XXII CONGRESSO NAZIONALE DELLA SOCIETÀ ITALIANA DI ECOLOGIA

Sostenibilità ecologica : scienza, scenari e partecipazione

2023

Patrocinato da:

Università di Catania

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FAI SICILIA

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Consorzio Nazionale Interuniversitario per le Scienze del Mare

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MINISTERO DELL'AMBIENTE E DELLA SICUREZZA ENERGETICA

Comune di Catania

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Università di Catania

2023 XXII CONGRESSO NAZIONALE DELLA SOCIETÀ ITALIANA DI ECOLOGIA

S.It.E. - Società Italiana di Ecologia

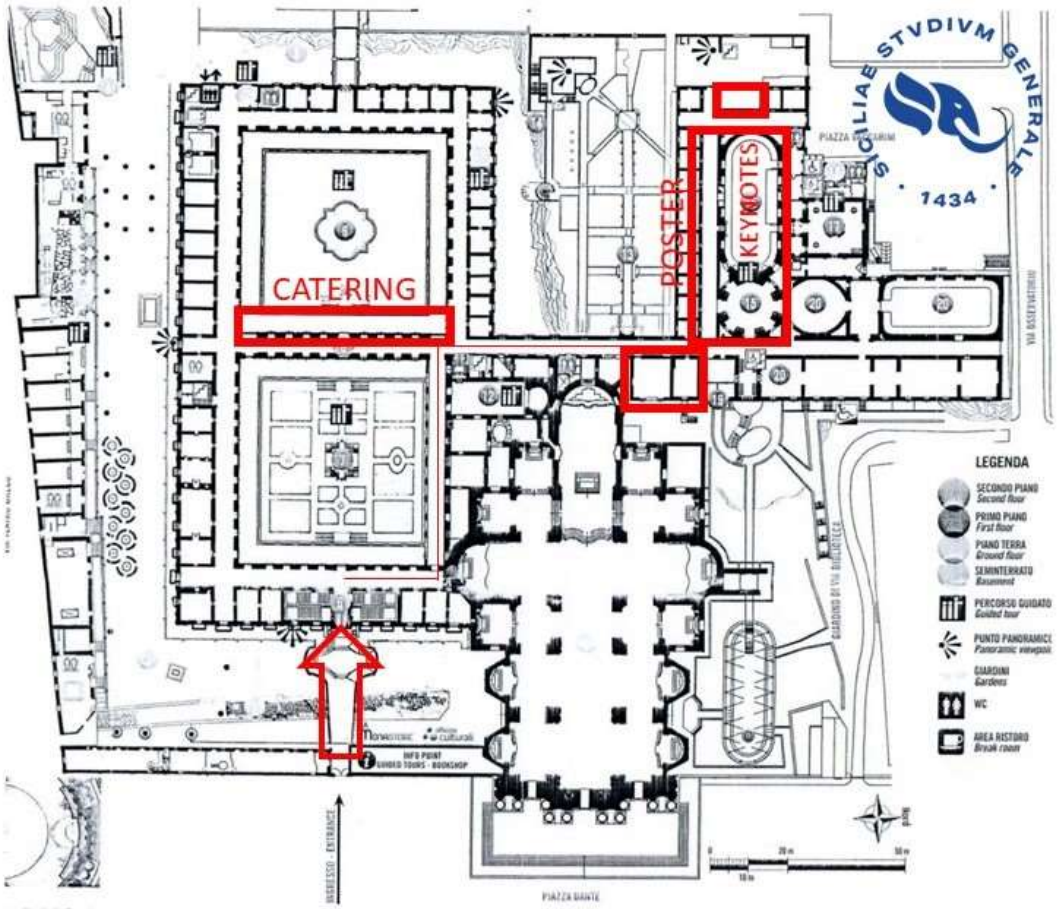
PROGRAMMA

Siate i benvenuti al XXXII Congresso Annuale della Società Italiana di Ecologia all'Università di Catania

Il clima sta sempre più rapidamente cambiando e la Sicilia, non a caso sede del XXXII Congresso della Società Italiana di Ecologia, è la regione italiana con il maggior numero di eventi estremi. Le ripercussioni ecologiche del surriscaldamento globale, della tropicalizzazione e della desertificazione si rispecchiano in drastiche variazioni della biodiversità, anche a livello funzionale, ed in alterazioni della struttura degli ecosistemi su scala planetaria.

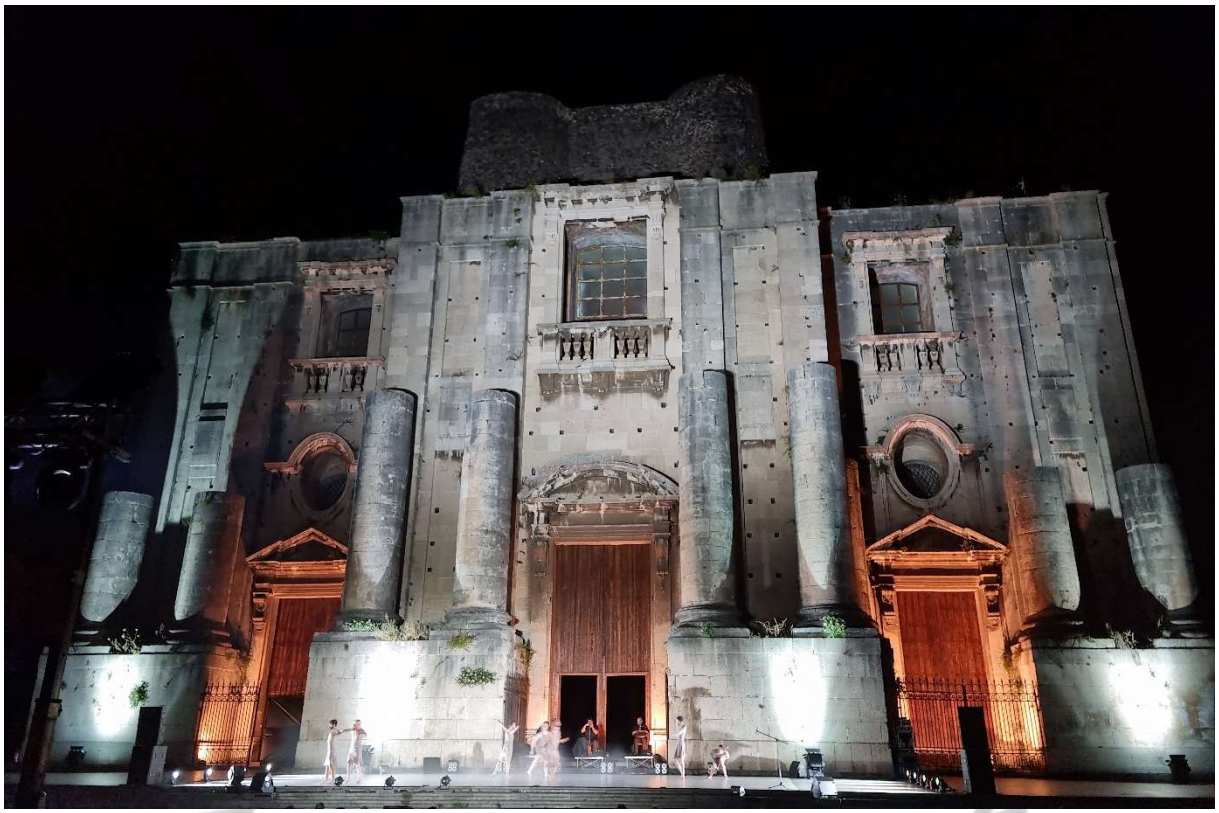
L'Unione Europea si è posta come obiettivo di aumentare significativamente la superficie delle aree comunitarie sottoposta a vincoli di conservazione entro il 2030. Pertanto, porre come focus del XXXII Congresso della S.It.E. le molteplici declinazioni della sostenibilità ecologica, con tutto ciò che ne consegue, dalle trasformazioni in ambienti estremi alle variazioni delle comunità, fino alle conseguenze socioeconomiche di tali cambiamenti, appare una scelta quanto mai attuale anche in risposta alle più recenti politiche europee e nazionali in tema di tutela del capitale naturale secondo approcci basati sugli ecosistemi.

