Sessione
Nuove frontiere della Zoologia:
innovazione e sinergie interdisciplinari

Comunicazoni

Ecohydraulics meets Zoology: a powerful partnership for river habitat assessment and modeling

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As environmental challenges intensify, the integration of ecohydraulics and zoology is emerging as a critical frontier for advancing river habitat assessment and modeling. This talk explores the powerful synergy between these disciplines, with a particular focus on the crucial role that species-specific biological knowledge plays in interpreting eco-hydraulic model outputs and predicting ecological responses.

Understanding the biology of aquatic and semi-aquatic species, such as their flow preferences, swimming capabilities, reproductive strategies, habitat use across life stages, and sensitivity to different environmental variables, is fundamental for linking hydraulic and geomorphic conditions to ecological relevance. Without this ecological context, hydrological and geomorphological outputs (e.g., velocity, depth, shear stress, sediment size, channel geometry) remain just physical quantities. However, when interpreted through the lens of species biology, they become indicators of aquatic habitat suitability, enabling us to translate physical metrics into meaningful ecological predictions.

In this framework, species traits guide the selection of relevant hydraulic and geomorphological parameters and help define threshold values for habitat availability in rivers. These biological requirements inform both the structure of habitat models and the interpretation of spatial and temporal patterns derived from hydraulic simulations across scales.

We present recent advances in high-resolution hydrodynamic modeling, species distribution modeling, and trait-based ecological frameworks that enable the estimation of species presence probability as a function of flow dynamics and river geomorphological characteristics. By combining ecological insight with robust physical modeling, this interdisciplinary approach enhances our ability to assess habitat quality, forecast species responses to hydrological changes, and design effective conservation strategies.

Through case studies, this talk will illustrate the current capabilities and future potential of ecohydraulics-zoology integration for guiding habitat restoration, environmental flow management, and biodiversity conservation under increasing anthropogenic and climatic pressures. Emphasizing collaborative approaches and knowledge exchange between engineers and zoologists, we aim to demonstrate how species biology is not just a complementary layer, but a foundational component for meaningful river habitat modeling.

Interdisciplinary insights into human–wildlife interactions: spatial responses of wolves and roe deer to anthropogenic pressures

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Human activities are increasingly reshaping wildlife behavior and spatial ecology, particularly for large mammals that require extensive, connected habitats. Understanding how multiple anthropogenic pressures influence species distributions and spatial behavior is critical for conservation planning. This study focuses on the spatial responses of wolves (*Canis lupus*) and roe deer (*Capreolus capreolus*) to various human activities, including livestock grazing, hunting, recreational activities, urbanization, infrastructure development, and landscape fragmentation. Adopting an interdisciplinary and innovative approach, we integrated camera trap data, GPS collar tracking, and genetic analyses in the western Alps to understand ecosystems processes. Spatial models were used to assess co-occurrences, habitat selection and movement patterns in relation to human disturbance. Our results reveal complex spatial responses: roe deer exhibited increased selection of high-wolf-density areas during the hunting period, supporting the risk enhancement hypothesis, where avoiding one predator increases exposure to another, and highlighting the temporary impact of hunting on predator–prey dynamics. During the period of the wild boar drive hunt, roe deer also showed stronger selection for proximity to buildings, supporting the human shield hypothesis. We also modelled the co-occurrence probabilities of roe deer, red deer and wolves, providing important evidence of interspecific dependence, revealing that pairwise interactions among species had a greater impact than only considering environmental effects. This work demonstrates how integrated ecological methods and cross-disciplinary tools can reveal patterns of wildlife response to overlapping anthropogenic pressures. The combination of spatial, behavioral, and genetic data allowed us to disentangle cumulative impacts on mammal distribution. Our findings stress the need for conservation strategies that account for the interactive effects of human activities, and highlight the value of interdisciplinary frameworks to support adaptive, context-specific management in human-modified landscapes.

Ground-nesting bees and wasps as possible indicators of soil traits: hardness and texture

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Soil is a main habitat of terrestrial ecosystems known to harbour a rich and diverse fauna, with many groups largely recognized as relevant for soil functioning and as important indicators of soil quality. Among hymenopteran insects, ants are well-known as soil engineers, modifying soil physical structure and in influencing soil fertility through nest digging. Along other abundant edaphic taxa such as mites, collembolans and nematodes, ants can be then used as indicators of soil quality. On the other hand, ground-nesting bees and wasps (Apoidea) were almost neglected as soil modifiers, and essentially we know nothing about their potential role as soil improvers in terms of, e.g. fertility. One first step to propose ground-nesting apoids as potential indicators of soil quality is to test if different lineages of such insects are actually specialized for nesting in particular soils. Here, using data on around 70 bee and wasp species, we found that hardness and texture of nesting soils were variable among species. At species-level, soil traits seemed to vary to minor extent, but this extent also changed among species. However, interesting, certain lineages seemed to nest in a relatively homogeneous soil, and such pattern seemed to be associated with the social behaviour of the species within the lineages. In particular, accounting for common ancestry, social species nest in harder soils than solitary species. Furthermore, social species nest in soils with less % of sand and higher % of silt compared with solitary species. The texture profiles of the analysed species, when represented in a classical soil triangle classification, showed that most species fall in the spaces “sandy loam”, loamy sand” and “sand”, with some species, especially from social lineages, falling in the spaces “clay loam” and “silt loam”. Through the intersection between pedology and behavioural ecology, our results preliminarily suggest that ground-nesting apoid communities over large areas may give insights on the distribution of soil types in the areas, and that the social behaviour of single species at a given restricted nesting area may reasonably give indirect information on soil type. Further studies devoted to the comparative analysis of other soil properties, such as organic matter content, respiration and acidity in and out of the nesting sites will help proposing ground-nesting bees and wasps as efficient indicator of soil quality.

Comparing chromatin accessibility profiles in two marine animals, the japanese clam and the european sea bass

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Genetic variants in non-coding regulatory elements are supposed to explain a large fraction of phenotypic variation within and across species. Identification of such non coding regulatory elements, however, remains more difficult than to annotate coding regions. Moreover, the functionality of regulatory elements is generally tissue-type specific, which requires the application of such approaches in different tissues. The assay for transposase-accessible chromatin using sequencing (ATAC-seq) provides an effective way to detect the unique chromatin landscape associated with a cell/tissue type. Patterns of chromatin accessibility are thought to be connected with the cell-specific gene expression patterns that mould identity and functions of cells and tissues. Here we report chromatin accessibility atlases for two marine species, the Japanese clam *Ruditapes philippinarum*, and the European seabass *Dicentrarchus labrax*. Using ATAC-seq on four tissue samples from five individuals of *R. philippinarum* and for four tissues from six individuals of *D. labrax*, an average of 103'000 open chromatin regions per sample were identified in Japanese clam and 66'000 ones in European sea bass. A first significant difference between the two species was the proportion of peaks falling into three categories of genomic regions: putative promoters (15% peaks in sea bass, 12% in clam), gene bodies (respectively 64% and 30%), and intergenic regions (21% vs 58%). After peak import, unsupervised PCA on each consensus peakset revealed that samples were clustered by tissue in the case of European seabass, while they clustered by individuals in the case of Japanese clam. Discriminant Analysis (DA) with permutations was successfully used to significantly discriminate the four tissues, identifying tissue-discriminant peaks for both species. Only in *R. philippinarum* DA significantly discriminate between individuals. Individual-discriminant were significantly over-represented in intergenic regions, therefore in putative distal enhancer elements. While enhancers have been shown to evolve rapidly, the inter-individual variability observed here is rather extreme. It might represent a substantial source of intra-specific variation in gene regulation that might translate into phenotypic variation across individuals. Analysis of ChIP-seq and RNA-seq data on the same samples are currently ongoing, to further elucidate the observed phenomenon at different levels of epigenetic regulation.

Investigating how global climate change impacts mosquito interaction with viruses

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Mosquito-borne diseases are re-emerging in Europe, mostly due to the establishment of new invasive vectors, in primis *Aedes albopictus*, which can transmit several arboviruses and the heart-worm. Being ectotherms, mosquitoes depend on environmental temperature to modulate their physiology, fitness, seasonal activity, and, ultimately, their interaction with viruses. Global climate change has already been shown to impact mosquito distribution and its phenology, but whether it also alters mosquito interaction with viruses is poorly understood. Global climate change manifests both as global warming, that is constant increase in environmental temperature and as increase in frequency of extreme whether events like heat waves. Global warming is a long-term challenge whereas heatwaves are temporary, short-term stress events.
We mimicked heatwaves and global warming by exposing *Ae. albopictus* mosquitoes to 32°C, a temperature above the optimum for this species, for one or ten generations generating warm-acclimated vs warm-evolved mosquitoes, respectively. We infected these groups of mosquitoes with the Cell fusing agent virus (CFAV) and studied the fitness and the response of mosquitoes to viral infection.
We saw that warm-acclimated mosquitoes fight CFAV infection, whereas mosquitoes conditioned to heat through several generations are healthier than those not exposed to a thermal challenge and tolerate CFAV infection.
These results highlight important shifts between resistance and tolerance dependent on the length of the thermal challenge. This immunological shift has far reaching implications for understanding viral transmission dynamics and has also long-term impacts on the evolution of both vectors and viruses under global climate change

Forensic zoology: The importance of an integrated zoological approach in legal cases in Italy

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In recent years, there has been an increasing use of naturalistic disciplines, including zoology, within the legal context, both during investigations and court proceedings.
This situation is well established in Anglo-Saxon countries but has been slow to develop in Mediterranean countries, including Italy. However, it is important to highlight that there is a growing attention from investigators, especially towards forensic entomology. The Italian research community is also moving very slowly in this direction.
This contribution aims to illustrate the current state of the art of forensic zoology in Italy by considering both scientific publications and forensic cases of national interest.
The work is structured into an initial presentation of articles published in recent years by Italian researchers concerning studies related to: 1) the development of methods to detect food frauds in laboratories and in the field (eg: market); 2) the evaluation of cadaver alterations caused by animals; and 3) advances in forensic entomology. In this last topic the effect of globalization and global warming on the italian entomofauna of forensic interest is also presented and discussed.
In the second part of the paper, some forensic cases that occurred within the national territory will be presented, in which zoologists were involved to provide scientific answers to investigators' questions. Additionally, some current limitations and challenges encountered in applying zoological knowledge in courtrooms will be discussed.

New frontiers in evolutionary analysis: integrating across phylogenetic comparative approaches to explore speciation and phenotypic evolution in a hyperdiverse fish clade

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Understanding how and how fast biological diversity arises is a central quest of evolutionary biology. While classical theories suggest that the rates of species origination and of phenotypic evolution should be correlated, empirical evidence to date has been mixed. Here, we investigate this relationship in wrasses, a hyperdiverse clade of marine fish. To tackle this complex question, we employ an integrated array of cutting-edge phylogenetic, morphometric, and statistical approaches. This interdisciplinary framework enables deeper insights into macroevolutionary dynamics and their potential links to microevolutionary processes.

We first constructed a novel time-calibrated phylogeny of 380 wrasse species. We captured phenotypic variation using advanced geometric morphometrics of body shape. We estimated rates of speciation and phenotypic evolution using a suite of maximum likelihood and Bayesian methods, including both tree-wide models and those allowing for localized shifts in evolutionary rates and tested for the association between rates using robust phylogenetic regression.

We found substantial variation in both speciation and phenotypic evolution rates across the wrasse phylogeny, superimposed on simpler patterns of tree-wide variation. Specifically, while speciation showed clear time-dependent variation, phenotypic evolution did not. Importantly, our integrative approach reveals how complex patterns of local variation in rates are superimposed on these general tree-wide patterns. Notably, we do find an association between rates of speciation and phenotypic evolution only for body elongation.

Our findings reveal intricate patterns of evolutionary rate variation and how the relationship between rates is complex and often trait-specific. Notably, elongation has been consistently linked to microevolutionary ecological divergence between benthic and limnetic forms in multiple teleost clades. Our results highlight the potential role of specific axes of morphological change in driving both species richness and the pace of the evolutionary process. These results underscore the importance of considering multiple phenotypic traits and lineage-specific dynamics and how simple, general, models might be largely inadequate to characterise the evolutionary history of hyperdiverse clades.

Applying deep learning and machine learning to decode animal communication signals

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In recent years, anyone interested in animal communication has wondered whether we can use machine learning and artificial intelligence (AI) to analyse communication signals and gain new information about how animals communicate. We will present two AI-powered animal communication analysis case studies, including bioacoustics and facial movement data. The applications on the datasets being proposed aim to classify signals of calls and facial configurations across a range of species. In the first task, using as models the vocal repertoires of nine Strepsirrhine primates (*Eulemur coronatus*, *E. macaco*, *E. flavifrons*, *E. fulvus*, *E. mongoz*, *E. rubriventer*, *Varecia variegata*, *Propithecus diadema*, *Indri indri*), we tested three machine learning (ML) approaches (Multi-layer Perceptrons, Support Vector Machines, and Random Forests) to compare performances in the classification of vocal types, previously submitted to feature extraction by one-third octave band filters. Despite differences across the species, we found that Random Forests performed better on average (also exceeding 80% of correct classification rate) than the other approaches. We then applied the same three methods over distances between key points estimated after a deep learning process of marker-less estimation. Our task was to identify faces where individuals from four primate species (*Propithecus diadema*, *Indri indri*, *Nomascus gabriellae*, *Saguinus oedipus*) showed an open or closed mouth. Again, we found that Random Forests performed better on average than the other approaches. We discuss how ML and AI may serve zoological research in the future by showing how flexible we can integrate feature extraction pipelines and sophisticated classification analysis on diverse communication signals.

OctoPartenopin and ink extract: novel anti-inflammatory and antioxidant from cephalopods

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OctoPartenopin is a novel antimicrobial peptide characterized from the suckers of *Octopus vulgaris*. In previous studies this peptide exhibited significant antibacterial activity against both Gram-positive and Gram-negative bacteria. Preliminary experiments demonstrated that one of its analogues was particularly effective at both inhibiting and eradicating biofilms formed by the tested microorganisms.
In this study, we analysed the anti-inflammatory activity of OctoPartenopin using an in vitro cell culture model with Caco-2 cell culture as model. Cell cultures were treated with lipopolysaccharides to induce inflammation, and subsequently with OctoPartenopin analogues to evaluate their effects. After treatment, RNA was extracted from the cells, and differential gene expression was analyzed for markers related to anti-inflammatory and antioxidant activity.
Additionally, we explored the anti-inflammatory and antioxidant activity of extracts from ink sacs of the Sepia officinalis for similar bioactivities.
The presence of OctoPartenopin in arm suckers also provides insights into octopus behavior, particularly in relation to maternal care of fertilized eggs. These findings suggest that octopus suckers are a rich source of multifunctional peptides, with potential for the development of alternative antimicrobial agents and natural food preservatives.
Peptides derived from natural sources—such as marine organisms, amphibians, or insects—may reveal unique mechanisms of action that expand our therapeutic toolkit. Investigating these molecules not only contributes to drug discovery but also enhances our understanding of the molecular basis of inflammation, with potential applications in the treatment of chronic conditions such as arthritis, inflammatory bowel disease, and neuroinflammation.

From a gene to a material: unraveling the mechanisms of silk production in the webspinner *Embia thyrrenica*

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Human societies have long benefited from nature's resources, obtaining materials that have transformed cultures and economies. Among these, lepidopteran silk has emerged as a cornerstone of the global textile industry. In recent years, scientific attention has increasingly focused on spider silk, whose remarkable mechanical properties offer exciting potential. Silk-based materials have found new applications in regenerative medicine, biomaterials development, and drug delivery. However, multiple animal lineages independently evolved silk-like materials, and most of these represent largely uncharted territory - and an exciting avenue for novel bioinspired materials. One such underexplored group is the webspinners (order Embioptera), insects that produce silk from specialized glands of their enlarged basitarsomeres in their forelegs. The molecular mechanisms and evolutionary origins of embiopteran silk remain largely overlooked. Here, we present an integrative and interdisciplinary study of silk production in *Embia thyrrenica* Stefani, 1953 a Mediterranean endemic. We first established laboratory colonies of *E. thyrrenica* and generated a high-quality reference genome using long-reads and long-range technologies, then mapped the ultrastructure of the enlarged basitarsomeres by nanotomography to reconstruct three dimensional gland models. We integrate these morphological data with spatially resolved transcriptomic and proteomic approaches to identify the cellular and molecular machinery underlying fiber synthesis, and we couple metabolomic analyses with tensile testing to quantify the composition and mechanics of the silk. Our interdisciplinary framework not only illuminates the developmental and evolutionary origins of embiopteran silk but is also expected to establish design principles for next-generation bioinspired materials.

Unveiling continent-wide migration in Odonata through unconventional approaches

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Insect migration has received considerably less attention from zoologists compared to that of vertebrates, despite its major ecological relevance in transferring large amounts of biomass between ecosystems. This gap is primarily due to methodological limitations: the small size of insects does not allow the use of technologies and approaches that have proven fundamental in understanding vertebrate migration (e.g. bird banding or satellite telemetry). Among Odonata, a significant number of species exhibit migratory behaviour—an adaptation that has likely evolved in response to seasonal changes in their aquatic breeding habitats. The biology of this order is well studied and, among insects, they are among the most conspicuous and well-known, making them ideal targets for studies on migration. However, the impossibility of directly tracking their large-scale movements necessitates the adoption of alternative unconventional approaches. *Anax ephippiger* is a tropical species that occurs seasonally in Europe and is known for its long-distance, and sometimes invasive, migrations. Despite this, very little is known about the characteristics of its migratory behaviour. This is due in part to the fact that, although it is one of the largest species in the European dragonfly fauna, tracking its large-scale movements remains challenging. In this study, we describe the spatial and temporal patterns of *Anax ephippiger* migration at the European scale using occurrence data derived from citizen science (¿27,000 records). The results show that the species undertakes long-distance movements (¿5,000 km) that follow consistent routes year after year. The migrants reaching Europe in early spring originate from Africa; these individuals reproduce in Europe, and their offspring give rise to a second migratory wave in late summer. These findings improve our understanding of dragonfly migration and highlight the need for unconventional approaches and methodologies to effectively describe their movements. Furthermore, they emphasize the conservation challenges posed by migratory insects, which exploit different areas and habitats at different stages of their life cycle and therefore require targeted conservation actions at different times of the year.

Biomineralogy: a study at the interface between petrography and marine biology

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Biomineralogy is a multidisciplinary approach investigating the complex of interactions between biological systems and lithological substrate features in marine and freshwater environments. The biotic components can recognize, select, respond to, and even utilize environmental minerals across various spatial, temporal, and biological scales.
This capacity is particularly relevant to understanding how benthic organisms colonize different substrates. To assess the potential influence of substrate type on benthic community settlement and development, we examined assemblages within the Tavolara—Punta Coda Cavallo MPA (NE Sardinia), where limestone and granite outcrops coexist within a confined area. Community diversity and structure were analyzed through photographic surveys conducted on the upper and lower surfaces of large boulders at approximately 30 meters depth.
On the illuminated upper surfaces, multivariate analyses revealed significant differences between limestone and granite sites. Limestone generally hosted a thicker and more heterogeneous coralligenous basal layer. Among the structuring species, the gorgonian *Eunicella cavolini* was more frequently found on limestone, while the sponges *Sarcotragus foetidus* and *Axinella spp.* were more abundant on granite.
Coralline algae growth and the presence of boring fauna contributed to highly three-dimensional limestone microhabitats characterized by cavities of varying sizes. In contrast, granite - virtually impenetrable - offers a more homogeneous substrate, with shaded areas and shelters formed through fracturing or rock accumulation.
Opposite patterns were observed on the shaded lower surfaces of the boulders: limestone was mostly bare, whereas granite was completely covered, likely due to differences in dissolution rates, stemming from the distinct mineral composition and texture of the two rock types. Limestone is more susceptible to dissolution, resulting in a less stable surface, thereby reducing its suitability for zoobenthic colonization compared to the more stable granite
These findings indicate that interactions between benthic organisms and substrate lithology occur on multiple levels. The lower physical and chemical stability of limestone is offset by the presence of coralline algae, which limits erosion and promotes the establishment of diverse communities. These differences may extend to higher trophic levels, influencing the distribution of mobile organisms and shaping their interactions.

