BORNH
ISSN 2724-4393
Volume 5 Number 1, 2025

BORNH Bulletin of Regional Natural History

Formerly **Bollettino della Societá dei Naturalisti in Napoli**

Bulletin of Regional Natural History (BORNH), formerly Bollettino della Società dei Naturalisti in Napoli, is an online peer reviewed open access journal from Società dei Naturalisti in Napoli that promotes studies dealing with environmental, natural and earth sciences at local and regional scale.

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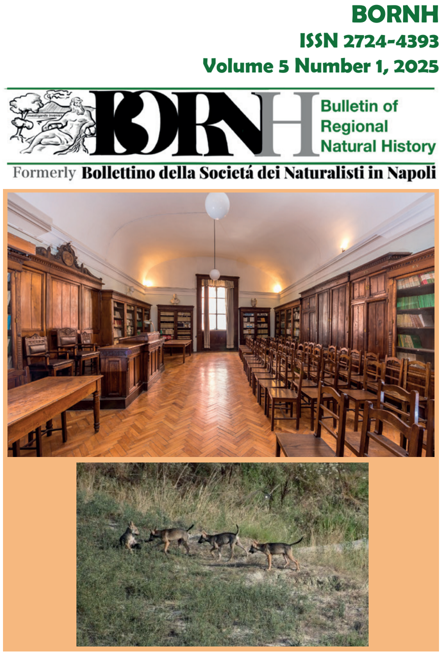

Volume 5, Number 1 2025

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The relict deposits of the Cilento offshore (Southern Tyrrhenian Sea, Italy) based on seismo-stratigraphic data

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DOI https://doi.org/10.6093/2724-4393/12459

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Competing interests: The Authors declare that they have no competing interests for this work.

Financial Disclosure Statement: the Authors declare that no specific funding was received for this work.

Submitted: 23 April 2025
Revised: 18 June 2025
Accepted: 20 June 2025
Published: 02 July 2025

Associate Editor:
Carlo Donadio

Abstract

Relict deposits (palimpsest and lowstand) deposits of the Cilento continental shelf were analyzed. Sub-bottom Chirp seismic sections were interpreted and calibrated with core data, previously known in literature. General seismo-stratigraphic framework has shown four main seismo-stratigraphic units, genetically related to the Cilento Group. The stratigraphic record of the palimpsest and lowstand deposits of the Cilento continental shelf is punctuated by significant stratigraphic surfaces, including the ravinement and the erosional surface of the acoustic basement, involved by wave-cut submarine terraces, carving the submerged portion of the Cilento Group. A seismo-stratigraphic unit with prograding clinoforms has been identified based on the seismo-stratigraphic interpretation and interpreted as genetically related to the MIS 4. These deposits are overlain by a seismo-stratigraphic unit, which is composed of coarse-grained organogenic sands, interpreted as relict sands, based on core calibration. The vertical stacking of these seismo-stratigraphic units forms sandy ridges (water depths of 130 m- 140 m), interpreted as submerged beach deposits, genetically related to the MIS 2 (Last Glacial Maximum; starting date 29 ky B.P.).

Keywords: relict deposits; seismo-stratigraphic units; Cilento offshore; Southern Tyrrhenian Sea, Italy.

Riassunto

In questo articolo vengono analizzati i depositi relitti (palinsesti e di stazionamento basso) della piattaforma continentale del Cilento. Le sezioni sismiche Sub-bottom Chirp sono state interpretate e calibrate con i dati di carotaggio, precedentemente noti in letteratura. L'assetto stratigrafico generale della piattaforma continentale ha mostrato la presenza di quattro unità sismo-stratigrafiche, geneticamente collegate con il Flysch del Cilento. Il record stratigrafico dei depositi palinsesti e di *lowstand* della piattaforma continentale del Cilento è caratterizzato da superfici stratigrafiche significative, che includono la superficie di *ravinement* e la superficie erosiva del basamento acustico, incisa da terrazzi marini (*wave-cut*), che erodono la porzione sommersa del Gruppo del Cilento. Un'unità sismo-stratigrafica con clinoformi progradanti è stata identificata in base all'interpretazione sismo-stratigrafica ed interpretata come geneticamente collegata al MIS 4. Tali depositi sono ricoperti da un'unità sismo-stratigrafica, composta da sabbie organogene grossolane, interpretata come sabbie relitte in base alla calibrazione con i dati di carotaggio. L'arrangiamento verticale di tali unità sismo-stratigrafiche forma dorsali sabbiose a profondità comprese tra 130 e 140 m, interpretate come depositi di spiaggia sommersa, geneticamente collegati al MIS 2 (Last Glacial Maximum; 29 ky B.P.).

Parole chiave: depositi relitti; unità sismo-stratigrafiche; terrazzi deposizionali sommersi; offshore del Cilento; Tirreno meridionale; Italia.

Introduction

This paper aims at analyzing the relict deposits of the Cilento offshore (Campania continental margin, Southern Tyrrhenian Sea). It is based on the geological interpretation of seismo-stratigraphic data, consisting of Sub-bottom Chirp profiles, calibrated by the result of a published sediment core (Ferraro et al., 1997). In the Cilento offshore, two kinds of relict deposits have been identified based on a previous geological interpretation of Sub-bottom Chirp profiles: the palimpsest deposits and the lowstand deposits (Aiello & Caccavale 2023). In this work, we complete the seismo-stratigraphic analysis of the relict deposits in the Cilento offshore (previously stated by Aiello & Caccavale 2023), interpreting further seismic sections to reconstruct the stratigraphic architecture of the Cilento offshore relict deposits.

Two types of sediments are present on continental shelves: sediments which are not in equilibrium with the present-day environmental conditions (relict sediments); and sediments which are in equilibrium with these conditions (Shepard, 1932; Emery, 1952; Curray, 1964; Emery, 1968; Belderson et al., 1971; Swift et al., 1971). The occurrence of coarse-grained sands, at a greater distance from the coast and at greater depths than fine-grained sands is an important evidence of the relict origin of sediments.

The concept of relict and palimpsest sediments has been deeply discussed by Swift et al. (1971). These authors have highlighted that the relict and the palimpsest sediments represent dynamic complexes in continuous modification, as a response to the actual depositional environment, and are controlled by the hydraulic regime. In this context, these deposits try to approach the equilibrium with the present-day environmental conditions. Using a stochastic process model for the simulations, several case histories in the continental margins of the world have been analyzed, including the high-energy, tide-dominated continental shelf deposits of the western Europe, undergoing an extensive reworking of the Pleistocene and Holocene transgressive deposits (Swift et al., 1971).

Orme (1982) discussed the concept of relict sediments in relationships to beaches and coastal geology. The present environment in which the relict sediments occur is not necessarily in equilibrium with the previous phases of sedimentation. It has been estimated that approximately 70% of the world's continental shelves are covered by sediment, which was deposited when the shelves were largely exposed due to low sea levels associated with the glacial maxima of the Pleistocene. The sediments accumulated in several environments (subaerial, littoral, lacustrine, fluvial, lagoon, shallow marine, and periglacial) and subsequently became submerged by the post-glacial deposits.

The relict deposits can be composed of organogenic sands, often associated with siliciclastic deposits. This happens also in the case of the Cilento offshore, where organogenic sands have been detected based on seismo-stratigraphic data calibrated with core results (Aiello & Caccavale, 2023). These data can be interpreted according to the zonation of benthic assemblages in the Mediterranean Sea (Peres & Picard, 1964; Carannante et al., 1998). In the Mediterranean Sea, bioclastic deposits have been detected at water depths ranging between 40 m and 100 m ("Detritique Cotier" of Peres & Picard 1964; Carannante et al., 1988; Aiello, 2021). They derive from the reworking of benthic communities and consequent deposition both on mobile seabeds (biocoenosis of the "Detritique Cotier") and on hard seabeds (biocoenosis of the "Detritique du Large"). Because of the sea level rise, the deep seafloor was overlain by relict and drowned sediments, characterized by slow sedimentation and by the presence of glauconite ("Detritique du Large"; Carannante et al., 1988; Aiello 2021).

Close to the study area, Aiello (2021) discussed the bioclastic deposits in the north-western sector of the Gulf of Naples, reporting rhodolith deposits occurring on the offshore of Ischia. Bioclastic deposits, consisting of coarse-grained volcanic sands with fragments of calcareous algae, medium-grained volcanic sands with fragments of echinoids and lamellibranch shells, and fine-grained sands with small bivalves, and gastropods, have been detected at several sectors of the Ischia Island. Abundant concretions of red algae also occur.

In this paper, further constraints on the stratigraphic architecture of the relict deposits of the Cilento continental shelf based on Sub-bottom Chirp profiles are provided, giving an up-to-date stratigraphic framework, useful for next planning, monitoring and management of the coastal zones of this sector of the Eastern Tyrrhenian margin.

Geological setting

The Cilento offshore is a structural high, corresponding to the seaward's prolongation of the Licosa Cape structural high, bounded northwards and southwards by the Salerno Valley and the Policastro Gulf half-grabens. The Salerno Valley is a half-graben basin, controlled in the Early Pleistocene by the Capri-Sorrento Peninsula extensional master fault, bounding southwards the Sorrento Peninsula, and offsetting the Meso-Cenozoic carbonate sequences up to 1500 m (Aiello et al., 2009). The morpho-bathymetric setting of the study area is shown by the Digital Elevation Model (Fig. 1), which has been constructed merging the bathymetric data previously recorded by the CNR ISMAR of Naples, Italy, during several oceanographic cruises, starting from 1998 (D'Argenio et al., 2004).

The Cilento offshore structural high has been the subject of geological and seismo-stratigraphic studies, since the end of the 90s, when the interpretation of seismic profiles showed wide structural highs, characterized by an acoustically-transparent to chaotic acoustic facies (Trincardi & Zitellini, 1987; Aiello et al., 2011; Conti et al., 2017; Aiello et al., 2020; Dalla Valle et al., 2024; Aiello, 2024; Aiello & Caccavale, 2024). The stratigraphic architecture of the southern Campania continental margin is shown in Fig. 2 (Aiello et al., 2009). In particular, the geological interpretation of the seismic profile SAM4, from the Salerno offshore towards the structural high of the Cilento continental

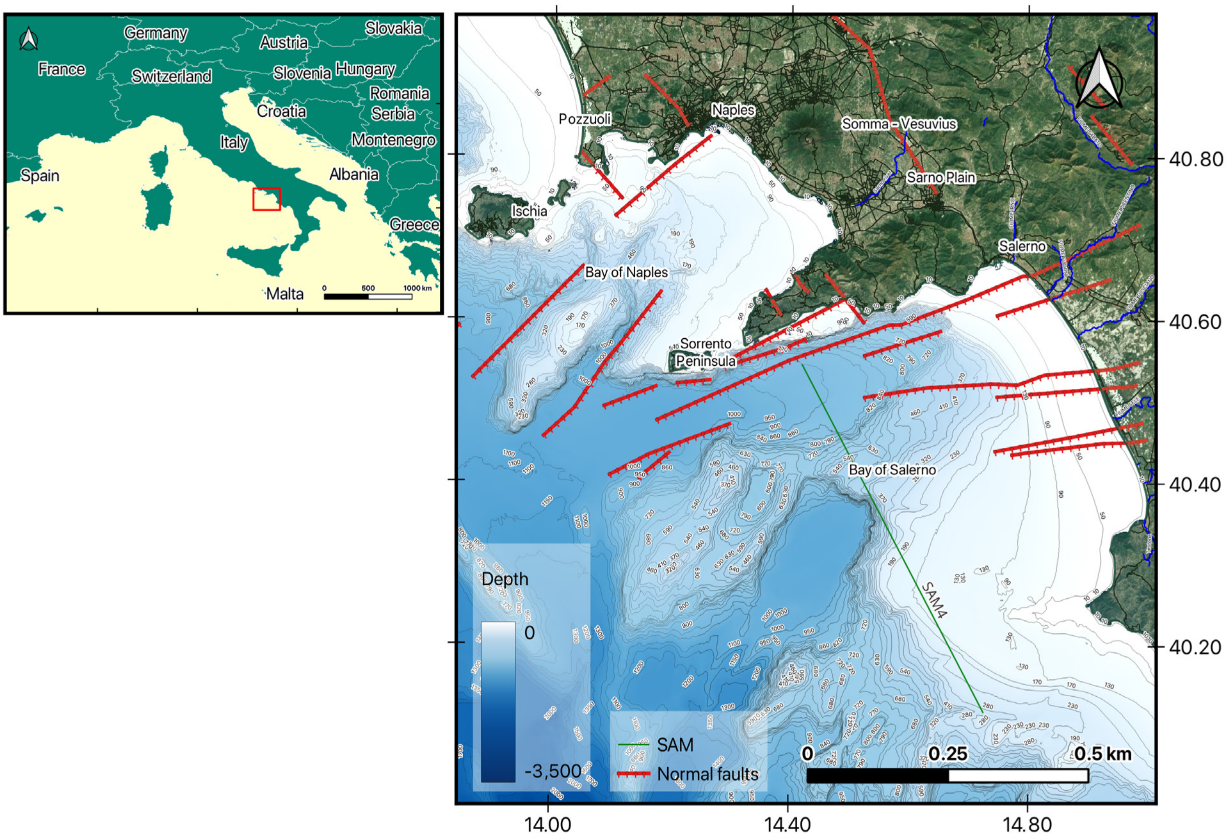

Figure 1: Digital Elevation Model of the Campania continental margin, including the Salerno-Cilento area. The location of the Naples and Salerno half-graben has been reported, coupled with the morpho-structural lineaments of the Campania continental margin. The source are the bathymetric data recorded by the CNR ISMAR of Naples, Italy, starting from the 1998 (D'Argenio et al., 2004).

shelf, shows the tectonic setting of the clastic multilayer, characterized by several normal faults. The seismo-stratigraphic units include Early Middle Pleistocene marine deposits (1 in Fig. 2), representing the bulk of the basin filling, and Late Pleistocene coastal and marine deposits (2 in Fig. 2). While the Early Middle Pleistocene seismo-stratigraphic unit is deformed by normal faults, the Late Pleistocene deposits are relatively undeformed and are characterized by progradational to parallel geometries in correspondence to the Cilento structural high and by parallel to subparallel geometries offshore of the Gulf of Salerno (Fig. 2). The acquisition of seismic profiles along the Tyrrhenian margin has confirmed this structural setting, highlighting how the Cilento structure is locally complicated by bending, reverse faults and basin inversion (Aiello et al., 2011; Conti et al., 2017; Zitellini et al., 2020; Loreto et al., 2021).

In the emerged sector of the Cilento Promontory, the siliciclastic sequences ascribed to the Cilento Group crop out and have been involved in the deformation of the Apenninic chain (Vitale & Ciarcia, 2018; Fig. 2). These sequences represent the rocky acoustic basement of the Quaternary deposits of the continental shelf from the Licosa Cape to the Palinuro Cape (Fig. 2). Marine landscapes and habitats of the Cilento Geopark have been previously investigated (D'Angelo et al., 2020), as well as submerged marine terraces (Ferraro et al., 1997; Savini et al., 2021; Aiello & Caccavale, 2024). Anomalous morphologies, genetically related with rhodolith beds and of a probable biogenic origin, are still in course of investigation in

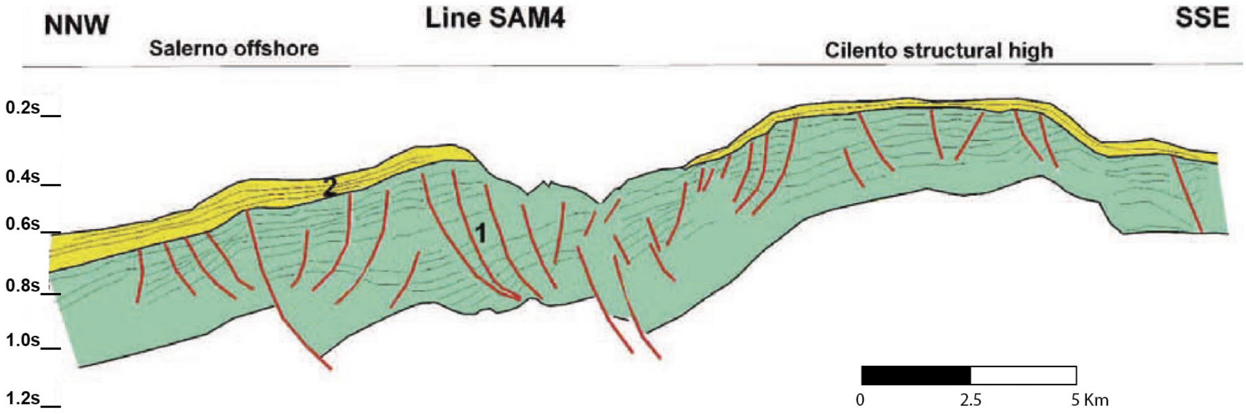

Figure 2: Line drawing of the multichannel profile SAM4, crossing the Salerno-Cilento area from the Salerno offshore towards the structural high of the Cilento continental shelf, already showing the stratigraphic architecture of the Campania continental margin (modified after Aiello et al., 2009). The location of the seismic profile is reported in Fig. 1. Vertical and horizontal scales have also been reported.

the frame of the CORSUB research project, funded by the Italian PRIN 2022 (Bazzicalupo et al., 2025). The morphological features have been divided into seven geoforms, including banks, ridges, fans, plains, ledges, terraces, boulder fields and boulder rocks, which, integrating information on the types of substrata and prevalent biota, have allowed for the identification of twelve landscape units in the 1:100.000 map (Martelli et al., 2016). These units have been grouped into 14 habitat units in the 1:30.000 habitat map (D'Angelo et al., 2020). The habitat map of the Licosa Cape area at the 1:30.000 scale has highlighted the occurrence of several submarine morphologies, including the spur of coralligenous bioconstruction, the wave-cut terraces with a mixed organogenic cover, the slopes with mixed organogenic sediments, the depositional terraces and the rocks. The habitat units genetically related to the coralligenous biota include the rocky banks, the banks with mixed organogenic sediments, the banks with a coarse-grained organogenic cover, the banks with a sandy organogenic cover, and the banks with a muddy cover. Subsequently, the wave-cut terraces offshore the Cilento Promontory have been studied based on the geological interpretation of high-resolution seismic profiles (Aiello & Caccavale, 2024), showing the complex morpho-structural setting of this area and the probable relationships with the tectonic uplift phases involving the Southern Apennines and the eustatic sea-level falls during the Late Quaternary.