Con la tematica "***Sostenibilità ecologica: scienza, scenari e partecipazione***", il Congresso a Catania si prefigge di alimentare in modo trasversale una discussione interdisciplinare sulle prospettive future, sulla tutela del nostro capitale naturale in mare e su terra, sulla salvaguardia di ecosistemi a rischio e sul recupero di quelli degradati.



Sessioni del XXXII Congresso Annuale della Società Italiana di Ecologia

1- Capitale naturale – servizi ecosistemici – contabilità ambientale
(Chairs: P.P. Franzese, F. Manes)
2- Ecologia del paesaggio e consumo di suolo
(Chairs: I. Petrosillo, M.L. Carranza, E. Padoa-Schioppa)
3- Educazione ambientale per la riconnessione con la Natura
(Chairs: G. Barbiero, M. Drius)
4- Stress singoli e multipli su ecosistemi acquatici e terrestri a diverse scale di indagine
(Chairs: A.P. Binelli, C. Mulder, F.A. Rutigliano)
5- Effetti del restauro ecologico sul funzionamento degli ecosistemi
(Chairs: G. Sarà, A. Pusceddu)
6- Reti trofiche ed ecologia di comunità
(Chairs: E. Calizza, G. Signa)
7- Ecosistemi montani e cambiamenti globali
(Chairs: A. Provenzale, M. Parolini)
8- Ambienti estremi
(Chairs: C. Gugliandolo, A. Lo Giudice)



6 Settembre 2023

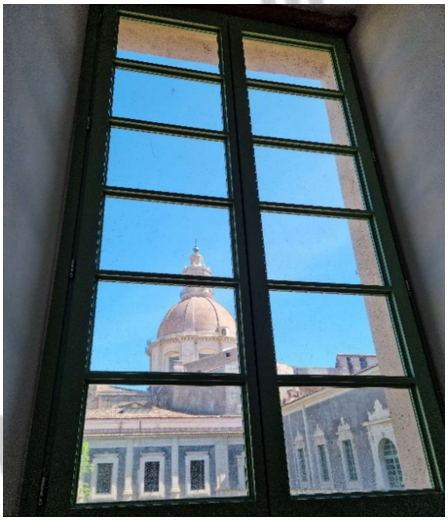
Cerimonia di apertura, Sessioni 2 (“Ecologia del paesaggio”), 4 (“Stress”, prima parte) e 8 (“Ambienti estremi”), visite

PRIMA GIORNATA : 6 SETTEMBRE 2023

	Corridoio dell'Orologio	Aula Magna Mazzarino	Aula 252	Aula 254	Chiostro di Ponente	Officine Culturali
11:00-11:30	SALA OTTA-					
11:30-12:00	GONALE :					
12:00-12:30	REGISTRA-					
12:30-13:00	ZIONE					
13:00-13:30					BUFFET DI	
13:30-14:00					BENVENUTO	
14:00-14:30		APERTURA				
14:30-15:00		E KEYNOTE				
15:00-15:30	**Esposizione**					
15:30-16:00	**poster**					
16:00-16:30	Sessione 2,	SESSIONE 4	SESSIONE 8	SESSIONE 2		
16:30-17:00	Sessione 4					
17:00-17:30	(A - F),					Visite guidate
17:30-18:00	Sessione 8					ai sotterranei
18:00-18:30		KEYNOTE				in gruppi di
18:30-19:00						25 persone
19:00-19:30					RINFRESCO	max
19:30-20:00						

PRIMA GIORNATA : COMUNICAZIONI DEL 6 SETTEMBRE 2023

	Aula Magna Mazzarino	Aula 252	Aula 254
14:00-14:15	**APERTURA DEL XXXII CONGRESSO S.It.E. (Prof. Pusceddu) E PREMI BRUSAROSCO E MORONI**		
14:15-14:30	**SALUTI DAL COMITATO ORGANIZZATORE (Prof. Mulder) E DEL RETTORE (Prof. Priolo)**		
14:30-15:00	**KEYNOTE SPEAKER: Prof. Michael Bonkowski**		
	SESSIONE 4	**SESSIONE 8**	**SESSIONE 2**
15:00-15:15	Accardo	Bolinesi	Baldi
15:15-15:30	Bellino	Fontaneto	Biella
15:30-15:45	Bises	Moretti	Bordoni
15:45-16:00	Campani	Nicolosi	Canedoli
16:00-16:15	Colletti	Papale	Fattorini
16:15-16:30	Coccia	Parolini	Rota
16:30-16:45	De Felice	Rizzo	Valente
16:45-17:00	Doretto	Zammuto	*DISCUSSIONE*
17:00-17:15	Dos Santos Barbosa Ortega	POSTER	
17:15-17:30	Farina		
17:30-17:45	Ferretti		
17:45-18:00	*DISCUSSIONE*		
18:00-18:30	**KEYNOTE SPEAKER: Prof. Kirk Winemiller (online)**		



7 Settembre 2023

Sessioni 1 (“Capitale naturale”), 4 (“Stress”, seconda parte) e 5 (“Effetti del restauro”); assemblea dei soci e cena sociale

SECONDA GIORNATA : 7 SETTEMBRE 2023

	Corridoio dell'Orologio	Aula Magna Mazzarino	Aula 252	Aula 254	Chiostro di Ponente	Aula Magna Rettorato	Palazzo Manganelli
9:00-9:30	REGISTRA-ZIONE	KEYNOTE					
9:30-10:00		SESSIONE 4					
10:00-10:30							
10:30-11:00	**Esposizione poster** Sessione 1, Sessione 4 (G - Z), Sessione 5						
11:00-11:30					CAFFÈ		
11:30-12:00		SESSIONE 4	SESSIONE 5	SESSIONE 1			
12:00-12:30							
12:30-13:00					PRANZO		
13:00-13:30							
13:30-14:00		SESSIONE 4	SESSIONE 5	SESSIONE 1			
14:00-14:30							
14:30-15:00							
15:00-15:30					CAFFÈ		
15:30-16:00		SESSIONE 4	SESSIONE 5	SESSIONE 1			
16:00-16:30							
16:30-17:00							
17:00-17:30							
17:30-18:00		KEYNOTE					
18:00-18:30							
18:30-19:00						RIUNIONE ANNUALE DEI SOCI	
19:00-19:30							
19:30-20:00							
20:00-20:30							CENA SOCIALE
20:30-21:00							
21:00-21:30							
21:00-22:00							

SECONDA GIORNATA : COMUNICAZIONI 7 SETTEMBRE 2023

	Aula Magna Mazzarino	Aula 252	Aula 254
9:00-9:30	**KEYNOTE SPEAKER: Prof. Riccardo Valentini**		
	SESSIONE 4 (cont.)		
9:30-9:45	Gambino		
9:45-10:00	Gobbato		
10:00-10:15	Gregorietti		
10:15-10:30	Lanzoni		
10:30-10:45	Madaschi	POSTER	
10:45-11:00	Magni		
11:00-11:15	PAUSA CAFFÈ		
11:15-11:30		**SESSIONE 5**	**SESSIONE 1**
11:30-11:45	Marchessaux	Abyaba	Babí Almenar
11:45-12:00	Marfella	Bianchelli	Castaldi
12:00-12:15	Marzaioli	Bosch Belmar	Cerri
12:15-12:30	Memoli	Cimini	Di Santo
12:30-12:45	Mirone	Costantini	
12:45-13:00	Montalbetti		
13:00-13:15	PAUSA PRANZO		
13:15-13:30			

SECONDA GIORNATA : COMUNICAZIONI 7 SETTEMBRE 2023

	Aula Magna Mazzarino	Aula 252	Aula 254
13:30-13:45	Nava	Falace	Gaglio
13:45-14:00	Nigro	La Marca	Grande
14:00-14:15	Panico	Mancuso	Nardella
14:15-14:30	Pansini	Marcelli	Picariello
14:30-14:45	Panti	Melià	
14:45-15:00	Papini	Paoli	
15:00-15:15	PAUSA CAFFÈ		
15:15-15:30			
15:30-15:45	Provera	Puccini	Rigo
15:45-16:00	Pulina	Pusceddu	Rova
16:00-16:15	Santorufo	Ruggeri	Stocco
16:15-16:30	Satta	Sarà	Vicari
16:30-16:45	Sbarberi	Stipcich	*DISCUSSIONE*
16:45-17:00	Schiavo	Vitale	
17:00-17:15	Terzaghi	*DISCUSSIONE*	
17:15-17:30	*DISCUSSIONE*		
17:30-18:00	**KEYNOTE SPEAKER: Prof. Hans Joosten**		

