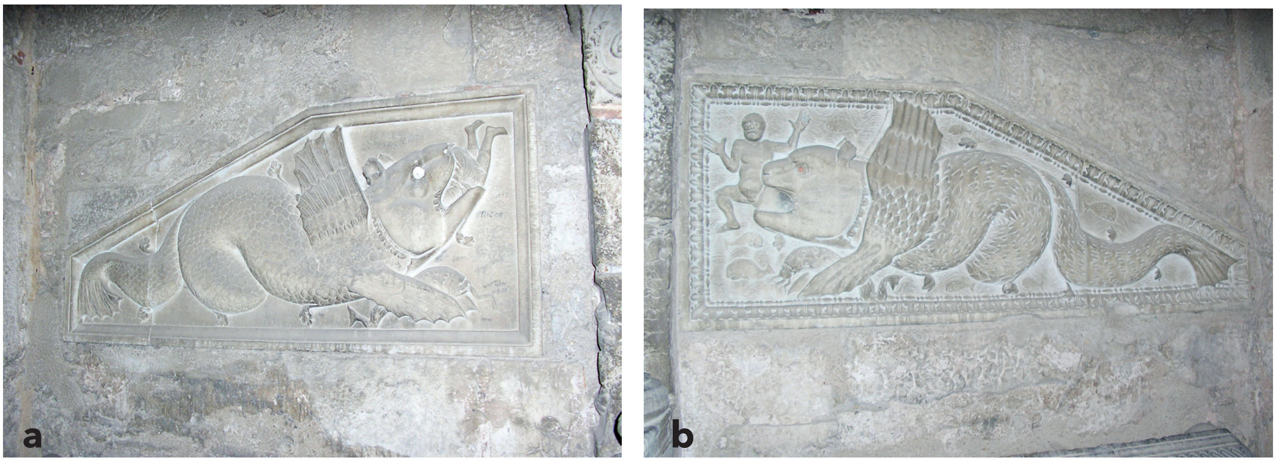

Figure 2. Bas-reliefs on the exterior of the Cathedral of Sants Erasmo and Marciano and St. Maria Assunta in Cielo in Gaeta, dating back to 12th-13th centuries, depicting the "Pistrice/Leviathan"; a) Left side of the entrance b) Right side of the entrance. Photo by N. Maio.

Two lower jaw fragments of *Balaenoptera* spp. (Figures 3a-b) are in the Cathedral of Sants Erasmo and Marciano and St. Maria Assunta in Cielo in Gaeta. Since the 1940s, the presence of *Balaenoptera* spp. has been recorded. These findings could be the same as Costa's citation or recent. In any case, they represent historical documentation of the presence of cetaceans in the Gulf.

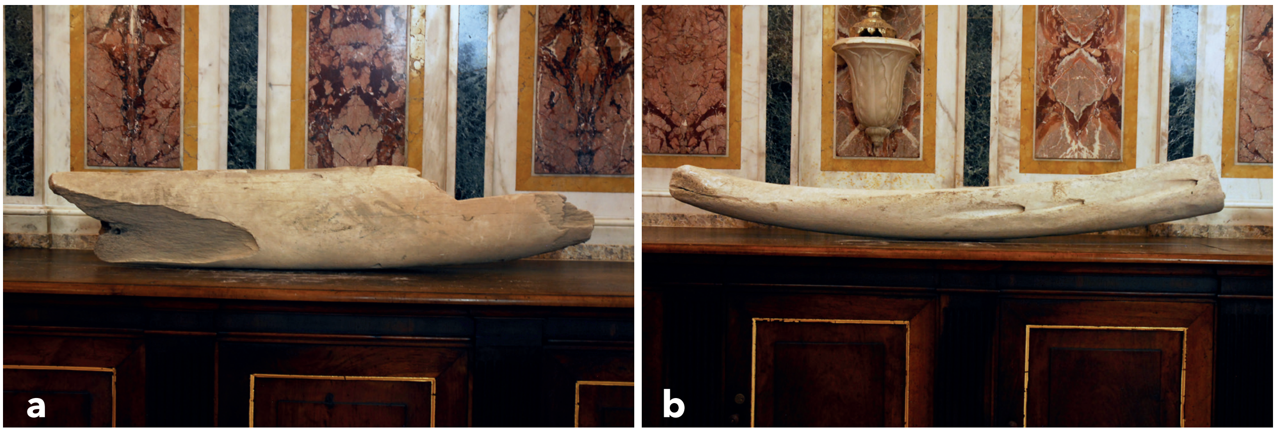

Figure 3. Two lower jaw fragments of Balaenoptera spp. preserved in the Cathedral of Sants Erasmo and Marciano and St. Maria Assunta in Cielo in Gaeta. Photo by A. Madonna.