Materials and methods

The relict deposits of the Cilento offshore have been analyzed through the geological interpretation of seismo-stratigraphic data, consisting of Sub-bottom Chirp profiles acquired during the oceanographic cruise GMS03_01 (R/V Urania, National Research Council of Italy) during the scientific and technical activities for the realization of the geological sheet n. 502 "Agropoli" at the 1:50.000 scale of the Italian Geological Survey (Martelli et al., 2016; Fig. 3). In this paper, we have considered and interpreted five seismic profiles (B51, B52, B53, BL15, BL29_2), whose location is reported in Fig. 3. The seismic processing of the Sub-bottom Chirp profiles has been carried out with the software

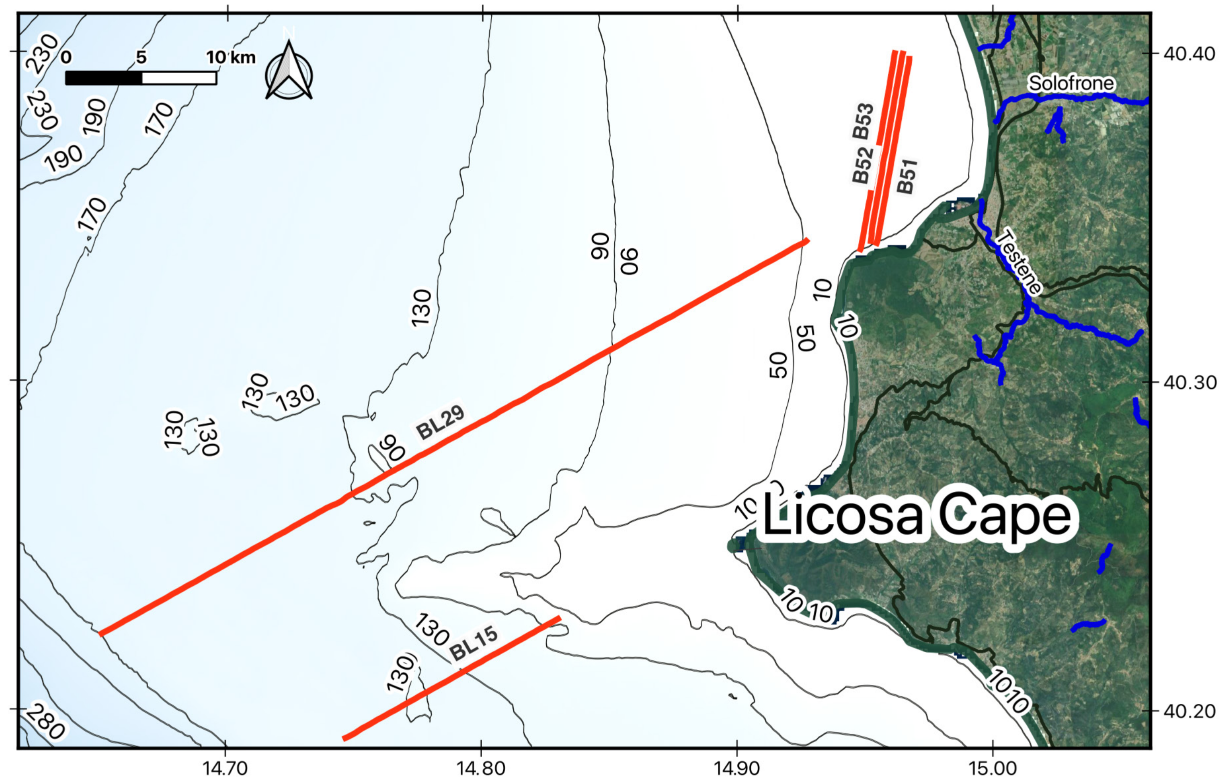

Figure 3: Location map of the seismic profiles analyzed in this paper (marked in bold red). The seismic profiles analyzed in this paper are respectively B51, B52, B53, BL 15, BL29.

Seismic Unix (SU), version SU44R28 (available online: https://wiki.seismic-unix.org/start), which has allowed a general improvement of the quality of the seismic sections and the production of the seismic sections as bitmap images. The main tasks in the processing of the seismic data were the exportation of the seismic traces from SEGY to SU, the analysis of the frequency of the seismograms, and the use of FFT (Fast Fourier Transform) to visualize and analyze the frequencies of the seismic signal. Furthermore, the implementation of a high-pass filter with a low-cut frequency of 150 Hz has removed the seismic noise and the dark signal. A uniform gain was built up for each seismic trace, while a time-variant gain filter was set up to further enhance both the seismic signal and the deeper seismic horizons and the entire visualization of all the seismic lines. The outcome of the processing procedure was the visualization of seismic profiles with Seismic Unix employing a graphic interface. In our interpretation, we refer to acoustic/seismic basement as a region of the subsurface showing a "strong" response to a seismic wave in the subsurface and represents the region beneath the deepest coherent or continuous seismic reflector or a stratified sedimentary succession.

The main lithological units in outcrop and the main landforms present offshore have been represented in the geological map (Fig. 4; Bonardi et al., 1988; Aiello et al., 2009; Vitale & Ciarcia, 2018; Guida & Valente, 2019; Aiello & Caccavale, 2021, 2022, 2023; Tursi et al., 2023). The source of the database used for preparation of the geological map is specified (Bonardi et al., 1988; Vitale & Ciarcia, 2018). We suggest which lithological units of the Cilento promontory could form the basis of the profiles in order to highlight a certain correlation between what has emerged and what is submerged, referring to the San Mauro and Pollica Formations (Fig. 4). These

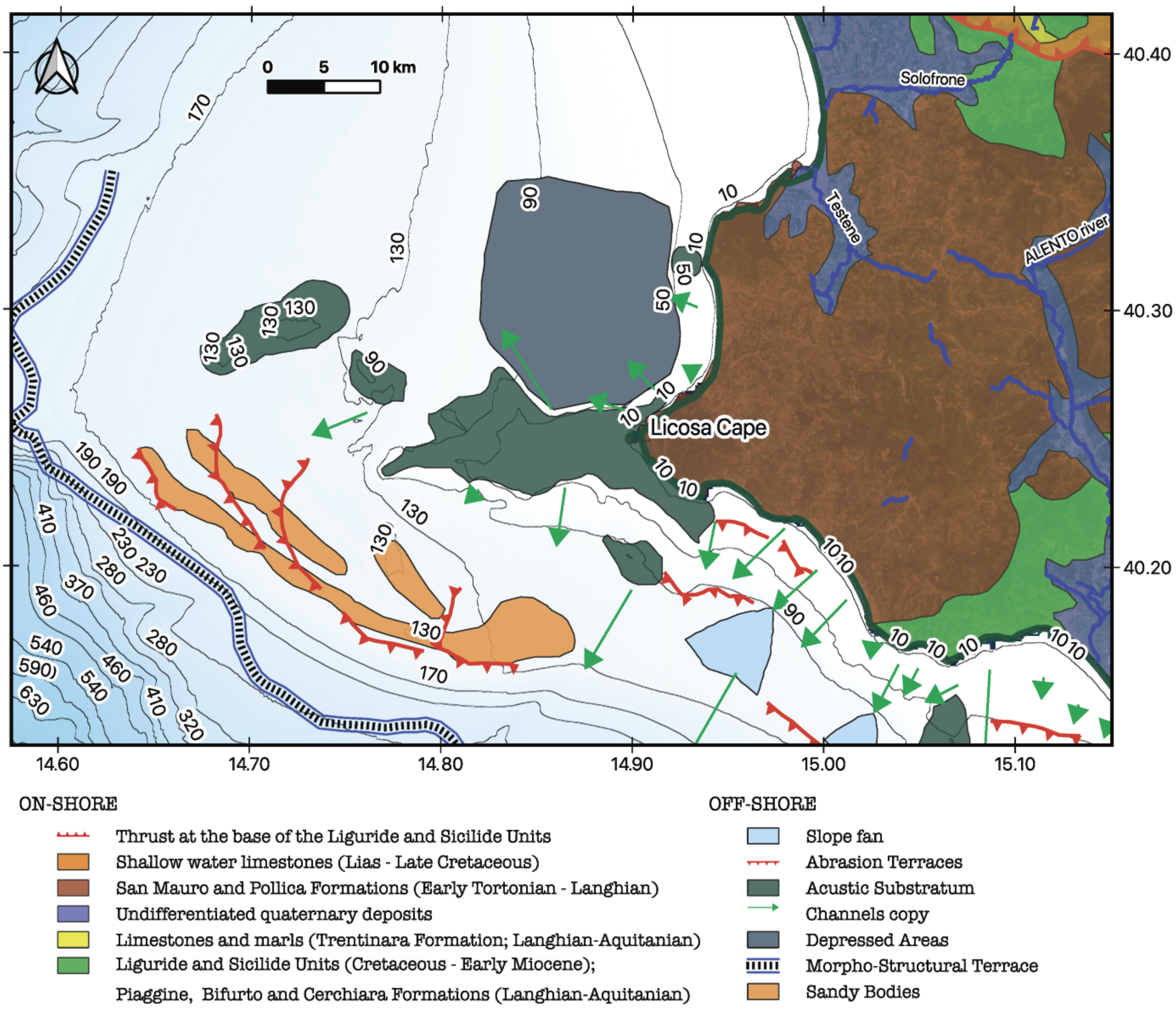

Figure 4: Geological map of the Cilento Promontory and geomorphologic map of the Cilento offshore (modified after Bonardi et al., 1988; Vitale and Ciarcia, 2018). Key. Onshore: Thrust at the base of the Liguride and Sicilide Units; Shallow water limestones (Lias-Late Cretaceous); San Mauro and Pollica Formations (Early Tortonian-Langhian); Undifferentiated quaternary deposits; Limestones and marls (Trentinara Formation; Langhian-Aquitanian); Liguride and Sicilide Units (Cretaceous-Early Miocene); Piaggine, Bifurto and Cerchiara Formations (Langhian-Aquitanian). Offshore: Slope fan; abrasion terraces; acoustic substratum; channels; depressed areas; morpho-structural terrace; sandy bodies.

lithological units could form the acoustic basement in the seismic profiles.

The geomorphological map of the Cilento offshore shows a wide continental shelf up to 250 meters deep (Fig. 4). While the continental shelf north of the Licosa Cape is flat, the marine area around the Licosa Cape is a E-W trending structural high, made up of remnants of terraced surfaces on rocky terrain (Aiello & Caccavale, 2024). They are especially prevalent in the bathymetric zone spanning 10 to 20 meters, though the rocky acoustic basement can reach 60 meters. A sudden break in slope from 60 to 80 m corresponds with the passage from the structural height of the Licosa Cape to the outer shelf. The mapped landforms include the outcrops of the acoustic substratum, the relict sandy bodies, the slope fans, the abrasion terraces, the morpho-structural terraces, the depressed areas, coincident with the depocenters, and the erosional channels, coupled with the rims of a wide submerged terrace (Fig. 4).

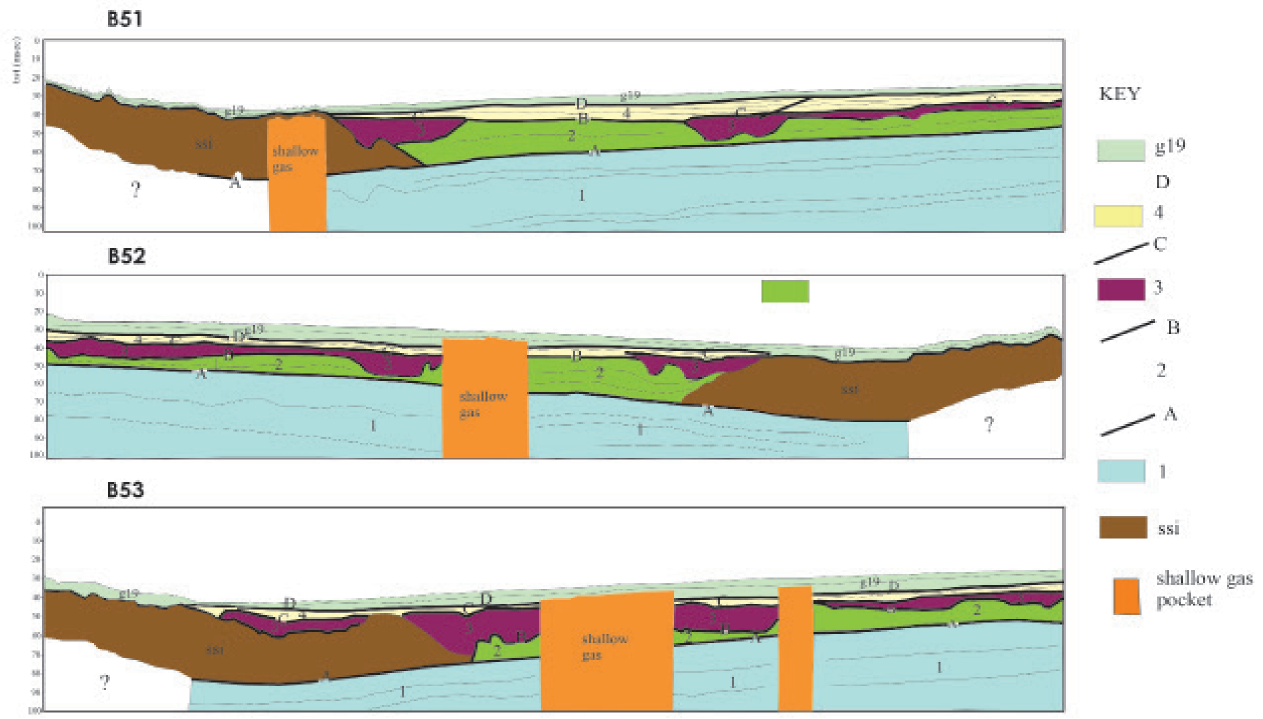

Figure 5: Seismic profiles B51, B52, and B53 and corresponding geological interpretation. Key: g19: Inner shelf deposits (Holocene); D: Regional unconformity located at the top of the seismo-stratigraphic unit 4; 4: seismo-stratigraphic unit 4; C: regional unconformity located at the top of the seismo-stratigraphic unit 3; 3: seismo-stratigraphic unit 3; B: regional unconformity located at the top of the seismo-stratigraphic unit 2; 2: seismo-stratigraphic unit 2; A: regional unconformity located at the top of the first seismo-stratigraphic unit; 1: seismo-stratigraphic unit 1; ssi: acoustic basement, genetically related to the Cilento Group; shallow gas pockets, suggested by wide acoustic anomalies in the seismic sections. The location of the seismic profiles is reported in Fig. 3.

Results

The general seismo-stratigraphic framework is outlined based on the geological interpretation of seismic profiles B51, B52 and B53, whose location is represented in Fig. 1. Six main seismo-stratigraphic units have been distinguished, separated by four regional or local unconformities (Fig. 5). The Cenozoic substratum (ssi), is composed of siliciclastic rocks, Cenozoic in age, genetically related to the Cilento Group and herein interpreted as the S. Mauro and Pollica Formations (Fig. 4); it corresponds to the acoustic basement of the sedimentary units. The first seismo-stratigraphic unit (seismo-stratigraphic unit 1) is characterized by an acoustically transparent seismic facies and a wedge-shaped external geometry, onlapping the Cenozoic substratum (ssi), Late Pleistocene in age. It is bounded by the reflector A, interpreted as a paraconformity or stratigraphic continuity. The second seismo-stratigraphic unit (seismo-stratigraphic unit 2) is characterized by an acoustically transparent seismic facies, and by a wedge-shaped external geometry, and rests in onlap the Cenozoic substratum (ssi). The reflector B represents a local unconformity, recognized at the top of the seismo-stratigraphic unit 2. The third seismo-stratigraphic unit (seismo-stratigraphic unit 3) is characterized by an acoustically transparent to chaotic seismic facies, and by a few discontinuous reflectors, representing the filling of intra-platform depressions and characterized by bidirectional onlaps on the underlying unconformity, probably Late Pleistocene in age. The reflector C represents a local unconformity, recognized at the top of pockets of coarse-grained residual materials,

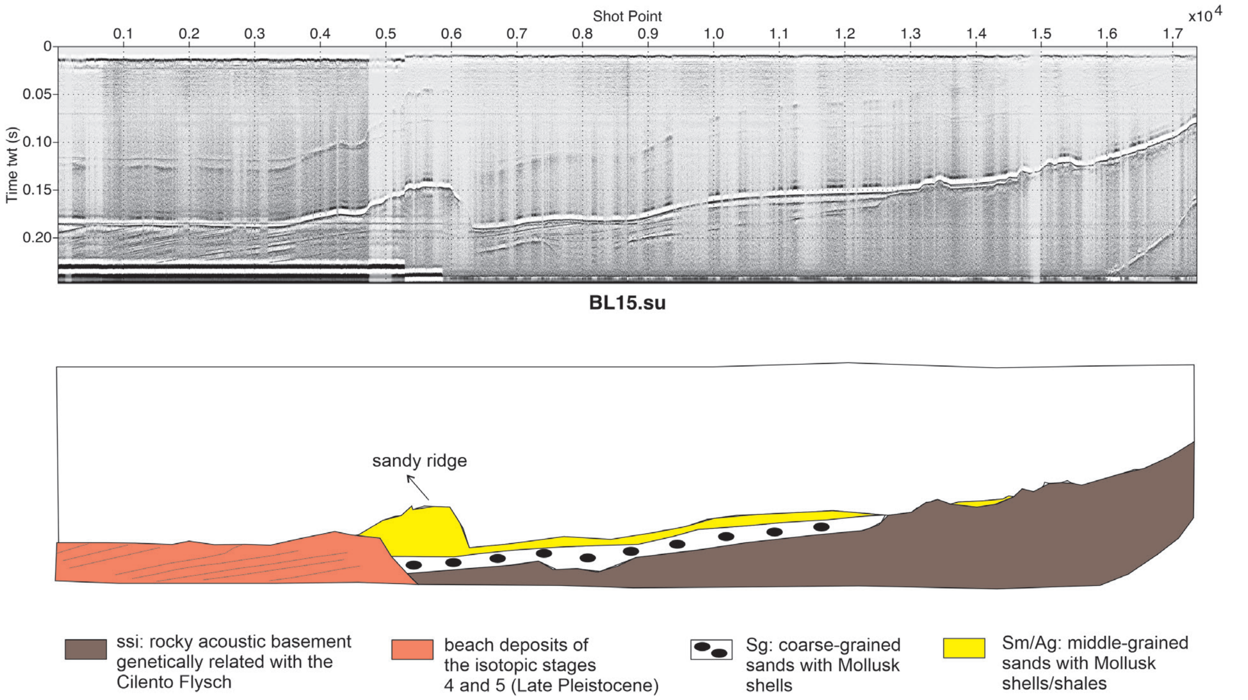

Figure 6: Seismic profile BL15 and corresponding geologic interpretation. The location of the seismic profile is reported in Fig. 3. Key: ssi: rocky acoustic basement genetically related with the Cilento Flysch; beach deposits of the isotopic stages 4 and 5 (Late Pleistocene); Sg: coarse-grained sands with Mollusk shells; Sm/Ag: middle-grained sands with Mollusk shells/shales.

deposited in depressions or channels involving the seismo-stratigraphic unit 3. The fourth seismo-stratigraphic unit (seismo-stratigraphic unit 4) is characterized by parallel to sub-parallel reflectors, from continuous to discontinuous, of high amplitude, probably composed of alternating sands and shales, probably Holocene in age. The reflector D represents a regional unconformity, genetically related to the Wurmian erosional surface. The uppermost seismo-stratigraphic unit is represented by the inner shelf deposits (g_{19}). According to the keys of the geological sheet n. 502 "Agropoli" (Martelli et al., 2016), they are represented by coarse-grained litho-bioclastic sands, with a scarce matrix, interlayered with middle-to-fine-grained litho-bioclastic sands.
Seismic profile BL15 has shown the ssi seismo-stratigraphic unit, overlain in onlap by the Sg unit, correlated with coarse-grained sands with Mollusk shells (Fig. 6). There is a main facies change, since the Sg seismo-stratigraphic unit changes into the progradational unit, which is involved by an erosional truncation at the sea bottom. The Sm/Ag seismo-stratigraphic unit composes a sandy ridge outcropping at the sea bottom. Its thickness is very reduced proceeding landwards. The ridge appears to be formed by basement rocks draped by the Sm/Ag seismo-stratigraphic unit.
Seismic profile BL29 (Fig. 7) displays the Pleistocene relict marine units (PLS). The corresponding seismo-stratigraphic unit is characterized by an acoustically transparent seismic facies and composes a morphological high at the shot point 0.3 (Fig. 7). The PLS unit is overlain by the progradational unit. Westwards of the morphological height, the progradational unit clearly shows prograding clinoforms, while to the east parallel reflectors appear, probably cut perpendicular to the direction of progradation (Fig. 7). A small palaeo-valley, filled by the Highstand System Tract deposits, has also been recognized (Fig. 7).