S.It.E. - Società Italiana di Ecologia

8 Settembre 2023

Sessioni 3 (“Educazione ambientale”), 6 (“Comunità”) e 7 (“Ecologia montana”), chiusura del Congresso e visita all’Orto

TERZA GIORNATA : 8 SETTEMBRE 2023

	Corridoio dell'Orologio	Aula Magna Mazzarino	Aula 252	Aula 254	Chiostro di Ponente	Orto Botanico
9:00-9:30	REGISTRA-ZIONE	KEYNOTE				
9:30-10:00		SESSIONE 6	SESSIONE 7	SESSIONE 3		
10:00-10:30						
10:30-11:00	**Esposizione poster** Sessione 3, Sessione 6, Sessione 7					
11:00-11:30					CAFFÈ	
11:30-12:00		SESSIONE 6		SESSIONE 3		
12:00-12:30						
12:30-13:00					PRANZO	
13:00-13:30						
13:30-14:00		SESSIONE 6				
14:00-14:30						
14:30-15:00						
15:00-15:30						
15:30-16:00					CAFFÈ	
16:00-16:30		KEYNOTE				
16:30-17:00		CERIMONIA CONCLUSIVA				
17:00-17:30						
17:30-18:00						
18:00-18:30						Visita guidata all'Orto Botanico
18:30-19:00						
19:00-19:30						

TERZA GIORNATA : COMUNICAZIONI 8 SETTEMBRE 2023

	Aula Magna Mazzarino	Aula 252	Aula 254
8:30-9:00	**KEYNOTE SPEAKER: Prof. Marco Abbiati (online)**		
	SESSIONE 6	**SESSIONE 7**	**SESSIONE 3**
9:00-9:15	Andolina	Bertoli	Barbiero
9:15-9:30	Appolloni	Bertolino	Compagnone
9:30-9:45	Bardelli	Di Blasio	De Leonardis
9:45-10:00	Basset	Elia	Drius
10:00-10:15	Bonato Asato	Magnani	Leonardi
10:15-10:30	Calizza	Marta	Marchini
10:30-10:45	Careddu	Pastorino	Padoa-Schioppa
10:45-11:00	Cariccia	Schiavon	Ricci
11:00-11:15	Casabianca	Stucchi	
11:15-11:30		PAUSA CAFFÈ	
11:30-11:45	Coppola		
11:45-12:00	Fanini		Provenzale
12:00-12:15	Giacobbe		TEST
12:15-12:30	Gjoni		INTERATTIVO
12:30-12:45	Iannucci		(Stocco & Pinna)
12:45-13:00	Mancinelli		
13:00-13:15		PAUSA PRANZO	
13:15-13:30			

TERZA GIORNATA : COMUNICAZIONI 8 SETTEMBRE 2023

	Aula Magna Mazzarino	Aula 252	Aula 254
13:30-13:45	Mikac	POSTER	
13:45-14:00	Piano		
14:00-14:15	Pinna		
14:15-14:30	Piquet		
14:30-14:45	Rakaj		
14:45-15:00	Rasino		
15:00-15:15	Rizzo		
15:15-15:30	Shokri		
15:30-15:45	Signa	PAUSA CAFFÈ	
15:45-16:00			
16:00-16:30	**KEYNOTE SPEAKER: Prof. Stuart Pimm (online)**		
16:30-17:30	**SALUTO DEL MINISTRO SEN. NELLO MUSUMECI, CERIMONIA CONCLUSIVA, ASSEGNAZIONE DEI PREMI E SALUTI**		

Percorso a piedi verso l'Orto Botanico

Visita dalle 17:45 alle 19:15 all'Orto Botanico dell'Università di Catania, via Etnea 397

Comitato Scientifico

Antonio Pusceddu (Presidente), Flora Angela Rutigliano (Vice-Presidente), Christian Mulder, Elisa Anna Fano (Presidente uscente), Andrea Binelli, Edoardo Calizza, Pier Paolo Franzese, Danilo Russo, Gianluca Sarà, Salvatrice Vizzini, Maria Cristina Mangano

Comitato Organizzatore

Christian Mulder (Presidente), Erminia Conti, Concetta Gugliandolo, Salvatrice Vizzini

Segreteria Organizzativa

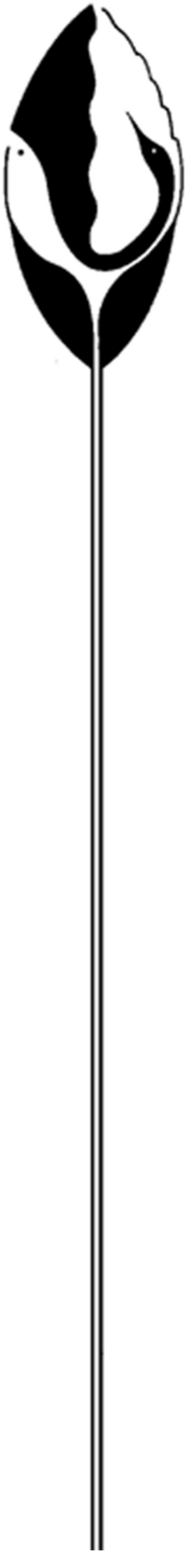
Fabio Viglianisi (Supervisore), Venerando Gambuzza, Diego Leone, Sonia Migneco, Giulia Miraglia, Ludovica Panfili, Francesco Tiralongo, Carla Tumino

Un ringraziamento particolare va ad EXEDRA per il supporto amministrativo ed all'Ateneo di Catania per la messa a disposizione dei locali tardobarocchi ed al loro supporto logistico.

S.It.E. - Società Italiana di Ecologia

Sitografia

Fotografie e grafica di Christian Mulder. Il logo del XXXII Congresso della Società Italiana di Ecologia è costruito in stile futurista attorno ad una incisione di Maurits Cornelis Escher (1898-1972) rappresentante Catania e l'Etna nel novembre 1936 (opus #289, modificata con il permesso della Fondazione Escher). *All M.C. Escher works © M.C. Escher Company B.V. - Baarn, Netherlands.*



INDICE

TUTTE LE COMUNICAZIONI ORALI SONO NUMERATE CONSECUTIVAMENTE, SEGUITE DAI POSTER, FACENDO RIFERIMENTO ALLE SEZIONI DI AFFERENZA

INDICE

SESSIONE 1

4. Di Santo
5. Gaglio
6. Grande
7. Nardella
8. Picariello
9. Rigo
10. Rova
11. Stocco
12. Vicari

POSTER

13. Capasso
14. Castaldi
15. Febbi
16. Figurati
17. Grande
18. Guarino
19. Monteleone
20. Rizzo
21. Silva
22. Sokolova
23. Summa
24. Tamisari

SESSIONE 2

2- Ecologia del paesaggio e consumo di suolo
(Chairs: I. Petrosillo, M.L. Carranza, E. Padoa-Schioppa)

ORALI

25. Baldi

26. Biella
27. Bordoni
28. Canedoli
29. Fattorini
30. Rota
31. Valente

POSTER

32. Carranza
33. De Francesco
34. Fattorini
35. Napolitano

SESSIONE 3

3- Educazione ambientale per la riconnessione con la Natura
(Chairs: G. Barbiero, M. Drius)

ORALI

36. Barbiero
37. Compagnone
38. De Leonardis
39. Drius
40. Leonardi
41. Marchini
42. Padoa-Schioppa
43. Provenzale
44. Ricci

POSTER

45. Costantini

46. Leonardi
47. Pinna S
48. Stocco

SESSIONE 4

4- Stress singoli e multipli su ecosistemi acquatici e terrestri a diverse scale di indagine
(Chairs: A.P. Binelli, C. Mulder, F.A. Rutigliano)

ORALI

49. Accardo
50. Bellino
51. Bises
52. Campani
53. Colletti
54. Coccia
55. De Felice
56. Doretto
57. Farina
58. Ferretti
59. Gambino
60. Gobbato
61. Gregorietti
62. Lanzoni
63. Madaschi
64. Magni
65. Marchessaux
66. Marfella
67. Marzaioli
68. Memoli
69. Mirone