Microarthropods as soil quality indicators among and beyond the timberline in Northern Apennines

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Soil biodiversity is pivotal for ecosystem homeostasis, especially in delicate high-altitude landscape. Microarthropods are effective bioindicators of soil quality due to their sensitivity to environmental fluctuations. We aim to investigate soil microarthropod quality along the upper forest–grassland ecotone in "Parco del Frignano" (Emilia-Romagna, Italy). This study is enclosed in the satellite project "BioBeRoots", coordinated by "Ente Parchi Emilia Centrale" under NBFC.
Soil samples were collected from the surrounding of lake: Santo Modenese, Baccio, Pratignano, and Ninfa characterized by different soil erosion statuses and vegetation types (e.g. beech and conifer forests, pastures and vaccinium heathlands) all above 1300 m a.s.l. Across 2024-25, 40 stations were sampled thrice, once for the three snow-free seasons, using a standardized protocol (three soil-cores of 1L in $1m^2$). GPS, altitude, vegetation type, soil temperature and relative humidity were recorded. Microarthropods were extracted using Tullgren-Berlese funnels, then preserved in alcohol for analyses, museum reference, education, and further studies. Soil biological quality was assessed through QBS-ar, Hill numbers, evenness indices, and statistical analyses.
Sampling campaigns are complete, while final sorting is ongoing. Preliminary analyses of microarthropods inhabiting soils under different vegetation types indicate that: pastures host high biodiversity and relatively high evenness but exhibit lower QBS-ar values; beech forests show moderate diversity and high evenness yet are also associated with significantly lower QBS-ar; coniferous forests consistently exhibit the highest QBS-ar values, despite hosting a slightly less even community; vaccinium heathlands tend to show variable conditions, with lower diversity and QBS-ar.
The QBS-ar discriminates significantly among vegetation types, but it should be interpreted alongside diversity and evenness metrics to capture the full complexity of pedobiological composition. Coniferous forests, though anthropogenic, prove to be valuable reservoirs of soil biodiversity. While vaccinium heathlands and beech forests display lower functional quality. Targeted management of forests and heathlands is therefore crucial to preserve biodiversity and safeguard soil-based ecosystem services with economic value.

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From shell shape to gonadal cycle: the case of *Ruditapes decussatus* population from capo Peloro lagoon (Messina, Italy)

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The grooved carpet shell clam (*Ruditapes decussatus* Linnaeus, 1758) has long been integral to the aquaculture traditions of Messina (Sicily, Italy), particularly within the Capo Peloro Lagoon, where its centuries-old breeding is part of the local shellfish farming heritage. However, the introduction of the allochthonous congener *Ruditapes philippinarum* (Adams & Reeve, 1850) into Italian waters has caused a marked decline in native *R. decussatus* populations. This shift was primarily due to the superior resilience and reproductive fitness of *R. philippinarum*, compounded by frequent hybridization events. Efforts to conserve *R. decussatus* are further complicated by the technical challenges associated with its controlled reproduction. In response to these issues, the aim of this study is to characterize a native population of grooved carpet shell clam within the Capo Peloro Lagoon. For this purpose, a total of 300 specimens were collected between September 2022 and September 2023 using a minimally invasive harvesting method. The species was first identified on a morphological basis and later confirmed by molecular analysis performed on some specimens collected. Several measurements were made in the laboratory and used to calculate the shell morphometric indices and ratios. Three size classes were determined, based on shell length (10 mm Class 1 22.9 mm; 23 mm Class 2 31.9 mm; 32 mm Class 3 48 mm). The innovative use of specific packages of R software allowed to assess the shape variation by analysing the outlines of binarized shell pictures to obtain a comparison between size classes. The Electronic Length Frequency Analysis (ELEFAN) was performed on shell measurements to estimate growth parameters, while basic histological techniques were used to assess the gonadal development. The results of shell shape analysis revealed significant differences (p ¡ 0.05) between all the size classes. Slight differences were also detected between left and right valves, suggesting possible adaptive asymmetry. Histological results and growth parameters indicate that individuals of this population regularly complete their gametogenic cycle, supporting stable recruitment dynamics. These findings not only contribute to the understanding of population structure and reproductive biology of *R. decussatus* but also provide a methodological baseline for future studies focused on the conservation and management of native bivalve species in the Mediterranean basin.

Does wing buzzing by key pollinators induce responses in *Antirrhinum litigiosum*?

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Plants and pollinators have coevolved for millions of years. This close relationship has influenced the anatomy and physiology of pollinators, enhancing their efficiency in collecting pollen and nectar. In turn, plants have evolved specific flower traits (e.g., shape, colour, scent, nectar) to attract efficient pollinators and increase their reproductive success. Our research aims to test the hypothesis that plants can sense and respond to the sounds emitted by their pollinators during flight. In this way, plants might activate the energy-demanding attraction processes only when their efficient pollinators are nearby, optimising resource allocation and increasing their fitness.
To investigate this, we first characterised the pollination network of the model plant species *Antirrhinum litigiosum* through observational surveys of four wild populations within their native range in the Iberian Peninsula, covering their entire flowering season. Then, we performed pollinator exclusion experiments to identify the key pollinators contributing to the plant's reproductive success. We correlated the identity of the visiting pollinator, as well as the number and duration of the visits to each flower, with the number of seeds produced by the corresponding fruits (i.e., seed set). Finally, we conducted a playback experiment on lab-grown plants to assess changes in their nectar composition after different vibroacoustic treatments.
A. litigiosum was visited by more than 40 insect species from four different orders, which interacted with the flowers in various ways (e.g., pollinators, nectar robbers, florivorous). Single visits by different pollinators resulted in varying amounts of seeds produced by the fruits, and a higher number of visits to a flower consistently increased seed set. We used the data on pollinator effectiveness to select the vibroacoustic stimuli for playback experiments. Preliminary results showed that plants exposed to the buzzing sounds of a key pollinator produced more nectar with a higher sugar content than those exposed to control sounds (background or pink noise).
These findings support the idea that attracting efficient pollinators and increasing their visitation rates can significantly benefit the plant's reproductive success. To achieve this, plants may have evolved the ability to sense and respond to the vibracoustic stimuli emitted by their pollinators during flight, activating the attraction mechanisms at the optimal time.

Unraveling the role of microbial communities in host response to chemical stress

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The microbiota of marine invertebrates is progressively recognized as a key player in modulating host responses to environmental stressors, including chemical pollution. The microbiota of Manila clams (*Ruditapes philippinarum*) inhabiting the highly contaminated area of Porto Marghera (Venice Lagoon) show consistent enrichment in detoxifying bacterial taxa and functional pathways linked to xenobiotic degradation. This suggests a possible adaptive interaction between host and microbiota in polluted environments. To explore the contribution of resident microbiota in modulating clam responses to chemical exposure, an innovative and previously untested microbiota transplantation approach was developed. Clams from a commercial hatchery were subjected to microbiota depletion via antibiotic treatment, then recolonized using two distinct methods: (i) cohabitation with adult donor clams from Porto Marghera and (ii) exposure to a homogenate prepared from donor soft tissues. Following transplantation, clams were exposed for one week under laboratory conditions to a mixture of metals at environmentally relevant concentrations (Cd 0.5 µg/L and Hg 0.03 µg/L), reflecting those frequently detected in Venice Lagoon. Digestive gland tissues were collected for host transcriptomic analysis (RNA-seq), and microbial communities were characterized using 16S rRNA sequencing. This intricate experimental design allows the assessment of both the efficacy of microbiota transfer and its influence on host gene expression in response to metal exposure. By integrating microbial and host-level analyses, this study aims to decode the functional role of transplanted microbiota in the modulation of clam tolerance to chemical stress, ultimately contributing to the understanding of microbiota-mediated adaptation mechanisms in marine invertebrates exposed to anthropogenic stressors.

Targeted seminal toxin delivery for mosquito suppression

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The global expansion of *Aedes albopictus*, fueled by climate change, urbanization, and global trade, presents a growing public health threat due to its competence in transmitting arboviruses such as dengue and chikungunya. Conventional control methods have shown limited long-term effectiveness, underscoring the need for sustainable and targeted solutions. In this context, and similarly to the the Toxic Male Technique (TMT) strategy, the TOXMOS project (TOXic Males for MOSquito Control) aims to develop a novel biocontrol strategy in which genetically modified males deliver seminal fluid-borne toxins to females. Once transferred, toxins disrupt the female reproductive capacity and reduce their lifespan, eventually suppressing vector populations and pathogen transmission. Notably, mathematical models highlighted this strategy has superior efficacy over classical Sterile Insect Techniques (SIT), particularly for polyandrous species like *Ae. albopictus*.

To achieve male accessory gland (MAG)-specific expression, two PiggyBac-based constructs were generated using the *Aedes aegypti* AAEL010824 promoter: one encoding eGFP alone, and the other including a signal peptide (SP) sequence to facilitate protein secretion. Transgenic lines were established through embryo microinjection and maintained under standard insectary conditions. Expression analysis by confocal microscopy showed successful eGFP localization into the MAGs, with the SP-enhanced construct leading to fluorescence accumulation in the glandular lumen. However, RT-PCR revealed off-target expression in other tissues, suggesting promoter leakiness. To address this, a binary expression system based on the *Neurospora crassa* Q-system is under development. This modular platform includes driver lines expressing the QF2W transcriptional activator under MAG-specific control, and effector lines in which eGFP—or future toxins—is regulated by a QUAS enhancer. In hybrid males, the effector gene will be activated specifically in the MAGs. Ongoing efforts also include screening additional promoters and testing genomic insulators to mitigate positional effects.

Together, these findings establish a solid foundation for a highly specific, genetically engineered biocontrol tool in *Ae. albopictus*, with broad implications for vector management and the prevention of mosquito-borne disease outbreaks.

The migration of a critically endangered damselfly calls for habitat-specific conservation actions

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Among Palaearctic Odonates, adult overwintering is an evolutionary feature exclusive to the genus *Sympecma*. In Italy, *Sympecma paedisca* preferentially breeds in the rice field district of Piedmont, while heathland fragments between Piedmont and Lombardy are its main overwintering habitat. It is not clear how this Critically Endangered species move between these two disjunct areas, located kilometres apart. To shed light on this, we investigated: 1) how habitat composition affects the abundance of the species at a landscape scale; and 2) its fine-scale habitat selection, accounting in both cases for the season. To this aim, we designed 60 transects located in the range of the species along a gradient encompassing heathland fragments and the surrounding agricultural matrix. We counted the species within 2 m from each transect and assessed habitat composition within 50 m. Then, each *Sympecma* location was attributed to a habitat (within 2 m) and then compared with random locations according to a use-availability design. Transects were repeated five times between August 2023 and April 2024 to cover the entire non-breeding phase.

On a 50-m scale, the abundance of the species increased significantly as the cover of well-conserved heathland increased, and this relationship does not vary between seasons. In contrast, the effect of farmland cover varied significantly between seasons, being positive in summer, strongly negative in autumn and slightly negative in winter and spring. The habitat selection analysis showed that in summer, the species used grassy field and road margins in cultivated areas, abandoning them as the winter season progressed. On the opposite, an increasing positive selection trend for heathlands was observed, while degraded heathlands were avoided. These results indirectly support the hypothesis that, in late summer, the species migrate from its breeding grounds to the overwintering heathlands, following the network of grassy margins found in the agricultural matrix. Individuals that survive winter, come back in spring following the same grassy margin network. Conservation efforts should be tuned on the different needs of the species throughout its life cycle: well-preserved heathlands are crucial for the overwintering of the species and thus require active management to limit forest encroachment. In parallel, grassy margins in agricultural landscapes must be preserved to maintain connectivity between wintering and breeding grounds.

Morfo-functional analysis of *Paracentrotus lividus* stereom for bioinspired material design: an interdisciplinary approach

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A crucial role in the evolutionary success of Echinoids has been played by their resistant and versatile endoskeleton, composed of a porous 3D calcitic network called stereom, which combines strength and versatility. Its well-defined structure-function relationship offers valuable bioinspiration for biomimetic applications in engineering, architecture, and materials design.
Our project adopted an interdisciplinary and innovative approach, integrating expertise from zoologists and mathematicians (Università degli Studi di Milano) paired with mechanical engineers (Politecnico di Milano). Constant communication among these disciplines enabled mutual guidance, aligning biology-driven morphological analyses, mathematical modelling, and design development. The research aimed to deepen morpho-functional knowledge of the stereom in *Paracentrotus lividus* (Lamarck, 1816), comparing three interambulacral plate types (aboral, ambital, oral) across different size classes (ages), ranging from 1 to 6 cm in diameter.
Individual plates were isolated and longitudinally abraded to expose the median section of the primary tubercle. A total of seven stereom types were identified and analyzed in detail: their porosity and trabecular organization were investigated through 2D imaging using Scanning Electron Microscopy (SEM) and 3D modeling based on scans performed at the Synchrotron. Using ImageJ software, porosity, trabecular orientation, and stereom thickness were quantified. Compression tests were carried out to examine the mechanical properties of the stereom, particularly focusing on the tubercles, which distribute point load evenly across the plate, providing a strategic combination of lightness and strength. The results show a statistically significant difference in porosity percentages among the investigated stereom types across various sea urchin diameter classes. However, these differences are not statistically significant among the different plate types. Mechanical tests reveal that among the three types of plates investigated, the primary tubercle of the oral plate is the most resistant. Moreover, additional data confirm that the tubercle stereom behaves similarly to a lattice structure, combining lightness with high impact resistance. Therefore, this study will provide valuable insights into the morpho-functional and mechanical properties of *Paracentrotus lividus* stereom, laying the basis for developing bioinspired structural materials.
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Photoreceptor control of animal growth and lifespan via evolutionary conserved molecular pathways

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Natural light is severely affected by human impact on Earth, yet little is known about the roles light receptors have outside vision and rhythmic processes, despite their tremendously wide abundance. Here we show that loss-of-function of the *light-receptive cryptochrome* (*l-cry*) in marine bristleworms significantly increases lifespan and adult size, similarly to wild-types reared in constant darkness. Quantitative transcriptomics revealed hormonal players crucial for invertebrate and vertebrate sexual development and reproduction affected in *l-cry* mutants. These include *nr0b1/2*, ortholog of *dax-1* (*nr0b1*) and *shp* (*nr0b2*), long considered vertebrate novelties. Depending on moon-phase, *nr0b1/2* is up- or down-regulated in *l-cry* mutants. Matching the complex regulation, loss of *nr0b1/2* function partially recapitulates *l-cry* phenotypes. Molecularly, *Platynereis* Nr0b1/2 affects steroidogenic and other endocrine pathways, nuclear receptor signaling, and transcription factor orthologs, involved in sexual developmental, reproductive, and timing processes in other organisms. Thus, our study suggests profound and quite direct effects of light on adult animal life-time, likely at least in part by conserved endocrine pathways involved in sexual maturation and reproduction in annelids and vertebrates.

Passive acoustic monitoring of pollinators: integrating IoT sensors and deep learning for species identification

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Pollinators, such as bees, hoverflies, and butterflies, serve as key bioindicators of biodiversity, providing insight into overall ecosystem health. Many species especially wild bees and hoverflies, are Data Deficient according to the IUCN, emphasizing the need for improved monitoring and conservation efforts. Emerging technologies can help close this information gap by providing enhanced transparency, traceability, and measurable assessments. This study focuses on the development of passive acoustic monitoring (PAM) techniques for the Apoidea and Syrphidae families through the integration of IoT-based bioacoustic sensors. These devices aim to capture species-specific flight sounds supporting automated identification via machine learning models, thereby reducing the dependency on physical specimen collection and associated mortality. While acoustic recognition has shown promising results for some wild bee taxa its broader application remains limited, particularly for hoverflies, which lack large acoustic datasets. To address this challenge, we created a reference acoustic library composed of 549 recordings representing 53 different species, with the purpose of training and validating the identification algorithm. Simultaneously, we installed IoT-enabled recording devices at six monitoring locations within the metropolitan area of Turin (TO), capturing flight-generated acoustic signals while conducting conventional surveys (e.g., pan traps and transects) to allow comparative analysis. Although these sensors do not perform onboard species identification, the collected sound data are continuously uploaded to the cloud via 4G for further processing. Buzz frequency data were subsequently compared with abundance data derived from conventional sampling methods, revealing a consistent trend between the sensor outputs and pan trap results.
The identification model, built using a ResNet50 Convolutional Neural Network (CNN) architecture in MATLAB, has shown high classification accuracy among species. Moreover, by segmenting flight-related acoustic emissions into distinct phases such as hovering, approaching, landing, and departure, the model's predictive performance has been further enhanced. Once the algorithm is fully implemented into the field sensors the system will enable extensive-scale PAM, allowing the acquisition of biodiversity data that is both spatially distributed and temporally continuous, representing a significant advancement in ecological monitoring.

Sessione
Nuove frontiere della Zoologia:
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Poster

Exploring the biodiversity of tube-dwelling coral simbionts from the Faafu atol (Maldives)

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Coral reefs are highly productive ecosystems. Species associated with coral reefs are estimated in over than a million, of which about 90% are still not described. The Maldives islands are characterized by a very diverse marine faunal assemblage associated with one of the world's most biodiverse coral reef ecosystems. This study aims to investigate the diversity of tube-dwelling coral symbiotic fauna associated with reefs around the Faafu atoll (Maldives archipelago), focusing on their host prevalence and dominance. Two underwater visual census campaigns were performed in different sites near Magoodhoo island, Faafu Atoll (Sep 2024, Feb 2025), meanwhile sampling the live and dead hard coral portion hosting the symbiotic organisms. Photo-video recording of domicile openings of the different animal taxa was carried out, to avoid over-sampling and to set a non-impacting method to identify the coral reef's associated animals. Samples were transported to MaRHE Center laboratory in Magoodhoo for a first morphological identification of associated macrozoobenthic fauna and photo reporting of their associated bores. Samples of corals and associated animals were stored in ethanol and transported to the Messina University laboratories for molecular identification. Porites and Echinopora represented the most monitored coral genera, while Plesiastera and Pleuractis genera were found less inhabited and therefore sampled. Interestingly, even dead coral resulted in housing epibionts, especially for the relationship between crustaceans and dead Echinopora coral. The preliminary analyses on 44 collected coral samples showed the presence of about 110 specimens of several taxa belonging to three main phyla, Crustacea (61%), Anellida (18%), and Mollusca (21%). The most represented orders resulted in Decapoda, Sabellida, and Mytilida. The crossing of both sampled and underwater photo-videographic material analyses helped to create a taxa-domicile opening relation, indirectly identifying 181 additional specimens in total (53% Crustacea, 27% Anellida, 20% Mollusca). Photographic determination is currently ineffective for species discrimination, but can certainly be improved. Further studies are needed to assess symbiotic species identification, type of interaction, and species-specific relationships with corals. Focusing on these relationships in changing environments is essential and these data shed light on interesting insights, achievable through non-invasive sampling methods.

Flyer or percher, bigger or smaller - a study on factors producing phenotypic diversity in dragonfly wings

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Flight is a key innovation in insects, driving immense morphological and functional variation in wings. Yet how this diversity arises under the combined influences of biomechanics, ecology, genetics, and phylogeny remains unclear. Dragonflies (Anisoptera), among Earth's oldest and most agile fliers, epitomize this puzzle: their wings vary widely across species due to both ecological factors and allometric scaling.
We investigate this topic in an integrative fashion combining molecular phylogenetics, geometric morphometrics, and phylogenetic comparative methods. Our goal is to determine not only whether different sources of variation shape wing morphology, but also their relative contributions, the similarity of the phenotypes they produce, and how they influence macroevolutionary patterns. We focus on two primary flight strategies – "perchers" (sit-and-wait predators) and "flyers" (sustained-flight predators) – and how these relate to shape variation and allometric trends. Using a dataset of over 2,000 dragonfly wings, we characterised morphological variation with a set of 42 landmarks and semilandmarks. Then, using phylogenetic comparative approaches we tested hypotheses about allometric and non-allometric contributions to wing shape and evolutionary dynamics. With unprecedented resolution in terms of number of species, we reveal shape differences consistent with flight strategies: flyers tend to have larger, more elongated wings, presumably to maximize efficiency, whereas perchers display shorter, robust wings for rapid bursts and hovering. Crucially, these differences partially aligned with allometric variation. In conclusion, our findings highlight the interplay of intrinsic (genetic correlations, previous evolutionary history) and extrinsic (adaptation to different food sources and hunting strategies) factors in shaping dragonfly wing morphology. Our study also demonstrates the power of advanced techniques and models to understand macroevolutionary patterns and lays a solid foundation for future investigations of form, function and evolution across Anisoptera.