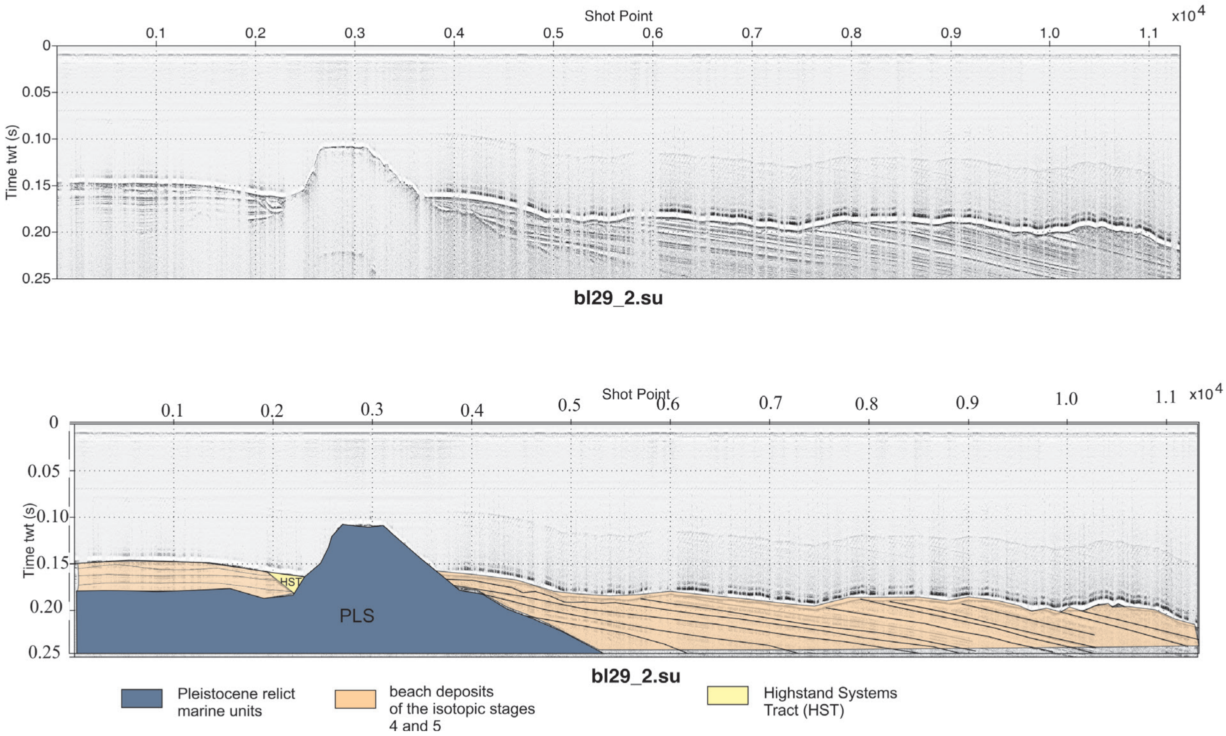

Figure 7: Seismic profile BL29_2 and corresponding geologic interpretation. The location of the seismic profile is reported in Fig. 3. Key. PLS: Pleistocene relict marine units; beach deposits of the isotopic stages 4 and 5; HST: Highstand Systems Tract.

Discussion and conclusions

The geological interpretation of the seismo-stratigraphic units, previously described, is herein provided. The ssi unit represents the rocky acoustic substratum and is genetically related with the Cilento Flysch Formation, widely outcropping in the surrounding coastal belt of the Cilento Promontory. The progradational seismic unit, overlying the ssi unit, is interpreted as the beach deposits of the isotopic stages 4 and 5 (Shackleton et al., 2003; Lisiecki & Raymo, 2005; Rohling et al., 2008; Railsback et al., 2015; Hearty & Tormey, 2017; Shackleton et al., 2021; Thompson & Creveling, 2021; Malmierca-Vallet & Sime, 2023). The Sg unit, overlying the progradational seismic unit has been interpreted as the submerged beach deposits, deposited during the last lowstand phase of the isotopic stage 2. The Sg unit has been calibrated by the core data, previously published (Ferraro et al., 1997), as composed of coarse-grained organogenic sands, rich in Mollusk shells (*Arctica islandica*, cold host of the Pleistocene). The high-water depths where this unit is located (130-140 m), together with its composition, let us suppose that it represents relict sands. The Sm/Ag unit has been calibrated by core data, previously published (Ferraro et al., 1997), suggesting that the Sm unit is composed of medium-grained sands, with Mollusk shells, while the Ag unit consists of shales. With the aim of discussing the MIS data, it is useful showing the correlation of submerged depositional terraces with Marine Isotope Stages based on the data of Savini et al. (2021; Fig. 8). Based on Savini et al. (2021), the submerged depositional terraces occurring in our studied areas are genetically related to the Marine Isotope Stage 4, but for sure affected also by the sea-level fluctuations of Marine Isotope Stage 2 (Fig. 8). Unfortunately, at the moment absolute datings (radiocarbon, OSL) are not

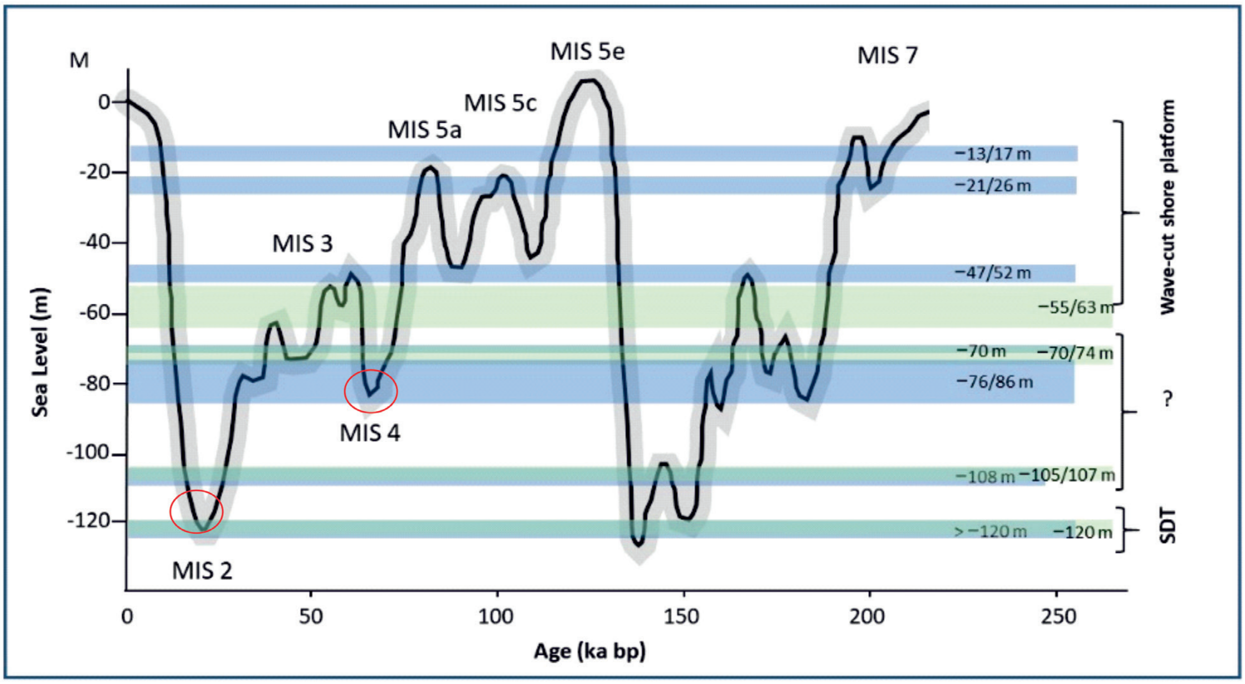

Figure 8: Marine Isotopic Stages (MIS) in the Cilento offshore (modified after Savini et al., 2021). This figure reports a graph of the eustatic sea level fluctuations (expressed in meters) referred to the last 200 ky (calibrated age). Major depth intervals where Submarine Depositional Terraces (SDT) are located have also been reported.

still available to strengthen this interpretation, but these data will be probably acquired in the future in the frame of the CORSUB project (Bazzicalupo et al., 2025).

The sedimentary distribution model (Peres & Picard 1964) has described the biocenosis of the "Détritique Cotier" and the biocenosis of the "Détritique du Large". Between the biocenosis of the mobile sea-bottoms, the most important one is the "Détritique Cotier", which is the most suitable in the study area. The nature of the "Détritique Cotier" is highly variable and depends on the nature of the substratum and of the surrounding circalittoral formations. It consists both of gravels and sands derived from the dominant rocks, and of bioclastic debris mainly composed of Mollusk shells, Bryozoans and calcareous algae. These organisms and the corresponding facies and biocenosis are compatible with the circalittoral zone, extending from the lower limit of the infralittoral down to the maximum depth where multicellular photosynthetic forms can exist; in practice this is about 200 m and light intensity, at such depths, is very low. Having discussed the characteristics of the Détritique Cotier based on literature data (Peres & Picard 1964), due to its sedimentological composition and bathymetric location, the Sg unit can be correlated with the "Détritique Cotier" and interpreted as relict sands. As previously stated, the relict sands are sedimentary deposits along the continental shelf that are out of equilibrium with the actual sedimentary dynamics. These deposits represent paleo-beaches, whose formation occurred at low sea-level conditions during the last glacial period or during the subsequent rising phase that characterized Holocene.

Some 22 thousand years ago, during the last glacial period, the sea was at about 120 m below the present-day sea level. The resulting global warming induced glacial melting (Ruddiman & Mc Intyre, 1981; Duplessy et al., 1981; Bard et al., 1987; Ruddiman, 2006), causing a rapid sea-level rise, up to a level comparable to the present-day one, which was achieved 6 thousand years ago (Chappell & Shackleton, 1986; Fairbanks, 1989; Lambeck & Nakada, 1992; Rohling et al., 1998; Lambeck et al., 2002; Siddall et al., 2003; Blanchon et al., 2009). This led to the establishment of different littoral environments along the continental shelf. Relict sandy deposits along the continental shelf may be buried by pelitic sediments of recent deposition or, alternatively, they crop out at the sea bottom. Even though relict sandy deposits are present on the continental shelf at depths ranging between 30 m and 130 m, the optimal exploitation zone for nourishment purposes is currently restricted between 50 m and 100 m of water depth (Beachmed, 2003).

In the Cilento offshore the relict deposits have been identified based on the geological interpretation of Sub-bottom Chirp profiles (Figs. 5-7). The obtained results have been integrated into the geological data, previously obtained by marine geological mapping (Martelli et al., 2016; Aiello & Caccavale, 2021), highlighting the occurrence of the Lowstand System Tract and of the Pleistocene relict marine units. The Lowstand System Tract is composed of coarse-grained organogenic sands, including abundant shell fragments, particularly of Mollusks (*Arctica islandica*), Echinids and Bryozoans.

The coarse-grained organogenic sands grade upwards into medium-grained sands and pelitic covers, having a variable thickness. They form coastal wedges overlying the shelf margin progradations and represent portions of submerged beaches, genetically related to the last sea-level lowstand (Antonioli, 2012; Maselli et al., 2014; Deiana et al., 2021; Mattei et al., 2022; Giaccio et al., 2024).

The Pleistocene marine units, relict or palimpsest, are made up of coarse-grained to fine-grained marine deposits, of well-sorted sands and gravels with bioclastic fragments and of medium-to-fine-grained sands with a pelitic coverage, having a variable thickness, but less than 2 m. They are in the north-western and south-western sectors of the study area and represent relicts or palimpsests of beach and continental shelf environments. Being located below the beach deposits of the isotopic stages 4 and 5, they stand for the remnants of older beach systems.

The geological evolution of the Cilento continental shelf can be outlined. In the context of a pervasive climatic warming phenomenon, occurring during the Late Pleistocene-Holocene, there was a pronounced elevation of sea levels on a global scale (Vellinga & Leatherman, 1989; Willis et al., 2010; Cazenave & Cozannet, 2014).

The sedimentary processes that controlled the deposition and consequent preservation of these relict deposits, especially concerning sea-level dynamics have been analyzed. Transgressive and highstand deposits have been identified on the continental shelves of all the world (Trincardi & Field, 1992; Cattaneo, Steel, 2003; Bozzano et al., 2006; Martorelli et al., 2010; Ridente, 2018). During this transgressive phase, the accelerated rate of sea level rise, coupled with the gentle gradient of the Cilento continental shelf, resulted in the nearly synchronous flooding of wide areas of continental shelf, as well as in a significant landward shifting of the coastal and marine facies. Consequently, the geological interpretation derived from the Sub-bottom Chirp profiles did not allow the identification of retrogradational seismo-stratigraphic units, which have constructed beach systems that were deposited during the transgressive period. Conversely, highstand and lowstand deposits have been thoroughly documented based on seismo-stratigraphic analyses.

Despite the cyclical oscillations, the sea continues to descend from the end of isotopic stage 5a (Oppo et al., 2001; Railsback et al., 2015; Fig. 8) until it reached isotopic stage 2, where it was situated in the Mediterranean Sea at a depth of roughly 120 meters. This situation stands for a forced regression.

The progradational wedges of the Cilento offshore were deposited during this forced regression, enabling a platform widening of several kilometers. The coastline's seaward migration in response to the relative drop-in sea-level controls the forced regression. This type of regression happens when the sea level drops because the coastline must regress because of the base level dropping, without accounting for the sediment supply (Hunt and Tucker, 1992; Posamentier et al., 1992; Posamentier and Morris, 2000; Trincardi and Correggiari, 2000; Ridente and Trincardi, 2005). In a shoreface setting, progradational deposits are deposited alongside the fluvial incision during the forced regression.

It can be concluded that the sea level dynamics was an important factor in controlling the deposition and the preservation of the relict deposits of the Cilento continental shelf. Sand prospecting in microtidal beaches focuses on relict deposits generated on the shelf when sea levels were lower than they are now. During the last post-glacial sea-level rise the coastal and marine facies underwent a landwards shifting. As the sea bottoms continued to deepen, they leave behind a variety of sedimentary deposits. The deposited materials display substantial lithologic, geometric and sedimentological differences, highlighting the complex relationships between erosional and depositional transgressive processes on the continental shelf that have been controlled by both tectonic uplift and sea level fluctuations. (Swift et al., 1971; Hunt & Tucker, 1992; Posamentier et al., 1992; Posamentier & Morris, 2000; Trincardi & Correggiari, 2000; Cattaneo & Steel, 2003; Ridente & Trincardi, 2005). The paleo-morphology of the continental shelf and the presence of morphological stages at its surface may be connected to the frequent preservation of shelf downlapping deposits (Trincardi and Field, 1991; Cattaneo & Steel, 2003). This preservation of marine deposits has been found also in the study area.

The limitations found based on the techniques and methodological approach used in this research mainly consist in the lacking of a systematic grid of cores in the Cilento offshore. In fact, we can only refer to the cores available in literature (Ferraro et al., 1997), but a few shallow cores have been recently collected during the TREMOR oceanographic cruise for the realization of the PRIN 2022 CORSUB project (Bazzicalupo et al., 2025). In the framework of the PRIN 2022 CORSUB, it is possible that absolute dates (radiocarbon, ^{14}C of shell fragments and rhodoliths) of the available samples will be realized, so integrating the geological analysis of the relict deposits of the Cilento continental shelf. Future perspectives for advancing knowledge of the relict deposits of the offshore Cilento coast will include the realization of a denser grid of high-resolution Sub-bottom profiles and detailed bathymetric maps using the R/V Gaia Blu of the National Research Council of Italy, equipped with three Multibeam systems (MBES), allowing for a detailed recognition of the morpho-structures genetically related to the relict deposits.

Author contributions

Conceptualization: G.A., M.C.
Data Curation: M.C.
Investigation: G.A., M.C.
Writing: Original Draft Preparation: G.A.
Writing, review and editing: G.A., M.
Writing, final draft preparation: G.A.

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Bulletin of Regional Natural History (BORNH) ISSN 2724-4393.

BORNH Bulletin of Regional Natural History
Formerly Bollettino della Societá dei Naturalisti in Napoli

Observations on the vocation of the protection dog of Abruzzo's pastoral civilisation to defend the flock from predators

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DOI https://doi.org/10.6093/2724-4393/12663

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Competing interests: The Authors declare that they have no competing interests for this work.

Financial Disclosure Statement: the Authors declare that no specific funding was received for this work.

Submitted: 8 April 2025
Revised: 28 July 2025
Accepted: 31 July 2025
Published: 15 Sept 2025

Associate Editor:
Roberto Sacchi

Abstract

This study aimed to assess the effectiveness of a group of livestock guardian dogs (LGDs) in independently protecting a sheep flock in the absence of the shepherd, while also evaluating the absence of aggressive behavior toward humans. The focus was on the Maremmano-Abruzzese sheepdog, a breed historically selected by Abruzzese pastoral communities for its guarding abilities.
Fieldwork was conducted over three autumn and winter seasons (2017–2020), totaling 258 observation days. The flock, consisting of approximately 300 sheep, was enclosed within an electrified fence and guarded by three LGDs. Observations took place during twilight, nighttime, and early morning hours, always without human supervision. Monitored variables included vocalizations (208 in total), behavioral responses to human or vehicle presence, and autonomous nighttime positioning patterns. Results demonstrated that the dogs effectively protected the flock, exhibiting strong motivation to defend, well-balanced behavioral responses, itinerant territoriality, and the ability to develop independent antipredator strategies. Vocalizations were distributed primarily at night (75), at twilight (53), and in combinations involving night, twilight, and dawn. Five distinct spatial positioning patterns (A, B, C, D, E) were identified, adopted spontaneously by the dogs to ensure coverage and surveillance of the area. Importantly, no aggressive behaviors toward passing humans were recorded, confirming the dogs' suitability for working in shared human-animal environments. These findings support the role of the Maremmano-Abruzzese sheepdog as a highly effective autonomous livestock guardian, whose behavioral traits are the result of centuries of selective breeding for pastoral purposes.

Keywords: Maremmano–Abruzzese sheepdog, Abruzzo, anti-predatory strategies, ethology, predators, breeders

Riassunto

Questo studio ha avuto l'obiettivo di valutare l'efficacia di un gruppo di cani da protezione del bestiame nel difendere un gregge in autonomia, in assenza del pastore, e di verificare l'assenza di comportamenti aggressivi nei confronti delle persone. La ricerca si è concentrata sulla razza Maremmano-Abruzzese, tradizionalmente selezionata dalla civiltà pastorale abruzzese per la custodia degli ovini. L'indagine si è svolta nel corso di tre stagioni autunnali e invernali (2017–2020), per un totale di 258 giornate di osservazione. Il gregge, composto da circa 300 pecore, era custodito da tre cani all'interno di un recinto elettrificato. Le osservazioni si sono concentrate nelle ore crepuscolari, notturne e del primo mattino, sempre in assenza del pastore. Sono stati monitorati comportamenti vocali (208 vocalizzazioni totali), reazioni a stimoli esterni (passaggio di persone e veicoli) e posizionamenti autonomi notturni dei cani. I risultati confermano che i cani hanno protetto efficacemente il gregge, mostrando forte motivazione alla difesa, capacità di elaborare strategie antipredatorie indipendenti e un buon equilibrio comportamentale. Le vocalizzazioni si sono distribuite principalmente nelle ore notturne (75), al crepuscolo (53) e in combinazioni tra notte, crepuscolo e alba. Sono stati individuati cinque schemi di posizionamento (A, B, C, D, E), adottati spontaneamente dai cani per garantire la sorveglianza dell'area. Importante è anche la totale assenza di aggressività verso le persone, a conferma dell'idoneità di questi soggetti a operare in contesti condivisi con l'uomo. Lo studio dimostra che il cane da pastore Maremmano-Abruzzese è un ausilio altamente efficace per la protezione degli ovini, in grado di operare con autonomia e affidabilità anche in assenza del pastore.

Parole chiave: cane da pecora abruzzese, Abruzzo, strategie antipredatorie, etologia, predatori, allevatori

Introduction

Shepherds have always seen the wolf (*Canis lupus*) as a constant and real danger to their activity. Sometimes the activity of predators on livestock has triggered a real conflict with man with no holds barred (Young and Goldman, 1944; Cluff and Murray, 1995; Piscopo et al., 2021). Among the many strategies to counter predator activity, e.g. poison, leghold traps, snares and firearms (Boitani, 1995; Browne-Nuñez et al., 2015), at the shepherd's side there has always been a valid and effective ally: the 'sheepdog' (*Canis lupus familiaris*), a descendant of the wolf, but its direct adversary (Andelt, 1992; Fritts, 2003). The man-dog partnership has been an essential element of pastoral civilisation: there was no flock without a shepherd, no shepherd without dogs in Abruzzo, where the wolf has always been present. This union has made possible over time the selection of dog breeds with different characteristics selected for defence or for livestock management. The culmination of this association was reached during the periods of transhumance: seasonal migration of flocks, herds and shepherds who moved, on foot, from the pastures located in hilly or mountainous areas (in the summer season) to those on the plains (in the winter season) along the natural routes of the 'tratturi', wide grassy tracks (Breber, 1993; Guacci, 2013; Breber, 2017).