70. Montalbetti
71. Nava
72. Nigro
73. Ortega
74. Panico
75. Pansini
76. Panti
77. Papini
78. Provera
79. Pulina
80. Santorufo
81. Satta
82. Sbarberi
83. Schiavo
84. Terzaghi

POSTER

85. Battiata
86. Bacchet
87. Baldantoni
88. Bonamano
89. Bosch Belmar
90. Calisi
91. Campani
92. Caorsi
93. Cilluffo
94. De Felice
95. De Marco
96. Descourvières
97. Dondero
98. Esposito
99. Fossati
100. Gallitelli
101. Gambuzza
102. Giacoletti
103. Gualandris
104. Ignoto
105. Isa
106. Mancinelli
107. Marsiglia
108. Nardi
109. Pinna
110. Pittalis
111. Rotondo

112. Santini
113. Scozzafava
114. Secco
115. Signorini
116. Tagliabue
117. Taurozzi
118. Tantillo

SESSIONE 5

5- Effetti del restauro ecologico sul funzionamento degli ecosistemi
(Chairs: G. Sarà, A. Pusceddu)

ORALI

119. Abyaba
120. Bianchelli
121. Bosch Belmar
122. Cimini
123. Costantini
124. Falace
125. La Marca
126. Mancuso
127. Marcelli
128. Melià
129. Paoli
130. Puccini
131. Pusceddu
132. Ruggeri
133. Sarà
134. Stipcich
135. Vitale

POSTER

136. Bianchelli
137. Bruno
138. LaManna
139. Musumeci
140. Vincenzi
141. Vitale

SESSIONE 6

6- Reti trofiche ed ecologia di comunità
(Chairs: E. Calizza, G. Signa)

ORALI

142. Andolina
143. Appolloni
144. Bardelli
145. Basset
146. Bonato Asato
147. Calizza
148. Careddu
149. Cariccia
150. Casabianca
151. Coppola
152. Fanini
153. Giacobbe
154. Gjoni
155. Iannucci
156. Mancinelli

157. Mikac
158. Piano
159. Pinna
160. Piquet
161. Rakaj
162. Rasino
163. Rizzo
164. Shokri
165. Signa

POSTER

166. Bevacqua
167. Gjoni
168. Penna
169. Piazzolla
170. Rasino
171. Spagnuolo
172. Sporta Caputi
173. Stipa

SESSIONE 7

7- Ecosistemi montani e cambiamenti globali
(Chairs: A. Provenzale, M. Parolini)

ORALI

174. Bertoli
175. Bertolino
176. Di Blasio
177. Elia
178. Magnani

179. Marta
180. Pastorino
181. Schiavon
182. Stucchi

POSTER

183. Gaglio
184. Innangi
185. Panico
186. Pastorino
187. Richiardi

SESSIONE 8

8- Ambienti estremi
(Chairs: C. Gugliandolo, A. Lo Giudice)

ORALI

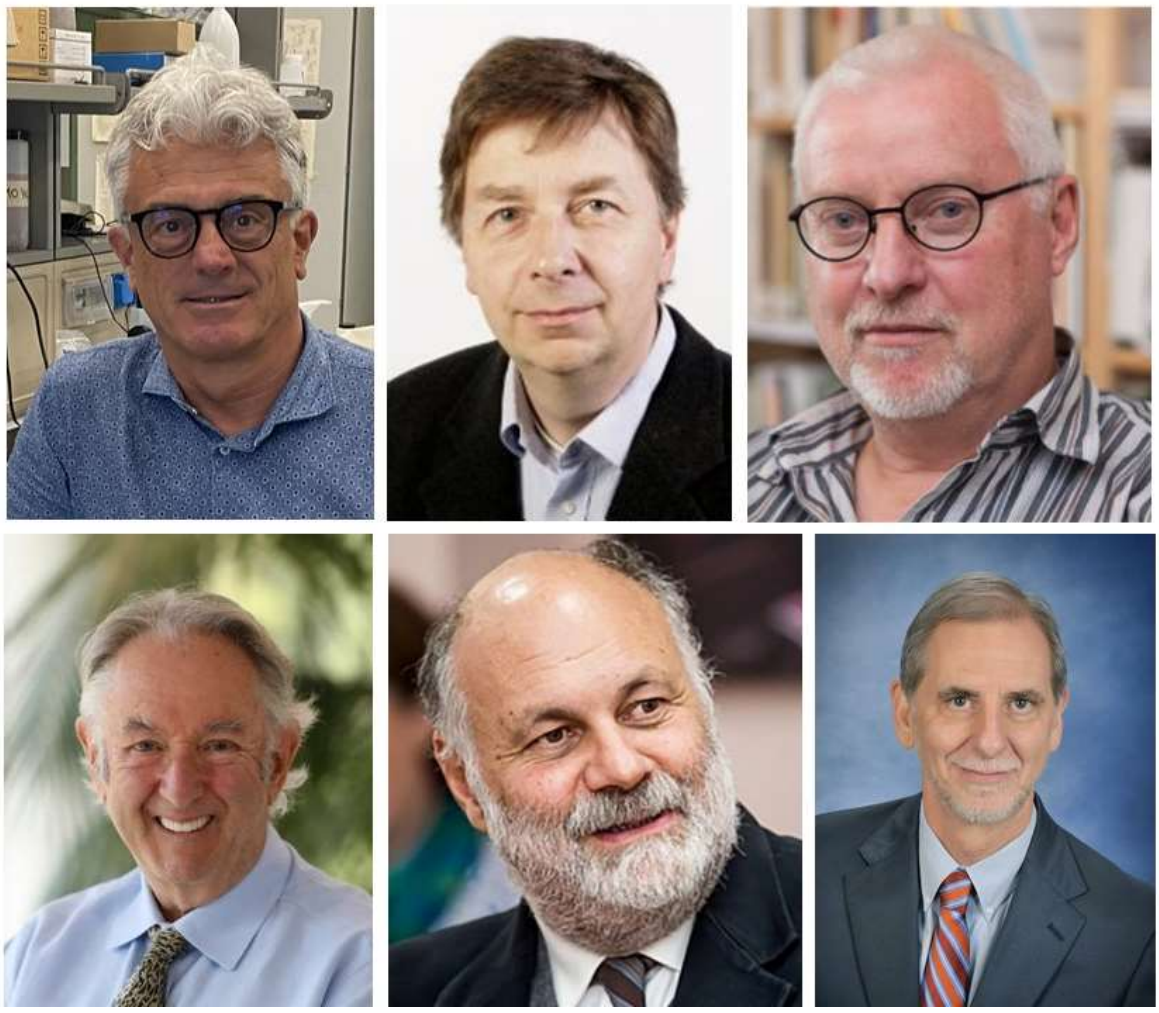
188. Bolinesi
189. Fontaneto
190. Moretti
191. Nicolosi
192. Papale
193. Parolini
194. Rizzo
195. Zammuto

POSTER

196. Agostino
197. Dias

198. Fabiano
199. Lena
200. Lo Giudice
201. Macrì
202. Nicolosi
203. Papale
204. Piano
205. Pusceddu
206. Rizzo
207. Soldano

KEYNOTE SPEAKERS



Marco Abbiati, Michael Bonkowski, Hans Joosten, Stuart Pimm, Riccardo Valentini, Kirk Winemiller

Towards a coherent urban ecosystem accounting framework compliant with SEEA-EA.