Integrated surveillance of arboviruses in Liguria: The regional plan for vector and pathogen monitoring

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Since 2024, the Liguria Region has implemented a regional plan for arbovirus surveillance, entitled "Piano regionale di prevenzione, sorveglianza e risposta alle arbovirosi" which includes coordinated actions targeting both vector monitoring and pathogen detection in humans and other animals acting as hosts or reservoirs.
The plan provides for a widespread monitoring network during the vector activity risk period, from May 1 to November 30 each year. Twenty-five fixed monitoring stations are in place, with additional stations activated in response to potential epidemiological emergencies. Sampling of culicid dipterans is performed using BG-Sentinel traps with BG-Lure and carbon dioxide attractants; water samples from drains and catch basins are also occasionally analyzed. Species identification is conducted at the laboratories of the Experimental Zooprophylactic Institute (IZS) of Piedmont, Liguria, and Aosta Valley, where molecular techniques are used for pathogen detection.
All four provinces in Liguria are considered high-risk areas, partly due to their proximity to France, where several Dengue cases have been reported in recent years. The collaboration among physicians, zoologists, and veterinarians has led to the detection in Liguria of invasive species such as *Aedes koreicus* and *Aedes japonicus*, in addition to the well-known *Aedes albopictus*, and to the timely implementation of containment measures for imported Dengue cases in returning travelers.
Constant vector surveillance and the ability to implement immediate containment actions are essential tools to prevent the emergence of autochthonous outbreaks, as already observed in other Italian regions.

The ontogeny of vocal rhythms in a non-human primate

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Some primates communicate by using changes in sound frequency and rhythm to convey information. However, are these rhythmic patterns innate, or do they develop over time? Species producing series of calls showing rhythmic categories corresponding to small-integer ratios, where sounds and pauses follow simple numerical relationships, are rarely observed in non-human mammals. In this study, we examine rhythm in the songs of the lemur *Indri indri*, focusing on how rhythms corresponding to small-integer ratios emerge throughout development. From 2010 to 2022, we recorded the songs of 62 individuals (29 females) from different age classes (0–2 years, 3–4 years, and adults) in the Maromizaha New Protected Area, Madagascar. We analyzed individual contributions to group songs, measured the intervals between the onset of each note (inter-onset intervals), and calculated rhythmic ratios between adjacent intervals. Our findings show that isochrony - a regular 1:1 ratio, like a ticking clock - is a consistent feature of indri songs across all ages and sexes. Furthermore, two additional small-integer ratios (1:2 and 2:1) appear during development, with distinct patterns in males and females. These findings suggest that indris undergo rhythmic development, likely reflecting an increasing ability to combine and structure vocal elements in more complex ways.

Functional anatomy of the eversible pharynx of *Glycera tridactyla* (Annelida: Glyceridae): A micro-CT contribution

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Polychaete annelids are characterised by a wide array of pharyngeal organisations, associated with different feeding strategies, which might represent useful inspirations for next-generation soft robots. Members of the family Glyceridae have a particularly interesting eversible pharynx, occupying up to one third of their body length and armed with mineralised jaws connected to venom glands, making it a particularly interesting model for the inclusion of hard elements in soft structures. Within the framework of the EIC Pathfinder Open project MAPWORMS (grant agreement No 101046846)In this study, the functional anatomy of *Glycera tridactyla* Schmarda, 1861 was reconstructed through micro-computed tomography (micro-CT) using several individuals fixed in different positions. Results from micro-CT scans were compared with historical reconstructions based on dissection, giving substantially consistent results, and confirming the usefulness of this technique for the reconstruction of the internal anatomy of small invertebrates.

Morpho-functional analysis of the madreporite plate in *Paracentrotus lividus*: implications for biomimetic design

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The sea urchin *Paracentrotus lividus* represents a valuable model for biomimetic investigations due to its distinctive morpho-functional adaptations. Among these, the madreporite plate is a key element of the water vascular system, located within the apical system and pierced by a network of canals that facilitate the intake of seawater into the organism. The aim of this work was to study the morpho-functional organization of the madreporite to obtain innovative constructional concepts and ideas for the development of design objects.
Madreporite plates were dissected from *P. lividus* specimens of different sizes (1-6 cm). Samples were processed and examined using different morphological techniques: scanning electron microscopy (SEM) to investigate both skeletal and cellular components; histological analyses to examine the detailed cellular and ultrastructural organization of the canals; micro-CT analyses coupled to mathematical modelling to evaluate the overall the 3D inner organization of the canal system. The obtained results indicated that, externally, madreporite pores display a constant diameter, regardless the individual's size, but their number increases proportionally with animal diameter, thereby expanding the effective filtering surface. Internally, the madreporite is organized into two distinct regions. In the upper region, canals follow a predominantly parallel course, they are lined by a cylindrical epithelium provided with a dense network of cilia and the actual lumen is small. In the lower region canals curve and converge toward a common collecting area, the lining epithelium is almost cubic, cilia are apparently less numerous and the lumen is larger than in the upper region, thereby facilitating seawater flow. Additionally, anastomoses between adjacent canals can be also observed. Overall, these data suggest that the madreporite functions as an extremely effective filtration system (against bacteria or nano-microparticles) and rely on a complex fluid transport mechanism which contribute to the regulation of pressure and volume within the water vascular system. By means of a biomimetic approach, these constructional principles served as a basis for the design of bioinspired functional objects, such as fruit bowls or other fluid-regulating containers, therefore allowing a conceptual transfer between extremely distant disciplines as Zoology and Design.

New insight into the crayfish *Procambarus clarkii* (Girerd, 1852) (Crustacea, Cambaridae): molecular and morphometrical tools to describe the case of sardinan population

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Invasive Alien Species (IAS) are ranked as the second greatest cause of species endangerment and extinction. Among them, *Procambarus clarkii* (Girard, 1852), originally from America and voluntarily introduced in the Mediterranean area for aquaculture and pet trade scopes, is an extremely invasive crayfish which is leading European freshwater ecosystems to a global biodiversity crisis. One of the causes of biodiversity loss linked to the crayfish invasion is the disease called "crayfish plague," spawned by the parasitic fungus *Aphanomyces astaci*, naturally carried by *P. clarkii*.
The invasive North American crayfish species appears, in fact, to tolerate and resist this infection as result of a balanced relationship arising from the coevolution with *A. astaci*. As a result, autochthonous crayfish populations are severally hit by the infection, while the alien one can overcome it. For this reason, early detection of this harmful crustacean, together with the study of its biological life cycle, is crucial to develop effective management plans aimed at minimizing its impact on the local fauna. Thanks to molecular taxonomy and pathogens molecular diagnostic techniques, a southern Sardinian population of *Procambarus clarkii* was studied. Molecular analyses allowed the taxonomic attribution of individuals and the diagnosis of the presence of *A. astaci* in their tissues (if any). Furthermore, with the use of morphometry, evidence of the presence of two biological alternative morphotypes in *P. clarkii* specimens was found. The relative growth of the body part of interest (Chela length, ChL), with respect to a reference dimension (Carapace length, CL), was examined through the allometric growth equation. Using the same method, applied to the secondary sexual character (Gonopod length), the Size at Onset of Maturity, from a morphometric point of view, was provided for the first time.
RESULTS: All the individuals were molecularly identified as *P. clarkii* and none tested positive for *A. astaci*. The presence of the two alternative morphotypes, linked to the reproductive period, was statistically proven for the first time for Sardinian red swamp crayfish. The Size at Onset of Maturity (SOM) was estimated between 35 and 37.1 mm CL.

Soil biodiversity under AgroPhotoVoltaic Systems: insights from arthropod communities

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The increasing implementation of AgroPhotoVoltaic (APV) systems, which combine solar energy production with agricultural practices, offers a promising solution to land-use conflicts between food and energy needs. While the effects of APV on crops and broader environmental parameters have been explored, impacts on soil biodiversity—especially soil arthropods—remain under-investigated. These organisms are essential for nutrient cycling, soil structure formation, and pest control, and respond sensitively to microclimatic and soil property changes induced by panel shading.

This study, conducted within the SUNRISE PNRR project at an APV site in Borgo Virgilio (northern Italy), assessed soil biodiversity under two types of solar trackers with different shading levels: standard (15%) and expanded (40%). Four treatments were compared: crops shaded by standard or expanded trackers, crops in full sun, and a grass-covered control area. Wheat and tomato were the selected crops; wheat was studied under all treatments, tomato under three (excluding expanded shading). Soil samples were collected over multiple growing seasons and analyzed for soil pH, organic matter (SOM), respiration (CO), and arthropod communities.

Results revealed that soil biological quality, CO emissions, and arthropod diversity were more influenced by crop type, and seasonal dynamics than shading intensity. Control plots generally supported greater QBS-ar values and higher Collembola richness and evenness, especially in wheat. Positive correlations were found between QBS-ar and SOM, CO emissions, and soil temperature, while pH showed negative correlations. Arthropod community composition shifted with crop phenology, with indicator species such as Thysanoptera and Polyxenida in early wheat, and Isopoda in late tomato stages. FAMD analyses highlighted that treatment-driven variations in SOM, moisture, and temperature contributed to distinct community structures, particularly among Isotomidae and Entomobryidae.

These findings emphasize the strong interplay between crop management, soil properties, and soil fauna under APV systems, highlighting their potential ecological impact. Understanding these dynamics is key to developing sustainable agroecosystems that balance productivity with zoology and biodiversity conservation.

Integrating zoological knowledge into river management: the role of fish ecology in the IDRAIM model

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Fish species play a key role in river and transitional ecosystems, and their biology is closely linked to sediment and vegetation dynamics. Understanding these interactions is essential to guide sustainable engineering choices. The European eel (*Anguilla anguilla*), a declining euryhaline species, is an emblematic case of complex migration (homing) and high sensitivity to habitat modifications.

In this study, zoological knowledge is integrated into an interdisciplinary river management project that applies the IDRAIM model, developed by ISPRA for hydromorphological assessment and solid transport analysis. By analyzing fish and plant communities as well as collecting environmental data, we provide essential inputs to assess river ecological status and support low-impact interventions.

In the case of Rio Geremeas, a small stream in south-eastern Sardinia, we applied non-invasive techniques (electrofishing, floating traps for glass eels, nets) for fish communities, while for riparian vegetation sampling, we used a physionomic-structural approach easily applicable for management purposes, with information on the presence and impact of "transformer" invasive alien species. To collect environmental data, we used multiparameter probes. This Mediterranean site, highly influenced by seasonality and environmental fragmentation, showed a reduced presence of fish fauna, likely due to anthropogenic pressure and climate variability. Based on our findings, we proposed a nature-based management of the river mouth opening to support natural processes since any classical intervention, like storm drain in the floodplain, would further disrupt ecological connectivity and water availability.

In addition, we propose the containment or, where it is possible, eradication with conservative methods for sediments (e.g. cover the plots with black geotextile tarp) of invasive alien plant species *Arundo donax*, *Eucalyptus camaldulensis* and *Acacia saligna* that reduce animal and plant diversity by compromising the functionality of the riverine ecosystem.

This case study highlights how integrating biological data is crucial to enhance the IDRAIM model's effectiveness in evaluating sediment transport, while simultaneously improving environmental quality and reducing hydrogeological risk. It demonstrates the value of an ecosystem-based, interdisciplinary approach in modern river management.

MonOrniTech: innovative technologies for ornithological monitoring in the Laghi Lungo and Ripasottile Reserve

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Italian wetlands play a crucial role in bird conservation, serving as breeding, resting, and feeding habitats for numerous species, including many threatened by anthropogenic and environmental factors. In this context, MonOrniTech was born: a pilot project aimed at developing and testing innovative technological solutions for participatory bird monitoring in protected areas, with particular focus on the Laghi Lungo and Ripasottile Nature Reserve, a wetland of community importance in the province of Rieti. The objective is twofold: on one hand, to improve the quality and continuity of ornithological monitoring through digital tools; on the other, to encourage the active involvement of citizens in citizen science activities.

The project foresees the integrated use of various non-invasive methodologies: internal and external environmental sensors, camera traps, digital applications for field data collection, supported by training activities for volunteers and birdwatching enthusiasts. The participatory component is central, with field days dedicated to guided observation, skill transfer, and sharing of collected data. An exploratory phase is currently underway, including the selection of installation sites, fine-tuning of devices, and the definition of standardized protocols. The MonOrniTech project is funded by the European Union - Next Generation EU (Mission 4 Component 1 CUP I13B24000010002).

Although quantitative results are not yet available, early qualitative feedback shows strong interest from the local community and a good response to outreach initiatives. Public events such as "Spring in the Reserve: discovering the MonOrniTech project," held in April 2025, allowed testing of field activities and the collection of preliminary observations on target species and participation levels.

In conclusion, MonOrniTech aims to serve as a replicable model for participatory bird monitoring, based on the integration of technology and citizen engagement. The next phases will include the analysis of collected data, evaluation of the effectiveness of the employed technologies, and dissemination of results to managing bodies and the scientific community.

PRIMATOLOGIA

Comparative Genomic hybridization (CGH) and satellite DNA pattern in Gibbons to Identify Hybrids

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Gibbons and Siamang include 20 species originated vary recently, characterized, among primates, by a very high level of rearrangements and where speciation is considerably faster than that observed in many other groups of mammals.
The small apes with four genera Hoolock, Symphalangus, Hylobates and Nomascus are included into conservation projects because in endangered status for the loss of their habitat and even because hybrids are common in nature and captivity. Here it is proposed an easy and fast method, the Comparative Genomic Hybridization (CGH) and DAPI inverted banding to detect balanced or unbalanced heterochromatin DNA distribution to study repetitive sequences origin and to identify hybrids. CGH has been performed intra and inter species on four gibbons' samples. The animals' samples coming from different zoo are a Symphylangus syndactilus (2n=50), Hylobates lar (2n=44), and two Nomascus samples (2n=50), one identified from zookeepers as N. leucogenis and the other as N. concolor. The CGH applied intra and inter species permitted to detect repetitive sequences pattern in genomes with telomeric, interstitial and centromeric distribution. Results permit to discuss the origin of these sequences among small apes considering the fact each genus have a representative pattern, with a few repetitive sequences being in common between genera and mostly being genus specific. Through this genus specific distribution of heterochromatin is possible also to identify hybrid due the fact they have two different patterns of heterochromatin in their genomes. Indeed, hybrid present half set of chromosomes with a CGH pattern from each parent. Through this approach and the Dapi inverted (like G bans) pattern analysis was possible to identify the two Nomascus samples as hybrids. The first hybrid having in heterozygosis the CGH pattern of Hylobates lar and Nomascus concolor and the second one of Nomascus leucogenis and N. siki.
This study shows the CGH usefulness in identify genera specific pattern of heterochromatin, hybrid among species and pure lines. For those reasons CGH is worthy to be included in project of conservation purpose.

From Conflict to Comfort: Post-Aggression Affiliation in Toddlers Reflects Non-Human Primate Strategies

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In both human and non-human primates, conflict of interests over resources naturally arises between individuals and can be resolved through tolerance, avoidance, or aggression. Aggression is a social behavior that can negatively affect group cohesion and individual emotional states. However, primates - like many other social species - have developed post-conflict behavioral strategies aimed at mitigating the negative consequences of aggression through affiliation. These strategies include reconciliation between former opponents and triadic contacts initiated by uninvolved third parties (unsolicited) or by aggressors or victims (solicited). In this study, we collected live and video data on post-conflict and anxiety-related behaviors in toddlers (N = 18; 18-30 months old) at the kindergarten "Armando Melis" (Turin, Italy) during their routine daily activities from February to May 2022. To evaluate the presence of such behaviors, we employed the Post-Conflict/Matched-Control method commonly used in similar studies on other social species, particularly non-human primates. We demonstrated for the first time in this age cohort the presence of reconciliation (mean Corrected Conciliatory Tendency 33.12% ± 7.33% SE) and triadic affiliations, both unsolicited offered by third parties toward victims (mean Triadic Contact Tendency-TCT 44.87% ± 12.00% SE) and solicited initiated by the victim (mean TCT 39.24% ± 11.02% SE) or the aggressor (mean TCT 33.76% ± 11.74% SE). Focusing on unsolicited triadic contacts - previously demonstrated in only a few other species - we found a significant decrease in anxiety-related behaviors in victims after affiliation, but neither in aggressors nor in third parties. This finding confirms the presence of genuine consolation behavior. In sum, from as early as 18 months of age, toddlers - like chimpanzees, bonobos, and some macaque species - may possess the capacity to perceive and respond to the emotional states of others. Detecting a peer's distress can elicit emotional arousal in third parties and promote other-oriented behaviors through emotional resonance. As a result, the third party's behavior may be implicitly aimed at reducing the emotional disparity between themselves and the distressed individual.

229 AAI PR

Automated detection of two lemur species for passive acoustic monitoring

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Passive acoustic monitoring (PAM) is a broadly employed practice in wildlife research, facilitating the non-invasive collection of information on presence, abundance, distribution, and behaviour of vocal species over large temporal and spatial scales. On the downside, the resultant data volume poses significant computational challenges, potentially hampering the data processing and analysis. Lemurs, with one-third of species classified as critically endangered by the IUCN, need meticulous and timely monitoring of wild populations. Many species live in remote forest remnants and possess typical vocal behaviour. Hence, they are optimal subjects for studies relying on passive acoustics. We focused on the vocal activity of indris (Indri indri) and black-and-white ruffed lemurs (Varecia variegata) recorded in Maromizaha Forest (Madagascar) from 2019 to 2023 via passive acoustics. We first built a convolutional neural network (CNN) trained to identify recordings with the presence or absence of indris' songs, loud distinctive vocal sequences, across 66,443 10-minute recordings. Once proved that our network was efficient in detecting songs (accuracy ¿90%; recall ¿80%) and hence that an automatic detection was indeed feasible thanks to a tailored process, we applied the machine learning software BirdNET—a CNN originally developed for ornithological applications—to the automatic recognition of the loud calls of indris and black-and-white ruffed lemurs. We manually adjusted CNN settings and employed the optimal model (achieving precision and recall rates of 90% for both species) to analyse 55,515 10-minute recordings. Lastly, we conducted temporal analyses to examine the species' diel and seasonal vocal pattern. First, thanks to our approach we were able to show that software like BirdNET can indeed be customed to analyse diverse sets of data. This would render the automatic processing of acoustic data viable also with a reduced computational background, increasing the reach of these studies across taxa and locations. Secondly, our study demonstrates the essential role of PAM in enhancing our understanding of the vocal behaviour of these threatened species, crucial for their detection and to provide critical information to plan data collection and conservation efforts and strategies.

265 AAI PR

Comparative Genomic hybridization (CGH) and satellite DNA pattern into representative species genomes from Cebidae and Atelidae (Platyrrhini)

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Heterochromatin sequences, also known as satellite DNA and consist of tandemly arranged repeats, at first seen as serving no useful purpose and known as the dark matter of the genome are recently evaluated showing different role and function. The intraspecies and interspecies Comparative Genomic Hybridization (CGH) between representative species of platyrrhini species, *Saimiri infilatus, Aotus trivirgatus*, (Cebidae) *Ateles paniscus chameck, A. fusciceps* (Atelidae) was performed to determines balanced and unbalanced repetitive DNA sequence distribution and reveals their dynamics during evolution. Platyrrhines species present a very high level of chromosome rearrangements, thus are a good model to studies genomic dynamics.
The CGH was performed mapping by Fluorescence *in situ* hybridization (FISH) total DNA from two individual animals labeled with two different fluorescent dyes on a target metaphase, which can be from the same species or from a different species. This approach permitted to obtain signals at centromeric positions, at telomeric position and with an interstitial distribution. The present work extends the previous Cross-species CGH study and results were compared with CGH repetitive DNA distribution previously found in other Cebinae species such as capuchin monkeys (*Cebus capucinus, Sapajus apella*), and the tamarins (*Saguinus mystax, Leontocebus fuscicollis*). The comparative study permitted to analyze repetitive sequences distribution from an evolutionary perspective to elucidate their genomic dynamics at the level of chromosomal organization. It has demonstrated genus-specific pattern of repetitive sequences while during evolution these sequences were differently organized among different genera possibly through a variety of mechanisms; in particular, re-arrangements, amplification and concerted evolution. Furthermore, some of these sequences could be seen as symplesiomorphies, and other sequences can be shared derived synapomorphies or can be automorphisms sequences. This study demonstrated repetitive sequences as useful markerers at phylogenetic level and for conservative purpose.