In the region of Abruzzo (South of Italy), rich in breeders, sheep and wolves, a particular dog breed has been selected and 'specialised' in the protection of herds: this is what is historically called the 'Mastino abruzzese' or 'Abruzzese sheep dog'. Nowadays the official ENCI (Ente Nazionale Cinofilia Italiana) nomenclature defines it as the Maremmano Abruzzese sheepdog. This dog breed presents itself as a large, strong and well-structured animal, which was born and lives among the herds and considers the cattle, the grazing area and the shelters where the animals are housed as

its 'territory', defending them with great effectiveness as it considers them its 'property' (Breber, 2017). A dog with such a structured and well-defined build is considered typical of the breed — a reflection of its functionality. This functionality is essential when breeding a working dog. In fact, today the main selection criterion is the preservation of both the breed and the pastoral culture that has shaped it, to the point of making it almost perfect (Cavalchini, 1991; Giuliani, 1997; Giannelli, 2002).
The Abruzzese sheepdog has obtained official recognition as a cultural heritage from the Abruzzo Region only recently; with Regional Law No. 21 of 9 July 2016, in which it is defined as an 'irreplaceable element in the eco-friendly herding activity of Abruzzo's pastoral tradition'. Even though today the phenomenon of transhumant herding has been considerably reduced compared to the past, it nevertheless maintains its millennia-old cultural connotations (Colapietra, 1972; Di Giustino, 2016).
In this paper we document some behavioural aspects related to the Abruzzese sheep dog effectiveness in protecting livestock. We made behavioural observations on a group of three protection dogs guarding a flock of about 300 Bergamasque sheep over three winter seasons from 2017 to 2020 near the city of Teramo, in Abruzzo.
The flock was led out to pasture by the herdsman from dawn until dusk, and from dusk until dawn it was kept within an electrified enclosure and entrusted to the custody of the three protection dogs. The herder practiced a nomadic grazing system, in which the flock remained in a given area for a few days, grazing around the temporary enclosure. When the availability of fresh pasture was exhausted, the enclosure was dismantled and relocated to a new grazing area. Each time the enclosure was relocated, the new position was georeferenced, thus documenting the various stopovers made by the flock during the transhumant grazing period. All flock stopovers took place within the designated study area located near the city of Teramo.
The aim of this study was to assess in the field the vocation of this dog breed for livestock protection and to study the intraspecific behavioural dynamics between the dogs and the predators present in the area (wolves and feral dogs). Furthermore, the study aimed to analyse the behaviour of the protection dogs in relation to the morphology of the territory, in order to document their effectiveness as a strategy for mitigating human-predator conflict, as well as the dogs' reactions to people and vehicles passing near the herd, to investigate the psychological balance of these dogs. By assessing the dogs at work with livestock and during interactions with possible dangers through direct observations, their functionality and effectiveness can be established, to select the best subjects or detect unsuitable dogs, so that the existing nucleus of dogs can be improved, and the defence system made more effective (Guadagno et al., 2023.

Materials and methods

Study area

The study area was located south-west of the city of Teramo (42,65875° N, 13,70294° E) and consists of a hilly environment with altitudes varying between 200 and 500 metres above sea level.
The soil is characterised by a strong clay component that in some places gives rise to small gully formations. From an environmental point of view, the territory is a mosaic, with natural areas and cultivated areas. The natural areas are mostly characterised by two basic components: 'wooden' areas and riparian vegetation. The areas covered by arboreal-arbustive vegetation are characterised by high scrubs slowly evolving towards a compact and highly intricate woodland, practically impenetrable by man. From an ecological point of view,

the areas located at the margin between the various environments are of particular interest. These ecotonal areas constitute systems in which the characteristics of the bordering environments merge revealing considerable dynamism and are extremely important for wildlife as they provide wildlife with places to rest and move around without being seen (Wildlife & Farming handbook). In this study area, large hilly zones are used for agriculture and are therefore open landscapes where wildlife is more easily observed, compared to small woodlands and scrubby areas that offer better concealment. Among the plant species present in the area are the stone pine (*Pinus pinea*), the maritime pine (*Pinus pinaster*), the white poplar (*Populus alba*), the downy oak (*Quercus pubescens*), the Turkey oak (*Quercus cerris*), the wild cherry (*Corylus avellana*), the blackthorn (*Prunus spinosa*), the dog rose (*Rosa canina*), the bramble (*Rubus ulmifolius*), and the Spanish broom (*Spartium junceum*).
The area, which covers over 100 km², has a high level of anthropisation both for the widespread presence of housing and urban agglomerations, as well as for intense human activity on the territory. The latter takes the form of various activities: agriculture (arable and tree crops), livestock breeding (especially sheep), tourism (agritourisms and B&Bs), hunting (mainly wild boar *Sus scrofa*) (Gallizia et al., 2018).
The study, which spanned three winters, was conducted in a very specific area where there was the simultaneous presence of a wolf pack (*Canis lupus italicus*) (Fig. 1) and a group of about twenty feral dogs (whose number varied during the breeding season) (Fig. 2) in contiguous areas. These feral dogs were observed preying on both wild animals and livestock. Continuous monitoring of these two predators enabled the creation of a predation risk map, on which the flock under study spent its winters. Three areas with different levels of danger were created: a green area with low danger, a yellow area with moderate danger, and a red area with high danger. The danger level was calculated based on the core areas primarily occupied by the predators, while the areas where the flock stayed depended on the availability of grazing areas each year.

Field methods

The field study took place over 258 days divided as follows: from 15 December 2017 to 15 March 2018 for a total of 91 days, from 13 November 2018 to 4 December 2018 and from 23 January 2019 to 10 March 2019 for a total of 69 days, from 20 November 2019 to 23 December 2019 and from 2 January 2020 to 5 March 2020 for a total of 98 days. The present study was conducted exclusively through direct observation sessions carried out during dawn, dusk and night (in the latter case using night vision equipment). Data on the vocalisation activity of the protection dogs were also recorded during the observation sessions. Vocalizations were documented as part of the dog's communication system. Despite contextual limitations and the multiple possible functions of vocal behavior (e.g., alert, territoriality, threat response, intraspecific interaction), data were collected on the frequency of vocalizations, mainly expressed through barking during observation sessions. The crepuscular observation sessions were primarily aimed at assessing the dogs' ability to autonomously choose night-time positioning in defence of the flock. During each observation session, the positioning of the dogs, their reaction to people passing near the flock, and their vocalization activity were evaluated. After grazing, the flock was led into the electrified pen around 4 p.m. and returned to the pasture the following morning after 9 a.m..
Each day was divided into three direct observation shifts: sunrise from 5 a.m. to 8 a.m., twilight from 4:30 p.m. to 7:30 p.m., and night from 9 p.m. to midnight. During these observation shifts, the herd was always kept with-

Figure 1. Apennine wolf (*C. lupus italicus)* pups photographed in the study area.

Figure 2. Individuals of the feral dog nucleus photographed in the study area.

in the electrified containment enclosure and was guarded exclusively by livestock guardian dogs. As an observational method, we used continuous ad libitum sampling (Bateson & Martin, 2021), made possible by the constant presence of researchers during the observation sessions.

The flock was guarded by three dogs, one female and two males: a young male about 2 years old, an adult female about 3 years old, and an adult male about 4 years old. None were neutered. The dogs came from a pastoral selection. During the day in the presence of the shepherd, the dogs played a supportive role while the sheep were grazing, remaining vigilant to control any dangers. At night the sheep were kept inside an electrified enclosure and the three dogs were kept outside the enclosure and entrusted with the care of the flock from dusk to dawn while the shepherd was absent. The electrified enclosure consisted of a 200-meter-long net, 120 cm in height.

The fenced area was 2,500 square meters The three dogs were fed commercial dry food (kibble). Direct observations were conducted using non-invasive methods, with the aid of a Bushnell Equinox 6 x 50 mm digital night viewer, a Konus Konuspot - 80 20- 60 x 80 spotting scope, a Nikon Monarch 5 10x42 binoculars, an Olympus DPS 1 10x50 binoculars, a Nikon d3300 camera, a Nikon d810 camera, a Nikon AF-S DX 55 - 200 mm f/4 - 5 telephoto lens. 6 G VR, a Sigma 150 - 600 mm f/5 - 6.3 DG OS telephoto lens. HSM S, a Sony ICD- PX240 sound recorder with a Karma DMC 943 microphone. The GPS positions of the herd were recorded via a mobile phone app called 'Conota' (https://conota.app), the phone used was a Samsung Galaxy Grand Neo and maps were created with the aid of Google Earth. The nighttime resting locations of the herd were taken into consideration to evaluate the level of risk associated with each site in relation to the proximity of core areas of wolves and feral dogs. Temperature and weather conditions were obtained from the 3B Meteo website (https://www.3bmeteo.com).

The researchers positioned themselves at no less than 200 meters from the herd in order to avoid interfering with the activity of the dogs, while still maintaining adequate visibility and an effective auditory range during observation shifts. Once the shepherd had left at dusk, the dogs autonomously positioned themselves, focusing their protection more on the areas where danger could more easily arise, particularly where dense vegetation was present (Fig. 3).

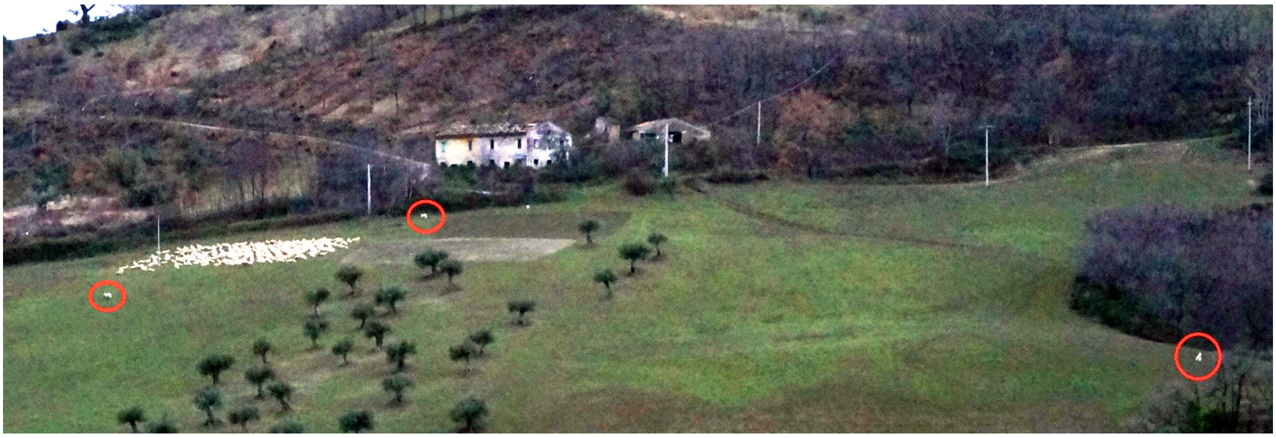

Figure 3. Dogs positioned around the flock once the herding shepherd had departed.

At certain stopovers, the flock enclosure was situated close to well-travelled roads. These circumstances provided opportunities to record the dogs' responses to human presence, with the aim of evaluating their behavioral equilibrium and confirming their suitability for work in anthropized contexts. Data were collected using ad libitum sampling, recording any behavior perceived as relevant at the moment of observation (Martin & Bateson, 1993 / 2007). The events considered were as follows: passage of people on bicycles, passage of people on foot, passage of people with agricultural vehicles, workers by the roadside, people on foot with dogs, and passage of people riding scooters. All considered events occurred at a minimum distance of approximately 50 meters from at least one of the dogs. It was assessed whether the dogs displayed aggressive or non-aggressive behavior towards people in the vicinity of the flock. Regarding vocalizations, only the dogs' barks were considered. The barks considered in this study are interpreted as alert signals and territorial marking behaviors, indicating the presence of livestock guardian dogs in that specific time and space. Under the conditions and context of the study, it was not possible to

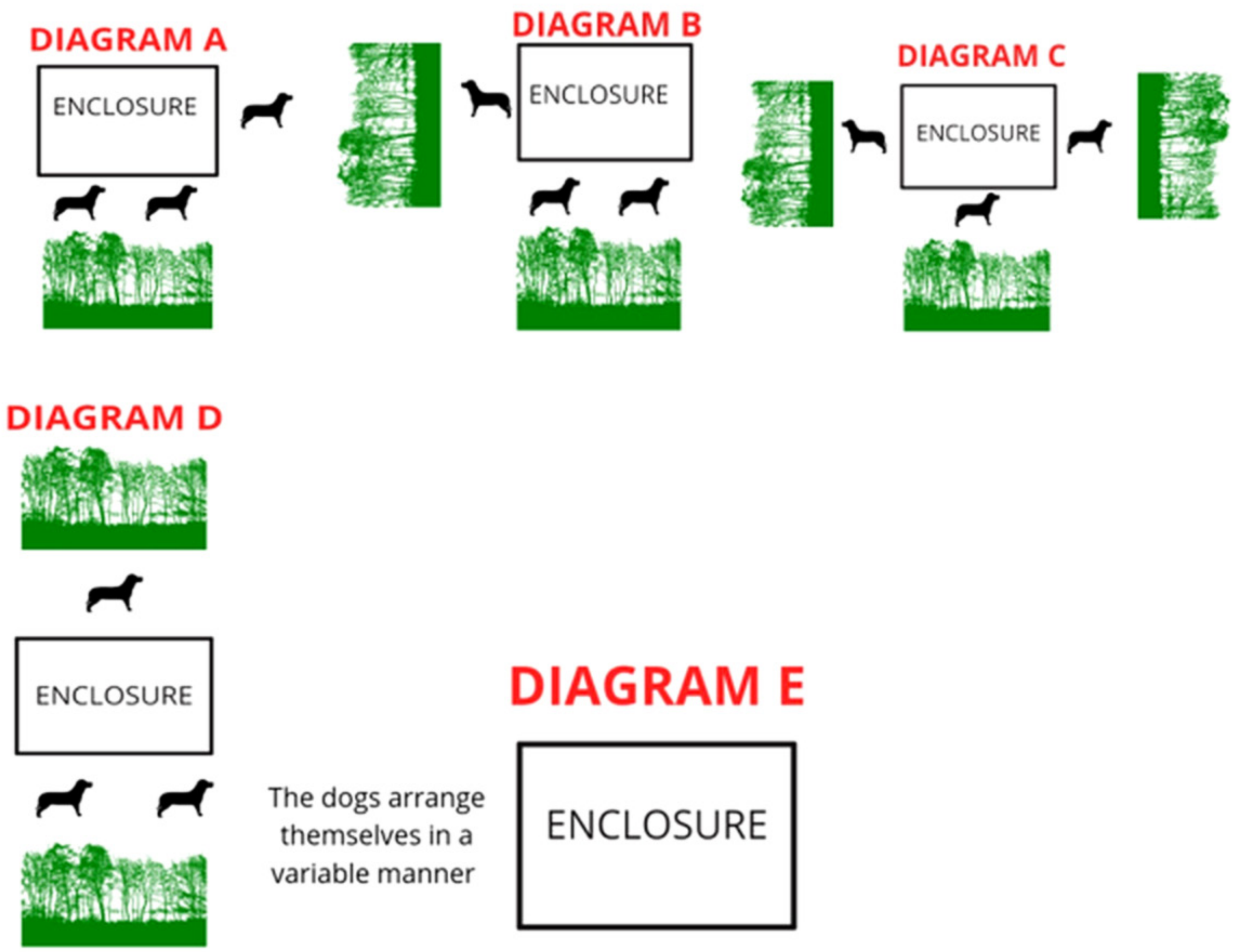

Figure 4. Disposition of dogs based on the surrounding territory; the green represents dense vegetation.

clearly determine the distance of the potential threat during periods of low visibility, and thus the precise meaning of the barking—except in cases where, after the herd had been secured inside the enclosure, the dogs circled around it while barking, as a form of territorial marking. The observations of feral dogs and wolves were made by the researchers and the herding shepherd, as there was constant exchange of information with the latter.

During the grazing period, the dogs still monitored the flock, some positioning themselves in the middle of the flock and others at the edges, interposing themselves between the grazing animals and the areas of reduced visibility so that they could easily monitor the flock and intervene promptly to signal or counter potential danger. After the shepherd departed at dusk, the dogs autonomously positioned themselves, prioritizing surveillance in areas with a higher likelihood of threat emergence, particularly those characterized by dense vegetation. Five positioning patterns were identified, labeled A, B, C, D, and E, which are described below. In pattern A, dense vegetation was present on one of the four sides of the sheep pen, and two dogs positioned themselves along that side. In pattern B, dense vegetation was present on two adjacent sides of the pen, with two dogs positioned along the longer side of the rectangle near the underbrush, and one dog positioned along the shorter side, also facing the underbrush. In pattern C, the underbrush was present on three of the four sides of the rectangle, and three dogs positioned themselves, each along one of the sides with the densest vegetation. In pattern D, the underbrush was pres-

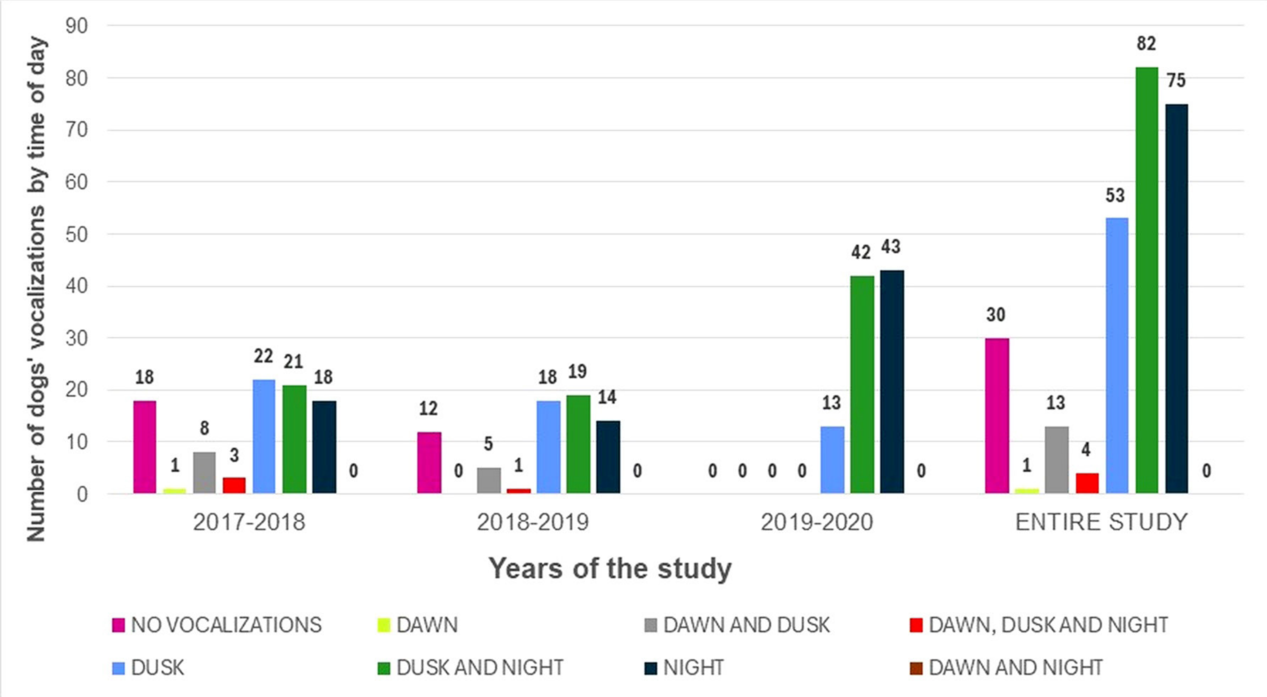

Figure 5. Number of dog vocalizations by time of day (dawn, dusk, night, and combinations thereof) across three study years and the overall study period.