Babí Almenar, J.[1], Casagrandi, R. [1]

[1]*Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano, 20133, Milano, Italia*

** e-mail: javier.babialmenar@polimi.it*

The adoption of the UN Statistical Standard for Ecosystem Accounting (SEEA-EA) has reignited interest in developing a coherent natural capital framework for urban environments among scholars and policymakers. As the EU Nature Restoration Law indicates, it is urgent to transition towards a pathway of continuous, long-term, and sustained recovery of biodiversity. To elaborate a system of standardised ecosystem accounts would help (i) monitoring continuously the state of natural and anthropogenic ecosystems, and (ii) tracking progress of ecosystem restoration targets. However, scholars have realised that SEEA-EA still does not offer a rigorous ecological conceptualisation for urban ecosystems and that the lack of a fit to purpose operational framework might hamper its practical implementation in EU cities. Here, we review current ecosystem accounting theory and practice with the aim of highlighting critical conceptual and operational challenges of SEEA-EA for urban ecosystem accounting. For some challenges, potential solutions are also discussed. We explored core grey and white literature on SEEA-EA and conducted our review using both traditional systematic and a cutting-edge review tool, which prevented overlooking relevant references not making use of SEEA-EA terminology. To complement, and double-check findings, insights from experts on challenges and potential solutions were also gathered. Our results highlight a greater number of conceptual challenges in extent and condition accounts. Among those, it emerges a lack of consensus on where and how to delineate the boundaries of urban ecosystems. Moreover, the definition of sub-functional groups of urban ecosystems reveals to be still in its infancy. We also identified challenges shared with other ecosystems (like wetlands or agroecosystems), thus making our findings relevant beyond urban accounting. By visibilizing challenges and discussing feasible solutions from an ecology lens, we expect to help building the basis of a coherent and ecologically robust system of SEEA-EA urban ecosystem accounts in EU.

Adaptive strategies of land management to recover ecosystem services and valorize natural capital in Mediterranean areas under desertification risk

Castaldi S.[1*], Grilli E.[1], D'Ascoli R.1, Ishaq H.M.1, Marzaioli R.[1], Mastrocicco M.[1], Rutigliano F.A.[1], Bijl M.[2], Pulido Diaz F.J.[3], Silva F.[4], Machados C.[5], Roxo M.[5]

[1]DISTABIF, University of Campania "Luigi Vanvitelli", Caserta, Italy
[2] FSG - Forestry Service Group, Netherlands
[3]University of Extremadura, Plasencia, Spain
[4] Associação de Defesa do Património de Mértola, Portugal
[5] NOVA University of Lisbon – School of Social Sciences and Humanities

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Climate change and unsustainable land management have led to land degradation and desertification risk in many areas of the Mediterranean basin. In these areas urgent restoration and adaptation measures are required to allow productive system to recover ecosystem services functional to ecosystem health, productivity and resilience to the progressively increasing climate stress. The project LIFE16 CCA/IT/000011 Desert Adapt tested in 9 sites adaptive models of land management base on multi-functional scapes, natured based solutions and adaptation measures. The potential benefits in terms of environmental and economic indicators were evaluated. We present the cost/benefit balance of the proposed choices, and we show the measured amelioration of environmental indicators over 5 years of sustainable land management in case studies.

Mangroves of the Maldives: undervalued and unexplored ecosystems

Cerri F. [1,2*], Louis L.[1,2], Fallati L.[1,2], Siena F.[1,2], Nicolai R.[3], Madaschi A.[1], Gobbato J.[1,2], Bises C.[1], Montalbetti E.[1,2], Galli P.[1,2]

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Mangroves are, on a biological and ecological point of view, one of the most important ecosystems in the world, supporting various terrestrial, estuarine, and marine species. They provide them crucial habitat and food, but also provide several ecosystem services, including fisheries enhancement, coastal protection, carbon storage and sequestration. However, in the Maldives, even though their role is even more important, knowledge about their distribution and biodiversity is scarce and their importance is still underestimated. The aim of our project is to conduct the first-ever survey of all mangroves in the Maldives to enhance and increase the understanding of its unique ecosystems in order to take more action to preserve them from human impact and help research teams plan mangrove-related activities in the archipelago. As a first step, we reviewed all the information about mangroves in the Maldives and found 11 true and 4 controversial mangrove species, unevenly distributed from north to south on 109 islands (9% of all islands) with various fauna and flora species associated. The next step was a preliminary exploration of the Maldives. We visited several islands, particularly those in the Gnaviyani and Addu Atolls, finding 2 islands with previously unreported mangroves. In addition, we noted the presence of the four macro-types of mangroves, i.e. fringing, lacustrine-based, banked and swamp-based, with different sub-types and instances of different types even within a single island. In relation to biodiversity, seven mangrove species and several crab and fish species were visually identified with distribution influenced according to the mangrove type. Future prospects will be the nationwide assessment of the mangrove species' composition and distribution and related fauna and flora with the help of molecular analyses, aerial mapping of areas, and the assessment of the temperature, pH, and salinity of these environments, with the fund of National Biodiversity Future Center.

Hydrochar treatment to recover soil functions linked to ecosystem services

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Soil is an important component of natural capital providing essential ecosystem services, as food supply, regulation of climate, water and nutrient cycling. Agriculture, which occupies about 33 % of Earth land surface, could have moderate to severe impacts on soil properties. Sustainable agricultural practices recovering soil exhaustion are advisable; among these, the use of organic fertilizers (as biochar, hydrochar) deriving from treatment of selected biosolids, which favour carbon sequestration in soil. To apply these fertilizers over a large scale, it is necessary to rule out any negative effects on the biotic community.
Within the interdisciplinary project "CHIMERA", this study evaluated the effect of hydrochar on soil microbial community and soil chemical properties. A greenhouse experiment was set up in pots (d=21 cm, h=16 cm) each containing 1 kg of soil. Two hydrochar types obtained by hydrothermal carbonization from two feedstock types (*Cynara cardunculus* L. residues, HC, and sewage sludge, HF, respectively) were added to the soil in two doses (3 kg m^{-2} and 6 kg m^{-2}) for a total of 5 treatments: four with hydrochar and a control without hydrochar. Experimental design included five replicates for each treatment and exposure time (18 and 92 days). After treatments, soil was sampled and analyzed for several microbial and chemical properties.
Results showed no toxic effect on soil microbial biomass and activity and genetic bacterial diversity and generally an improvement of pH, total and mineralizable organic carbon content and soil respiration. The best results were observed in the highest doses of HF and HC, the latter also showing the greatest bacterial diversity. However, the potential application of hydrochar as soil amendment requires further studies to ascertain whether the positive effects persist over the long term, whether they can also be observed for other feedstocks, and what the effects are on plants.

Applying the SEEA-EA framework in the River Po delta: an example in an exploited brackish lagoon

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The United Nations Statistical Commission recently adopted the System of Environmental-Economic Accounting - Ecosystem Accounting (SEEA EA) as global standard for the evaluation of ecosystem services. The framework encompasses the assessment of ecosystem extents and conditions, the biophysical and monetary evaluation of ecosystem services and the ecosystem asset account and related changes over time. While the SEE-EA was designed to be applied mainly at national of regional extent, investigations at ecosystem level are required to provide needed information for upscaling analyses. This issue is particularly pressing in the case of transitional environments, such as the case of the river Po delta, where ecosystems have peculiar characteristics that require specific investigations and knowledge of ecological functioning.

The study aims to apply the SEEA EA framework to the Sacca di Goro lagoon, a coastal brackish lagoon intensively exploited for clam aquaculture, selected as ideal case for the river Po delta. The lagoon experienced salinity increase during the last decades, as a result of sea water intake to support clam production, thus leading to the deterioration of environmental conditions in the eastern area of the lagoon. Recently, water gates between the Po river and the lagoon have been opened permanently with the aim of increasing the freshwater inflow and favoring ecological restoration.

The results underline a moderate amelioration of the ecosystem conditions after the intake of freshwater from the Po river, which are expected to slight increase the provision of ecosystem services in the area. Ecological restoration of exploited transitional systems may be difficult and slow but leading to multiple benefits for human well-being. The study demonstrates that the SEEA EA framework can be successfully applied also at ecosystem scale and that such investigations constitute a necessary ground for environmental accounting at wider extent.