Current cetofauna

Cetartiodactyla Montgelard, Catzeflis & Douzery, 1997
Cetacea Brisson, 1762
Mysticeti Flower, 1864

Family Balaenopteridae Gray, 1864

Balaenoptera physalus (Linnaeus, 1758) – Balenottera comune – Fin whale
Endangered Global and Mediterranean (Last assessment 2021)

Common species. Sightings are concentrated mainly north of Ischia Island, in the Cuma Canyon, a feeding site during summer (Mussi & Miragliuolo, 2003; Maio et al., 2019). Single individuals and pairs are observed, while larger aggregations are rare (Mussi et al., 1997, 1998; Mussi & Miragliuolo, 2003). Several beachings with even large individuals have been recorded since 1996 (Maio et al., 2001; Maio & Quercia, 2006; Manfrini et al., 2022). No breeding events, sightings, or beachings of calves or juveniles are known (Maio et al., 2024).

Megaptera novaeangliae (Borowski, 1781) – Megattera – Humpback whale
Least concern Global (Last assessment 2018)

Occasional species. A humpback whale juvenile was photographed on 20 July 2016, north of Procida Island (Naples) (Maio et al., 2019a, 2019b; Maio et al., 2024).
Family Eschrichtiidae Ellerman & Morrison-Scott, 1951

Eschrichtius robustus (Lilljeborg, 1861) – Balena grigia – Gray whale
Least concern Global (Last assessment 2017)

Occasional species. On 14 April 2021, a Gray whale juvenile was sighted near Ponza Island (Lazio). It was the first sighting in the Italian seas (Manfrini et al., 2023). Then, it reached Baia (Bacoli) and Sorrento in the Gulf of Naples and then ascended toward Gaeta on April 19 of the same year (Figures 4). Considering its peculiar feeding behavior, it is presumable that the animal traveled the stretch between the Gulf of Naples and Gaeta under the coast to feed. Also, the same individual was observed in Fiumicino (Lazio), Viareggio (Tuscany), the Ligurian Sea, the Provençal coast (France), and the Valencian coast (Spain). The last documented sightings were in May 2021 near the Balearic Islands (Spain) (Maio et al., 2023b; Maio et al., 2024).

Figure 4. Close-up of the gray whale. Source: https://napoli.repubblica.it/cronaca/2021/04/18/news/balena_di_sorrento_ancora_un_avvistamento_stavolta_nelle_acque_del_porto_di_baia-296941399/

Odontoceti Flower, 1867

Family Physeteridae Gray, 1821

Physeter macrocephalus Linnaeus, 1758 – Capodoglio – Sperm whale
Endangered Mediterranean (Last assessment 2006)

It is a common species, although difficult to observe. Sightings mainly concern single individuals, while larger aggregations (e.g., three individuals) are rare. Most reports are concentrated in summer and autumn, especially in the Canyon of Cuma, between Ventotene and Ischia Islands (Mussi et al., 1997, 1998; Pace et al., 2014; Figures 5a-d).

The first record of the species dates back to 1821, concerning the sighting of an individual in the Gulf mentioned by Giuseppe Sanchez (1827). In 1979, a sperm whale (about 9 m long) was captured in Gaeta (L. Cagnolaro, pers. comm.). In 1980, the beaching of a 5.50 m calf near Terracina and the capture in a net of a second calf (6.5 m long) in Gaeta in 1982 indicated a possible nursing area for the species (L. Cagnolaro, pers. comm.; figures 6a-b). The last beaching in the study area dates back to 2021 (Maio et al., 2024).

Figure 5. Sperm whale observed in the Cuma Canyon, between Ventotene and Ischia Islands. Photos by R. Gabriele.