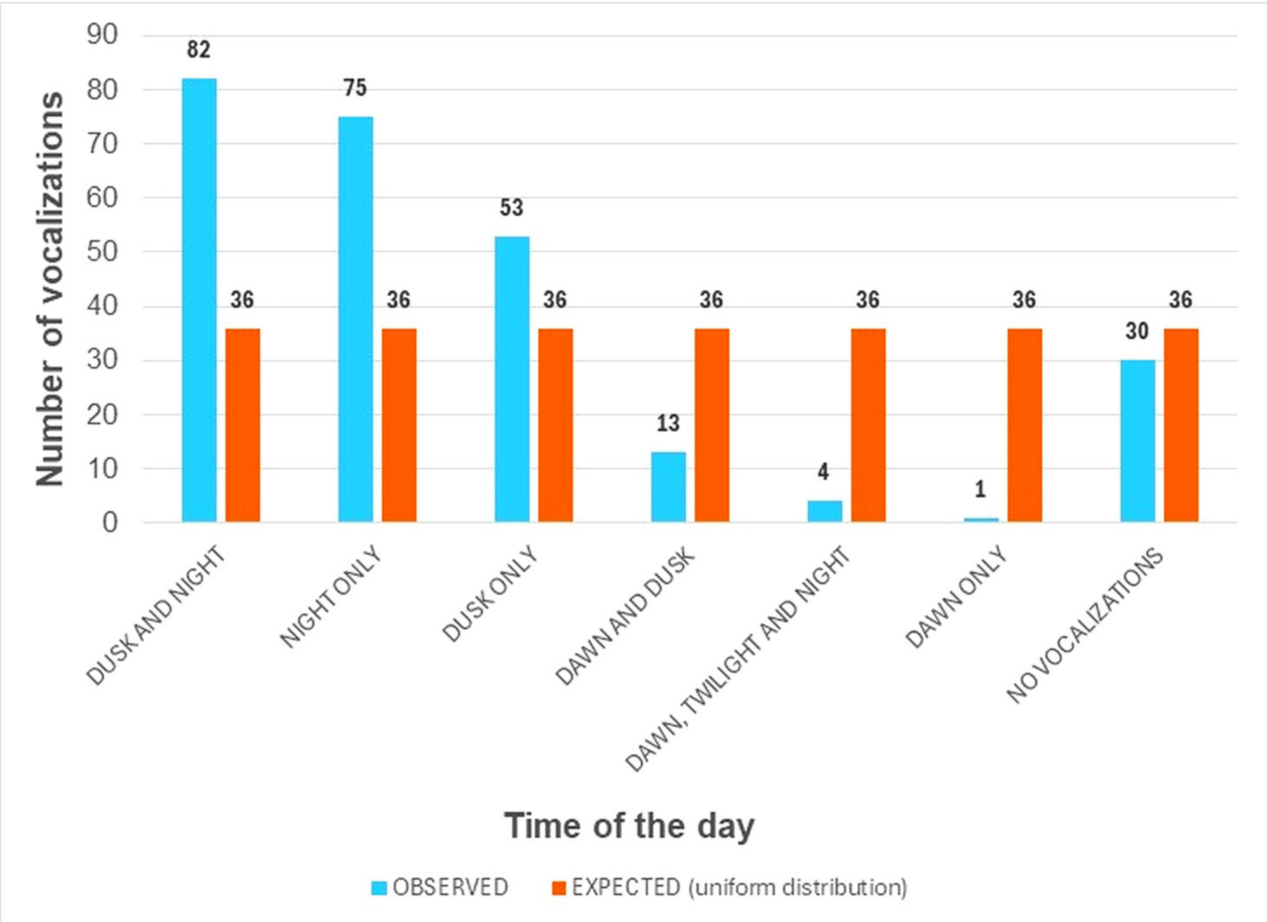

Figure 6. Chi-Square test: observed vs. expected dog vocalizations during flock defense.

ent on two non-adjacent sides of the rectangle, with two dogs positioned along one side with denser vegetation and one dog along the other side with underbrush. In pattern E, no underbrush was present, and the dogs positioned themselves variably (Fig. 4).

Data analysis

The collected data were entered into a Microsoft Excel spreadsheet (Microsoft Corp., Redmond, WA, USA) and used to generate descriptive graphs and chi-square tests. We used a chi-square goodness-of-fit test to compare the observed frequency of dog vocalizations across six temporal categories (dawn, twilight, night, and combinations thereof) against a uniform distribution. The null hypothesis assumed an equal probability of vocalizations across all categories. To test whether the dogs' reactions to the passage of people near the flock were evenly distributed, a chi-square goodness-of-fit test was conducted comparing the observed frequencies of "no reaction" and "barking while remaining with the flock" against a uniform distribution. The distribution of the dogs' positioning patterns (A–E) was tested against a uniform expectation using a chi-square goodness-of-fit test, with five categories and df = 4. Geographic data and spatial visualizations were created using Google Earth Pro which was employed to generate maps.

Results

During the 258 days of observation, a total of 208 vocalizations by the livestock guardian dogs (LGDs) were recorded. The distribution by time period was as follows: 82 vocalizations occurred both at twilight and during the night, 75 only at night, 53 only at twilight, 13 both at dawn and twilight, 4 at dawn, twilight, and night, and 1 only at dawn. In 30 cases, no vocalizations were recorded (Fig. 5). Consecutive barking episodes within the same event were considered a single vocalization. The number of individual barks was not recorded, as it was not relevant to the study's aims. Vocalizations clearly directed at people passing near the flock were included. In most cases, it was not possible to determine the specific target or trigger of the vocalizations, particularly at night when visibility was limited. Therefore, we could not assess whether the barking was in response to an actual threat or served other functions such as territorial marking. A chi-square goodness-of-fit test was used to evaluate whether the distribution of vocalizations differed significantly among the time categories. The result showed a significant deviation from uniformity ($\chi^2 = 182.73$, df = 6, $p < 0.001$), indicating a non-random distribution with vocalizations more concentrated during twilight and night hours (Fig. 6).

One of the aspects taken into consideration was the dogs' reaction to the passage of people near the flock, a relevant factor given the high degree of anthropisation in the study area. Over the three years of observation, we recorded 37 such events: 15 involved people on foot, 10 on bicycles, 7 on scooters, 2 with agricultural vehicles, 2 with dogs on leashes, and 1 involving roadside workers (Fig. 7). In none of these cases did the dogs show aggressive or playful behavior, nor did they abandon the flock to approach or interact with people. This behavior is particularly relevant in a region with a strong tourism vocation, as it demonstrates the dogs' ability to remain focused on their protective role while avoiding potential conflicts with humans.

During stopovers when the flock was located near the road, we evaluated the dogs' behavioral response to the presence of people in the vicinity. In these conditions, the dogs remained passive in 24 instances, while in 13 cases they barked but did not move away from the flock, maintaining a protective position (Fig. 8). In 26 stopovers, the flock was positioned too far from the road to reliably observe the dogs' reaction to human pas-

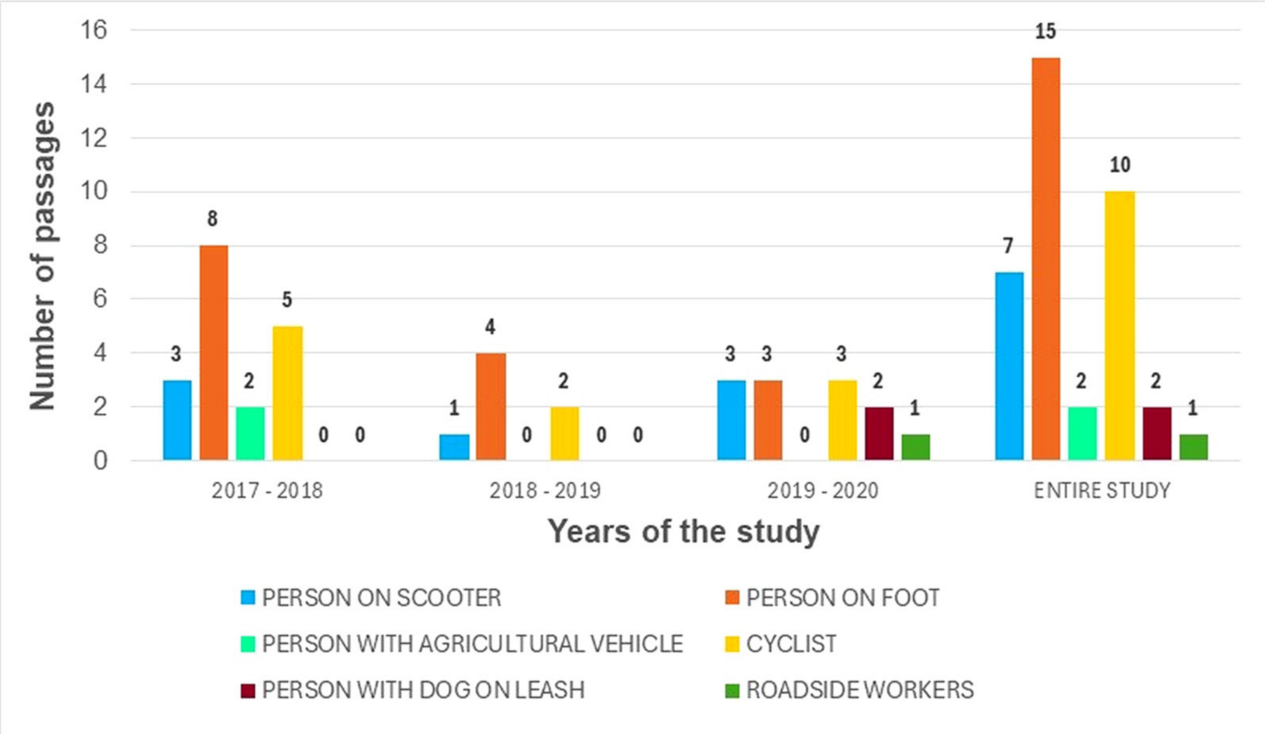

Figure 7. Number of people passing near the flock, categorized by type (scooter, on foot, agricultural vehicle, cyclist, person with dog on leash, roadside workers) across three study years and the entire study period.

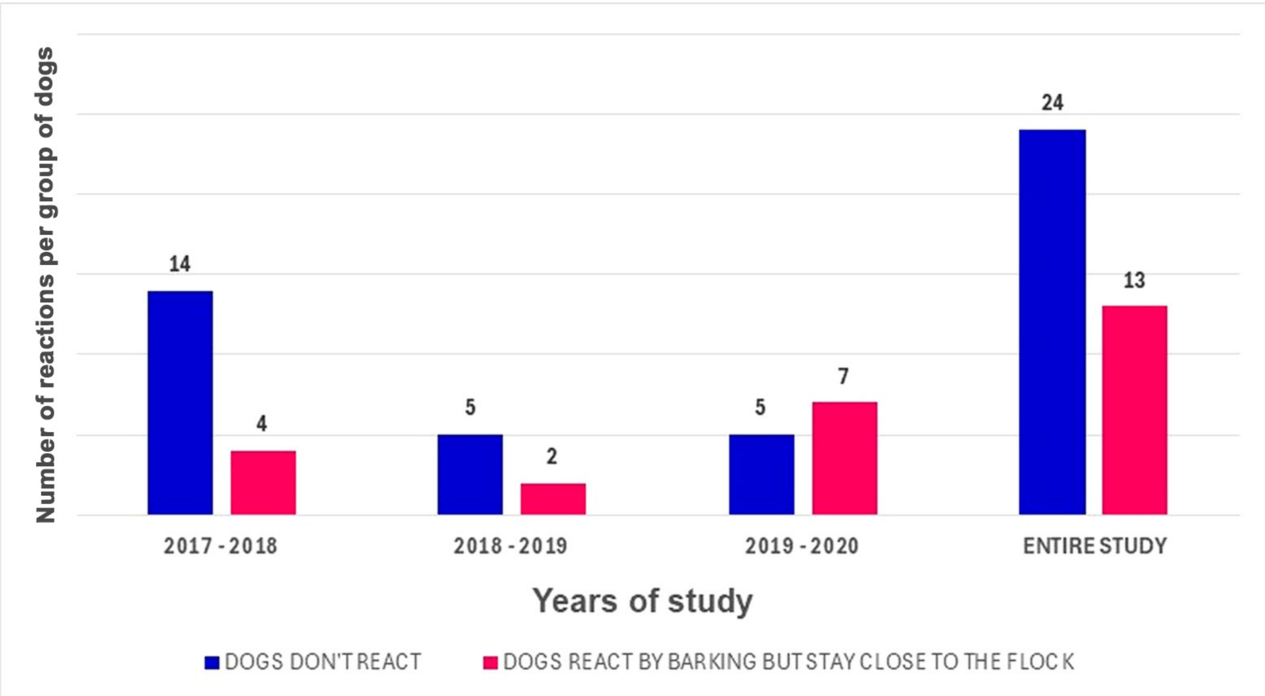

Figure 8. Dogs' reaction to people passing near the flock.

sage. This trend, although not statistically significant, supports the observation that the dogs were able to remain vigilant without displaying aggression or abandoning their position, highlighting their behavioral balance in human-influenced environments.

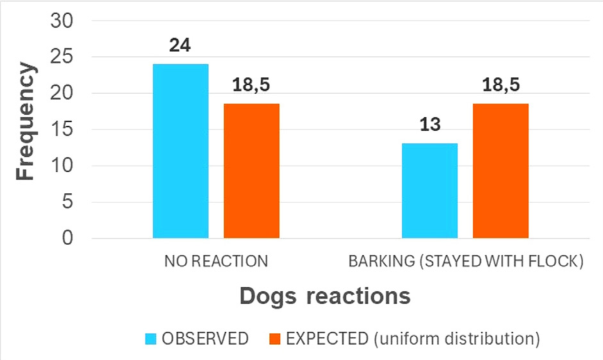

Figure 9. Chi-square test: Observed and expected frequencies of dog reactions to people passing near the flock.

Unlike other dog breeds commonly used in livestock farming that require verbal or gestural commands from the shepherd (like border collie or Australian shepherd), this breed demonstrated full autonomy in carrying out its protective role (Lamberini et al., 2012; Bigi et al., 2018). This independence was observed both when predators were potentially nearby and during routine relocations of the flock. In the presence of potential threats, dogs autonomously positioned themselves between the flock and the perceived source of danger, without shepherd intervention. Similarly, when the flock was moved to a new resting or grazing site, and the shepherd departed, the dogs initiated a consistent sequence of behaviors: they marked the perimeter of the electrified enclosure with urine and feces, and then positioned themselves based on the specific morphological and vegetational characteristics of the terrain. This behavior was observed daily, particularly at dusk.

Based on these observations, we identified five recurring positioning patterns corresponding to different environmental configurations in the resting areas. The dogs adopted pattern A 16 times, pattern B 10 times, pattern C 9 times, pattern D 2 times, and pattern E 3 times (where no dense vegetation was present and the dogs chose freely which side to defend) (Fig. 10). If all patterns were equally likely, each would be expected to occur eight times. A chi-square goodness-of-fit test indicated a significant deviation from uniformity ($\chi^2 = 16.25$, df = 4, $p < 0.01$), with pattern A

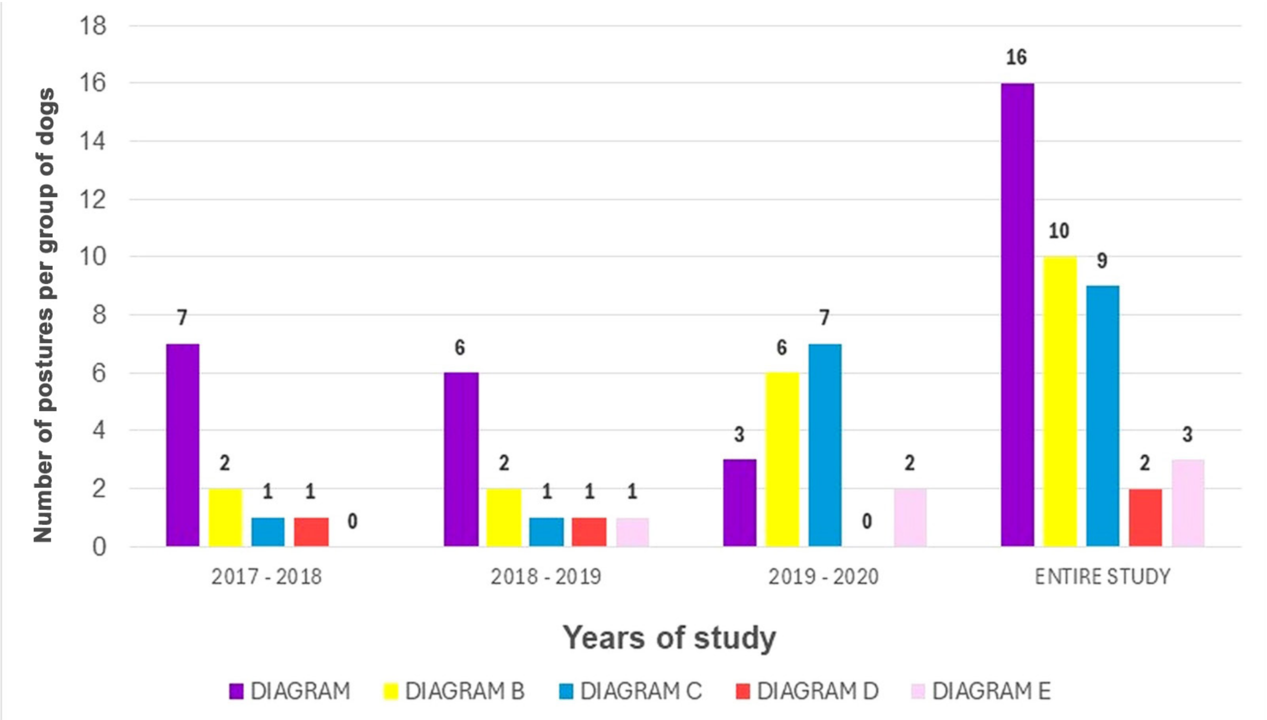

Figure 10. Positioning of dogs during shepherd-free hours.