Applying the System of Environmental Economic Accounting-Ecosystem Accounting (SEEA-EA) Framework to Forest Ecosystems

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The contemporary era is facing several global environmental challenges that raise growing concerns about the sustainability of human societies. These challenges are largely attributed to human activities which have led to the deterioration of natural systems, undermining human health and well-being. It is widely recognized that ecosystems and human well-being are strongly interconnected. Indeed, ecosystems play a vital role in supporting human society by providing a wide range of Ecosystem Services (ES). Conserving and monitoring natural ecosystems is an urgent need to ensure the long-term provision of ES and human well-being. Several approaches and methodologies have been developed over time to assess and value ES, leading to the establishment of the System of Environmental Economic Accounting-Ecosystem Accounting (SEEA-EA) as a standardized statistical framework. The SEEA-EA provides an integrated spatially explicit approach organizing biophysical data, measuring ecosystem services, tracking changes in ecosystem extent and condition, thus highlighting links between natural ecosystems and human economy. In this study, we implement the SEEA-EA framework in the context of the Tuchola UNESCO-MAB Biosphere Reserve (Poland). In particular, we focused on two key aspects: 1) assessing the extent and condition of the Biosphere Reserve tracking changes in ecosystem types, 2) assessing ES provided by the Biosphere Reserve in biophysical and monetary terms. The assessment primarily focused on the forests which are the predominant ecosystems within the Biosphere Reserve. In addition, the evaluation mainly focused on regulating ES to better highlight the ecological value of the Biosphere Reserve. To our knowledge, this is the first study implementing the SEEA-EA framework within the context of a UNESCO-MAB Biosphere Reserve.

Nature-Based Solutions and the multifunctional role of Ecosystem Services

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Ongoing Climate Change, widespread ecosystem degradation and biodiversity loss are capable of causing severe environmental impacts, while fostering socio-economic crises. Due to the progressive loss of natural environments, and the occurrence of highly emission-intensive anthropic activities, urban areas contribute greatly to global warming, while also causing local climate alterations, referred to as the Urban Heat Island (UHI) effect. Atmospheric pollution is another consequence of land-use change with intensive urbanization, and is responsible for detrimental effects on the human health, with cascading impacts on socio-economic systems. The European Union identified cities as one of the main targets of several policy efforts aimed at avoiding ecosystem structural and functional degradation, and preventing the impacts of Climate Change**,** as envisioned in the recently approved proposal for the EU Nature Restoration Law. Nature-Based Solutions have been proposed as fundamental multifunctional tools to counteract current climate- and pollution-related issues. Urban and peri-urban forests are capable of providing a variety of Ecosystem Services that support the health and well-being of citizens in different ways, from the removal of pollutants to the net decrease in temperatures. In the present study, we focused on seven Italian Metropolitan Cities located in coastal environments and along a geographical gradient. Because they host about 20% of the Italian population, despite occupying only 7% of national land, while being prone to environmental risks, these cities represent particularly vulnerable contexts. By using a spatially-explicit modelling approach, integrating high-resolution land cover, pollution and vegetation data, we mapped the supply of some Regulating Ecosystem Services, and performed a biophysical and monetary assessment. For the year 2019, urban and peri-urban forests in the seven investigated cities removed a total of 17,349 Mg of PM_{10}, and 132.01 Mg of O_3, for a monetary value of EUR 1.8 billion for PM_{10} and EUR 3.81 million for O_3 removal.

Managing Mediterranean forests: effects on soil microbial community and related ecosystem functions

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Healthy ecosystems provide services which sustain life and increase resiliency in a world of increasing pressures. From an ecological perspective, forestry interventions can be defined as disturbances actively implemented with the aim of obtaining forest-based ecosystem services. Since forest management influences the occurrence of tree species and the organic matter input to the soil decomposer system, these practices can affect soil microbial community and key functions they perform. In this study we assess the effects of forest management (coppice and high forest) on functional diversity of soil microbial community in two forests (turkey oak and beech) in Southern Italy, in summer and autumn. The soils were characterised for physico-chemical properties (SOM, pH, WHC), and the soil microbial communities were investigated for metabolic fingerprint by Biolog EcoPlates™ method and for some enzyme activities linked to biogeochemical cycles of C, N and P.

It was demonstrated that in both forests, in autumn microorganisms utilised carbon substrates more intensely in soils under the high forest regime than coppice, conversely in summer although with differences in C source group utilization, putting forward the influence of the type of management on soil microbial community. SOM content and microbial community diversity indices differed depending on the management and forest systems. Hydrolase activity in soil under beech and arylsulfatase activity in soil under turkey oak showed in summer significant differences between management.

The correlations found between utilization of C source and some soil properties combined with the different trend of the measured indices will provide useful data for: adopting forest managements strategies able to increase SOM; improving the sustainability of forest ecosystems in a scenario of climate change; establishing the effects of these management practices on soil quality in order to clarify if the reintroduction of coppicing in abandoned coppice forests is a good practice.

Natural capital lost as a result of *Pinna nobilis* die-off in the Mediterranean Sea

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In the Mediterranean Sea, the endemic fan mussel *Pinna nobilis* (Linnaeus, 1758), which inhabits sandy bottoms and *Posidonia oceanica* meadows, plays a crucial ecological role providing essential ecosystem functions and services.
It contributes to water clarity by filtering suspended organic matter and it creates habitat for other species, being an ecosystem engineer since its shell can be colonized by benthic invertebrates and the sandy sediment beneath it hosts epifaunal communities. Thus, *P. nobilis* can enhance the biodiversity and richness of benthic communities.
However, increased pollution and anthropogenic activities led to its decline since 1980, with a recent collapse (between 2016 and 2019) due to pathogens spread (i.e., *Haplosporidium pinnae*, *Mycobacterium* spp., *Vibrio* spp. and *Perkinsus* spp.) and climate change. For this reason, *P. nobilis* has been included in the IUCN Red List as a "critically endangered" species.
Moreover, in the Ligurian Sea, a strong sea storm in October 2018 further exacerbated the mass mortality of this species.
This study aims to quantify the biophysical and monetary value associated to the loss of *P. nobilis* in the Portofino Marine Protected Area (MPA).
In this regard, visual transects were carried out through scuba diving at three MPA sites between 2017 and 2019. The data collected during these surveys were used to perform a system analysis, which assessed the natural capital loss as resources required (expressed in solar emergy Joules - sej) to generate and maintain the natural capital *per se*. These values were then converted into monetary terms to facilitate understanding for policy makers and managers.
The value of a *P. nobilis* individual accounted for 5.91±8.82E+11 sej (6.16±0.92 em€) generating an overall natural capital loss in the Portofino MPA due *P. nobilis* death of more than 2 million em€, such loss must therefore be managed through prevention and restoration measures.

How (un)sustainable are we? Analysing multiple ecosystem services for sustainability and management

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One of the biggest challenges for ecosystem services (ES) science is to make the concept operational for decision-making purposes. Our capacity to understand the long-term sustainability of multiple ES is still limited, while being highly needed to improve the management of natural resources. In this work, we aim to use ES, and particularly the assessment of their capacity and flow, to explore the sustainability of the ES provision in the coastal social-ecological system of the Venice lagoon, Italy, by adopting a spatially explicit approach. By applying multivariate analysis on the ES maps, we derive a zonation which reflects the different bundles of ES. We propose an approach that analyses the ES bundles found in the lagoon to determine their degree of sustainability. Building on the rationale that not all combinations of ES are desirable for the long-term maintenance of ES capacity, we propose a 'sustainability threshold' for the ES. This threshold corresponds to a balance between ES capacity and flow, and to a balance between the flow of regulating ES and the flow of ES mediated by human activities. The results show that about 53% of the lagoon's surface is exploited to a level that falls beyond the 'sustainability threshold' and thus should be considered in an unsustainable condition. This reveals the need to intervene to change the patterns of ES uses in some areas of the lagoon, to enjoy the benefits offered by the ecosystem without impairing its capacity to provide them. Some potential directions for change are discussed, moving towards a more sustainable management of the lagoon social-ecological system.

The interplay of human activities and Ecosystem Services in the *valli da pesca* of the Venice lagoon

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Coastal lagoon ecosystems are continuously affected by human activities, leading to changes in their structure and landscape. During the last decades, in the Venice lagoon, specific areas known as *valli da pesca* underwent significant modifications due to human interventions. The morphological evolution of these areas depends on the ecosystem structure transformations related to maximizing some provisioning Ecosystems Services (ESs), such as fishing and hunting. However, the *valli da pesca,* while primarily focused on provisioning ESs, contribute to several other ESs, including climate regulation, water purification, lifecycle support, and recreational activities. Therefore, changes in the land cover of the *valli da pesca* could influence the capability to provide essential ESs to the entire lagoon. To describe the historical changes in land cover and landscape elements within the *valli da pesca*, historical cartography and remote sensing data have been collected and classified with a machine learning approach, creating a comprehensive geodatabase spanning from 1901 to 2021. By analyzing indicators related to land, saltmarshes, and water, we found that, at the beginning of the 20th century, the landscape features were similar across all the *valli da pesca* due to similar management objectives and regulations. However, between 1975 and 1987, a process began where different management strategies were implemented to maximize specific ESs (e.g fishing and hunting), resulting in distinct land cover patterns. These findings enhance our understanding of human-nature interactions in the Venice lagoon and highlight the dynamics of ESs in response to human interventions, allowing us to suggest some exploratory considerations about the future of these areas in terms of persistence, viability, and resilience.