295 AAI PR

Social Familiarity Enhances Positive Responses to Tickling in Bonobo Infants

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In humans, intense tickling elicits a complex behavioural response characterized by withdrawal, protective movements over sensitive areas, wriggling, and uncontrollable laughter. This reaction is socially modulated: the experience of tickling can be perceived as either pleasurable or aversive depending on the nature of the relationship between the individuals involved. While similar tickling behaviours have been documented in other great ape species, they remain largely understudied. This study investigates the behavioural and vocal responses of bonobo infants to tickling and examines whether these responses vary according to the degree of familiarity with the tickler. Using an experimental paradigm, we collected acoustic and video data from seven bonobo infants housed at the Lola ya Bonobo sanctuary in Kinshasa, Democratic Republic of Congo.
Our findings show that tickling (experimental condition), but not simple touching (control condition), evoked a complex response in the bonobo infants. Furthermore, the infants laughed more, engaged more often in mutual gaze, and more frequently solicited additional tickling when the interaction came from a familiar individual compared to an unfamiliar one. These results suggest that bonobos' responses to tickling are modulated by social bonds, pointing to the possible involvement of empathy-related mechanisms.

59 AAI PR

Tracing oral and skeletal pathologies in Wild Nonhuman Primates: A Study of Colonial-Era Specimens from Lisbon's National Museum of Natural History and Science

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Nonhuman primates experience illness and injury in the wild. There is considerable variability in how pathologies affect various primate groups, often linked to their diet and behavior. Injuries can also impact survival in the wild, with the timing of their occurrence in the life cycle being crucial for an individual's survival and overall fitness. Such injuries are likely more fatal in adults than in juveniles. During a review of the nonhuman primate collection at the National Museum of Natural History and Science in Lisbon—comprising specimens collected in the 1940s and 1950s from the former Portuguese colonies in Africa (Mozambique, Guinea-Bissau, São Tomé and Príncipe, and Angola)—we examined the presence of dental and skeletal pathologies. Our methods included macroscopic observation and X-ray examinations of the most noteworthy cases. We identified oral and skeletal pathologies—including carious lesions, apical lesions, dental enamel hypoplasias, periodontal disease, calculus, enamel wear, dental fractures, *cribra orbitalia*, bone fractures, and osteomyelitis—in approximately 20% of the 151 individuals studied. Among the most notable cases were two individuals. Case 1 - an adult female *Papio papio* from Guinea-Bissau showed extensive dental wear on both the mandible and maxilla, with numerous carious lesions, apical lesions, and alveolar bone osteolysis caused by penetrating caries. Case 2 - an adult male *Papio ursinus* from Mozambique with an exuberant osteomyelitis and a bony callus (approximately 7 cm wide) formed around the fused broken bone segments. The affected femur is shortened by nearly one-third. This likely caused the individual to walk using three limbs. The same leg also had a more recent, unhealed fracture of the tibia and fibula, which had led to additional infection. Despite these severe conditions, both individuals had reached adulthood and showed signs of overall health in the rest of their skeletal remains, suggesting that they were able to survive and function in the wild. These cases illustrate that, even with compromised health and chronic infections, some individuals can survive for extended periods in natural environments. While oral health directly affects longevity in free-ranging mammals, recent literature also suggests that bone fracture recovery in wild primates is less common than previously believed.

Empathy in the Homininae: insights from paly ontagion in gorillas, chimpazees, bonobos and humans

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According to perception–action and neurocognitive models of empathy, behavioural contagion—where a behaviour performed by one individual (the trigger) acts as a releasing stimulus and automatically induces the same behaviour in another (the responder)—can mediate emotional contagion, a basic form of empathy. This transfer is enabled by shared neural representations built between trigger and responder. In this study, we investigated the presence and modulators of play contagion in the subfamily Homininae. From December 2021 to March 2025, we used audio–video recordings and all-occurrence sampling to collect data on play, affiliation (grooming, contact sitting), and agonistic interactions in lowland gorillas (*Gorilla gorilla*, n = 21), chimpanzees (*Pan troglodytes*, n = 16), and bonobos (*Pan paniscus*, n = 35)—two groups per ape species—at Beauval, Palmyre, and Vallée des Singes (France), and Ouwehands Zoo (Netherlands). We used the same method to collect data on human toddlers (*Homo sapiens*, two nursery classes, n = 28) at Melis nursery (Turin, Italy). Data were analysed using GLMMs. We found that play was contagious in all species, as individuals were more likely to start playing after seeing others play (Post-Play condition) than when they had not observed any prior play session in the same socio-environmental context (Matched-control condition). Play contagion level was not species-dependent, but modulated by group demographics (sex and age ratio) and social dynamics (affiliation frequency). Play contagion increased with more males, more young individuals, and higher affiliative rates—consistent with the idea that play, and the related emotion transfer, mostly affects juveniles and males who establish playful networks to build social bonds or compete non-aggressively. These findings—obtained using the same ethological methodology across species—demonstrate for the first time that play contagion is widespread among Homininae and point toward basic empathy being hard-wired shared biology of humans and social great apes.

134 O 01 MU

The museum anthropological collections within the context of the decolonization practice: challenges and perspectives.

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The anthropological collections housed in many Italian museums encompass a wide range of assets. In addition to human skeletons, these collections are enriched by a large variety of items (anthropometric instruments, ornaments, objects for daily or sacred use, ethnographic materials of various kinds, etc.). Among these, plaster face casts represent particularly unique objects, positioned midway between human remains and artifacts.
Originally produced to illustrate so-called racial differences, most of these casts were made from living individuals during scientific and colonial expeditions. They were not merely trophies, but rather legitimate tools for research and education, capable of conveying human features that could not be fully captured through photographs or measurement tables. As such, they played a relevant role in the development of Physical Anthropology as an independent scientific discipline between the mid-nineteenth and early twentieth centuries.
A considerable number of plaster casts are still held in institutions across Europe, the United States, and Africa. In particular, many Italian scientific museums preserve these assets. The Anthropological Collections of the University of Bologna, for instance, include hundreds of plaster face casts. Among them, the Lidio Cipriani (1892–1962) collection consists of 95 replicas of such casts, realized during the expeditions in Africa and in Asia between 1927 and 1935.
Many of us anthropologists are actively involved in the management, research, and education on the museum collections, which we have inherited from the founders of the discipline. This legacy now presents new challenges regarding the destin and future of this critical and vulnerable heritage, for which we bear great responsibility.
Within this context, the Horizon Europe project COLUMN (Colonial Legacies of Universities: Materialities and New Collaborations) (2025–2029) aims to thoroughly investigate the meanings and future perspectives of these collections, with a particular focus on the plaster face casts housed at the University of Bologna. This is a collaborative project led by Utrecht University, involving other European institutions as well as universities in the Global South (South Africa and Mexico). Here, we present the project's design and initial findings, reflecting on the current role of scientific anthropological museums facing with these new and complex challenges.

221 O 02 MU

The Museum of Sardinian Anthropology and Ethnography and the Museum of Zoology at the University of Cagliari

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The Museum of Sardinian Anthropology and Ethnography and the Museum of Zoology, both part of the Interdepartmental Centre for Museums, Collections and Historical Archives at the University of Cagliari, are engaged in activities in the fields of conservation, education, and science communication. While maintaining their distinct disciplinary focuses, the two museums collaborate closely to promote the integration of cultural and natural heritage, and to enhance public engagement and interdisciplinary teaching.
The Museum of Zoology (https://web.unica.it/unica/it/museo_zoologia.page) was founded in the very early 1800s at the behest of the Viceroy of Sardinia, Carlo Felice. Although the main nucleus was established during the 19th century, the acquisition of new specimens has continued up to the present day, so that many of the collections cover a time range of 200 years. The collections now comprise over 10000 specimens of the main animal types, many of them of high scientific, conservation and educational interest. Sardinian fauna is particularly represented, but species from all around the world are present. Among vertebrates, the ornithological and ichthyological parts are the most numerous, with about 2000 specimens. Arthropods, mainly Insects and Arachnids comprise approximatively 7000 specimens. The osteological collection ranges from the few centimeters of the mole skeleton to the over 15 meters of that of the finwhale. Since their inception, the collections have been utilized in research and education, and they continue to have a significant influence on our comprehension of animal biodiversity.
The Museum of Sardinian Anthropology and Ethnography (MUSAE; https://www.unica.it/unica/page/it/musae) was founded in 1953 with the aim of promoting knowledge of the prehistory and history of the Sardinian population through the study of human skeletal remains and evidence of recent cultural traditions. The museum houses and partially exhibits a wide range of materials, including over 10,000 human skeletal remains from prehistoric to modern times, cranial casts illustrating hominid evolution, two mummies, historic anatomical preparations from the last century, and objects from traditional agro-pastoral daily life, including furnishings, tools, musical instruments, clothing, and ex-votos. It also has a collection of more than 20,000 slides and videos. A large sample of skulls has been reconstructed in 3D and will be made freely available for research purposes.

220 O 03 MU

Studying the Italian tardigrade biodiversity through the Citizen science project "Tardigrades go to school!"

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Italy is a biodiversity hotspot in Europe, rich in species, endemic organisms, and diverse biogeographical regions—with tardigrades contributing to this richness. The knowledge of Italian terrestrial tardigrade biodiversity remains incomplete, as many regions are almost unexplored. Due to their distinctive appearance and remarkable stress resistance, tardigrades have captured public interest, especially in younger generations. The Citizen Science project 'Tardigrades go to school!' engages students in mapping the distribution of moss-dwelling tardigrades, aiming to develop awareness of biodiversity and a sense of responsibility for its conservation.
Students are introduced to tardigrades and their ecological importance through meetings and educational materials. During hands-on activities at school, they collect moss samples from the garden, extract and observe tardigrades using everyday tools. School trips provide further opportunities to collect mosses, complete data sheets, search for tardigrades, and send samples to tardigrade specialists for faunistic analysis using integrative approach.
Participating classes receive certificates, and findings are shared via reports, public meetings, and the EvoZooLab website. Samples collected from primary and secondary schools in Northern Italy have already revealed a high degree of biodiversity, including rare and new tardigrade species. The project is now expanding to involve more schools throughout Italy, enabling a comprehensive study of tardigrade biodiversity and distribution, as well as monitoring their conservation status. It fosters citizen participation in scientific research and promotes environmental awareness and interest in tardigrades among students.

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247 0 04 MU

Imaginary creatures in the classroom: speculative biology as didactic tool

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Speculative biology is a discipline between art and science, proposing to make physiologically and evolutionarily plausible descriptions of imaginary organisms. Having existed for decades as a niche pastime, it is now increasingly featured in popular entertainment; its subdiscipline concerned with the possibility of life on other planets, known as exobiology or astrobiology, is increasingly treated as a scientific branch worth of study. Since speculative biology requires a solid grasp of the principles of evolutionary biology, but also engages the imagination and creativity of the practitioner, its use as didactic tool suggests itself. Some previous efforts have already taken place, such as asking students to build phylogenies of imaginary organisms or construct fictional but plausible biospheres. We propose a similar exercise in which zoology students (bachelor course in Natural Sciences) are asked to analyse and deconstruct creatures from folklore and mythology, pointing out biologically implausible traits, and then redesign them with a plausible physiology and place them in a plausible evolutionary and ecological context. We present preliminary results of such designs, as well as considerations about the potential of this sort of exercise in helping the students engage critically with the biological principles learned in the classroom, without resorting to rote memorization.

230 P 01 MU

The Recovery and Valorization of an Ancient Zoological Collection

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The University Museum of the "G. d'Annunzio" University of Chieti – Pescara has stood out in recent years for its research activities in the fields of anthropology, geo-paleontology, and natural sciences. It has significantly expanded its collections, affirming its role as a "place of memory" and an exhibition space dedicated to the knowledge and dissemination of Natural Sciences as well.

A recent addition to the museum is a new zoological collection, consisting of a large number of animals preserved using various methods (in formalin, dried, or taxidermied), mainly comprising specimens collected and prepared locally in the second half of the 19th century. The collection is the result of a series of donations and bequests from public institutions, such as the "G.B. Vico" High School of Chieti, and private individuals. It also includes specimens prepared in the museum's own laboratories, where disinfestation was carried out on samples—fish, birds, and small mammals—that had been affected by insect larvae.

Following the disinfestation, a cleaning phase was undertaken to remove external pollutants from the birds' plumage, mammals' fur, and keratinized parts (beaks, legs, etc.). The specimens were relabeled in a clear and accessible manner, while still preserving the historical labels, and were newly catalogued.

The portion of the collection currently on public display includes rare specimens and even extinct species, all originating from the Chieti area or, more broadly, the Abruzzo region. Particularly noteworthy are the specimens collected around 1863 by students of the Royal High School of Chieti under the guidance of Professor Florindo Rocchetti (Torrevecchia Teatina, 1820 – Chieti, 1867), a physician who, in 1854, left his profession to dedicate himself to teaching Natural Sciences.

The historical value of this collection—composed largely of passerine birds—is truly exceptional, representing the only and irreplaceable testimony of the local fauna present on the hills of Chieti more than a century and a half ago. Due to all these characteristics, the zoological collection also holds great educational value, but above all, it has significant scientific importance.

Keywords: zoological collection, restoration, taxidermy

279 P 02 MU

The Museum of the Sea and Wetland Areas of Marceddì Comes to Life in Sardinia

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The project "Museum of the Sea and Wetland Areas of Marceddì," promoted by the Municipality of Terralba (OR) with scientific support from the Department of Biology, Ecology and Earth Sciences at the University of Calabria, aims to enhance and showcase the rich environmental, natural, and cultural heritage of the Marceddì wetlands. Funded under Regional Law no. 17/2021, the project involves the setup of an exhibition center in a municipally owned building located at Via Lungomare 49, Marceddì, in the municipality of Terralba (OR).
The exhibition will span two floors and five thematic areas: the lagoon room, the sea stairs, the marine animals room, the bird room, and the Marceddì fishing world. Visitors will be guided through an itinerary that explores marine, lagoon, and coastal environments, with a special focus on the interaction between nature and human activities.
The exhibition spaces will include display cases, life-sized dioramas, informational panels, aquariums, terrariums, and interactive multimedia totems. The tour will be enriched with digital content such as drone-filmed videos, multimedia guides on flora and fauna, educational games for children, and teaching materials for schools, supporting both hands-on and learning activities.
Outside, the museum will feature an institutional sign and a traditional fishing boat, an iconic symbol of the local community. The project also includes public and scientific outreach events to promote civic engagement, environmental awareness, and local identity. This initiative stands out as one of the few museums in Italy, and the only one in Sardinia, specifically dedicated to wetland ecosystems.

227 P 03 MU

Soil Meiofauna Advanced Taxonomy School – SoilMATs: Advancing Taxonomic Knowledge Through Training

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Recent applications of integrative approaches in taxonomy have accelerated species descriptions; however, much remains to be done to understand the diversity and distribution of meiofauna in soil environments, primarily due to the taxonomic impediment. To address this gap, the SoilMATs project aims to train a new generation of taxonomists, also selected through an open European call, by combining online and hands-on activities to equip 25 young researchers with specialized knowledge in Tardigrada, Rotifera, and Nematoda. The large number of applications (84 for 20 open positions) highlights the strong demand for advanced training in taxonomy, even for seemingly "neglected" taxa. Additionally, the program's secondary goal is to enhance soil meiofaunal knowledge in three target protected areas across Europe through teaching.

The first field training and sampling took place in two natural protected areas in the Northern Apennines: Rocca Malatina Park and Panaro River Park (Italy). The demonstrative analyses conducted during the training focused on taxa identification, integrating both morphological (LM, SEM, and CLSM) and molecular (DNA barcode) approaches.

Sampling during the training contributed to a broader understanding of the biodiversity within the sampled protected areas. For instance, a rare tardigrade species lacking claws was discovered in a conspicuous population, in a previously unsampled moist riverbed sediment. The specimens were assigned to the known species Apodibius confusus through morphological analyses and the first DNA barcode sequence for the taxa were produced. Furthermore, advanced microscopy techniques, showed during the training, revealed the complete absence of claws as a structural trait, with no associated vestigial characters.

The training activities accelerated faunistic analysis, facilitated by the number of students, which allowed for more effective and faster sampling, sorting, and taxonomic work. Beyond direct training, the project's multi-local approach is expected to have a wider impact by, for instance, enhancing faunistic studies and identification of new taxa, as demonstrated in the given example.

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161 P 04 MU

The digitisation of the University of Bologna's "Collezioni di Antropologia": a virtual exhibition through innovation, research and conservation

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In the context of the increasingly widespread use and applications of digital tools in museums to enhance accessibility and the conservation of cultural heritage, this ongoing project aims to create a virtual exhibition of the University of Bologna's "Collezioni di Antropologia". The first nucleus of these collections dates back to 1908, when Professor Fabio Frassetto established the first chair of Anthropology at the University of Bologna. Over the subsequent years and up to now, various items have enriched the collections, particularly elements from the Documented Human Osteological Collections (DHOC) of the University of Bologna. This project involves scanning selected anthropological items within the museum halls of the "Collezioni di Antropologia" using an ARTEC Space Spider 3D structured light laser scanner. These digitised selected anthropological items will form the core of the virtual exhibition, which will be divided into three thematic sections, mirroring the physical tour of the museum. The first section will focus on the origin of Anthropology as a discipline in Italy, featuring a selection of anthropometric and osteometric instruments, along with the famous casts from the Cipriani collection. The second section will explore human evolutionary history, focusing on some of the most significant fossil hominins, such as the Taung Child (A. africanus), especially relevant this year as it marks the centenary of its first publication in Nature. The third section will be dedicated to skeletal biology, bioarchaeology and paleopathology. The skeletal biology section will help virtual visitors understand which human skeletal traits are important for identifying sexual dimorphism and patterns of bone growth. The bioarchaeology will connect anthropological knowledge with cultural practices, illustrated by examples of cranial deformation. At the same time, some individuals will be digitised to showcase pathognomonic traits of skeletal pathologies. Finally, a dedicated virtual exhibition space will be developed to present these elements in an engaging and informative way, supporting a deeper understanding of the collections and their digital presentation. The online experience—enhanced with accessible content and interactive tools—aims to boost public engagement, make scientific knowledge more widely available, and support museum operators in communication, outreach, and heritage conservation of these sensitive cultural assets.