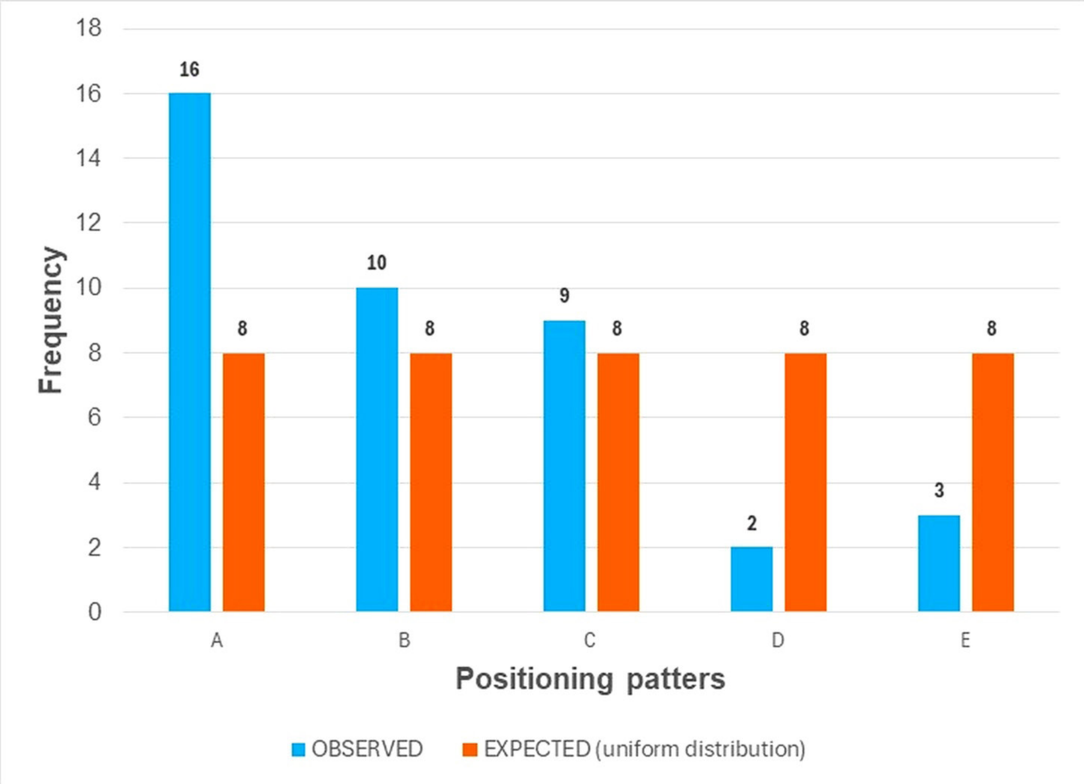

Figure 11. Chi-square test: observed and expected frequencies of livestock guardian dog (LGD) positioning patterns (A–E) during flock surveillance.

being chosen disproportionately often (Fig. 11). This suggests that the dogs actively selected positioning strategies most suited to the protection of the flock, particularly favoring defensive positions near dense underbrush or other features that could conceal predators. These results further highlight the dogs› ability to assess environmental risk and act independently to ensure flock safety.

During positioning, the dogs remained oriented toward the bush or away from the flock, in order to maintain a clear view of their surroundings and to prevent ambushes from predators approaching from behind. These areas are where predators emerge to transit through open fields or approach the flock undisturbed.

The final aspect we wanted to assess was the actual defense function of this group of dogs in protecting the flock. During the first winter (2017 – 2018) the flock made eleven stops within the study area, 2 of which in the low-risk area, 1 in the moderate-risk area and 8 in the high-risk area.

During the second winter (2018 – 2019) the flock made eleven stops within the study area too, of which 1 in the low-risk area, six in the moderate-risk area and 4 in the high-risk area. During the third winter (2019 – 2020) the flock made eighteen stops within the study area, of which 3 in the low-risk area, 7 in the moderate-risk area and 8 in the high-risk area (Fig. 12). Over the three-year study period, 20 out of 40 total stopovers (50%) occurred in areas classified as high risk, where the likelihood of predator presence was highest.

During the three years of monitoring, a total of 14 predator encounters near the flock were recorded: 9 involving wolves and 5 involving feral dogs. Specifically, during the winter of 2017–2018, 9 events were observed (5 involving wolves and 4 involving feral dogs); during 2018–2019, 4 events occurred (3 involving wolves and 1 involving feral dogs); and in 2019–2020, only one wolf encounter was recorded. In all cases, the livestock guardian

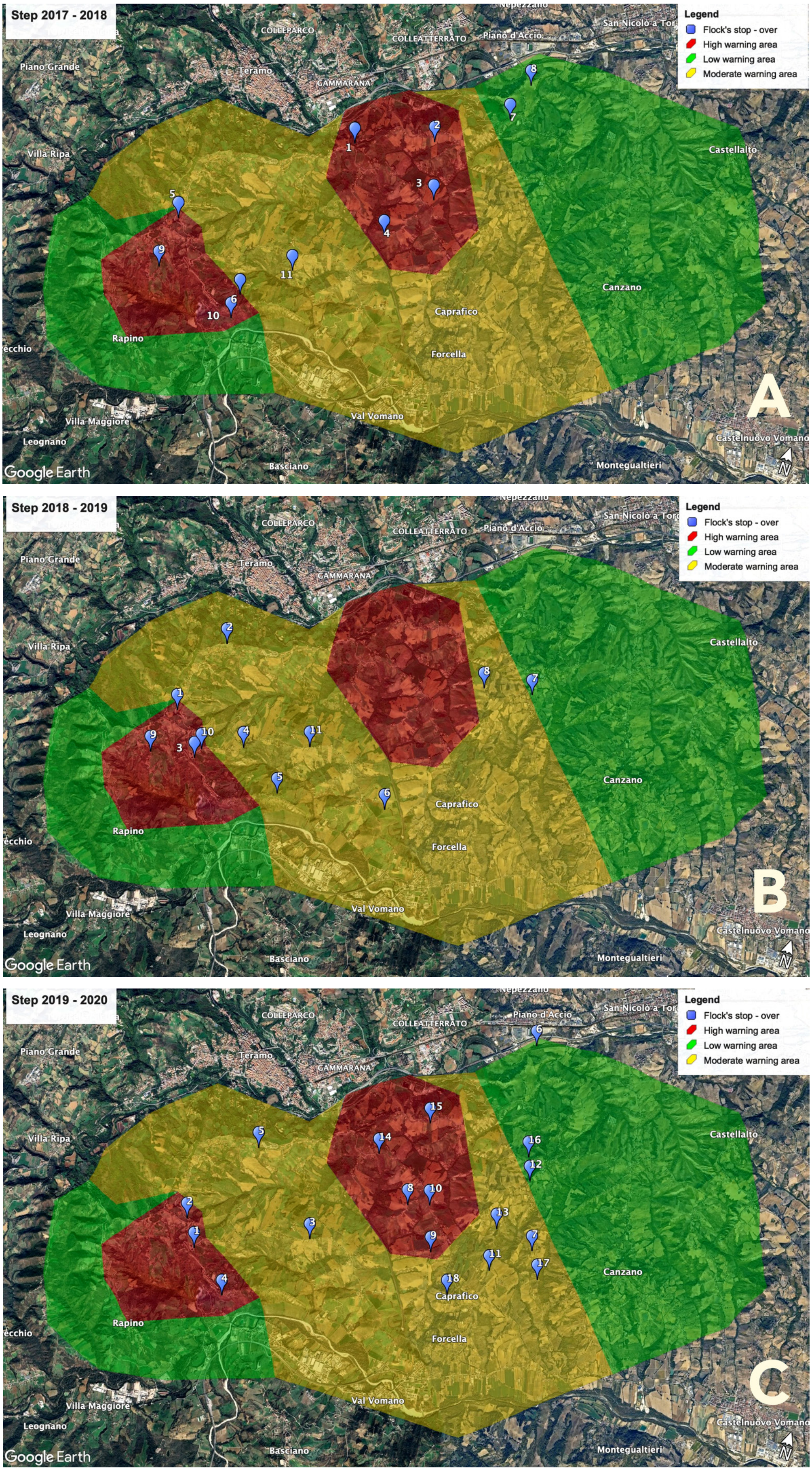

Figure 12. Flock stops during the study years.

dogs reacted autonomously, without instructions from the shepherd, and successfully repelled the threat. No livestock losses were recorded following these events (Fig. 14).

Discussion

The present study aimed to evaluate whether a small nucleus of livestock guardian dogs (LGDs) could autonomously and effectively protect a flock under real-world grazing conditions, where human disturbance and predator presence (wolves and feral dogs) are part of the environment. Overall, the behavioral observations, supported by statistical results, provide solid support for the hypothesis that this breed exhibits high suitability and efficiency in flock protection.

The chi-square analysis on vocalization timing ($\chi^2 = 182.73$, $df = 6$, $p < 0.001$) demonstrates that LGD vocal activity is significantly concentrated during twilight and night hours. This aligns with numerous ecological studies showing that wildlife is primarily crepuscular or nocturnal especially in areas with a strong human presence, with peaks in hunting-related movements at dusk and night (Ciucci et al., 1997; Theuerkauf et al. 2003; Gaynor et al. 2018). This also shows how these dogs are very alert especially when there may be the greatest danger to the herd

The significant non-uniform distribution of positioning patterns ($\chi^2 = 16.25$, $df = 4$, $p < 0.01$) indicates that dogs consistently selected pattern A– positioning along sides with dense vegetation–far more frequently than expected by chance. This suggests a deliberate strategic placement, likely aimed at improving visibility and intercepting predators that use vegetated cover to approach the flock. The dogs' orientation toward bush or dense cover corroborates this hypothesis and reflects a predictive, risk-based behavior.

Dogs rarely responded aggressively to human passage near the flock; instead, they displayed a balanced vigilance, with most reactions being passive vocalizations while maintaining flock protection. The chi-square result ($\chi^2 = 3.27$, $df = 1$, $p = 0.07$) indicates a non-significant trend toward more passive responses, reinforcing the notion of stable, non-aggressive behavior in populated areas. This behavioral equilibrium is essential in heavily utilized regions such as Abruzzo with significant tourism and human presence.

The flock spent a considerable proportion of stops in moderate to high-risk areas, based on field-assessed predator presence; long-standing stopovers took place in areas frequented by wolves and feral dogs. Despite this, no predation events or livestock losses were recorded across three winters, even though 14 predator encounters were documented (9 wolves, 5 feral dogs; 2017–2020). In all such instances, the LGDs responded autonomously and effectively, successfully deterring threats without shepherd intervention. This ancient breed requires no training from humans to perform its tasks, and its efficiency can be attributed to centuries of adaptation, its natural abilities, and, in part, the imitation of adult specimens by younger dogs in learning the defence strategies for the animals under their care (Coppinger et al., 1983).

This study provides a detailed account of the behaviors and spatial strategies adopted by a small nucleus of livestock guardian dogs (LGDs) under specific environmental and management conditions. The results suggest that, within this particular context, the dogs demonstrated effective deterrent behavior and a capacity for strategic positioning in response to potential predator threats. However, given the limited sample size (three dogs) and the homogeneity of the observed group, caution must be exercised when attempting to generalize these findings to the entire breed or to other ecological and management settings. Numerous variables may influence the effectiveness of LGDs, including but not limited to the sex and age of the animals, the number of individuals deployed, the size of the flock, environmental characteristics, and

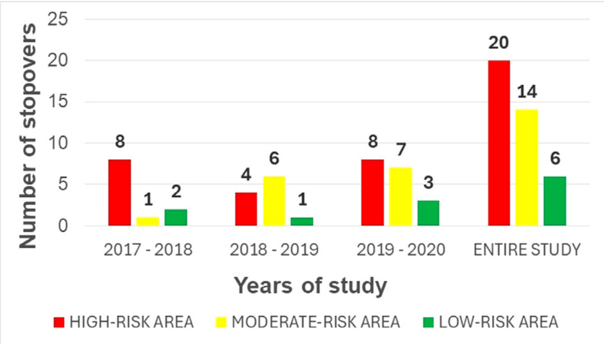

Figure 13. Number of flock stopovers by risk category and year.

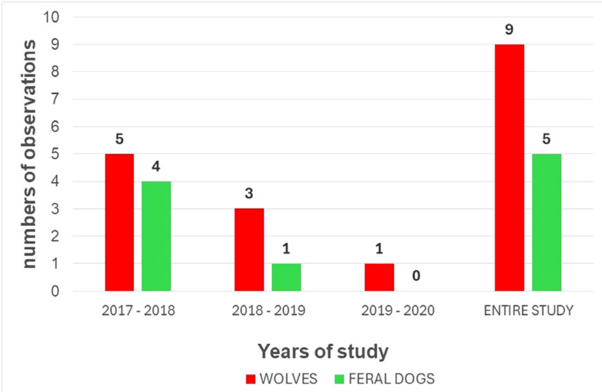

Figure 14. Number of observations of wolves and feral dogs in proximity to the flock.

the dogs' genetics and experience. Future research should aim to systematically investigate these factors, ideally through comparative studies across different contexts and larger, more diverse samples. Such studies would help clarify the extent to which the observed behaviors are representative of the breed and identify the conditions under which LGDs are most effective in flock protection. In conclusion, while our observations provide valuable insights into the functioning of LGDs in a real-world setting, further research is necessary to deepen our understanding of the variables that contribute to their success and to inform evidence-based guidelines for their deployment in livestock management.

A key limitation of this study is that observations were conducted on a single group of three livestock guardian dogs (LGDs), working together and potentially related, although their degree of kinship was not verified. This aspect restricts the generalizability of the findings, as the behaviors observed may reflect specific group dynamics rather than broader behavioral patterns applicable to other LGD groups. Ideally, future research should include independent observations across multiple groups, with varied compositions and unrelated individuals, to strengthen the reliability and applicability of the results.

Despite this limitation, the present study provides valuable insights into the cooperative behavior of livestock guardian dogs–an increasingly relevant category of working animals in the context of managing coexistence between large carnivores, such as wolves, and livestock farming. Understanding group dynamics, coordination, and responses to potential threats is essential for improving the effectiveness of these dogs in their protective role, and for informing more sustainable, evidence-based strategies to mitigate human–wildlife conflict.

Our results add to the growing body of literature highlighting the utility of LGDs in livestock protection, particularly in settings where predators are active during low-light hours and human presence is moderate to intense. The breed's ability to work autonomously, responding adaptively to ecological and anthropogenic cues, suggests potential for improved livestock management strategies that rely less on direct human control.

Future studies could explore comparative performance across different LGD breeds or lineages, the impact of learning dynamics within multi-age LGD groups, such as whether younger dogs learn effective positioning from older ones and a longitudinal monitoring of flock outcomes under LGD supervision across different predator landscapes and management regimes.

In conclusion, within the specific environmental and management context of this study, the LGDs displayed consistent, adaptive defensive behaviors that aligned with theoretical expectations of risk-based vigilance. Their vocalizations corresponded with predator activity peaks, their spatial positioning was strategically oriented toward threat corridors, and they maintained a non-aggressive posture in interaction with humans. While constrained by sample size and setting, these findings illustrate the potential of this LGD breed—and carefully selected individuals—for robust, autonomous flock protection in real-world grazing systems.

Author Contributions

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Formal Analysis: F.T.
Investigation: A,G., M.M., F.T., M.F.
Methodology: A.G., F.T.
Project Administration: A.G., F.T.
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Bulletin of Regional Natural History (BORNH) ISSN 2724-4393.

BORNH Bulletin of Regional Natural History

Formerly **Bollettino della Societá dei Naturalisti in Napoli**

Pareto model for species diversity

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DOI https://doi.org/10.6093/2724-4393/12712

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Competing interests: The Author declares that they have no competing interests for this work.

Financial Disclosure Statement: the Author declares that no specific funding was received for this work.

Submitted: 08 May 2025
Revised: 05 Sept 2025
Accepted: 15 Sept 2025
Published: 26 Sept 2025

Associate Editor:
Marco Guida

Abstract

There are several mathematical models that describe the relationship between the number of species and the number of individuals per species. This article aimed to verify whether the Pareto mathematical model could be applied to ecological data regarding species and their abundance. The Pareto model has proven to be a valid descriptor of the relationship between species and the number of individuals per species, managing to measure the level of equality and/or dominance of the same. The Pareto model, therefore, is a candidate to be a valid aid for community ecologists in describing species diversity. In this paper, using a dataset taken from scientific literature I set out to verify the application of the Pareto model to the study of the relationship between species and abundance, with the ultimate aim of suggesting this method as an addition to those traditionally used.

Keywords: Species, Biodiversity, Pareto, Alpha, Models.

Riassunto

Esistono diversi modelli matematici che descrivono la relazione tra il numero di specie e il numero di individui per specie. Questo articolo mirava a verificare se il modello matematico di Pareto potesse essere applicato ai dati ecologici relativi alle specie e alla loro abbondanza. Il modello di Pareto si è dimostrato un valido descrittore della relazione tra le specie e il numero di individui per specie, riuscendo a misurare il livello di uguaglianza e/o dominanza delle stesse. Il modello di Pareto, quindi, è un valido aiuto per gli ecologi delle comunità nella descrizione della diversità delle specie. In questo articolo, utilizzando un set di dati tratto dalla letteratura scientifica, ho cercato di verificare l'applicazione del modello di Pareto allo studio della relazione tra

specie e abbondanza, con l'obiettivo finale di suggerire questo metodo come integrazione a quelli tradizionalmente utilizzati.

Parole chiave: Specie, Biodiversità, Pareto, Alfa, Modelli.

Introduction

In no natural community do all species have the same number of individuals, the observed pattern is always that of finding few species with many individuals and many species with few individuals (Magurran, 1988). This regularity in the relationship between species and their abundances has prompted the development of mathematical models that describe this relationship (Magurran, 1988). Mathematical models that relate the number of species to the number of individuals per species represent the most complete mathematical description of the data (Magurran, 1988). Currently, the mathematical models that describe the relationship between the number of species and the number of individuals for each species are mainly four: the Log-Normal series, the Geometric Series, the Logarithmic Series, the Broken Stick (Magurran, 1988; Krebs, 1999; Southwood & Henderson, 2000). The Italian economist Vilfredo Pareto (1848-1923) devoted much time to the study of personal income inequality, in particular the observations suggested to Pareto the formulation of a universal law of income distribution, expressed in a hyperbolic mathematical model (Guarini & Tassinari, 1990). The Pareto distribution highlights how low incomes affect a greater number of people, compared to high incomes, which instead affect a minority of people. Furthermore, the parameter α present in the Pareto mathematical model, represents a real index of income concentration widely used in economics (Fraire & Rizzi, 2005).
If we consider the monetary income per person as equal to the number of individuals per species, and the income earners as the species, it is possible to adapt the Pareto model to ecological data regarding the relationship between the number of species and the number of individuals per species, furthermore the parameter α also allows us to quantify the level of concentration, or dominance, of the species in the community.
This work aims to apply the Pareto model for analyzing the relationship between the number of individuals per species and the number of species within Vertebrates using a data set reported in Magurran (1988). This work highlights that Pareto model can represent a useful analysis tool that integrates other mathematical models and indices such as Log-Normal series, the Geometric Series, the Logarithmic Series, the Broken Stick (Magurran, 1988; Krebs, 1999; Southwood & Henderson, 2000), so far used for studying the relationship between the number of individuals per species and the number of species.

Materials and methods

The Pareto mathematical model arises from the observation that the logarithm of the number of people is in inverse linear relation with the logarithm of income (Guarini & Tassinari, 1990); given N(x) the number of income earners and x the income, the relation is:

$$[1] \quad \log N(x) = \log(K) - \alpha \log x$$

the ordinate at the origin is the log(K) while the slope is represented by the constant α. From [1] we obtain the Pareto law:

$$[2] \quad N(x) = K / (x^\alpha)$$

defined for values of x included in the interval h and $+\infty$ with h corresponding to the initial level of the empirical distribution, with $h > 0$; $K > 0$ and $\alpha > 0$ (Guarini & Tassinari,

Table 1. Bird species abundance in remote European woodlands (from Magurran, 1988).

id	Species	Hidden Glen	Wild Wood	Lonely Pines
1	Spotted ratcatcher	1	2	0
2	Killer quail	3	16	354
3	Riff raff	2	3	7
4	Slyneck	1	2	4
5	Oat crake	4	10	29
6	Cold start	5	13	4
7	Big dipper	1	30	3
8	Shylark	1	14	12
9	Startling	18	22	18
10	Deadwing	1	1	2
11	Crook	2	4	1
12	Nightcap	63	5	1
13	Golden lover	2	19	1
14	Baby bunting	1	18	1
15	Mute swain	1	14	2
16	Chinese kite	1	15	0
17	Brownie owl	16	1	3
18	Hen hurrier	15	27	1
19	Grrr falcon	60	36	0
20	Gosh hawk	1	3	2
21	Cought	1	47	0
22	Flapping	8	38	18
23	Not	16	4	0
24	Bar-tailed nitwit	127	6	0
25	Snoop	9	7	0
26	Funny tern	18	8	1
27	Cut throat	3	16	0
28	Throttled dove	4	32	0
29	Ribbon	3	19	1
30	Backchat	11	6	1
31	Missile thrush	6	7	1
32	Cold tit	7	8	11
33	Twit	8	16	9
34	Yellow spanner	63	27	10
35	Born owl	17	4	3
	Σ =	500	500	500

1990). The value of h for the application that propose is equal to 1, a single individual per species. The constant α, the slope of the line, is used as an index of income concentration, with respect to income earners (Fraire & Rizzi, 2005). The parameter α is connected to the shape of the curve and is interpreted as a descriptive and direct index of the inequality of the distribution, in the sense that it increases as the inequality (concentration) of income increases (Guarini & Tassinari, 1990). The minimum value of the slope is 0 in this limiting case N(x) = K, which represents perfect equal distribution of individuals across species. The maximum value of the slope, on the other hand, is undefined, because the tangent of an angle grows to infinity. Table 1 reports the data on which the Pareto model was applied, taken from Magurran (1988). Thirty-five species of birds are represented with their respective abundances resulting from reserache carried out in three differnt locations. For each series of data referring to a location, a distribution of the number of species for the equally large classes of individuals was first constructed. Once the distribution of species-abundance classes was obtained, for each class its central value was considered, so as to obtain an ordered series of points in a Cartesian plane. This operation was necessary in order to estimate the parameters of the model [1], in fact with these series of points by applying the ordinary least squares (OLS) estimation method regressing the log of the number of species on the log of the abundances of individual species, it was possible to obtain the value of Log(K) and α for each of the three locations. The logarithms used are the Neperian ones. Once Log(K) was obtained, it was possible to easily obtain K = Exp[Log(K)], while for α the negative sign was not considered. With the obtained parameters K and α, the model [2] was applied to the real data, always using the central value of the class for the variable x, in order to obtain the theoretical values to be compared with the observed values. Finally, to evaluate the goodness of the adaptation of the real data to the theoretical data predicted by the model, the non-parametric adaptation test for a theoretical distribution of Kolgomorov-Smirnov was used (Siegel & Castellan, 1988).