Figure 6. Sperm whale captured in July 1982 near Gaeta. Photos by G. Soccorso, C. Di Nitto, pers. comm.

Family Delphinidae Gray, 1821

Stenella coeruleoalba (Meyen, 1833) – Stenella striata – Striped dolphin
Vulnerable Mediterranean (Last assessment 2010)

It is the most common species in the study area, sighted most frequently in late summer (August - September), often with *Delphinus delphis* and *B. physalus* with groups of up to 200 individuals (Mussi et al., 1997; Mussi & Miragliuolo, 2003). Both sightings and beachings confirm that the species use the Cuma Canyon as a breeding site during the summer, although a second breeding period in late winter or early spring is likely (Mussi & Miragliuolo, 2003). One beached individual was a newborn less than a year old, ranging in size from 100 to 140 cm, suggesting that this species probably uses the study area as a nursery in addition to giving birth (Maio et al. 2012, BDS, Guarino et al., 2021). There were at least five reports of beached animals still alive. Of three individuals it was possible to recover the skull for musealisation (Maio & De Stasio, 2014). In recent years, following diagnostic investigations conducted by the "Istituto Zooprofilattico Sperimentale del Mezzogiorno" (IZSM, public health control institution) in collaboration with other Italian "Istituti Zooprofilattici Sperimentali", three beached individuals tested positive for Dolphin Morbillivirus (DMV) (a male from Giugliano, Campania, in 2013, a female

Figure 7. Common bottlenose dolphins in the Gulf of Gaeta. a) Photo by N. Maio b) Photo by R. Gabriele c) Photo by L. Valerio.

and a male in Bacoli in 2021). The latter two individuals tested positive for *Herpesvirus*, and the male also for *Toxoplasma gondii* (Casalone et al., 2014; Fernández-Escobar et al., 2022; Giorda et al., 2022; Grattarola et al., 2023; Vargas-Castro et al., 2023; F. Di Nocera, pers. comm.; W. Mignone, pers. comm.).
The male from Giugliano died of infectious diseases and was 19 years old, as determined by skeleton-chronological survey. It supports the hypothesis that the longevity of the individuals examined is much lower, probably due to the diseases they suffered from (Guarino et al., 2021; Maio et al., 2024).

Tursiops truncatus (Montagu, 1821) – Tursiope – Common bottlenose dolphin
Vulnerable Mediterranean (Last assessment 2009)

Common species. Sightings are concentrated along the lower sandy coast of the Gulf of Gaeta, including the mouths of the Garigliano and Volturno Rivers, as far as Monte di Procida (Figures 7a-c). The species is sighted all year round with a greater frequency in summer, with groups of up to 200 individuals (Mussi et al., 1997; Mussi & Miragliuolo, 2003). Data from Mussi & Miragliuolo (2003) confirm that common bottlenose dolphins also choose the area for breeding: newborns have been observed in summer with a peak in August (Mussi et al., 1997, 1998). Diagnostic surveys conducted by the IZSM found two beached individuals positive for DMV: a male in 2017 and a female in 2019 both from Mondragone (Caserta); the latter individual also tested positive for *T. gondii* (Giorda et al., 2022; F. Di Nocera, com. pers.; W. Mignone, com. pers.; Maio et al., 2024).

Delphinus delphis Linnaeus, 1758 – Delfino comune – Short-beacked common dolphin
Endangered Mediterranean (Last assessment 2003)

Rare species. Since 1997, its presence has been documented in the Cuma Canyon (Mussi et al., 1998). The presence of newborns and juveniles suggests that the Gulf is a breeding area during the summer (Pace et al., 2015; Maio et al., 2024; figures 8a-b); however, this species is difficult to observe.

Figure 8. a) Adult Short-beacked Common dolphin. b) Female with calf. (Photos by R. Gabriele).

Globicephala melas (Traill, 1809) – Globicefalo – Long-finned pilot whale
Endangered Global and Mediterranean (Last assessment 2021)

Rare species. In the 1990s, was observed in the waters of the Pontine Islands with pods composed of 6 to 35 individuals, even with juveniles (Mussi et al., 1997, 1998). It has subsequently become rare. In recent years, no sightings in the Gulf have been reported (Maio et al., 2024).