226 P 05 MU

The bird collection of the 'Museo di Zoologia' at the University of Cagliari: past and present importance

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The ornithological collection of the Museum of Zoology at the University of Cagliari (Sardinia, Italy) has been recently re-organized and revised. The collection mainly comprises specimens representing Sardinian fauna that were most likely collected on the island. However, it also contains a significant number of exotic, land and sea birds from different parts of the world. It currently hosts more than 1000 mounted specimens, tens of skins and a few skeletons with representatives of 30 orders, 111 families and 465 species.
The original nucleus was established in 1802 by order of Carlo Felice, Viceroy of Sardinia, who later donated it to the then Royal University of Cagliari. This historical collection had its greatest development in the first half of the 19th century, especially during the period 1840-1858, in which Gaetano Cara was director of the Museum. Although to a lesser extent, the acquisition of new finds has continued up to the present day.
The most complete section is represented by the birds of prey, for which there are several specimens of all the species historically present in Sardinia, including those now extinct on the island, such as the Bonelli's Eagle (*Aquila fasciata*), the White-tailed Eagle (*Haliaeetus albicilla*), the Cinereous Vulture (*Aegypius monachus*) and the Bearded Vulture (*Gypaetus barbatus*). Similarly, other taxa, extinct in the Island, are present, such as the White-headed Duck (*Oxyura leucocephala*), and the Black Wheatear (Oenanthe leucura). The collection includes also some rare specimens, exceptionally captured in Sardinia: Little Bunting (*Emberiza pusilla*), Rosy Starling (*Pastor roseus*), and Cream-coloured Courser (*Cursorius cursor*). Among the 'exotic birds' numerous species of hummingbirds and sunbirds certainly stand out, as well as the specimens of highly threatened species, such as the Yellow-crested Cockatoo (*Cacatua sulphurea*) or the Tristan Albatross (*Diomedea dabbenena*) or even globally extinct species such as the Passenger Pigeon (*Ectopistes migratorius*) and the Slender-billed curlew (*Numenius tenuirostris*).
The historical collection has still an undoubtable importance, not only to scientists but also to pupils and amateurs. It can help to understanding the distribution and composition of the ornithofauna in Sardinia and its changes through time, to educate children and sensibilize to public as well as it can provide irreplaceable information to protect our stunning bird biodiversity.

239 P 06 MU

"INCONSAPEVOLI INVASORI": increasing awareness on biodiversity loss

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The Natural History Museum of the University of Pisa designed and installed a temporary exhibition entitled "Inconsapevoli invasori. Le specie aliene nelle acque interne e le minacce alla biodiversità" from October 2024 to January 2025. Theme of the exhibition was the invasion of alien species in Italian freshwater environments, with a focus on their impact on biodiversity loss and on the causes of the invasions.
Live animals were displayed in aquaria and aqua terraria, for a total of 15 species including fish (6 species), invertebrates (2 species) and freshwater turtles (6 exotic species and the native European pond turtle, *Emys orbicularis*). We selected both highly invasive species (e.g. *Trachemys scripta*, *Procambarus clarkii*) and other species representative of the main impacts of aliens: direct competition, predation, hybridization, transmission of pathogens. We included also species arrived more recently on the national territory (e.g. *Pseudemys* sp.), to show how this threat is still ongoing and developing.
The use of live animals was aimed at maximizing public involvement, promoting better transmission of the scientific concepts of the exhibition. All the individuals on display came from Tuscany's natural or semi-natural environments, with the purpose of helping the visitors to better understand how the problem of alien species is rooted in every territory, including their own. The exhibition panels included general information on the topic, as well as updated scientific data on the quantity of invasive species in Italy, economic damage and problems related to the spread of aliens; there were also descriptive sheets of the non-native species on display and a section dedicated to the Life URCA ProEmys project on the European pond turtle, of which the Museum is a partner.
The exhibition was integrated with a multimedia display of photos and videos of alien species specially created by professionals, expert naturalists and photographers of national relevance.
To raise awareness among visitors of the various topics covered in the exhibition, we organized three events held by various experts, in line with the objectives of Agenda 2030. These dissemination activities aimed at increasing public awareness about the impact of alien species on biodiversity loss and provided indications on the correct behaviors to be held in case of purchase or discovery of these species in the wild.

140 P O7 MU

The heterobranch Corner Project at the Unisalento Marine Biology Museum "Pietro Parenzan" in Porto Cesareo (LE).

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In the XXI century, advancements in technology and the growing abundance of information have led to significant changes in communication strategies, aiming to capture people's attention and facilitate their understanding of scientific topics.
In this framework, we are going to combine a traditional exhibition method (the exhibition panel) with the use of soft toys to increase the attractiveness of the scientific and informative proposal, especially towards a younger audience. Multimedia content can be accessed via QR codes placed in the different sections, in order to foster a user-friendly and accessible experience and an in-depth comprehension of scientific concepts.
The main objective of the "Heterobranch corner" project at the UniSalento Marine Biology Museum "Pietro Parenzan" in Porto Cesareo (Lecce), is to provide everyone with the chance to discover the Mediterranean heterobranch diversity, a group of specialized gastropod molluscs to foster knowledge and inspire a heightened sense of appreciation and concern for their protection and conservation.
In order to reach a wide-ranging audience, the "Pietro Parenzan" Marine Biology Museum was chosen as the ideal location to install these panels: recently renovated and re-opened in December 2024, it has high visitor footfall, particularly comprising of students who visit the museum during the school year and families who go there during the summer.
The corner consists of a 2m by 2m panel and a 2m by 1m panel, inside which there are photographs dedicated to nudibranchs, sacoglossans, anaspids and cephalaspids, chosen as representatives of the extreme variability of shapes and colors present within the subclass of heterobranchs. There are also insights into their life cycle, defense strategies and how to find and describe a new species; each section features QR codes that link to videos and multimedia storytelling created specifically for the purpose. A plexiglass cube houses the soft toys of two nudibranchs, each about 40 cm large.
In a time when the protection of the sea has a fundamental role and conservation actions are increasingly urgent, to promote knowledge of the sea fauna becomes an essential task of marine biology museums to widen ocean literacy among the civil society.

Sessione
Tema libero

Poster

How microhabitat characteristics influence the females' nest site selection of the invasive alien species *Trachemys scripta* in the Angitola Lake (Calabria, Southern Italy)

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Invasive alien species (IAS) represent a major threat to global biodiversity, ecosystem functionality, and native species, with particularly pronounced impacts in protected areas. The red-eared slider turtle (*Trachemys scripta elegans*) is recognized as one of the 100 most damaging IAS worldwide due to its adaptability and widespread distribution. This research focused on the nesting ecology of *T. scripta* within Angitola Lake, a significant Ramsar site and WWF Oasis located in Calabria, Southern Italy. The primary objectives were to gain a deeper understanding of its reproductive strategies in this environment and to provide crucial information to guide the development of effective management interventions.

The study was carried out during the active nesting season of 2007, spanning from April to October. Through field surveys, three primary reproductive zones and three secondary sites along the lake's shoreline were identified. A total of 309 natural predated nests were documented across these locations. At each recorded nest, four measurements of the nest microhabitat were taken: the distance to the shoreline, nest depth, vegetative cover, and soil characteristics. Univariate analysis and a Generalized Linear mixed model (GLMM) were employed to investigate the nest site preferences of the females.

The findings revealed a clear preference for mixed habitats characterized by soil combinations such as dirt/sand and dirt/clay, suggesting these conditions offer optimal characteristics for oviposition. Nesting activity was predominantly concentrated within the first 30 meters from the shoreline. Notably, habitat and soil selection appeared to shift throughout the nesting season, potentially in response to changing environmental factors, including water availability. However, the results of the generalized linear mixed model (GLMM) indicated that only the distance from the shoreline was significantly influenced by vegetation type (with greater distances observed in reforested sites). The ecological plasticity exhibited by *T. scripta*, enabling it to exploit a broad range of nesting microhabitats, represents a significant ecological threat to local biodiversity. This study provides detailed insights into the reproductive ecology of this invasive species, underscoring the need for the implementation of integrated management strategies aimed at mitigating its ecological impacts.

Insights into the solitary ascidian *Ciona robusta*: a zoological model to study innate immunity

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Ascidians (Tunicata) are important models for studying the innate immune system due to their evolutionary proximity to vertebrates. As sessile filter feeders, they are exposed to environmental stressors, including pathogens, requiring a strong immune response. *Ciona robusta*, a solitary ascidian found in temperate marine environments, is a widely used model in zoological research, known for its well-characterized immune system, transparent body, and simple anatomy. This species has distinctive morphological features, such as a thick outer tunic for water filtration and a prominent pharyngeal basket, where immune cells play a key role in pathogen defense.
This study investigates the immune responses of *C. robusta* under bacterial challenge, specifically focusing on the effects of lipopolysaccharide (LPS) exposure. Using immunohistochemistry and enzyme assays, we observed activation of key immune pathways, including Toll-like receptor (TLR) and nuclear factor kappa B (NFB) signaling, central to the inflammatory response in both invertebrates and vertebrates. These immune molecules were significantly upregulated in the pharyngeal tissues 4 hours post-LPS injection. Inflammatory nodules were found in the lumen of pharyngeal vessels, with endothelial cells actively participating in the inflammatory process. Histological analysis of untreated and buffer-injected ascidians confirmed the positive immune reactions. Enzymatic assays revealed a marked increase in the activity of immune-related enzymes, such as phenoloxidase, glutathione peroxidase, lysozyme, alkaline phosphatase, and esterase, following LPS exposure. These enzymes, involved in pathogen recognition, oxidative stress response, and antimicrobial activity, play critical roles in mediating the inflammatory response.
Our findings underscore a complex, multi-faceted innate immune activation in *C. robusta*, resembling vertebrate immune processes, and provide valuable insights into the molecular and cellular dynamics of pathogen defense. These results suggest that ascidians may serve as an excellent model organisms, offering opportunities to explore universal principles of immune regulation from tunicates to vertebrates. Future research should focus on bridging knowledge gaps and further elucidating the evolutionary conservation of immune mechanisms across species.

Loss of meiofaunal biodiversity under thermal stress regime: the vulnerable seagrass-bivalves association

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Biological positive interactions are key drivers in shaping the biosphere, yet climate change can alter these relationships with consequences for biodiversity. In the marine realm, a notable example is the mutualism between lucinid bivalves and seagrasses, both acting as ecosystem engineers. Despite their ecological relevance, the response of such interaction and associated benthic biodiversity to extreme climatic events remains poorly understood. In this study we investigated how meiofaunal biodiversity and trophic status change in the presence or absence of the association between the seagrass *Cymodocea nodosa* and the lucinid *Loripes orbiculatus* under simulated marine heatwaves (MHWs). A 17-day mesocosm experiment was conducted in laboratory, including four conditions: bare sediment, sediment with *C. nodosa*, with *L. orbiculatus*, and with the association. A MHW was simulated by gradually increasing water temperature to +5°C above in-situ one, then maintaining it for 10 days, while control mesocosms remained at 25°C. The highest meiofaunal richness (8 taxa) was found in the *C. nodosa* condition, followed by the seagrass-lucinids association (7 taxa). After the MHW, all conditions showed a decline in taxa richness, with the greatest loss (43%) found in the plant-bivalve condition where we report the extinction of Copepoda, Polychaeta and Oligochaeta. At the end of the MHW, taxonomic composition significantly varied with a decrease in the abundance of heat-sensitive taxa (e.g., copepods and foraminifera) and an increase of more tolerant ones (e.g., nematodes). In parallel, the quantity and nutritional quality of sedimentary biopolymeric carbon declined across all impacted conditions, especially in the seagrass-lucinids one. Our results suggest that the ecosystem characterized by the association between *C. nodosa* and *L. orbiculatus* seemed to be the most sensitive one among those tested to extreme ocean warming events, showing the greatest loss of meiofaunal biodiversity and available resources after MHWs. This finding contributes to our understanding of how disturbances may impact biodiversity and reduce the resilience of ecosystems especially those with complex interactions.

Multimodal communication in ants: the interaction between chemical and vibro-acoustic signals in three Myrmicinae species

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Communication is a fundamental aspect of animal behaviour, with signals playing essential roles in courtship, foraging, and predator-prey interactions. In social insects like ants, chemical communication prevails, guiding a wide range of collective behaviours. However, some ant species use a stridulatory organ to produce vibro-acoustic signals that can trigger a behavioural response, either independently or in conjunction with chemical cues. Despite the widespread occurrence of stridulation in ants, its biological significance and interaction with other signalling modalities remain poorly understood. In this study, we explored the interplay between chemical and vibro-acoustic signals in the context of alarm communication in three Myrmicinae ant species: *Crematogaster scutellaris*, *Myrmica scabrinodis*, and *Manica rubida*. We used Laser Doppler Vibrometry and Stir Bar Sorptive Extraction (SBSE) to characterize vibrational signals and volatile pheromones produced by restrained ants. We designed an artificial arena to investigate workers' behavioural responses to pheromones and vibrations separately, as well as in combination. Our findings confirm chemicals and vibro-acoustic signals to be specie-specific. Furthermore, we found different response to multimodality in different species. In particular, chemical and vibro-acoustic signals are both necessary to trigger an attractive response in *C. scutellaris* and *M. rubida*, while only chemicals are sufficient to attract nestmates in M. scabrinodis. Interestingly, in *M. scabrinodis*, the addition of a concomitant stridulatory signal disrupts this attraction. These findings suggest the presence of modulatory effects that are potentially subject to environmental constraints. In particular, the differences in the active space of each signal component can result in varying responses depending on the environment or distance from the source. Furthermore, the three species occupy distinct microhabitats (*C. scutellaris* is primarily arboreal, *M. rubida* inhabits open high-altitude areas, and *M. scabrinodis* is a generalist) which may influence how chemical and vibrational signals propagate, ultimately affecting receiver perception. Overall, our results reveal species-specific response to multimodality in species that inhabit different micro-habitats, providing insights into potential selective pressures and constraints shaping the evolution of multimodality in complex social systems.

Peripheral sensory learning and "Taxonomic Behavior" in *Octopus vulgaris* arms

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Octopus vulgaris serves as an excellent model organism for the study of motor control and sensorimotor integration due to its highly specialized nervous system and advanced manipulative abilities. Each arm possesses a remarkable degree of functional autonomy, supported by a decentralized neural architecture in which over two-thirds of the neurons are located in peripheral ganglia. This organization enables the execution of complex movements without needing continuous central control. This decentralized neural organization, combined with a highly flexible morphology and refined manipulation skills, enables the octopus to explore and interact with its environment in a highly adaptable manner.
In this study, we present a novel experimental protocol developed for the controlled analysis of sensory systems at the level of individual arms. This protocol maintains the ability to monitor motor patterns accurately and assess taxonomic behavior in terms of species-specific behaviors. The protocol includes a progressive training sequence: the pre-training phase, in which the animal is trained to interact with a device containing a single real food stimulus, and the experimental phase, in which it is required to discriminate between two 3D-printed artificial anchovies and one real anchovy. The goal is to condition the animal to associate specific interactions with a food reward. For this protocol, a transparent plexiglass device was developed, consisting of three independent compartments, each equipped with an opening for arm insertion and a removable lid. A dedicated "ethological photo set" was also assembled for behavioral data collection, enabling detailed analysis using the BORIS software. *O. vulgaris* demonstrates the ability to distinguish between real and artificial stimuli using tactile/chemical and visual cues. Through the training phases, octopuses exhibit learning behaviors, such as associating specific tactile/chemical and visual stimuli with food rewards. This would be consistent with documented evidence of their ability to learn through conditioning and retain information over time and exhibit taxonomic behavior. Individual variability in response to stimuli could indicate behavioral plasticity and personality-like traits, suggesting that *O. vulgaris* can adapt its exploratory strategies based on past experiences and environmental changes.

Preliminary analysis of benthic fauna associated with vermetid reef along the Ionian coast of Apulia (Southern Italy)

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Vermetid reefs are considered very important ecosystems, due to their role in enhancing habitat complexity, modulating coastal morphological processes and providing shelter and food resources for many invertebrates. This study aims to investigate for the first time the benthic associated fauna with vermetid bioconstructions newly reported along the Apulian coast of the Ionian Sea, in the province of Taranto. The research area was located along 40 km of coastline, between the localities of San Vito and Campomarino (TA). Three study sites were selected and, at each site, two quantitative samplings, using squares 10 × 10 cm, were carried out along three transects by scraping off thin vermetid encrustation. Samples were sorted and preserved in 70% ethanol for species identification and counting.

The present study reports a rich and diverse fauna associated with vermetid bioconstruction, comprising 3266 individuals across 63 different taxa and 6 Phyla (Porifera, Nemertea, Mollusca, Annelida, Arthropoda, Chordata). Amphipods were found to be the most abundant, followed by Bivalves and Polychaetes. Some species (e.g., *Perinereis cultrifera*, *Syllis amica*, *Mytilaster minimus*, *Caprella grandimana*) were common across all three sites, representing typically species found in other Mediterranean vermetid reefs. Among the identified taxa, alien species such as Pseudonereis anomala and Mesanthura romulea were also detected. Notably, the high number of new crustacean species has never been reported in association with vermetids, partially addressing the knowledge gap for this taxonomic group.

The comparison with the benthic fauna associated with the vermetid bioconstruction newly described along the Adriatic coast of Apulia, revealed that only 27% of the species were shared, highlighting the unique species composition of each vermetid formation depending on the geographic location. This finding has important conservation implications, as it suggests that each vermetid bioconstruction supports site-specific biodiversity, underscoring the ecological value of vermetid bioconstructions in the coastal areas. Therefore, it is crucial to integrate these habitats into regional and national conservation policies to ensure the protection of their unique associated biodiversity.

New methodology for monitoring fishery-target species in Marine Protected Areas

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Marine Protected Areas (MPAs) represent ideal contexts for the application of experimental approaches and co-management models, facilitating the reduction of conflicts between the Managing Authority and local stakeholders, and promoting more effective and participatory governance. Among the most relevant activities in terms of biological impact and management interest is small-scale fishing, which represents an extensive pressure on target species and coastal habitats. This study focuses on the MPA "Penisola del Sinis–Isola di Mal di Ventre" (central-western Sardinia). Over the years, numerous monitoring campaigns of fishing activities have been conducted, but the reliability of the self-reported information by fishermen through logbooks has raised concerns about data accuracy. In 2023, to improve the spatial resolution and traceability of fishing activities, GPS geolocation systems were installed on a voluntary sample of nine vessels. Between 2023 and 2024, a total of 317 fishing trips were recorded over 130 days (an average of 1.5 ± 0.6 trips per day). Of the GPS tracks collected, 61% were complete and usable for analysis. Data collected from 2018 to 2025—via logbooks, onboard observations, and visual inspection of landings—enabled in-depth analysis of fishing dynamics within the MPA. These efforts contributed to a more detailed understanding of fishing patterns and behaviors. The comparison between the two data sources showed a match in 60% of cases (118 trips), indicating a fair level of reliability in the self-reported data, while also highlighting areas for improvement in field data collection and validation.

The integrated analysis of GPS tracks and catch records allows for the correlation of fishing trajectories with benthic habitats and zones of varying biological vulnerability, contributing to the understanding of the spatial ecology of fishing effort and its implications for fish communities. The technological advancement of these tools, combined with the expansion of their functionalities, makes them particularly effective in promoting constructive dialogue between MPAs and fishermen, fostering stronger, more transparent collaboration based on objective data.

First record and biological analysis of *Pyroteuthis margaritifera* in Sardinian waters

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The jewel enope squid, *Pyroteuthis margaritifera* (Rüppell, 1844), is the only known representative of its genus in the Mediterranean Sea. Specimens are rarely encountered, and to date, existing records have merely confirmed its presence in the region. Throughout its entire distribution range, only few biological data are available mainly focused on the comparative morphology of its distinctive photophores located on the tentacles, eyes, anus, gills, and abdomen. In June 2016, for the first time in Sardinian waters, a specimen identified through molecular analysis as *Pyroteuthis margaritifera* was accidentally captured by a trawl net at a depth of 250 meters. The individual, which measured 42 mm in dorsal mantle length and weighed 11.3 g, exhibited all the photophores previously described for the species except those on the tentacles. This absence contrasts with observations from six other Mediterranean specimens (from the Strait of Messina) recovered from the stomach contents of Thunnus thynnus, in which tentacular photophores were clearly present. Biological analysis of the Sardinian specimen revealed that it was a mature male, containing 372 spermatophores inside the Needham's sac, with a mean total length of 8.62 mm. Meristic data were recorded on the hooks present on the tentacle club and on the fourth arms, and the main measures of the beak were also recorded. Overall, the morphometric and meristic data reported herein represent the first comprehensive biological information and anatomical documentation available in Mediterranean for this elusive species. The absence of tentacular photophores in this specimen, in contrast with what reported in the literature, highlights the need for further studies on additional Mediterranean specimens using an integrative approach that combines morphological and genetic analyses.