Results

Location of hidden glen is given in Fig. 1; the value of K = 33,87 and α = 0,77 , the value of the fit statistic D = 0,041 n.s. the theoretical model fits the real data. Location of wild wood is given in Fig. 2; the value of K = 29,13 and

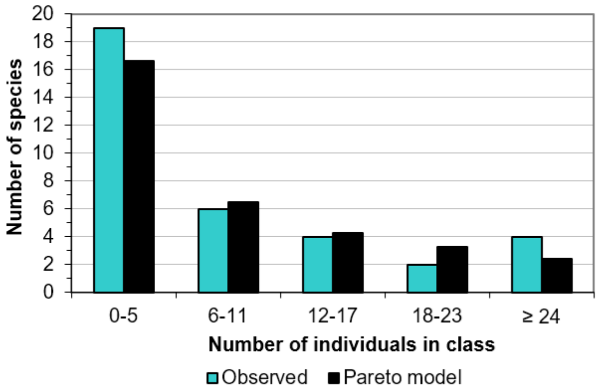

Figure 1. Hidden glenn, observed values and theoretical values of the number of species per abundance class.

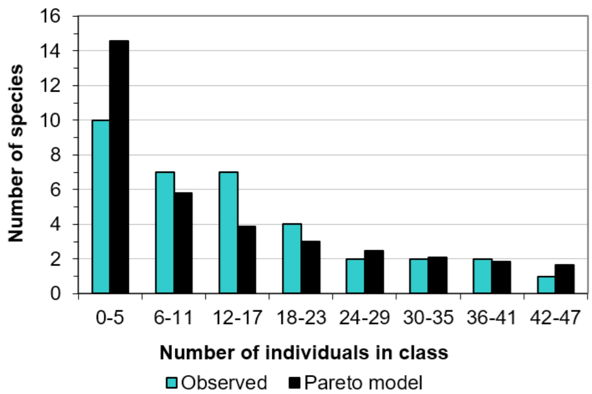

Figure 2. Wild wood, observed values and theoretical values of the number of species per abundance class.

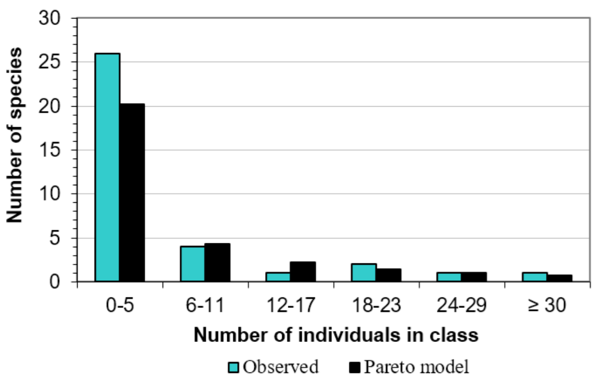

Figure 3. Lonely Pines, observed values and theoretical values of the number of species per abundance class.

α = 0,75 , the value of the fit statistic D = 0,13 n.s. the theoretical model fits the real data. Location of lonely pines is given in Fig. 3; the value of K = 63,78 and α = 1,26 , the value of the fit statistic D = 0,069 n.s. the theoretical model fits the real data. The value of α for the Lonely Pines locality is higher than the value of α for the other two localities, and this is also clearly highlighted by the graph, therefore the level of concertation of individuals per species in the Lonely Pines locality is higher than that of the other localities. The two locations Wild Wood and Hidden Glen have an equal value of α and consequently an equal diversity of species. The value for K and α all three examined localities is reported in Table 2.

Table 2. Parameters estimated using. Pareto model: For details see text

Pareto model	Hidden Glen	Wild Wood	Lonely Pines
K	33,9	29,1	63,8
α	0,77	0,75	1,26

Discussion

To the best of my knowledge, this work represents one of the first study that applies the Pareto Model for analyzing the relationships between the number of species and the number of individuals per species in vertebrates. In fact, this relationship is generally addressed using many other models such as those previously mentioned (Magurran, 1988; Krebs, 1999; Southwood & Henderson, 2000), or more recent models obtained using ad hoc algorithms (Yingnan et al. 2025; Chave, 2024; Moradi et al. 2025).

In general, species diversity measures take into account two quantities: the number of species and the number of individuals per species, the latter also known as evenness or equitability, furthermore the greater the regularity of the number of individuals for each species, the greater the diversity of a community (Magurran, 1988). Mathematical models that describe the relationship between the number of species and the number of individuals per species are able to highlight when there is a situation of concentration or equidistribution of individuals in species, and furthermore if a single diversity index is needed, a parameter of an appropriate species-abundance distribution can be used (Magurran, 1988). The Pareto model, born to measure and describe the concentration/inequality of income for human societies (Guarini & Tassinari, 1990), has adapted well to data regarding the biodiversity of bird species, and this is because the principle on which the Pareto model is based is universal. Furthermore, the parameter α of the Pareto model, which is a direct descriptive index of the inequality of distribution (Guarini & Tassinari, 1990), has highlighted how among the three locations examined there is a difference in the diversity of species with a better evenness in the locations of Wild Wood and Hidden and a worse diversity in the location of Lonely Pines. A greater concentration of individuals in a few species means less diversity and greater dominance of a few species, when one or a few species are prevalent within the community, these organisms are therefore defined (taxa) dominant; dominance is the opposite of diversity (Smith & Smith, 2006).

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Bulletin of Regional Natural History (BORNH) ISSN 2724-4393.

BORNH Bulletin of Regional Natural History

Formerly **Bollettino della Societá dei Naturalisti in Napoli**

The gradual separation process from naturalistic knowledge: travel instructions for geologists and mineralogists in the eighteenth century

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DOI https://doi.org/10.6093/2724-4393/12761

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Competing interests: The Author declares that they have no competing interests for this work.

Financial Disclosure Statement: the Author declares that no specific funding was received for this work.

Submitted: 4 Mar 2025
Revised: 18 Sept 2025
Accepted: 22 Sept 2025
Published: 20 Oct 2025

Associate Editor:
Edoardo Razzetti

Abstract

Between 16th and early 19th Centuries collecting data with economic and scientific purposes have been deeply articulated through writing travel instructions oriented to define actions at the distance. This association took place in different geographical and institutional settings within Europe, the Americas, Asia. Instructions were a key textual devices used since 16th-Century in order to surveying territories and collecting data. These documents concentrated and spread a set of concepts and practices related to making knowledge process which was in debt with data and agencies located on territories beyond the original locus where instructions had been wrote.
According to this framework the article aims to discuss the intimate relationship between travel, writing instruction and the gradual separation process from naturalistic knowledge focusing on travel instructions for geologists and mineralogists.

Keywords: Travel Instructions; Earth Sciences History; 18th Century

Riassunto

Tra il XVI e l'inizio del XIX secolo, la raccolta di dati a fini economici e scientifici si articolò profondamente attraverso la redazione di istruzioni di viaggio volte a definire azioni a distanza. Questa associazione ha avuto luogo in diversi contesti geografici e istituzionali in Europa, nelle Americhe e in Asia. Le istruzioni erano un importante strumento testuale utilizzato fin dal XVI secolo per esaminare i territori e raccogliere dati. Questi documenti concentravano e diffondevano un insieme di concetti e pratiche legate al processo di creazione della conoscenza, che era in debito con dati e agenzie situate in territori diversi da quello in cui erano state scritte le istruzioni.

Secondo questo schema, l'articolo si propone di discutere la relazione intima tra viaggio, istruzione sulla scrittura e il graduale processo di distacco dalla conoscenza naturalistica, concentrandosi sulle istruzioni di viaggio per geologi e mineralogisti.

Parole chiave: Istruzioni di viaggio; Storia delle scienze della Terra; XVIII secolo

A new way to talk about travelling

The drafting of instructions, carried out more frequently all over Europe throughout the second half of the eighteenth century, was meant to provide the travelling scientists with specific principles for mastering the techniques of observation and analysis of natural phenomena (Bossi & Greppi 1988; Kury 1988). In so doing, scientific mission was to become instrumental for the government, which could enjoy the benefits of technical-scientific advances to strengthen its economic and political power over the nations (Chappey & Donato 2016).
During the eighteenth century, the progressive research into the structure of the earth's surface and its components was closely linked to the experience of travel. The "oryctologists" and "mineralogists", as the Earth's scholars used to call themselves at that time, moved around the territory not only to collect rock, mineral or fossil samples for specialised museums, but also to gather crucial data for the interpretation of certain geological phenomena. If it was true that planning was crucial to the eighteenth-century geological investigation, the development of itinerant research into the inorganic natural world relied on different variables (Guntau 1984; Ellenberger 1994; Stafford 1984; Leed 1992). The simplest form of travelling was in fact, the short hike, namely a short-distance route covered by a single individual and referred to as a scientific practice linked to herborisation for pharmaceutical purposes during the sixteenth and seventeenth centuries. Later, in the second half of the eighteenth century, the most popular way of travelling matched the definition of the county or regional trip, which would include at the most, two or three scholars or, more rarely, a small group of people. This medium-distance journey, also consisting in crossing some regions, or even some mountain ranges like the Apennines (Vaccari 2000a), required special training and the support of local guides. Finally, geological research found significant reflection in European journeys, in the Grand Tour itself and in the great non-European expeditions, which became popular thanks to the scientific work of Alexander von Humboldt and Charles Darwin (Bertrand 2008).
In the early eighteenth century, the "oryctological" and botanical trip was probably the most widespread journey over limited distances. It was particularly popular with the German naturalists and the Italian scholars among which Giuseppe Monti, Jacopo Bartolomeo Beccari and Jacopo Biancani (Cooper 1998; Cavazza 1990) working at first at the Accademia degli Inquieti and later on at the Institute of Sciences in Bologna. It was in fact, in this academic context, that the Apennine trips from Bologna to Mount Cimone organised by Luigi Ferdinando Marsili and Domenico Gusmano Galeazzi in 1721, and by Ferdinando Bassi up to the surrounding mountains in Porretta in 1754, took place. Institutional support was however, not always requested, since, between 1704 and 1711, the doctor and naturalist Antonio Vallisneri, on his own initiative, had, on several occasions, passed through the Modenese-Reggiano Apennines and more precisely from Scandiano to Garfagnana, to the Gulf of La Spezia and the Apuan Alps (Luzzini 2013).
From the middle of the eighteenth century onwards, trips on a county and regional level intensified, especially as a way to observe more closely the geological characteristics of valleys, mountain chains and hills. In France,

for example, Jean-Étienne Guettard managed to publish in the *Mémoires of the Académie Royale des Sciences* numerous papers on his mineralogical and lithological journeys between 1746 and 1764. Likewise, in Italy between the 1950s and 1990s, geological field researches increased considerably, including: Veneto, Tuscany, Emilia-Romagna, Lombardy, Piedmont regions and other central and southern areas of the peninsula (Ciancio 1995; Vaccari 1993). Through this prism, the observation of mountains became a key element for the development of an Earth sciences' branch known today as historical geology or stratigraphy.

Between the final decades of the eighteenth century and the beginning of the nineteenth century, the growing need to compare a wide range of data and observations - encompassing the study of extinct volcanism, endogenous phenomena and the origin of rocks like basalt and granite - led to organize extended and articulated journeys. In Italy, a major example is the well-known *Viaggio alle Due Sicilie e in alcune parti dell'Appennino* (*Journey to the Two Sicilies and in some parts of the Apennines)* by Lazzaro Spallanzani, not by chance referred to as a "volcanic journey" by its author (Spallanzani 1792-1797; Vaccari 1998).

However, most of the scientific journeys of the eighteenth century were, in the broadest sense of the term, still committed to the naturalistic model: geological, paleontological and mineralogical research included in fact, numerous botanical, zoological and anthropological observations as shown in the printed version of their reports. However, as early as the end of the seventeenth century, some naturalistic journeys appeared particularly oriented towards more descriptive geological research, as they reflected the individual traveller's major interests. This trend can also be seen in the first scientific travel instructions, and more precisely, *the Brief Instructions for making observations in all parts of the world* (1696), *the Brief Directions for making Observations and Collections*, and *for composing a travelling Register of all Sorts of Fossils* (1728) by John Woodward. The English scholar was the author of a successful theory of the Earth, which became quite widespread in Italy during the eighteenth century. In the first text, Woodward seems to focus his attention more on the hydrographic, mineralogical, lithological, geomorphological and paleontological features than on the botanical and zoological ones. In this respect, he urges us to observe the various types of rock visible both on and under the surface including the metal minerals, the mountains rocks, the places where fossils could be found and all the geomorphological changes due to earthquakes, volcanic eruptions and water erosion. The second text, intended for Woodward's collaborators, expanded the contents of the Brief Instructions and focused more on the stratigraphic aspects including instructions on how to compile a traveling logbook containing all geo-paleontological fossils information, basically all the mineral and rocky objects identified on and within the earth's surface (Torrens 1985).

Under the current historiography on Earth sciences, the definition process of geological journeys, including their different styles and specific requirements, warrants further explorations. In this respect, although it is clear that notion of geological mobility came with the emergence of geology as an autonomous discipline during the crucial forty years between 1780 and 1820, early signs of this trend can already be found in previous decades. If, in fact, the textbooks for travelling geologists were issued between the last years of the eighteenth century and the beginning of the nineteenth century, other early writings dedicated to geological, paleontological and mineralogical research already contain specific indications on how to embark on a travel. Nonetheless, in order to be able to draw a more precise historical picture of the instruction process for travelling geologists, a further systematic investigation of reports dating back to the eighteenth and nineteenth centuries seems essential.

Travel's instructions in Vallisneri e Targioni Tozzetti missions

The journey along the Apennine chain between Emilia-Romagna and Tuscany, which ended in Garfagnana at the foot of the Apuan Alps in 1704, inspired Antonio Vallisneri - then professor of practical medicine at the University of Padua - to draw up a series of indications for another trip in the surrounding areas of Tuscany and Liguria. This text, divided into twenty-six points on geological research, is a veritable "index of observations", which appeared to be instrumental to finally settle the universal question on the origin of springs (Perucchini 1726). In the second paragraph, special emphasis is placed on the description of fossils and the importance of closely observing the outward appearance of the mountains and their colour composition. While indicating how to study animals, insect and plants, Vallisneri also stressed the need of embracing the history of crops, breeding and hydrography, including site climate and topography. He then examined the mineralogical features, along with the economic viability of the metal mines.

According to Vallisneri's instructions, a precise definition of how the paleontological study should be carried out is evident, even though in the scientist's text, there is no reference to any geological or mineralogical instruments for investigation, as opposed to barometers and thermometers for measuring air quality, which are instead mentioned. In his research plan, Vallisneri finally elaborated an extremely precise research method that favoured, alongside the usual description of "natural productions", a structural analysis of mountain reliefs, which should focus on the lithological content and morphology of their layers, as well as on the different types of fossils and position.

The indications contained in Vallisneri's text, although not strictly conceived by their author as instructions for other scholars, were all the same presented by Giovanbattista Perrucchini, editor of the Vallisneri's text. The Venetian "oryctologists" of the second half of the eighteenth century certainly treasured it as a precious vade mecum for their frequent research in the field, while in Tuscany, around the middle of the eighteenth century, Vallisneri's methodological heritage was ideally collected by the Florentine doctor and naturalist Giovanni Targioni Tozzetti. Il *Prodromo della Corografia e della Topografia Fisica della Toscana (The harbinger of Chorography and Physical Topography of Tuscany)*, published in 1754 immediately after the publication of the first edition (1751-1754) of *Relazioni di alcuni Viaggi in diverse parti della Toscana* (*Reports of a few journeys in different parts of Tuscany*), contains an interesting overview of the physical topography of Tuscany (Targioni Tozzetti 1754).

The Targionian travel style was taken up by Tuscan scientists, among them Giuseppe Baldassarri, Antonio Matani, Ambrogio Soldani. These scholars, while committing themselves to the geological description of some delimited territories like Siena and to the analysis of their paleontological and mineralogical features, often drew on the Florentine naturalist's theoretical conclusions based on the lithological and morphological distinction between primary mountains and secondary hills (Vaccari 2000b). Moreover, the methodological indications developed in the early eighteenth century by Vallisneri and Targioni Tozzetti can be treated as a means of comparison to the *Instructio Peregrinatoris* written and published in 1760 by the well-known Swedish botanist Linnaeus (Linné 1759).

Mountains, mines and natural cavities of the earth's surface, recognised as vital places for geological observation, started to become increasingly popular in the naturalistic instructions of travelling scientists like Alberto Fortis and Peter Simon Pallas in the late eighteenth century, as well as in the geological field investigation methods developed for personal use, as in the case of Lazzaro Spallanzani.

From Piedmont to the heart of mining Europe

In this period, the definition of "mineralogical journey" began to appear more frequently in the titles of volumes and articles published in the scientific journals, with a rather broad meaning, which was not limited to the exclusive study of minerals. In this respect, Targioni Tozzetti's Reports became *Voyages minéralogiques* for the French edition of 1792, while Alberto Fortis's *Lettere geografico-fisiche sopra la Calabria* (1784) *(Physical map Letters about Calabria and Apulia)* had already been translated into German as *Mineralogische Reisen durch Calabrien und Apulien*. Among others, the *Briefe über Mineralogische Gegenstände auf seiner Reise durch das Temeswarer, Bannat, Siebenbürgen, Ober-und-Nieder-Ungarn* (1774) by the Austrian mineralist Ignaz von Born, had turned, a few years later, into *Voyage Minéralogique fait in Hongrie et en Transylvaniein* as edited by Antoine-Grimoald Monnet.

In reality, a "mineralogical voyage" stood for long mining education tours, such as those undertaken by some Piedmont officers and artillery cadets on the orders of government both in the mid-eighteenth century and from 1787 to 1790.

Furthermore, in the eighteenth century, the Savoy State, within the framework of an intense reforming programme, financed a number of educational trips to the most popular scientific training centres in Europe involving a new technocratic class of scholars from the *Royal Schools*. This new team of technicians was supposed to take an active role in the army, the management of mines, and in bridges and roads building. Through this prism, in 1749, Nicolis Spirito di Robilant, together with other four young cadets from the Royal Piedmontese schools set off to Saxony, Austria, Bohemia and Hungary by Carlo Emanuele III to carry out a thorough study of local mines' production system. The trip was promoted by the Savoy ambassador to Saxony, Francesco Perrone di San Martino, who strongly advocated for a restructuring of the mining sector the House of Savoy had been supporting since the sixteenth century, thus favouring the arrival of foreign technicians and workers in Piedmont. At the time of Carlo Emanuele III, and thanks to the support of Minister Bogino, the management of private mines was put under state control and entrusted to the artillerymen. Despite little practical results on an economic level, this operation led to the creation of an invaluable technical and scientific reserve, bound to have a positive impact on all business sectors of subalpine territory.