Competition for resources between *Apis mellifera* L. and wild Apoidea: ecological and ethological approaches on a small island in the Tuscan Archipelago

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Managed honeybees (*Apis mellifera* L.) provide an essential ecosystem service as pollinators. However, given their characteristics -big colonial size, generalist diet, wide foraging ranges- and their management, honeybees are capable of monopolising trophic resources (pollen and nectar), thus potentially impairing the survival of other species of wild bees. Competition can be especially harsh in small and homogeneous ecosystems, such as small islands. Here I will present a project which aims to investigate such potential competition on Giannutri, a small island within the Tuscan Archipelago National Park, on which a population of managed honeybees was imported in 2018. Spatial and flower-visits overlap between managed honeybees and wild bees suggests potential exploitative competition. Our experimental approach was to manipulate honeybees' density on the island by closing, opening or partially closing the beehives and then assess the effect on: a) trophic resources availability (on *Teucrium fruticans* L. and *Salvia rosmarinus* Spenn.) through quantification of nectar volume and pollen abundance; b) foraging pattern behaviours of target wild bees (*Anthophora dispar* Lepeletier and *Bombus terrestris* L.) through focal behavioural sampling and monitoring plots. Our hypotheses are that in days with presence of honeybees there will be less trophic resources available and that wild bees will spend more time foraging for trophic resources, resulting in less time spent in single flower-visits and in a decrease in frequency of pollen collection. Moreover, we started to investigate how trophic resources vary through time on *T. fruticans* by studying nectar replenishment dynamics in previously emptied flowers, so as to better assess trophic resources availability and understand the beehive load that the island can sustain without compromising the integrity of the endemic Apoidea's fauna. In this talk I will provide an overview of the project and present preliminary results, which seem to suggest changes in wild bees foraging behaviour.

Potential loss of ecosystem services due to the removal of *Posidonia oceanica* banquette

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The Mediterranean basin hosts an impressive natural heritage, representing one of the world's biodiversity hotspots with important and unique habitats. Among them, the endemic seagrass *Posidonia oceanica* forms extensive meadows providing valuable ecosystem services (ES), underwater as well as on the shore. Indeed, like terrestrial plants from which it originates, *Posidonia oceanica* constantly produces new leaves, shedding the older ones. Depending on weather conditions, hydrodynamic characteristics and coastline conformation, significant quantities of dead leaves may be deposited on the shoreline, locally and seasonally. These deposits, often mixed with sediments, may vary from scattered layers to extensive piles with varying thickness from few centimetres up to several metres. These formations, known as *Posidonia oceanica* "banquettes", act as natural barriers against coastal erosion since they prevent sand loss and dissipate the wave energy. Moreover, the degradation of the washed-up leaves gives back large amounts of nutrients, relevant for the functioning of the coastal food web. However, the presence of Posidonia banquettes in touristic areas is perceived as a nuisance, discouraging the presence of visitors, thus leading local administrations to dispose their removal and/or displacement. This is often done by particularly damaging means (e.g., excavators and heavy wheeled vehicles), which may disturb the dynamics of coastal ecosystems. In this study, we propose the monitoring of the *Posidonia oceanica* banquettes along the coastline of the Campania Region (Southern Italy), estimating its biomass and the associated concentration of nutrients and other chemical compounds, with the final aim to assess the potential loss of ES due to their removal from the beaches. Results shed light on the ecological importance of *Posidonia oceanica* banquettes, with particular reference to the health of coastal ecosystems and benefits to humans.

Sustainability evaluation of "Greco di Tufo" grapes production strategies to increase resilience to climate stress

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Agroecosystems have a significant impact on planetary sustainability as they affect soil, water, air quality as well as biodiversity. On the other end, climate change strongly impacts agro-production, in particular in the Southern Mediterranean areas, where increasing temperatures and decreasing rainfall, together with more frequent extreme events, strongly challenge the sector. Wine production, one of the most significant Italian agro-economic sectors, is experiencing in many areas a significant fall in the production yield, hence strategies to increase plant resilience and resistance to climate change are being tested. The Farm to Fork strategies advocates a new era of sustainable production, hence the evaluation of the sustainability of management options has become a key aspect for competitive companies. Feudi di San Gregorio, one of the most well-known wine producers of Campania region, has set in 2021, within the PSR project "Grease", an experiment to test more effective vine-growing methods for the current climatic trends, combined with 3 different land management scenarios. We have evaluated the sustainability of such scenarios using field data obtained from 3 years of experiments using a multi-footprint approach combined with scenarios of C compensation/sequestration to identify the most promising win-win options for sustainable wine production.

The analysis of ecosystem services and climate change impact assessment: the Palo Laziale case study

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The main objective of the study is to quantify ecosystem services of the Palo Laziale Forest growing in a coastal site North of Rome. Estimates are made by following the LIFE MGN+ guidelines, through a collection of climate data, pollutant data, and the use of existing or original regression models from the survey area, standardized monthly values are produced and thus comparable with references to the 2021 – 2022 period of the supply of some ecosystem services. The estimated ESs supply are supply of the "wood products" service at 65.42 t/y, the "drinking water" service is 1076305.68 m3/y, for the "carbon sequestration" service the total stock and a process quantification is considered; For the C stock, there is a supply estimation of 2765.28 tC, while for the C sequestration process sets 39.46 tC/y, for "PM_{10} sequestration" service is 14189.12 kg/y, for the "water regulation" service is 2115840.00 m3/y. Further, a demand and a monetary evaluation are also performed.

A secondary but not unimportant goal is to use ecosystem services, to give them ecological importance, as simple surrogates for understanding complex natural processes from which they are generated. The "drinking water", "water regulation", and "PM_{10} sequestration" services show cyclical trends (seasonal alternation), whereas the first two are correlated each to other.

The last objective is focused on the prediction of the supply in a climate change scenario (RCP pathways scenarios 2.6 and 8.5) provided by the IPCC and CHELSEA data for "water provisioning" and "water regulation". These ecosystem services show an increase in the supply but a reduction of the seasonal cycles in both pathways.

This study has increased the knowledge level about ecosystem services occurring in the Palo Laziale Forest at different time scales and under two climate change RCP pathways. This could be useful to improve more adaptive management, already performed within the LIFE PRIMED project, for both decision-makers and policy actions.

Air Quality Mitigation by Urban Green Infrastructures: PM_{10} Removal in the Bydgoszcz-Toruń Metropolitan Area (Poland)

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Atmospheric pollution is regarded as one of the main environmental risk factors affecting the European population. Particulate Matter (PM) is considered as one of the most hazardous pollutants, especially in urban areas where anthropic activities are highly emission-intensive. By providing several Ecosystem Services (ES), Urban Green Infrastructures (UGIs), such as urban and peri-urban forests, contribute to the improvement of living conditions in urban environments. In particular, urban vegetation is capable of mitigating PM concentrations by adsorbing suspended particles through deposition mechanisms, depending on the vegetation functional and structural characteristics. In this study, we aimed to quantify and map the ES of PM_{10} removal by UGIs in the Bydgoszcz-Toruń area (Poland). We performed a biophysical and a monetary assessment of ES provision on a seasonal basis, further aimed at investigating the role of the functional diversity of the vegetation. A spatially-explicit modelling approach was used, integrating high-resolution, remotely-sensed Leaf Area Index, Green Cover, and PM_{10} concentration data in a GIS environment, which allowed to obtain maps of average seasonal removal efficiency and to estimate total removal and ES total monetary value. According to our findings, although deciduous broadleaves exhibits peak seasonal removal efficiency averages in spring and summer, coniferous vegetation displays a higher annual average efficiency (11.95 kg/ha against 9.80 kg/ha), highlighting its ability to provide ES continuously throughout the year. This is particularly relevant in light of the increment in PM concentrations typical of the winter months. Total removal is also higher for conifers (329.32 Mg, against 32.52 Mg of the deciduous broadleaves), reflecting the great disbalance in the total surface cover between the two Functional Groups. This work highlights that the biophysical and economic assessment of ESs can help policy-makers in developing planning strategies aimed at maximizing ES provision and human well-being in urban areas.