The use of the otolith reading technique to determine the age of Silver eels in Sardinia, Italy

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The European eel *Anguilla anguilla* (Linnaeus, 1758) inhabits rivers and lagoons during its continental growth phase, where the silvering process, essential for reproductive migration, occurs. The timing of silvering is influenced by factors like latitude, environmental conditions, and food availability. This study investigates the metamorphosis to the reproductive stage within the Sardinian lagoon environment where eels are traditionally fished, focusing on the age by otolith analysis, size, and sex at the onset of silvering.
In 2019, 229 eel specimens were collected from two Sardinian lagoons: 109 from Porto Pino (495 ha, southern Sardinia), and 120 from Sa Praia (97 ha, eastern Sardinia). For each specimen parameters as livery, sex, total length, pectoral fin length, eye diameter, ocular index (OI), total weight, and gonad weight were recorded. For age determination, otoliths were processed using a grinding and polishing technique and stained with toluidine blue to enhance the visibility of annual growth rings. The age of each specimen was subsequently correlated with its biometric values and indices.
Out of 229 examined eels, 150 were yellow eels. Among these, 109 were females, with length range 26.0-72.8 cm and weight range 24.5-326.3 g. The remaining 41 were males, with length range 30.5-43.1 cm and weight range 33.8-170.0 g. The other 79/229 were silver eels. Of these, 41 were females, with length range 50.2-72.7 cm and weight range 191.6-778.5 g. The remaining 38 were silver males, with length range 34.0-45.6 cm and weight range 65.0-142.7 g. Female yellow eels age ranged between 2 and 10 years (mean: 4.47±1.36), while male yellow eels age ranged between 2 and 7 years (mean: 4.37±1.22). Silvering females age ranged between 6 and 12 years (mean: 8.49±1.50), while silvering males age ranged between 3 and 7 years (mean: 5.21±1.02). The OI was correlated with the transition from the yellow to the silver eel stage. For females, OI values exceeding 7.40 were consistently associated with the migrant stage. For males, this threshold was at 5.33.
These values are relatively low compared to those observed in continental Europe, which aligns with the evidence that maturation age increases with increasing latitude. Given that *A. anguilla* is both a commercially important species and critically endangered according to the IUCN, this information can be valuable for guiding conservation efforts related to both fisheries management and environmental protection.

A polychaete under pressure: *Sabella spallanzanii* as a zoological model for marine invertebrate immunity and environmental stress response

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The Mediterranean polychaete *Sabella spallanzanii* is emerging as a zoologically relevant model for studying innate immune mechanisms and stress responses in marine invertebrates. Its ecological niche, phylogenetic placement within Lophotrochozoa, and the presence of a mucus-based immune system make it a valuable organism for investigating interactions between environmental pollutants and invertebrate immunity.

Recent studies have focused on the response of *S. spallanzanii* to various stressors, including inorganic arsenic, copper sulphate, methylmercury, and bacterial infection (*Escherichia coli*). Mucus secreted by this species contains a calcium-dependent galactose-binding lectin (SsGBL), with specific agglutinating activity toward Gram-negative bacteria. This component plays a key role in non-self recognition and first-line immune defense.

Following arsenic exposure, which is naturally bioaccumulated in tissues possibly as an antipredatory strategy, the agglutination capacity of mucus lectins was significantly reduced, suggesting a trade-off between chemical defense and immune functionality. Seasonal variations in biological activity were observed, but arsenic tolerance seemed consistent across conditions, pointing toward possible evolutionary adaptation.

Additional experiments investigating the effects of copper sulphate and methylmercury, both alone and in combination with *E. coli* infection, revealed modulation of several immune markers, including esterase, alkaline phosphatase, glutathione peroxidase, lysozyme, and haemagglutination activity. Notably, co-exposure to bacterial and chemical stressors led to suppressed immune responses and altered protein expression profiles.

These findings support the use of *S. spallanzanii* as both a bioindicator in marine biomonitoring and a model system for understanding invertebrate immunity. Its complex immunophysiological responses to natural and anthropogenic pressures provide valuable insights into the evolution of immune strategies and resilience mechanisms in benthic marine organisms.

Terrestrial arthropods as indicators of restoration success in an active limestone quarry

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Limestone quarries are industrial sites that impact natural areas, thus their restoration is crucial for mitigating these impacts and reducing biodiversity loss. Restoration can be achieved through active management projects, such as hydroseeding and soil amelioration. Our study aims to evaluate the results of an active restoration project performed at a limestone quarry in Piedmont (NW Italy) using terrestrial arthropods as ecological indicators. We sampled four areas of the quarry restored in different periods between 1999 and 2016, following the quarry development, and showing different stages of vegetation succession, from sparse grassy vegetation to woodland. Additionally, we included a semi-natural xerothermic grassland outside the quarry as a control area. Arthropods were sampled at 20 points (four for each successional stage, and four at the control site), each consisting of three pitfall traps, filled with 100 ml of 20% propylene glycol as preservative liquid and spaced about 3 metres apart. All traps had been activated for seven days each month, from May to October 2024, for a total of five sampling sessions. Overall, we collected 13164 individuals belonging to 107 families. RDAs and GLMMs were applied to test for differences in community composition and biodiversity indexes according to the restoration stage, and between the quarry and the control area. RDAs showed that the community composition was mostly similar at the different restoration stages and in the control area. Some coprophagous beetle families, such as Scarabeidae and Geotrupidae, were associated with the semi-natural xerothermic grassland, while predators such as Carabidae and several spider families were associated to the earlier successional stages created by the quarrying activity. GLMMs revealed a higher arthropod diversity in the oldest successional stage, now colonized by broadleaved woodlands. On the other hand, species richness reached a higher value in the control area, outside the quarry. These results suggest that predator arthropods can thrive in restored quarries, leveraging on sparse grassy vegetation in the newly restored areas of the quarry. On the contrary, coprophagous and necrophagous beetles are more abundant outside the quarry. Notably, high arthropod diversity in the oldest part of the quarry suggests that active restoration management is a profitable tool for restoring these post-industrial sites and achieving biodiversity conservation targets.

First observations on the electrosensory system of the common smooth-hound shark, *Mustelus mustelus* (Linnaeus, 1758), from the Mediterranean Sea

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The common smooth-hound *Mustelus mustelus* (Linnaeus,1758) is a demersal shark widely distributed in temperate and subtropical coastal waters, including the Mediterranea Sea. Like other cartilaginous fish, it possesses a specialized electrosensory system: the ampullae of Lorenzini (AoLs). These structures, functionally adapted to detect minute electric fields, consist of subdermal sensory organs connected to the environment via canals ending in pores. The morphology, histology and spatial distribution of AoLs vary among species.
This study provides the first description of the gross anatomy and histomorphology of AoLs in *M. mustelus*, aiming to clarify their structure and infer possible ecological adaptation.
Specimens were collected as by-catch from artisanal trammel net fishery in the Egadi Archipelago. Following deep anaesthesia with MS-222 Sandoz, AoLs samples were fixed in paraformaldehyde and processed for macroscopic and histological analysis. Cephalic distribution and gross anatomy were examined macroscopically, while histological sections were stained with Alcian blue and Milligan's trichrome to reveal cellular features.
AoLs are organized into distinct clusters (supraorbital, buccal, hyoid, and mandibular clusters), each composed of a canal and a dilated ampullary portion (AP), both filled with gel and surrounded by connective tissue. Each cluster comprises at least five ampullae, connected to an afferent nerve. Nerve fibre bundles branch at the base of each AoL, enabling separate innervation.
Histological analysis confirmed the general organization of the AoLs, which are primarly located in the rostral cephalic region. The canal is lined with simple squamous epithelium, while the AP is composed of simple columnar epithelium containing supporting and sensory cells. Each AP includes eight alveolar sensory chambers, which are proximally connected to afferent nerves. Nerve bundles reach the base of each AP beneath the central cup, with terminals extending to the base of the sensory cells only.
Our findings seem to highlight a high density of cephalic AoLs and pronounced alveolar subdivision in *M. mustelus*, suggesting enhanced electrosensory reception and signal processing. These characteristics may be linked to specific ecological traits, encouraging future studies on the evolutionary drivers and ecological implications of AoL system in this species.

Monitoring of eel ladder on the Casteldoria dam in the Coghinas River (northern Sardinia, Italy)

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The European eel *Anguilla anguilla* (Linnaeus, 1758), a catadromous species classified as "Critically Endangered" on the IUCN Red List, faces several anthropogenic pressures that have led to stock progressive decline since the late 1980s. One of the most severe ecological problems, beyond the direct effects of adult fishing and the capture of juveniles for aquaculture, is habitat loss due to the fragmentation of watercourses by weirs and dams.
This study describes the monitoring of the eel ladder installed at the Casteldoria dam (Sardinia, Italy), located along the Coghinas River, 15 km upstream from its mouth. The dam is used for power generation by Enel Green Power and the water is also used for drinking and irrigation purposes by ENAS and Consorzio bonifica of North Sardinia. The eel ladder is a total of 37 meters long with an average slope of 63%. It operates by means of water flowing down a covered canal with plastic bristle substrate, which allows eels to ascend upstream. Data for this study were collected through weekly sampling from fall 2022 to fall 2024. For each monitoring day, the total weight of eels was recorded, and biometric analyses of length and weight were performed on a subsample of 30 individuals.
During the reference period, a total of 8,754 eels were counted, with a total weight of 18,612 g. The highest number of individuals counted was 4,814 in winter 2022–2023, while the lowest number was 5 individuals in autumn 2024. The biometric values recorded from the eel subsample across the different seasons were: mean length ranged from 10.24 ± 0.32 cm in autumn 2023 to 17.50 ± 0.71 cm in autumn 2024, while mean weight varied from 1.03 ± 0.58 g in autumn 2022 to 5.47 ± 6.42 g in winter 2023–2024.
The eel ladder is of vital importance to ensure the natural and complete colonization of eels along the river's main channel. The installed ladder has proven effective in allowing the transit of elvers and yellow eels. No glass eels were detected, likely due to the ladder's 63% slope, which is probably too steep for this stage. Restoring river continuity, even with structures like eel ladder, is fundamentally important to protect the species and enable its presence even in habitats impacted by human activity. Adopting measures of this kind is definitely a strategy to complement the regulation of the direct exploitation of the species.

Integrative taxonomy unravels the origin and introduction pathway of non-indigenous *Ceratonereis* in the Mediterranean Sea

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The Mediterranean Sea is one of the regions most affected by biological invasions, especially after the opening of the Suez Canal determining the arrival of Info-Pacific species from the Red Sea. Ports and marinas are important gateways for alien species, fuelling the spread of lessepsian migrants that raise concerns due to their impact on local ecosystems. Although polychaetes are among the most abundant taxa in marine benthic communities, genetic data and critical taxonomic revisions are still lacking for many groups compared to other invertebrate taxa, which hinders proper identification of non-indigenous species (NIS). With the aim of tracing the distribution and invasion routes of polychaete NIS in the Mediterranean, this study focused on *Ceratonereis mirablis*, a species originally described for the tropical western Atlantic and reported as a NIS in the eastern Mediterranean. Specimens of *C. mirabilis* from Lebanon and Cyprus were compared with material from the Arabian Gulf, Oman and the Caribbean using an integrative approach combining molecular, morphological and ecological data. Genetic and morphological data highlight the presence of two distinct *Ceratonereis* species in the Mediterranean, one of which occurs on vegetated hard bottoms, while the other in soft sediments only. Even though these lineages were historically referred to as *C. mirabilis*, molecular data show a clear distinction from specimens collected in the western Atlantic. Conversely, the Mediterranean lineages also occur in the Red Sea, which suggests a lessepsian origin of both species and that *C. mirabilis* as currently identified represents a species complex, emphasising the need for a critical revision of this genus.

The arthropod communities of the *Posidonia oceanica* banquette of Sant'Agostino (Latium, Central Italy)

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Banquettes are an important coastal ecosystem formed from the accumulation on the coasts of plant biomass, represented by the dead leaves of the marine phanerogamous plant *Posidonia oceanica* (L.) Delile, and many species of invertebrates and small vertebrates are present within them. These environments are still poorly studied from an ecological and faunistic point of view and are increasingly at risk due to human activities. In Latium, at the locality of Sant'Agostino, near Civitavecchia (Rome), there is one of the most well-preserved banquettes in the Region, which is part of the protected area "La Frasca" Natural Monument. Eight sampling points were selected in a portion of beach approximately 610m long. For each point, two pitfall traps were placed and remained active for 7 days, the first one placed at the surface level of the banquette and the second one at a depth of 50cm. In addition, two samples were taken for analysis by visual census and the other by Berlese-Tullgren funnel extraction. The sampling sessions were carried out approximately every 40 days from January 2024 to November 2024. Sampled individuals were identified at Order level. For spiders, a more detailed identification was conducted at Species level. GLMM models were developed to analyse abundances, the number of taxonomic groups and Simpson's indices, in function of seasons and sampling method, and a CCA analysis to highlight the relationships between taxonomic groups, seasons and sampling methods. The most significant seasonal variations are in the abundances of individuals captured, with the subterranean pitfall and Berlese-Tullgren funnel recording the largest numbers of individuals. For taxonomic groups and Simpson's indices, the differences are less marked or non-significant. Fifteen species of spiders were identified, including three new for Italy (*Dysdera cf. gamarrae* Ferrández, 1984; *Gnaphosa jucunda* Thorell, 1875; *Erigone dentosa* O. Pickard-Cambridge, 1894) and one new species for Latium (*Chaerea maritimus* Simon, 1884). The results obtained extend a still limited literature, helping to highlight the biological importance of Posidonia oceanica banquettes, which often remain underestimated and poorly studied.

Circadian and sleep-like rhythmicity in the scalloped hammerhead shark (*Sphyrna lewini*)

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Understanding biological rhythms in continuously swimming marine animals is crucial to elucidate their rest-activity balance and internal timekeeping. Scalloped hammerhead sharks (*Sphyrna lewini*) are ram ventilators with high energetic demands, and have recently been shown to display a rhythmic rolling swimming behaviour (RSB). We investigated the presence and function of biological rhythmicity in wild *S. lewini* using high-resolution accelerometry and time-series analysis. Our results reveal robust circadian rhythmicity in activity levels, with a consistent nocturnal acrophase and significant anticipation of light transitions, indicating entrainment by an internal circadian clock. Concurrently, we identified a structured ultradian rhythmicity in rolling behaviour, which differed markedly between day and night. Daytime rolling cycles were shorter, less frequent, and associated with low metabolic effort, suggesting a restorative function. Nighttime rolling was longer and more active, potentially supporting navigation and environmental sensing. We observed a homeostatic relationship between night and day rolling intensity, consistent with compensatory rest regulation. Additionally, we detected a modulatory effect of moonlight on nighttime activity and subsequent daytime rest, suggesting masking effects. Altogether, our findings support the presence of circadian and sleep-like processes in *S. lewini*, and raise new questions about how these rhythms support energy conservation, navigation, and sensory integration in pelagic predators.

Wild bees (Hymenoptera, Apoidea, Anthophila) and flowers: evaluation of visit frequencies in urban nature reserves

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Urbanisation is a pervasive global process that contributes to habitat fragmentation and biodiversity loss. Nevertheless, large urban green spaces can serve as important refuges for wildlife, offering critical habitats that support biodiversity conservation even within metropolitan contexts. Also in the urban ecosystem, wild bees represent key pollinators among urban fauna, playing a crucial role in ecosystem functioning. Their diversity and activity are closely linked to the availability and characteristics of flowering plants, which provide essential food resources. This study investigates the interactions between wild bees and spontaneous flowering plants within selected large urban nature reserves in Rome, Italy. Specifically, we analysed bee visitation frequencies at the genus and family level and examined the role of functional traits of flowers and bees in shaping these interactions. For bees, we considered traits such as the ligula's relative length and position of the scopa on the body. We focused on inflorescence type, corolla structure, and flower colour combinations for plants. Our goal was to characterise the structure of pollination networks in large urban green areas and to understand how morphological and functional traits of both bees and flowers influence interaction patterns. Preliminary results suggest that specific trait combinations are associated with higher visitation rates, indicating a degree of trait matching that may enhance pollination efficiency and network stability. Emerged that a few plant families are highly represented and visited by many bee species, while many other botanical groups are visited by small groups of wild bees. Regarding morpho-functional traits, long-ligula bees visit a wider range of flowers and preferentially visit deep and tubular flowers, while short-ligula bees visit a smaller number of plant taxa. From the analysis of scopa position to corolla structure, significant results didn't emerge. The findings highlight the importance of functional traits in mediating ecological interactions in urban ecosystems. This approach provides a deeper understanding of how urban green spaces can sustain complex pollination networks, offering practical insights for urban biodiversity management. By identifying the traits that facilitate effective plant–pollinator interactions, this research can inform targeted conservation strategies aimed at promoting pollinator diversity and abundance in cities.

Accumulation of trace elements and assessment of oxidative stress in three European eel (*Anguilla anguilla*) populations in Calabria

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The European eel (*Anguilla anguilla*), a widely distributed catadromous species currently classified as *Critically Endangered* by the IUCN, is experiencing a marked decline on a continental scale. This decline is attributable to multiple factors, including chemical contamination of aquatic ecosystems.
This study investigated the concentrations of 16 trace elements (Al, As, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Se, Sr, Zn, Ba, Bi) in the muscle tissue of 20 specimens collected from three sites in Calabria (Crati River, Raganello Stream, La Vota Lakes), using inductively coupled plasma mass spectrometry (ICP-MS).
Statistical analysis revealed significant differences in the bioaccumulation of 10 out of the 16 elements among the populations, raising particular concern over the significant results for cadmium and arsenic.
In parallel, ecotoxicological assays were conducted to assess oxidative stress (SOD, TBARS, ketonic and aldehydic OMPs) in four target tissues (muscle, heart, liver, gills). In muscle tissue, populations showed statistically significant differences for all biomarkers: OMP values were highest in La Vota Lakes, while SOD was highest in the Crati River.
Correlation analysis between bioaccumulation and stress revealed site-specific responses: no significant relationships were observed in Raganello; in the Crati, Mo and Cr were positively correlated with TBARS, while Zn was negatively correlated with SOD; in La Vota Lakes, Al was negatively correlated with TBARS, Bi was positively correlated with aldehydic OMPs, Se and Co were positively correlated with SOD, and Cr was negatively correlated with SOD.
The results highlight complex interactions between chemical contamination and physiological responses, underscoring the vulnerability of *A. anguilla* in ecotoxicologically critical environments.

"That's a trap!": Identifying extracellular traps formation in invertebrates and vertebrates

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All living animals possess multiple conserved mechanisms for regulated cell death (RCD) like apoptosis, but among these, the formation of extracellular traps (ETs) or ETosis is an innate immune mechanism to cope with the invasion of pathogens, recent studies have also shown how ETosis takes part into various auto-immune diseases. Although described in many vertebrates, few are the descriptions in crustacean, and almost none for echinoderms and sharks. Thus, this research characterized ETosis in four species: two invertebrates (*Cherax quadricarinatus*, Crustacea and *Arbacia lixula*, Echinodermata), as well as two vertebrates (*Cephaloscyllium umbratile* and *Triakis scyllium*, Chondrichthyes). Haemolymph, coelom or blood was extracted from *C. quadricarinatus*, *A. lixula*, *C. umbratile* and *T. scyllium*, then the respective immune cells were fractionated. Consecutively, to induce the release of ETs the cells were exposed in-vitro to Gram+ and Gram- bacteria: Escherichia coli or its LPS alone, S. aureus or L. garvieae (DNase or cytochalasin-D as positive controls). Lastly, fluorescent microscopy analyses and further quantification using ImageJ were performed. The results show species-specific differences in the morphology of the ETs and the time of release after exposure to each pathogen. Specifically, *C. umbratile* and *A. lixula* exhibited more diffuse ETs. Whilst in *T. scyllium* and *C. quadricarinatus*, produced conspicuous ET filaments when induced by Gram- and Gram+ bacteria respectively. However, the amount of exDNA vary among species depending on the concentration and activator specifically, sharks undergo ETosis releasing a lower amount compared with invertebrates. Moreover, after analysing all the results obtained, mainly two ETs morphologies are the most common: filamentous and diffuse. Those results, according with previous studies, suggest an effective recognition and a extraneous molecules and consecutive clearance of the bacteria. Thus, this is the first comparative report among different taxa, assessing the highly specificity of ETosis in each organism, and how it is strictly influenced by the concentration of the stimulant. Overall, ETosis in both invertebrate and vertebrate's immune cells was identified, suggesting it is a conserved RCD mechanism with insights for further studies on the specific activation and the implications on how this process can be regulated.