One only has to read the reports of the Royal mining engineers to understand the nature and extent of information the mining system (Ferrone 1984) was able to provide.

Nicolis di Robilant belonged to a team of scientists who, during the second half of the eighteenth century, helped to re-establish and restore the technical-scientific system in Piedmont. Inspired by what was happening abroad, they were in fact identified as the bearers of that innovative movement that would lead, on the one hand, to the creation of companies and academies, privileged places for information sharing, and on the other hand, the adoption of those new skills learned elsewhere in Europe to improve the Piedmontese economic-productive system. At the height of the reformistic season promoted by the Savoy family was the activity of the Spirito di Robilant who in 1749, embarked on a long educational journey to Saxony, Bohemia, Thuringia, Hungary, Hesse, Styria, Carinthia and Tyrol with his four artillery cadets. This experience was extremely important to Robilant because the visit to both the academies and metallurgical plants in Central Europe enabled him to broaden his field of knowledge in the mining and metallurgical sectors, and to enhance and develop his scientific and technical expertise in his own country.

The first stop on the mineralogical journey of the Piedmontese artillerymen was Saxony. During one-year study in Freiberg, Nicolis di Robilant and his four cadets managed to attended lessons in metallurgical chemistry and mineralogy at Christlieb Ehregott Gellert and Frederich Hoffmann, and also in underground geometry (Johannes Zeibt) and in docismastic i.e. mineral tasting (Johann Andreas Klotsch). In addition to the theoretical lectures, the Piedmontese group also did a practical apprenticeship by visiting the mines and production facilities in Saxony.

After that stay in Saxony, the Piedmontese troops continued their journey towards the Ergebirge, a region on the border of Saxony and Bohemia, renowned for its rich mineral deposits. The team visited both the mines and the tin and copper processing plants in Zinnwald, Alterbeng, Grasliz and Johanngeorgenstadt. Particular interest was aroused by the blue cobalt[1] manufacturing plant, whose production process had been one of the main targets of industrial espionage during the eighteenth century.

In this framework, the Oberbergamt's officials, namely the superior collegiate mining management body, were ultimately responsible for allowing foreign visitors to access the Saxon workshops. Robilant and his travelling companions were issued with a pass so that they could become acquainted with the cobalt blue production process. At the Grünthal plant in Olbernhau[2], the Piedmontese engineers were trained in copper processing and the technique used to separate silver from copper by lead melting. The workshop was a large building, further subdivided into several complexes, in which the different phases of copper processing[3] were being carried out.

In 1752, after visiting other mining plants in Saxony and Hungary, Robilant returned to Turin with six thick volumes of new findings4. This major collection of data meticulously described each processing stages ranging from metal extraction, metalworking and the operating facilities. Robilant's work could indeed rival Gabriel Jars' *Voyages métallurgiques* in terms of detail accuracy and the amount of information provided.

In the work's preliminary speech, addressed to the Savoy government, the author openly stressed the political and strategic value of the Saxon journey for the economy of the

[1] The production process of the blue colour used in the glass and porcelain factories was carried out in several stages, probably in separate buildings, as can also be seen in the drawings by Robilant during the mineralogical journey. Firstly, the cobalt stone was shredded and passed through roasting furnaces. Afterwards, the roasted mineral was melted in an oven with the addition of quartz and potash to obtain a glassy material. This was grinded and then gradually passed into different water basins to obtain, after several passages, an increasingly fine powder.

[2] In the Erzgebirge district, Saxony.

[3] The copper, containing silver, was refined with lead in a furnace to form a copper-silver-lead alloy. This alloy was then heated in a special furnace until the lead and silver had turned liquid, while the copper continued to be in solid form. The lead-silver alloy was further separated into another furnace. Once the processing processes were completed, silver was sent to Dresden for coinage, while copper kept being processed for the production of copper sheets and other objects.

[4] Of Robilant's mineralogical journey to Saxony, two manuscript copies of the six volumes are available, generically entitled *Viaggi alle miniere d'Alemagna*. A copy is kept in the Royal Library of Turin, while the other one is in the library of the Academy of Sciences of Turin.

Piedmontese kingdom. Those who know the decisive value "*of a State political economy should not disregard the importance of the mines and metals manufacturing and other products of the Kingdom*" (Ferrone 1984, 462). Robilant's reports, in fact, provided a detailed and comprehensive description of the Saxon and Austrian mines, as well as their organisational structure, machinery, work shifts, the collateral processing facilities, the safety systems, mine access roads, transport, accommodation and formularies.

However, his reports did not strictly focus on the technical-scientific aspects of metalworking, but rather on the careful evaluation of production cycles. In fact, many pages keenly focused on the physical movement of products from mines and forests to foundries and factories, their specific routes and economic costs in particular with regard to the availability of raw materials and their proximity to fuel supplies and factories location. Furthermore, two entire volumes report the costs of each single operation, the balance sheets, the expenses of the porcelain factories and saltpans. Finally, the kilns, mills, metalworking machines and all industry-related aspects were described. Nicolis di Robilant's extraordinary volumes collection was ultimately completed during the 1780 probably because its potential publication could benefit the support of the great aristocrats' reformist programme of the Academy of Sciences (Ferrone 1984, 463).

The outcome of the Piedmontese artillerymen's mineralogical voyage led by Robilant and his technical reports gave rise to important initiatives aimed at developing the subalpine manufacturing sector. The pride and joy of the projects put forward from 1755 onwards, strongly backed up the knowledge acquired in the mines and mining academies of Central Europe included: the general recasting of coins in the Sospello foundries[5] under the control of Spirito di Robilant, the creation of the Conflans[6] and Moûtiers salt pans, the modernisation of the mines in Valsesia through the construction of machinery and the development of new production cycles, the establishment of new arms factories and copper processing plants (Ferrone 1984, 463-466).

Among the different proposals by the group of artillerymen returning from the German States, worthy of mention is the "*hypothetical project of a building bringing together all the operations on iron and the arts in that kingdom and elsewhere, akin to introducing a great trade and industry* (Ferrone 1984, 464-466)"7. This was an analytical description, carried out by Robilant in 1764, on the aspects related to the creation and operation of a large iron and steel plant, which summed up the results of the training trips abroad made by the artillerymen a few years earlier.

In addition to introducing the techniques tested in Central Europe, the journey of the Piedmontese team prompted the Savoy sovereign to recognise the need to establish new schools of mineralogy to train new workers, who had been crucial to the economic development of the state in the second half of the eighteenth century. In the preliminary speech of the six volumes on the mineralogical journey, Robilant expressly asked the sovereign to "introduce the schools

[5] Currently a French municipality located in the department of Alpes-Maritimes in the Provence-Alpes-Côte d'Azur region. In the past, it was part of the Piedmontese possessions.

[6] The towns of Conflans and l'Hôpital, in the current department of Savoy, were united in 1836 by King Charles Albert of Savoy of Sardinia in the town of Albertville, founded and baptised after the sovereign's name. Conflans in Savoy is not to be confused with Conflans-Sainte-Honorine in the department of Yvelines in Île-de-France.

[7] Please refer to "*Ragionamento che ha per oggetto il ferro ed i suoi trattamenti con cui si accompagna il gran edificio di cui si unisce li disegni, stato concepito per raccogliere in un sol corpo e presentare con una semplice occhiata tutte l'arti che ne derivano*, in *Memorie riguardanti la mineralogia, la metallurgia, le scienze naturali e altro*". The manuscript is kept in the library of the Academy of Sciences of Turin, ms. 0382.

of mineralogy, chemistry, underground architecture and metallurgy". To this end, he brought the publications, translated into Italian by Georg Ernst Stahl, Andreas Sigismund Marggraf, Johann Heinrich Pott and Friedrich Hoffmann to Turin marking the beginning of a cultural information campaign in Piedmont, similar to what was happening at the same time in France thanks to the German mineralogists' manuals translated by Baron d'Holbach.

Robilant's projects soon found practical implementation, confirming the Savoy family's interest in the management and exploitation of mineral deposits. In the fifties of the eighteenth centuries, within the Turin Arsenal, the Mining Magistrate and the Mineralogy School began to operate (Ferrone 1984, 466). Spirito di Robilant, at the turn of his brilliant career, while affirming the importance for European governments to foster scientific research, he also stressed the great educational value of cultural exchange and international relations in the book *De l'utilité et de l'importance des voyages*, published in 1790 (Di Robilant 1790). The outcome of the study period from Robilant to Freiberg, described in the pages of the six volumes of *Viaggi alle Miniere di Alemagna* had opened up "an important gate in Piedmont, which would boost the economic development and create the conditions for the recovery of an intellectual life" (Ferrone 1984, 467).

A few decades after his travels in Europe, Robilant, who in the meantime had become Inspector General of the mines, decided to send other young officers to the countries of the Habsburg Empire. In fact, it was necessary to continue to stimulate the economic activity of the State by focusing on mining and metallurgy in order to give consistency and continuity to Robilant's achievements. In this respect, Robilant, while believing in the effectiveness of the regional missions to Piedmont and Valle d'Aosta, also assumed that beside the theoretical background in the mineralogical school of Turin, further training abroad was indispensable. In this context, Carlo Antonio Napione was chosen as the person in charge of the new mineralogical journey between 1787 and 1790 at the Saxon mines and academies (Argentieri 2012, Bulferetti 1970). Born in Turin in 1757, he began his military career at the Piedmontese academies where he studied mathematics and artillery. He then moved on to the Robilant's school where he learned mineralogy, metallurgy and chemistry. After completing his theoretical studies in autumn and winter, Napione, similarly to other academic and royal students, used to practice in the Piedmontese mines of the Aosta Valley and Savoy during the summer.

Napione was chosen by Robilant to undertake a seminar trip in the same territories he himself explored in 1749. In March 1787, he drew up the instructions for "those members of the artillery who, while excelling in mathematics, physics and chemistry would be able to go to Germany and Hungary and gain adequate and practical experience in metallurgy to operate for the mines of His Majesty in Sardinia" (Bulferetti 1970, 12). The itinerary included several stops at the Noric Alps[8], the course of the Danube to the Oder and the Vistula, the mountains that separate Silesia from Bohemia - the Riesengebirge to the Fichtelgebirge - the mining mountains of Saxony.

Before crossing the Alps and heading towards the German states, the officers made a trip to the valleys of Aosta, Andorno, Sesia, Ossola and visited the iron foundries of Giaveno[9], Canavese and Aosta. The aim was to prepare a report on mineral deposits to compare the data collected with what they would see outside Piedmont.

[8] They take their name from Noricum, a historical region including the central part of Austria, part of Bavaria, Slovenia and Italy.

[9] Piedmontese municipality in the province of Turin.

The mission continued towards to the Mineralogical Museum and the mint in Pavia, and ended up in Milan, Bologna and Verona. After crossing the Austrian border, the group decided to head on to Vienna, where the Piedmontese ambassador, Ludovico di Breme, gave Napione the necessary documents to keep on travelling. Following Robilant's indications, the young artillerymen visited the mineral deposits and the foundries of Saxony and Hungary, studied the techniques of mineral processing, cobalt blue, glassworks and saltpetre production processes. At each stop, the cadets compiled accurate reports, which were sent, to the General Finance Office in Turin on a regular basis.

After completing his Styria and Carinthia tour, Napione made a long stay in Schemnitz, travelled to Transylvania before arriving in Saxony and more precisely in Freiberg. In June 1788, he attended Werner's courses at the Bergakademie, considered at the time, «*la meilleure école pour l'exploitation des mines en Allemagne et peut être en Europe*» (Bulferetti 1970, 20). In that period, Napione not only began to prepare a volume on the amalgamation of metals including the notes taken at the Saxon Academy, but he also made sure that Turin received the model of some of the machines he had encountered during his journey.

Going towards the insular Europe, England and Scotland, and then returning to Piedmont in 1792, Carlo Antonio Napione concluded an important new mission. The organisation of mineralogical journeys, in the second half of the eighteenth century, gave a decisive boost to the Piedmontese science and economy of the time, owing to an organic restructuring project for mining and metallurgy, which would "*pilot the transition from the empirical, semi-artisan activity of mine and mineral processing to a more proto-industrial approach*", in line with the most avant-garde centres in Central Europe. Thanks to the foundation of the school of mineralogy and a theoretical-practical system inspired by the travelling scientists' transalpine model, the Savoy State was bound to become an effectively autonomous entity in both mining management and metallurgy.

Southern travellers on their way to find mines

In addition to the Piedmontese officers and artillery cadets' trips in the mid-eighteenth century, missions to Freiberg in Saxony and other well-known mining centres in Central and Northern Europe were also financed in Southern Italy, both during the Austrian viceroyalty (1707-1734) and the first Bourbon period (1734-1799). Given the official nature of the expeditions and the complexity of the itineraries both journeys highlight the need to draw up and assign precise travel and mining research instructions.

In June 1753, the Secretary of State Giovanni Brancaccio gave Pietro Conca, an official of the General Direction of Mines of Naples and Sicily, the instructions for an upcoming trip with Augusto Knoblauch, assistant to the director, and Giovanni Heidenreich, administrator of the quarries of Fiumedinisi, "*in the mines of foreign countries in order to acquire the basic knowledge and master the art where it appeared to be more profitable*"10.

According to the trip and its objectives, travel instructions, which depended on the traveller's cultural and scientific background, became of highest importance. In fact, as in the Neapolitan case, the most relevant missions financed by governments between the second half of the eighteenth century and the French Decade were always accompanied by specific instructions (D'Angelo 2016, 2018)[11]. Actually, those given to Pietro Conca

[10] Archivio di Stato di Napoli (from now on ASNa), *Ministero delle finanze*, fs. 2633.

[11] In addition to the aforementioned example of Pietro Conca, travel instructions were given to the expedition lead-

and his fellow travellers contained a wide range of indications, and suggestions for making the journey more comfortable and worthwhile. Ultimately, this programme provided a comprehensive set of tips and precise information for the mission to become an asset for the country and not to satisfy one's own personal sense of accomplishment[12].

Beside the observance of Catholic religion's rules, the distribution of payments among the members of the group, the appointment of the expedition leader, the instructions enabled Conca to acquire a wide range of knowledge and technical skills[13].

If the drafting of the travel instructions was completed in June 1753, the actual group only took off at the beginning of 1756[14]. On 9th January, the Councillor of the court of Vienna, Ignaz Kempf von Angret issued three permits to the subjects of the Kingdom of Naples to visit the mines and metallurgical plants of Upper and Lower Hungary, Banat, Transylvania and finally Tyrol. They were also authorised to assist quarrymen and miners from Carinthia and Bohemia during the extraction of minerals from the caves. On this occasion, Conca, Knoblauch and Heidenreich could therefore practically train in metallurgical activity, in the techniques of opening and draining the water in the quarries, the construction of metalworking furnaces, in particular those for silver and copper purification. Beyond the practical and technical aspects, the Neapolitan group was committed to getting information on how account books and registers were produced along with all the documentation relating to the extraction and processing of raw materials, including their implementation in the different branches of industry.

Conca's journey ended, presumably by the spring of 1756, with a visit to Neusohl, now Banská Bystrica, and Kremnitz, both cities in Slovakia[15]. Since then, archival traces have been lost. In this respect, it is not possible to know with certainty about the mission outcome, nor is there any available documentary footage that would allow a clear and precise reconstruction of the organisation and the findings during the 1756 trip. It nonetheless marked a new phase, financed by the Crown, which should have been more consistent to ensure its sustained impact over time. If, in fact, in Piedmont, only a few years had elapsed between Robilant and Carlo Napione's mineralogical journeys in Saxony, in Naples, the time gap was of twenty-six years, and more precisely from the study stay in the imperial dominions of Conca to the new trip financed by King Ferdinand IV, in 1782.

In that year, the "Nunziatella" Military School's future commander-in chief, as well as patron of the mineralogical journey of 1789, Giuseppe Parisi, was authorised by the court of Vienna to visit the mines of Lower Hungary

er, Giacomo Dillon and the four hydraulic engineers in charge of a mission to France between 1787 and 1789, as well as to the six naturalists who travelled in Europe between 1789 and 1796.

[12] «Ordina sua Maestà a Don Pietro Conca di regolare i designati viaggi di sorte che si miri a dirittura al prefisso fine del desiderato profitto loro ed interesse reale e non già a fini particolari travianti dal principale». "His Majesty orders Don Pietro Conca to arrange for the designated voyages of fortune to be made at the prefix of the desired profit and real interest for them and not for any particular purpose that would be of benefit to the principal". ASNa, *Ministero delle finanze*, fs. 2633, *Istruzioni del Marchese di Brancaccio a Don Pietro Conca*, Napoli 3rd June 1753.

[13] «Debbono osservar bene le diverse armature delle grotte sì di legno che di pietre murate e come cavansi o faccino perder le acque, come si procuri l'aria e necessario respiro e sfogo con far disegno o mostre del più rimarchevole. [...] Piglino pure le vere idee delle fornaci e focolai pella fondazione e separazione de' metalli, del modo e divario delle fabbriche a fondere e separare, della qualità delle miniere che si uniscono per far meglio riuscire le fondazioni e separazioni». *Ibidem*.

[14] From the documents available it is not possible to establish the reasons for this delay. Diplomatic or financial problems may have arisen.

[15] Slovenský Banský Archív v Banskej Štiavnici (SBA), *Banská komora v Banskej Bytrici*, fs. 603, f.lo 21.

(D'Ayala 1845, 200)[16]. Unfortunately, Parisi's expedition ended before it even started, as there is very little information about his mission in the overseas territories and therefore it is impossible to assess its impact on the economy and the metallurgical sector of Southern Italy.

As shown by the instructions prepared for the two Piedmontese and Neapolitan groups and in general, for the Italian and European naturalists who travelled across the continent, the detailed nature of the texts specifically intended to provide a thorough picture on the activities of the travelling scientists. The drafting of instructions process went hand in hand with the definition of geology and mineralogy as autonomous disciplines, whose contributions would reach its peak in the nineteenth century. Thus, the geo-mineralogical journey developed during the eighteenth century, while complying with the main operating procedures, managed not only to acquire its own disciplinary independence during the first decades of the nineteenth century, but also to mark the beginning of a new specialisation process bound to establish a direct and indissoluble link between geologist, mineralogists and the practice of travelling.

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[16] *Ivi*, *Baský* úrad v Kremnici, fs. 603, f.lo 169. Mariano d'Ayala, biografo di Parisi, ricorda: «[…] Nel 1782 andavano ad ammaestrarsi in Germania Giuseppe Parisi, Macri, del Re, Brune, Gensano, Roccas, Pignatelli Cerchiara, Carnavè, Serrano e qualcun altro quale di artiglieria, chi ingegnere e chi delle fanterie. […] Onde in Germania il nostro Parisi, aggiungendo a geometrico acume una leggiadra incantevole locuzione, si ebbe fama di altissimo ingegno, e però il volle tra suoi confidenti il generale austriaco Pellegrini dell'arma sapiente degli ingegneri, che lo fece tenere in ugual prezzo al ministro Caunitz, primo a que' dì nel concistoro dell'aulico consiglio. E la Maestà di Giuseppe II, al quale era già chiara la valentigia del giovane uffiziale napoletano, spesso invitavalo al suo desinare, facendolo incontrare col poeta chiarissimo degli affetti Pietro Metastasio; e reiterate volte con ogni guisa di ricompensa offrivagli il posto di maggiore fra suoi ingegneri di campagna, che rispettosamente sempremai quei rifiutò, tenero come egli era della sua terra natale e devoto alla bandiera nostra».

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Bulletin of Regional Natural History (BORNH) ISSN 2724-4393.