Grampus griseus (G. Cuvier, 1812) – Grampo – Risso's dolphin
Endangered Global and Mediterranean (Last assessment 2020)

Rare species. In the 1990s, pods of about 7-10 individuals, both adults and females with young, were observed in the area Northwest of Ischia: the largest aggregations were 40 individuals, usually a few kilometers from the coast in September, sometimes in association with striped dolphins *Stenella coeruleoalba* (Figure 9). The presence of newborns has been observed in spring and summer (Mussi et al., 1997; Mussi & Miragliuolo, 2003). Only two documented beachings are known: in 1987 in Formia and in 1991 in Gaeta, whose skeletons were preserved in the Museo Civico di Zoologia in Roma (Cagnolaro et al. 2012, 2014; Maio et al., 2024).

Figure 9. Risso's Dolphin in association with Striped Dolphin (Photo by R. Gabriele).

Orcinus orca (Linnaeus, 1758) – Orca – Orca/Killer whale
Critically endangered Global and Strait of Gibraltar subp. (Last assessment 2019)

Rare species. Bompar (2000) reports the sighting of a pod of about 12 specimens in July 1987 between Ponza and Ventotene Islands (Cagnolaro et al., 2015).

Family Ziphiidae Gray, 1865

Ziphius cavirostris G. Cuvier, 1823 – Zifio – Cuvier's beaked whale
Data deficient Mediterranean (Last assessment 2006)

Rare species. There is only one report of an individual found off Ponza Island in 1989 in an advanced state of decomposition (BDS). For the central Tyrrhenian Sea, there is only one report for the Gulf of Naples in 1989, one month before the Ponza report, and a further six reports for the Lazio Region between 1988 and 1999 (Podestà et al., 2006).

Carnivora Bowdich, 1821
Caniformia Kretzoi, 1938
Pinnipedia Illiger, 1811

Family Phocidae Gray, 1821
Subfamily Monachinae E. L. Trouessart, 1897

Monachus monachus (Hermann, 1799) – Foca monaca mediterranea – Mediterranean monk seal
Critically endangered Mediterranean (Last assessment 2008)

Regionally extinct species. The oldest traces of its presence date back to 1836, when Oronzio Gabriele Costa (1787-1867), professor of zoology at the University of Naples, states in "Statistica Zoologica" (Costa, 1836): «la Foca monaca e vitellina appariscono a quando a quando sulle coste del regno provvenienti dall'Arcipelago» [the Monk (*M. monachus*) and Common (cfr. *Phoca vitulina*) seals appear from time to time on the coasts of the Kingdom (of Naples) from the Archipelago (presumably referring to the Pontine Neapolitan or Campanian Archipelago)]. Cornalia (1870) in "Fauna d'Italia" states: «Nel 1863, ne fu preso un individuo all'Isola di Ponza» [In 1863, an individual was captured on the Ponza Island]. Furthermore, a juvenile was caught and photographed on Ponza

Figure 10. Capture of a Monk seal, Ponza Island, 1872-1921. Unidentified author, slide on glass plate, hand staining of Giorgio Roster (© Collezione Archivi Alinari-archivio Roster, Florence).

between 1872 and 1921 (Figure 10). There are also several recent testimonies by fishermen from 1975 until 2009, such as the sighting of a specimen in late summer-early autumn in the "Grotta dei Siluri" (Gaeta) (D'Amante, pers. comm.) (De Luca A., 2025; Anonimous, 2009; Lambertucci, 2024). However, without photos, these records cannot be confirmed.

Discussion

To date, four cetacean species are sighted regularly in the Gulf of Gaeta: *Balaenoptera physalus*, *Physeter macrocephalus*, *Stenella coeruleoalba*, and *Tursiops truncatus*, and (Maio et al., 2001, 2006, 2012, 2019a, 2023a; 2023b). *Eschritius robustus* and *Megaptera novaeangliae* are occasional, as in the Mediterranean basin, while sightings of *Globicephala melas* and *Delphinus delphis* seem to have drastically decreased. Finally, *Ziphius cavirostris, Orcinus orca,* and *Grampus griseus* are rare despite the presence of the Canyon of Cuma in the Gulf, a potential foraging area for these species. However, for these species with elusive behavior, much depends on the research effort in the field. So, eleven cetacean species have been recorded