A spatio-temporally explicit distribution model to support conservation strategies for isolated small-ranged species: a case study from Galápagos

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Species Distribution Models (SDMs) represent the gold standard to investigate how environmental factors affect the occurrence of animal species and estimate their actual and potential distribution. However, SDMs often lack a formal hypothesis-driven selection of environmental predictors and require independence among observations. In contrast, actual occurrence data are often spatially and temporally autocorrelated, particularly when most observations originate from a limited number of surveys, as frequently happens in studies focusing on isolated, small-ranged species of high-conservation priority. Here, we explored the application of a hierarchical Bayesian spatio-temporal SDM to model the probability of occurrence of small-ranged species living in isolated and difficult-to-access areas, combining Integrated Nested Laplace Approximation (INLA) with Stochastic Partial Differential Equation (SPDE). To do so we used the Galápagos Pink Land Iguana (*Conolophus marthae*) as a model organism. This species is well suited for our scope in being critically endangered and endemic to an extremely small and remote area on Wolf Volcano on Isabela Island, Galápagos. Our approach enabled us to obtain reliable estimates of the effects of environmental variables on species distribution using opportunistic occurrence data, which exhibit a pronounced spatio-temporal structure. A spatially explicit cross-validation of the model demonstrated that the INLA-SPDE approach allows elucidating the relationship between small-ranged species and their areas of distribution, resulting in accurate predictions (Cohen's K = 0.86; True skill statistics = 0.84). We also used the INLA-SPDE model to map the actual and potential distribution of the species across the Galápagos archipelago. Our approach provided a first formal measure of the range of *C. marthae* (*ca.* 42 km2) and indicated that abundance of trophic resources, availability of open areas, and terrain roughness limit species' distribution. We also identified *ca.* 400 km2 of suitable areas clustered into three main sites outside the species' actual range. These results constitute an essential starting point to evaluate a species translocation, a key conservation strategy outlined in the Conservation and Management Plan for this species.

Phoresy by ants: despersion of Tardigrades enhanced by anhydrobiotic capabilities

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Phoresy is a temporary symbiotic relationship where an organism, generally with limited active dispersal capabilities, uses a more mobile host for dispersion to reach new habitats or resources. Tardigrades are known to use as phoretic hosts various vertebrates and invertebrates with limited mobility. This study investigated the potential role of ants as dispersal hosts for tardigrades, a possibility not yet explored, as similar behaviours have already been documented in ants with other invertebrates.

To verify the tardigrade-ant associations, a field survey was conducted on arboreal ants. Oak galls of the cynipid wasp *Andricus quercustozae* colonized by four ant species were collected, the presence of tardigrade in these ants' gall nests and on ant bodies were assessed. The transport of tardigrades by ants was also evaluated by isolating galls for one year and then exposing them to ant colonization, as well as by laboratory experiments on tardigrade phoresy focusing on the behaviour of the ant *Colobopsis truncata*.

Ants carried tardigrades on their bodies, providing the first evidence of ant-mediated tardigrade phoresy, especially with *C. truncata*. Moreover, ants transport moss and lichen fragments inside their nests, thus tardigrades and other meiofaunal organisms were retrieved in galls. The high humidity conditions within galls spongy material allow tardigrades to be alive and active. The intense foraging activity and long distance walked by ants together with the high number of potential "transporters" within colonies explain the diversity of the tardigrade species retrieved within the galls. Finally, desiccated tardigrades may withstand potential long-distance transport by ants. Indeed, animals able of undergoing anhydrobiosis could properly desiccate on the body of an ant or within fragments of substrates (e.g. mosses, lichens) and being transported for long distances withstanding extreme conditions.

Thanks to the ant widespread abundance, myrmecophoretic dispersal may contribute to the spread of meiofaunal organisms in terrestrial habitats. These findings represent just the "tip of the iceberg" of an unexplored passive dispersal modality over significant distances for terrestrial hydrophilic micrometazoans, broadening our understanding of ecological interactions and phoresy.

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Diversity and distribution of Apoidea across conventional and organic crops in the MAB-SILA UNESCO biosphere reserve (Calabria, Italy)

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Pollination sustains plants and is therefore pivotal for the environment. Wild bees (Hymenoptera, Apoidea, Anthophila) represent the most significant group of plant pollinators, with a total of over 20,000 species identified worldwide. Nonetheless, these species are in decline due to a range of stressors, including habitat fragmentation, pesticides and pollution. These factors primarily affect their diversity and abundance. In order to design effective conservation programmes, it is necessary to collect information about bee presence and distribution, however more than 50% of wild bee species in the IUCN Red List for Europe are data deficient. This underscores the need for more ecological studies on species distribution and diversity. Mediterranean countries have the most diverse bees, including more than 1,000 species in Italy. Nevertheless, data on wild bees in certain areas, such as Calabria, are either limited or lacking.

The present study was performed in a MAB area in Calabria (Italy), as part of the BIONETPARKS Project – Protecting Pollinators and Plant Species in the MAB-SILA UNESCO Biosphere Reserve. A total of four sampling sites were chosen in cultivated areas, of which two were under conventional management and two under organic management. The sampling method employed, in accordance with the EU Pollinator Monitoring Scheme (PoMS), was permanent transect walks. The monitoring period (2022-23) resulted in the identification of 38 species, which belonged to 14 genera and 4 families. The most prevalent genera were *Andrena*, with a total of 14 species documented, and *Lasioglossum*, which accounted for 7 species.

A diversity analysis was conducted, with the alpha and beta diversity indices employed as the primary analytical tools. Subsequently, these indices were correlated with agroforestry activity, temperature and altitude. Furthermore, the relative abundances of the various genera at different sites were taken into account, showing a greater abundance of social managed species (*Apis*, *Bombus*) in the conventional areas, while organic farms exhibited a greater abundance of wild bees (*Andrena*, *Lasioglossum*). In addition, the interaction between the identified wild bees and the host plants was analysed and an overview of the knowledge on the ecological characteristics and conservation status of the identified species was considered. This study presents a preliminary investigation into the current status and diversity of Apoidea in Calabria.

A national reference for wild bee identification: Italian adaptation of Michez et al. (2024) key to bee genera

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In recent years the interest and concern for nature and its safeguard has grown. The European Commission has adopted the Law for the Restoration of Nature, which establishes and guides member states in implementing measures to promote the conservation of biodiversity. Pollinators, and in particular wild bees, play a significant role in this plan because of their key role in the ecosystem functioning and the critical decline they are facing. Several European projects for monitoring and conservation of wild bees have been launched. These have encountered problems due to a lack of resources for taxonomic identification. It is therefore evident that there is a need for both information and tools for taxonomic identification, as well as for training a new generation of experts. Projects such ORBIT and SPRING were launched for this purpose. ORBIT was created to provide a tool to support the taxonomic identification of European wild bees, while SPRING project aimed to test the implementation of the EU Pollinator Monitoring Scheme (EU PoMS) for wild bees and other pollinators. In this framework an international team of experts is working on adapting at national scale the "Key to the genera of European bees (Hymenoptera: Anthophila)" (Michez et al., 2024), a reference identification tool, at genus level, for the Apoidea fauna of each European country. The purpose of this work is to introduce the Italian version of the key.

The Italian key, to be published as a volume, is an adaptation of the European key by Michez et al. (2024). It has been rearranged to focus only on the Italian fauna of Apoidea Anthophila, removing the genera not present in the peninsula. In Italy, we have 61 genera of the 77 European genera listed on the original key.

The volume encompasses a general overview of the life cycle, ecology and morphology of bees. It also summarises the families, subfamilies, tribes, and genera present in Italy, including the number of species and the main bibliographic references available for species-level identification. Finally, the work provides two illustrated identification keys, one for females and one for males, and also includes species factsheets covering some of the most common and representative Italian species. This work, intended for students but also enthusiasts or amateurs, aims to help facilitate the dissemination of taxonomic knowledge on Apoidea, and therefore, approach the monitoring and conservation goals set by the European Union.

Trophic shift in *Mustelus mustelus* and M*ustelus punctulatus*: a vertebral stable isotope approach

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The increasing vulnerability of demersal elasmobranchs to overfishing, and the consequent global decline of their populations and their ecological role as apex predators in epi-benthic ecosystems, has led to growing scientific interest in understanding their trophic ecology. This aspect is considered essential for developing effective conservation and management strategies, especially in areas subject to high anthropogenic pressure.
Stable isotope analysis has proven to be a powerful tool in this kind of investigation. Soft tissues such as muscle reflect dietary input over relatively short periods, weeks to a few months, due to their higher metabolic turnover. In contrast, hard tissues, like vertebrae, are known to incorporate isotopic signals more slowly, reflecting feeding patterns over months or even years. This slower turnover rate allows vertebral isotopes to serve as a biological archive, providing long-term insights into individual trophic histories and ecological changes across life stages.
In this study, we analysed the stable isotopes of nitrogen (^{1}N) and carbon (^{13}C) along the vertebrae of *Mustelus mustelus* and *Mustelus punctulatus*, two demersal shark species that are increasingly threatened in various Mediterranean regions. A total of thirty vertebrae from *M. mustelus* and thirty-five from *M. punctulatus* were examined using isotope ratio mass spectrometry, enabling the reconstruction of individual trophic trajectories across ontogeny. The results revealed distinct species-specific patterns. *M. punctulatus* exhibited a general increase in ^{1}N values with increasing body size, suggesting a trophic level shift as individuals grow, reflecting a dietary transition toward larger or higher-level prey. In contrast, *M. mustelus* showed stable isotopic signatures throughout ontogeny, indicating a more consistent diet over time and potentially a narrower ecological niche.
These findings highlight the value of vertebral stable isotope analysis in detecting ontogenetic trophic changes and contribute to a better understanding of the feeding ecology of demersal sharks. Such insights are fundamental to inform conservation policies and improve the management of species like *M. mustelus* and *M. punctulatus*, which are especially vulnerable in heavily exploited marine environments.

An habitat fight: the interaction between the polychaete *Sabellaria spinulosa* and the phanerogam *Posidonia oceanica*

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Posidonia oceanica (L.) Delile (1813) is the most important Mediterranean seagrass, and its meadows perform a pivotal role within the coastal marine environment. The polychaete *Sabellaria spinulosa* (Leuckart, 1849) is a biogenic reef builder in sandy environments and is included in the Red List of Marine Habitats and it is a priority habitat in the OSPAR convention. In the framework of the projects MOSSHA and NBFC, we analyze the interaction between the two habitat formers in an area adjacent to the Nature Reserve "Le Cesine", in the Southern Adriatic Sea. The morpho-structural characteristics of *P. oceanica* and both the qualitative and the morphometric characteristics of *S. spinulosa* bioconstructions were analyzed in eight subareas where the two habitats co-occur and where they are isolated from each other. A visual and photographic census was conducted in each sub-area using a standard 40 x 40 cm reference square. *P. oceanica* was analyzed following ISPRA's reference methodologies, while the analysis of the bioconstructions of *S. spinulosa* was performed by both non-destructive (video and photographic records) and destructive (collection of 18 blocks of 20 x 20 cm) sampling. The morpho-structural characteristics and the macrofauna associated with each block were determined. Density, coverage, and leaf production of *P. oceanica* exhibited higher values in absence of *Sabellaria*, showing instead a decline in the areas where interaction took place. The analysis of phenology and lepidochronology demonstrated a marked decline in the health status of the meadow in the presence of *Sabellaria*. Conversely, the qualitative analysis of S. spinulosa revealed that the presence of *P. oceanica* caused erosion, reduced compaction, more fractures, and reduced cover of epibionts. No effect of the interaction on the size of *S. spinulosa* individual was detected while their density was higher in the interaction areas. Finally, the macrofauna associated with the blocks was more abundant and diversified in the interaction areas. Thus, S. spinulosa tended to impair the growth of *Posidonia*, reducing the production and development of new rhizomes and causing a considerable decline in the productivity of the plant, while the interaction caused both positive and negative effects on the polychaete bioconstruction.

Bridging a two-decade gap: new insights into wild bee diversity of Circeo National Park (Latium, Italy)

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Circeo National Park (CNP) is one of the most important natural areas in Central Italy, encompassing a remarkable variety of habitats — including coastal dunes, wetlands, forests, and agricultural landscapes — and preserving numerous endemisms. Among its faunal communities, wild bees represent key pollinators, providing essential ecosystem services that sustain both plant populations and agricultural production. Despite their ecological importance, their diversity within the CNP has been scarcely documented over time. In fact, the last systematic surveys date back to two distinct periods: the first in 1963, and a later campaign between 1993 and 1998. Since then, no comprehensive monitoring has been conducted. The present study is part of the national framework of actions titled "*Pollinating Insects: Biodiversity and Ecosystem Services*", promoted and funded by the Italian Ministry of the Environment (MASE) through the 2019 Directive addressed to Italy's National Parks and Marine Protected Areas, and aims to investigate current wild bee diversity across different environments of the CNP. Field sampling was carried out from March to September over three consecutive years (2021–2023). Bees were collected using entomological nets along fixed transects (200x4m), evenly distributed across three main habitat types: agricultural areas with varying management practices, coastal sand dunes, and the Circeo Promontory. The data obtained are compared with results from previous surveys to assess changes in species composition. Moreover, differences in wild bee communities among the sampled habitats are discussed. This study contributes to updating the knowledge on the current status of wild bees within CNP, providing essential data to support conservation strategies.

Peracarida fouling communities along a Mediterranean North-South axis

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Marine ecosystems, including marinas and harbours, are hotspots for Non-Indigenous Species (NIS), which pose significant threats to marine biodiversity. Boating activities are a major vector for the introduction of NIS, particularly Peracarida, whose natural dispersal capabilities are limited. This work aimed to examine the variability and dynamism of Peracarida fouling fauna in three Italian key sites: Palermo and Trapani marinas, both highly impacted by recreational boating and located near the Ustica and Egadi marine protected areas (MPA), and the marina of Licata. Two additional sites were sampled for the first time: the Bergeggi MPA, Italy, and the Kerkennah archipelago in Tunisia, enabling a comparative analysis of communities along a north-south latitudinal and anthropogenic impact gradient. In addition to simply assessing species diversity, the study also considered the species' biological traits. A total of 25 species were identified, including eight NIS or cryptogenic species. The NIS *Caprella scaura* Templeton, 1836 was abundant in all marinas and surpassing in both abundance and frequency the other present predators, *Phtisica marina* Slabber, 1769 and NIS *Paranthura japonica* Richardson, 1909, likely due to its plasticity of feeding behaviour, being able to rely on filter-feeding when fully matured instead of being limited to carnivorous predation. The cryptogenic grazer *Jassa slatteryi* Conlan, 1990, efficient in detritus generation, was found only in Trapani. Wherever *J. slatteryi* was absent, we found the detritivorous *Eritchtonius brasiliensis* (Dana, 1853) and NIS *Stenothoe georgiana* Bynum & Fox, 1977, in Palermo, Licata and a sampled pier in Trapani. The highly invasive detritivorous NIS *Laticorophium baconi* (Shoemaker, 1934) was found at all sites except one in Licata, where the NIS *Monocorophium acherusicum* (A. Costa, 1853) occured. NIS *Paracerceis sculpta* (Holmes, 1904) was absent from all Trapani piers. In Kerkennah, NIS *Ampithoe bizseli* Özaydinli & Coleman, 2012 was recorded; in Bergeggi *S. georgiana* was present. Fouling community structures and NIS assemblage varied not only among marinas but also between individual piers in Trapani and Licata. These differences were not linked to seasonality. Across all sites, species showed a broad range of trophic strategies, with suspension-feeders dominating the community structure.

Experimental setup for the study of behavioral responses of *Octopus vulgaris* to acoustic stimuli

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The sea is a complex acoustic environment, encompassing a wide range of sounds - from natural to anthropogenic sources - that influence how marine organisms communicate, navigate, and detect predators or prey. Although marine vertebrates have been extensively studied in this context, the role of sound in the sensory perception of cephalopods, and particularly in *Octopus vulgaris*, still remains poorly understood. Physiological evidence indicates a potential sensitivity to low-frequency sounds (¡400 Hz), but systematic behavioral studies are lacking.
The aim of this work is to develop an experimental protocol to evaluate the behavioral responses of *O. vulgaris* to artificial and natural sound stimuli in an acoustically controlled environment.
We designed a dedicated experimental tank to perform a comprehensive assessment of animal behavior under different sound stimuli across a wide range of frequencies and sound pressure levels, monitoring background noise levels. The behavioral responses of individual *O. vulgaris* to each sound combination were categorized as follows: no response, posture, startle, body pattern change, arm movements, grooming, jetting, and inking. These responses are plotted against stimulus conditions for the construction of a behavioral audiogram.
This experimental approach allows us to explore the octopus's auditory capabilities and contribute to a better understanding of its sensory strategies, with potential implications in field ethology, zoology and conservation.

Tracking chromosomal damage across species: the micronucleus assay as a versatile biomarker

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The micronucleus (MN) assay is a cytogenetic technique that allows to detect small, extra-nuclear bodies ('micronuclei'), arising from an incorrect integration of chromosomes or chromosome fragments into daughter nuclei during cell division. The technique is widely applied to evaluate chromosomal damage resulting from exposure to environmental pollutants or physical stress. Our primary aim is to review how the assay has been applied across diverse aquatic and terrestrial animals. Moreover, here we develop two new protocols to further broaden the applicability of the test, on the freshwater snail *Lymnaea stagnalis* and on the invasive blue crab *Callinectes sapidus*.

Methodologically, the MN assay involves collecting specimens —whether from controlled laboratory cultures or from the field— from which cells are gathered, fixed, and stained on lab slides. Typically examined tissues are buccal mucosa and circulatory tissues like blood (for vertebrates) and hemolymph (for invertebrates). Microscopic examination of the lab slides then allows to score the frequency of micronuclei or other nuclear aberrations. Focusing on size, shape, and staining intensity, these structures can be discerned from the main nucleus of from staining artifacts.

This method's simplicity and cost-effectiveness have allowed it to be successfully employed on many vertebrates and invertebrates, revealing a wide spectrum of genotoxic responses, such as those caused by some industrial waste, pesticides, and heavy metals. Fish and amphibians generally represent sensitive models due to their permeable tissues and are tested through straightforward blood sampling, while terrestrial mammals have often been sampled using mucosal cells. Even invertebrates have provided valuable data, despite some sampling challenges. *L. stagnalis*' behaviour of extruding hemolymph when prodding the animal's foot with a micropipette makes it particularly suitable for this test, while *C. sapidus*' invasive nature in the Mediterranean makes it a widespread and easily accessible resource as well.

Overall, the assay is a valuable tool for environmental monitoring and risk assessment through the use of various taxa, and findings from *L. stagnalis* and *C. sapidus* further confirm its versatility. By implementing robust methodologies and exploring its application to new organisms, it is possible to exploit the assay to detect the effects of genotoxic pollutants in various environments.

Macrozoobenthic non-indigenous species colonization in a Mediterranean Coastal Lagoon: comparison between natural and anthropogenic substrates

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Macrozoobenthic coastal communities are among the most productive in marine ecosystems, often threated by biological invasions. Proliferation of non-indigenous species (NIS) outside their natural boundaries depends on several factors, including life-cycle, physiological plasticity, introduction pathways and substrates availability. The aim of this study is to compare the variability of hard bottom macrozoobenthic diversity and NIS abundance related to substrate type. Sampling was carried out in the Natural Oriented Reserve of Capo Peloro Lagoon (Messina, Italy) in 2023, collecting 115 marine litter objects (Anthropogenic Substrate-AS) and 115 *Pinctada radiata* (Natural Substrate-NS). NSs and ASs were transported in laboratory and sorted to collect the associated macrozoobenthic fauna. A total of 201 associated species were identified in both the substrate types, belonging to Polychaeta (85 species), Crustacea (49), Mollusca (41), Echinodermata (10) and 16 species belonging to minor represented groups. Nineteen NIS were identified during the analysis, representing almost the 10% of the total number of detected species. Concerning abundances, NIS represented the 4.5% of the total macrozoobenthos abundance, with the 95% of NIS abundance detected from NS. SIMPER analysis based on substrate typology showed an average similarity of 16.07% for AS, due to high abundance of *Pileolaria pseudomilitaris*, *Aiptasia mutabilis* and *Janua heterostropha*, and 33.91% for NS, given by Serpulidae and *A. mutabilis* as well; dissimilarity between substrates was of 90.98%, with NIS contributing for the 11.73%. *Hydroides dianthus*, *Paracerceis sculpta* and *Dorvillea similis* were the most responsible for the detected dissimilarity. Diversity was explored through a species abundance Bray-Curtis similarity matrix followed by Hierarchical Cluster analysis and Multidimensional Scaling. Results showed the 40% of similarity among natural and anthropogenic substrates, and the 60% among the same substrates from different sampling sites. Findings from the present research confirmed the influence of substrates type and sampling site on macrozoobenthic assemblage composition and abundance. Considering the sensitivity of coastal lagoons to anthropogenic pressure, monitor the NIS spreading inside these ecosystems, and improve the knowledge base on their distribution and abundance, is essential to plan effective management actions to face and prevent potential negative impacts of biological invasion.

Otolith variability, age composition, and ontogenetic diet shift in *Trachurus trachurus* , Linnaeus, 1758, from the Southern Tyrrhenian Sea

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Overexploitation of marine resources poses a global threat to biodiversity and food security, with the Mediterranean Sea particularly affected due to intense fishing activity and multiple anthropogenic pressures. This study provides new insights into ontogenetic changes in diet and otolith morphology of *Trachurus trachurus*, a commercially important Mediterranean species. A total of 282 specimens were collected from the commercial fishery in the Gulf of Palermo (Southern Tyrrhenian Sea) for analyses of otolith morphometry, age structure, and diet composition. Otoliths were analysed using wavelet transformation methods, and age was determined by counting annual growth zones, each consisting of one translucent and one opaque ring. The diet composition was assessed through stomach content analysis. Wavelet analysis revealed clear differences in rostrum length, notch depth, and posterior dorsal margin, with six distinct morphotypes identified in the sample. Age composition was dominated by juveniles and intermediate-aged fish: 38.7% belonged to age group 1, 46.8% to age 2, 13% to age 3, and only 1.5% to ages 4–6. Dietary analysis revealed a total of 1,418 prey items from 33 taxa, with 254 stomachs containing food remains and 28 being empty. It was also examined the diet variability in relation to specimens age, revealing an ontogenetic dietary shift: : juveniles (ages 1-1+) primarily consumed small pelagic crustaceans, individuals aged 2- 2+ included more fish and decapods, and older fish (ages 3-6) specialised in larger crustaceans and fishes. These results demonstrate dietary specialization and trophic flexibility across age classes in response to resources availability. These findings highlight the importance of integrating morphological, age, and dietary data to better understand life history strategies and ecological dynamics in commercially exploited fish species.

Early-stage Medaka Embrioys (*Oryzias latipe*s) as an alternative model for evaluating the toxicity of of bromuconazole in vivo

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Bromuconazole (BRO) is a triazole class of chemical fungicides widely used worldwide since the 1970s. BRO is currently authorized as a Plant Protection Product (PPP) under Regulation EC 1107/2009, with approval renewed until 30/04/2027 in 14 EU Member States. Despite its ongoing utilisation, the substance has been designated as an EU candidate for substitution, as it fulfils the criteria of "Persistent-Bioaccumulative-Toxic" according to the EU Pesticide Database and EFSA evaluations, namely with respect to its persistence in the environment and its toxicity to aquatic organisms. Due to concerns about its ecotoxicity, BRO has been included in the 5th Watch List established under the EU Water Framework Directive (2000/60/EC), which identifies emerging pollutants that require further environmental monitoring. BRO's Predicted No-Effect Concentration (PNEC) for aquatic environments is 0.015 µg/L. Recent studies have shown that exposure to BRO may cause cardiotoxicity, oxidative stress, and lipid metabolism disorders in zebrafish (*Danio rerio*) larvae and adults. This finding raises further concerns about potential consequences of its use on aquatic organisms (Huang et al., 2024; Qin et al., 2022). Therefore, the current study aims to assess the effects of BRO on the development of medaka (*Oryzias latipes*) from early stage to 5 days post-fertilization (dpf). Medaka is particularly suitable for toxicity study due to the optical transparency of the eggs, rapid embryonic development, and the high sensitivity to environmental contaminants at early stages of its development. After determining the Lethal Concentration 50 (LC50) through acute toxicity tests, the embryos were exposed to various concentrations of BRO to assess potential effects on early development. The dose selection was based on environmentally relevant levels and available literature data. Morphological and functional endpoints such as survival, somite development, heartbeat, and overall embryonic morphology were evaluated. This approach represents a valuable tool for the early toxicological assessment of persistent fungicides such as Bromuconazole, providing the basis for future studies on their environmental impact and safety profiles. Furthermore, the use of medaka embryos up to 5 dpf allows for in vivo testing in compliance with the 3Rs principles and EU Directive 2010/63/EU.

Effects of environmental microplastics on soil microarthropods survival, behaviour biodiversity

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Microplastics (MP, min di 1 mm) are ubiquitous in terrestrial ecosystems. Their presence is associated with potential alterations in the physico-chemical characteristics of soil and with impacts on the behavior and survival of soil organisms. Nevertheless, to date, studies on the effects of MP have mostly been limited to model organisms, such as the collembolan *Folsomia candida*.

In this study, the effects of MP derived from the degradation of plastics present in urban environments were assessed on different species of soil microarthropods. MP were tested on three wild collembolan species (*Parisotoma notabilis*, *Onychiurus* sp., and *Ceratophysella denticulata*), on the model species *F. candida*, and on the oribatid mite *Scheloribates* sp. The wild species used were acclimated in the laboratory for 2 years before testing, achieving stable populations.

The MP tested originated from HDPE paving blocks commonly used in urban parking areas, which were fragmented in the laboratory to obtain the sub-millimetric fraction (10–832 µm) used in the tests. The effects of MP (at 1000 mg/kg) on microarthropod behavior were evaluated with ISO avoidance tests, while the effects on survival were assessed in *P. notabilis* and *F. candida* using OECD chronic exposure tests, exposing organisms to increasing concentrations of MP (from 10 mg/kg up to 1000 mg/kg). The standardized protocol for *F. candida* (28 days and 20 °C) was modified for the wild species *P. notabilis* based on its life cycle characteristics, extending the duration of the test to 35 days and setting the temperature at 17 °C.

The results show a clear trend of avoidance of MP-contaminated soil by all tested microarthropod species, with significant differences compared to the control groups. *F. candida* proved to be the least sensitive species to the presence of MP (avoidance of 34 ± 13%), while the highest values were recorded for the collembolan *Onychiurus* sp. and the mite *Scheloribates* sp., with avoidance rates of 53 ± 13% and 53 ± 19%, respectively.

In chronic exposure experiments (28–35 days), a significant decrease in collembolan survival was observed in response to MP exposure, with mortality rates at the highest concentration tested reaching 57.8 ± 13% in *F. candida* and 92.2 ± 4.4% in *P. notabilis*.

This study contributes to understanding and quantifying the effects that MP present in terrestrial environments have on both model microarthropod species and wild species endemic to the Italian territory.

Conservation insights from morphometric and demographic monitoring of *Patella ferruginea* in Northen Sardinan MAPS

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Patella ferruginea Gmelin, 1791 is an endemic limpet of the Mediterranean Sea and is currently considered the most endangered marine species. Its distribution has been drastically reduced by human collection for ornamental, food and bait purposes and is now largely restricted to protected or inaccessible coastal areas. In this context, long-term monitoring is essential to support effective conservation strategies. This study, to be conducted between 2024 and 2026, aims to assess the population density and structure of *P. ferruginea* in La Maddalena Archipelago National Park through a complete census of the smaller islands and representative transects on the main islands. All individuals were and measured using biometric parameters (length, width, height). Morphotypes (*rouxi* vs. *lamarcki*) were identified based on the ratio of shell height to shell length, and sex was determined based on the length of the shell.

During the first survey phase (summer–autumn 2024), a coastal section of 3,709 meters was surveyed, in which 205 individuals were recorded, corresponding to a linear density of approximately 0.055 individuals per meter. The *rouxi* morphotype was dominant with 175 individuals (85%). Statistical analyzes revealed significant differences in size metrics and sex ratios between sites. The population in La Maddalena had the highest proportion of females (78%) with 160 individuals, 35 males and 10 immature individuals. The data were compared with other data from previous surveys (2018) in two other MPAs in northern Sardinia: Asinara NP and Tavolara MPA. All sites showed a similar dominance of morphotypes. However, there were significant differences in biometric variables and sex composition. Specifically, the mean shell length in Tavolara was 49.6 ± 17.1 mm, lower than in Asinara (53 ± 17.8 mm) and La Maddalena (50.7 ± 14.7 mm). Tavolara also had the highest
proportion of males (27.4%), which probably affected the size differences, as males are generally smaller than females. The distribution of immature individuals was the same at all sites and did not appear to affect morphometric variability.

These results emphasise the importance of including morphometric and demographic data in conservation efforts. Continuous monitoring of *P. ferruginea* populations is crucial to identify local vulnerabilities and initiate management measures to conserve one of the most endangered endemic marine invertebrates of the Mediterranean.

From degradation to recovery: 30 years of illegal date mussel fishing impact on Apulian rocky shores

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This research evaluated the environmental consequences of the illegal harvesting of date mussels (*Lithophaga lithophaga*) along the Apulian coastline. The study primarily investigated the spatial distribution of habitat degradation, the formation of barren grounds, and the relationship with the population densities of sea urchins, specifically *Paracentrotus lividus* and *Arbacia lixula*. Between summer 2023 and winter 2024, a total of 42 locations were monitored, organized into six distinct sectors, covering an area of 59,196 m^2. The findings indicated a generally low impact of date mussel extraction, with a mean Damage Index (Dw) of 0.07, suggesting that recent disturbances are limited and localized. Nonetheless, sporadic instances of more recent damage were detected in both the Ionian and Adriatic Seas. The Rock Desertification Index (RDI) revealed the presence of barren grounds, particularly pronounced in the Ionian sector, where elevated sea urchin densities were recorded in the most severely affected areas. Statistical analysis demonstrated a strong association between sea urchin abundance and barren grounds, with larger individuals appearing to stabilize these degraded zones, while smaller specimens were linked to the freshly impacted areas from *L. lithophaga* exploitation. This study underlines the necessity of continuous monitoring and proactive conservation to safeguard biodiversity and the ecological balance of Mediterranean coastal environments. Additionally, it provides an updated cartographic representation of the current state of rocky coastal zones, forming a foundation for forthcoming ecological restoration initiatives.

Exploring neglected marine invertebrate fauna in Tunisian ports and marinas: NIS, rare taxa and first records.

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The introduction and spread of Non-Indigenous Species (NIS) are widely recognized as a primary global threat to native biodiversity, with variable consequences by regions and ecosystems. Maritime transport and global warming are key drivers of this process, primarily through vectors associated with international shipping. The Mediterranean Sea, hosting over 6% of all known marine species, is both a biodiversity hotspot and a major NIS introduction zone, particularly in ports and marinas. Owing to its central position in the Mediterranean basin and relatively warm waters, Tunisia represents a strategic region for NIS monitoring and dispersal dynamics, notably related either to Lessepsian species advancing westward from the eastern Levant Sea, and to taxa introduced through the Gibraltar Strait. However, comprehensive studies of NIS in Tunisian waters remain scarce, particularly for small invertebrate taxa, whose status is still poorly documented. To address this gap, eight Tunisian ports and marinas (Marina Bizerte, Sidi Bou Said, Port Yasmine Hammamet, Port el Kantaoui, Sousse port, Marina Cap Monastir, Sidi Mansour, Sfax port) were surveyed in April 2025. At each site, a standardized sample of four liters of fouling organisms was collected from artificial substrates, including concrete walls, floating pontoons, mooring lines, and buoys, using surface-operated scraping tools. Samples were sorted, organisms photographed alive, preserved in 80% ethanol, and identified via integrative taxonomic method. This survey yielded new records of NIS and rare native species within Heterobranchia (Mollusca: Gastropoda), Peracarida (Arthropoda: Crustacea), and Polychaeta (Annelida), increasing our knowledge on the marine invertebrate fauna of Tunisia, particularly on the marine invertebrate diversity and distribution patterns in port environments, paving the way for future biogeographic and comparative studies. Furthermore, filling gaps on NIS distribution across the Mediterranean is critical for achieving effective biodiversity management and conservation planning.

Antennal sensillar equipment in the Apoidea: morphology, diversity and proposition of a consistent terminology

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Insect sensilla are the structural units responsible for the perception of chemical, hygro-thermal and mechanical stimuli, and they are especially abundant in the antennae. A number of studies have reported that the *Antennal sensilla* play a critical role in kin recognition, detection of natural enemies, foraging activity and mating activity. Given the wide range of ecological diversity of insects, it is not surprising that differences in antennal sensory system were reported between species with different life-history traits and within species between sexes. In the Apoidea (Hymenoptera: Aculeata), a large group including bees and stinging wasps, the morphology and distribution of *A. sensilla* have been investigated in several species, though the level of detail is very variable and quantitative analyses are rare. Moreover, entire lineages have not yet been investigated. We present here new data from a Scanning Electron Microscopy (SEM) analysis of *A. sensilla* in 14 species of bees, spanning six of the seven known bee families (Andrenidae, Halictidae, Colletidae, Apidae, Megachilidae and Melittidae), including lineages that have been particularly underrepresented in previous studies. A total of six types of *Sensilla* are present in the studied bee species: *Sensilla trichoidea* (ST, with three subtypes), *S. basiconica* (SB), *S. placodea* (SP), *S. coeloconica* (CO), *S. ampullacea* (AM) and *S. campaniformia* (CA). All these sensillar types occurred in the studied species. However, there was considerable variation in their density, which can be partly explained by body size variation. Indeed, head width (a proxy for body size) positively affected both antennal length and density of several sensillar types. Some differences among species, however, seem to be unrelated with variation in body size and may be linked to differences in life-history traits such as pollen specialization. These findings provide a foundation for more detailed investigations into the ecological pressures that may have influenced the evolution of antennal sensillar equipment in the Apoidea. Furthermore, this work has also given us the opportunity to review the currently available information on the antennal sensilla of Apoidea with the aim to address issues, such as the lack of a standardised terminology for sensillar types, which is essential for future comparative studies.

The Italian wall lizard *Podarcis siculus* (Rafinesque-Schmaltz, 1810) as a bioindicator of environmental quality in three Calabrian sites with different degrees of anthropic disturbance.

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Podarcis siculus (Rafinesque-Schmaltz, 1810) is a synanthropic species widely distributed and often used as an environmental bioindicator. This study evaluated its role as a bioindicator of the ecotoxicological quality of environments placed under different degrees of anthropization, verifying both the effectiveness of indirect methods such as leukocyte count, and of minimally invasive methods, such as the use of the tail, to analyze the different environmental conditions and quantify the levels of trace elements. Two sites were identified in the municipality of Rende (CS, Calabria): the Industrial Zone (IZ) and the Botanical Garden of the University of Calabria (BO); a third control site was located in the municipality of Fagnano Castello (CS, Calabria). From 2022 to 2024, five samplings were carried out per site on a seasonal basis, allowing a total of 250 lizards to be captured. Sex, age, morphometric measurements (SVL, TL, weight), ectoparasite load were recorded for each individual, leukocytes (basophilic, heterophilic, eosinophilic) and haemoparasites were counted. At the same time, pectoral muscles and unregenerated tails were analyzed for 30 individuals (10 per population) to evaluate their concentration of trace elements by ICP-MS spectrometry. In the ZI, individuals are larger and have a higher leukocyte load than those in BO; in both sites, females show higher leukocyte values than males. Lizards in BO have greater ectoparasite diversity and haemoparasite abundance than in the ZI; no significant difference between parasite load and leukocyte and emerged response. Regarding bioaccumulation, there were no statistically significant differences between males and females, except for copper. For the three populations, however, it emerged that for As, Mn, Fe, Cu, Mo and Ba the differences were statistically significant; elements such as As and Mo increased with increasing anthropization. Thus, the tail can actually be used as a substitute for muscle, but only for some elements of all those evaluated and cited previously, such as As, Se, Sr, Mo and Ba. *Podarcis siculus* confirms itself as an effective bioindicator for all three types of analyses carried out, capable of highlighting differences in the state of health of environments placed under different pressures. Caudal sampling represents a valid alternative to more invasive analyses.

Out of sight, out of mind? A Sicilian case study on the distribution of less charismatic species

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Addressing the biodiversity crisis requires an accurate knowledge of species distribution and their conservation status. However, our current knowledge remains largely fragmented, hampered by several well-known "biodiversity shortfalls", including the Linnean and Wallacean ones. These knowledge gaps particularly affect the so-called neglected species, i.e., those species that are less charismatic and often excluded from research and conservation priorities, despite their diversity and potential ecological roles.
Sicily is a recognised biodiversity hotspot in the Mediterranean area with a high number of endemic species. In this context, we investigated the inland water copepod fauna in a small area of northwestern Sicily, i.e., the San Vito Peninsula, with the explicit aim of assessing species richness in a restricted sampling area, estimating expected species occurrence, and evaluating the sampling effort required for an exhaustive faunal survey.
Through extensive sampling over two years, we identified 18 taxa, i.e., approximately 42% of the freshwater copepod species known for the entire island, also finding one species previously unrecorded in Sicily. These results, obtained in such a geographically restricted area (about 165 km^2), highlight the outstanding biological diversity currently overlooked, and often hidden within seemingly "minor" areas and habitats. Moreover, species accumulation curves, analysed using different asymptotic species richness estimators based on occurrence data, pointed out that the real copepod species richness of the area is expected to be considerably higher than what currently observed, suggesting that many species may have gone undetected despite the intensive sampling effort we realised.
These findings highlight the need of extending scientific surveys dealing with neglected taxa and environments. In fact, small water bodies, often overlooked in conservation agendas, actually represent biodiversity hotspots that harbour rich, unique and often vulnerable faunal communities. Therefore, it is essential to allocate sufficient resources to the systematic study of these habitats in order to close existing knowledge gaps and strengthen conservation strategies from an inclusive perspective on biological diversity.

Effects of heavy metal contamination on *Hermetia illucens* (Diptera: Stratiomyidae) physiology and development

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The larvae of the black soldier fly (BSFL), *Hermetia illucens* (Diptera: Stratiomyidae), are widely used to reduce organic waste and produce a protein-rich insect biomass which has potential applications in various industrial fields. However, contaminated substrates may expose BSFL to numerous pollutants, including persistent xenobiotics as heavy metals (HMs), which can not only negatively affect larval development and health, but also accumulate in insect tissues and organs, raising concerns about their potential transfer into BSF-derived products.
To explore the effects of HMs on insect growth, physiology, and immunity, BSFL were reared on the organic fraction of municipal solid waste supplemented with two PbCl concentrations (15 and 1000 mg/kg of diet), and their development and survival rates were monitored over the time. Additionally, markers of the cellular (hemocyte count and phagocytosis) and humoral (antimicrobial and lysozyme activities) branches of the immune system were analyzed. Finally, lead accumulation in whole larvae, midgut epithelium, and rearing residue (the so-called frass) was measured at the end of the bioconversion process.
The results revealed a concentration-dependent accumulation of lead in the larval tissue. The exposure to the highest PbCl concentration caused reduced weight and higher mortality rates, indicating the strong toxic effects of lead on BSFL. Moreover, the activation of both cellular and humoral immune responses was observed, highlighting negative impacts of heavy metal exposure on larval health.
This research offers valuable insights into how BSFL react to HMs contamination, reinforcing the evidence of lead's toxicity on this insect, and emphasizing the importance of thoroughly assessing the safety of using BSFL for the bioconversion of contaminated-substrate bioconversion for industrial applications.

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