in the gulf, representing about 58% of the Italian cetofauna (19 species) and about 46% of the Mediterranean cetofauna (24) (Maio, 2015; Loy et al., 2019; Cozzi et al., 2021).
The presence of *Monachus monachus*, recorded in the past, is to be excluded. Recent sightings without photos are doubtful and, in any case, would only demonstrate a casual passage of individuals, not their settlement or attempted reproduction as occurred in Apulia (Southern Italy) (Fioravanti et al., 2020).
Overall, local data confirm regional and national ones, with the relative abundance of *S. coeruleoalba* and *T. truncatus*, the most common species in the Mediterranean Sea (Maio, 2015; Loy et al., 2019). The high frequency of calves suggests that females of these species use the gulf to deliver and as a nursery site (Mussi et al., 1997; Mussi & Miragliuolo, 2003; Guarino et al., 2021; Maio et al., 2019a, 2023a, 2023b). The most interesting data is the sighting of the *E. robustus*, which has never been observed in Italian seas before (Manfrini et al., 2023). In the Mediterranean, the species was present in the 4th-6th century AD (Rodrigues et al., 2018). Recently, there have only been two reports dating back to May 2010, off the coast of Israel and the Catalan coast in Spain (Scheinin et al., 2011).
Note the detection of DMV, *Toxoplasma gondii*, and Herpesvirus in a *S. coeruleoalba* and DMV and *T. gondii* in a *T. truncatus*. These reports are essential for public health safety because these pathogens are zoonotic agents (Casalone et al., 2014; Fernández-Escobar et al., 2022; Giorda et al., 2022; Grattarola et al., 2023; Vargas-Castro et al., 2023; F. Di Nocera, personal communication; W. Mignone, personal communication). At the "Dipartmento di Biologia" of the "Università di Napoli Federico II", in cooperation with the "Università Politecnica delle Marche", molecular analyses are currently underway to identify the geographical origin of beached individuals and specimens preserved in museum collections (Fioravanti et al., 2022; Maio et al., 2022; Fioravanti et la., 2024a, 2024b, Latini et al., 2024) and studies on the determination of their age and growth rates to understand the population structure of the various species in their natural environment (Guarino et al., 2021).
Finally, the results obtained are useful for assessing the health status of these species and contribute to the development of effective management and conservation plans for the species in the study area and central Tyrrhenian Sea.

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Author contributions
Conceptualization: N.M., V.M.
Data curation: N.M., F.P.
Formal analysis: N.M., V.M.
Investigation: N.M., A.P.
Project administration: N.M.
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Bulletin of Regional Natural History

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Nomenclatural remarcks on *Galdieria* (Galdieriaceae, Cyanidiophytina, Rhodophyta) with description of three new species and a new lectotypification.

Del Guacchio E.[1,2], Pollio A.[1,2], De Natale A.[1,2]*

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***Correspondence:**
denatale@unina.it
https://orcid.org/0000-0002-1481-449X

Affiliation:
[1]Department of Biology, Univesity of Naples "Federico II", Italy
[2]Società dei Naturalisti in Napoli, Naples, Italy

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There was an error in the original publication (Del Guacchio et al., 2023). When validating the names *Galdieria daedala*, *G. partita* and *G. maxima* on the basis of material strained in ACUF, the type localities cited in the protologues were incorrect, due to a clerical error in querying the ACUF database.

Namely, the holotype of *G. daedala* Sentzova ex Pollio, De Natale & Del Guacchio (i.e., NAP0002462), was NOT isolated "from URSS, Kamtchatka, Uzon" BUT from Kunashir Island (Kuril Archipelago); the holotype of *G. maxima* Sentzova ex Pollio, De Natale & Del Guacchio (i.e., NAP0002463), was NOT from "URSS, Kamtchatka, Uzon" BUT from Kunashir Island as well; and the holotype of *G. partita* Sentzova ex Pollio, De Natale & Del Guacchio (i.e., NAP0002464) was NOT isolated "from Kunashir Island" BUT from the caldera Uzon in Kamtchatka (Russia). The correct localities fully match the information originally provided by Sentzova (1991).

Fortunately, as the holotypes have been correctly and univocally indicated by barcode numbers, those errors do not compromise the validity of the names (Turland et al., 2018).

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