Applying a Multi-Methodological Framework to Assess Natural Capital and Ecosystem Services in the Strait of Sicily (Southern Italy)

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Marine ecosystems are recognized as among the most productive ecosystems in the world. The interactions between biotic and abiotic components of marine ecosystems are able to generate ecosystem functions providing a wide range of Ecosystem Services (ES) vital for human well-being. Nonetheless, marine ecosystems are among the most heavily exploited ecosystems worldwide. Within the context of the Mediterranean Sea, the largest and productive semi-enclosed basin in the world, human activities are undermining its ecological integrity. The Strait of Sicily (SoS) is identified as a Mediterranean biodiversity hotspot able to provide multiple ES, supporting human life at different scales. Nevertheless, the SoS is one of the most threatened areas in the Mediterranean basin. Stressors and anthropogenic pressures are degrading the SoS natural capital and its ability to provide ES, negatively affecting human well-being. In this context, the study and conservation of the SoS marine ecosystem represents an urgent need. Although several studies on the SoS have been conducted over time, there is a gap of studies adopting a multi-methodological approach to comprehensively assess natural capital stocks and ecosystem services flows. The present study aims to implement a multi-methodological assessment framework combining environmental accounting methods and conventional ecological indicators. In particular, the eco-exergy method is proposed to account for the complexity and organizational level of the SoS marine ecosystem, coupled with a biomass-based Shannon diversity index. In addition, an ecosystem accounting framework is applied to assess a set of ES provided by the SoS, in both biophysical and monetary terms. The results of this study will be useful to policy makers in charge of developing strategies to achieve impelling conservation actions and sustainability goals.

Assessing the Ecological Unequal Exchange in International Trade

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Ecological unequal exchange refers to the imbalanced distribution of environmental advantages and disadvantages caused by uneven patterns of resource consumption and pollution discharge. This research presents a comprehensive examination of global trade in environmental terms. In particular, we used Input-Output analysis to track material and energy flows between nations, and Ecological Network Analysis (ENA) to explore the structure of worldwide trade. The integration of both methodologies enables a thorough evaluation of the embodied resources and ecological impact of different countries. This assessment allows to go beyond the monetary evaluation of economies and countries on production basis by assessing inequalities on consumption basis. Thus, it helps overcoming the "Netherlands fallacy" and the pervasive "decoupling" narrative.

The findings underscore the intricate and interwoven nature of global trade. Preliminary results reveal how countries in the Global North extract significant quantities of natural resources from nations in the Global South while exporting high-value products and substantial amounts of waste. In other words, the economic output of Global North countries tends to incorporate more natural resources, greenhouse gas emissions, and pollution compared to others. The utilization of ENA enables us to examine where and how exploitation dynamics occurs by emphasizing ecological relationships between countries, facilitating an understanding the level of synergy and mutualism in trade exchanges. Through a comprehensive assessment of direct and indirect transactions between countries, we identify which nations are major contributors to the global economy and which ones excel in acquiring resources from third countries.

In conclusion, this study demonstrates that international trade is increasingly characterized by ecological unequal exchange, wherein the economies of the Global North continue to expand by exploiting the resources of the Global South, thus limiting their opportunities to overcome poverty. Given the substantial quantity of resources required (with a majority originating from the Global South), a sustainable and just global transition calls for a new balance in the global economy.

ASSESSING REGULATING ECOSYSTEM SERVICES IN URBAN AREAS: A CASE STUDY IN SOUTHERN ITALY.

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Urban areas have been recognized as hubs of innovation, employment and wealth generation. However, rapid urban expansion due to population growth is becoming a primary global concern. In particular, urban sprawl is causing significant environmental impacts, posing serious risks to ecosystems and human health. In response to the pressing need to address challenges associated with urbanization, a global awareness has arisen for sustainable management in urban areas. Sustainability of cities and urban ecosystems is one of the key topics of the United Nations 2030 Agenda for Sustainable Development, which suggests cities should become inclusive, safe, resilient, and sustainable human settlements. In this context, Nature-Based Solutions (NBSs) are considered a long-term solution to deal with urban environmental issues, being able to provide multiple Ecosystem Services (ES). Among NBSs, Green Infrastructures (GIs) can play a crucial role in improving the life quality of citizens and achieving Sustainable Development Goals. GIs can be defined as strategically planned networks of natural and semi-natural areas designed and managed to provide a wide range of ES capable of improving human well-being in cities. In this study, we aimed to assess a set of regulating ES generated by GIs in the municipality of Casalnuovo di Napoli, a highly urbanized area in the province of Naples (Southern Italy). Benefits derived by GIs in removing atmospheric pollutants, carbon sequestration and avoided runoff were assessed using the i-Tree Canopy software, allowing the estimation of land cover (such as tree, herbaceous area, agricultural fields, buildings, and roads) and the biophysical and economic assessment of ES provided by GIs. Finally, plantable areas of the city were identified, providing information to policymakers on the potential benefits that could be obtained if GIs would be enlarged.

Conservation measures for benthic suspension feeders: protected and neglected Marine Animal Forests

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Marine macrobenthic communities can provide three-dimensional environments that substantially increase the complexity of otherwise bare sedimentary bottoms, thereby providing habitat to a number of additional associated species, and ultimately resulting in biodiversity hotspots. Marine Animal Forests (MAFs) encompass some of the most important marine benthic habitats into which diversified sessile suspension feeders like anthozoans, sponges, bryozoans, corals, sea pens, ascidians, tube worms, and bivalves occur. Such mix of sessile species raises unique structures and supports important ecosystem functions. In the last decades, some MAFs have been object of international conventions, EU directives, and national policies to address human-induced disturbances. Effective conservation, monitoring, and restoration actions require summarizing the available information to include MAFs in conservation plans. In the present research, the main international policies for the protection of coastal and marine fauna were screened in order to provide a list of protected species occurring in Mediterranean MAFs. These international normative documents include the Washington Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Convention on the Conservation of European Wildlife and Habitats (Bern Convention), The Habitats Directive, the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA/BD Protocol) of the Barcelona Convention and the International Union for Conservation of Nature (IUCN) Red List of Threatened Species. Reporting the status of the MAF species that should be considered in management and conservation measures will be crucial for by policy-makers, as well as for mitigating current and future impacts on these unique marine environments.

Assessing Natural Capital value of the coralligenous habitat in marine protected areas of the Campania Region (Southern Italy)

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Italy has a unique biodiversity heritage in the European context, mostly along the marine-coastal strip. It hosts habitats whose protection is considered to be a priority for biodiversity conservation and management. Among marine habitats, the coralligenous stands out for its biodiversity and role in the carbon cycle. Nevertheless, it is also one of the most vulnerable marine habitats as it is extremely sensitive to environmental alterations, especially those related to human activities. Therefore, it is crucial to raise awareness about the ecological importance of this habitat and the role it plays for human well-being. In this context, environmental accounting tools are useful to assess the value of biotic and abiotic natural capital stocks embedded in marine ecosystems and the ecosystem services they generate. Marine Protected Areas (MPAs) can be considered as socio-ecological systems and laboratories for putting into practice sustainable development strategies, combining the conservation of marine ecosystems with sustainable socio-economic activities. Given this premise, this study aimed at assessing the biophysical value of natural capital stocks embedded in the coralligenous habitat of three MPAs located in Campania Region (Southern Italy), implementing a biophysical and trophodynamic environmental accounting model. The environmental accounting model was based on biomass data collected through sampling campaigns in the investigated MPAs. The biophysical values of natural capital stocks were also converted into monetary units to facilitate the understanding of the importance of this habitat in socio-economic and policy contexts. The results of this study can support local managers and policy makers in charge for achieving biodiversity conservation and sustainable development goals.

Assessing ecosystem services generated by green infrastructures: The case study of the city of Bolzano (Northern Italy)

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Since the publication of the Millennium Ecosystem Assessment in 2005 and the UN 2030 Agenda in 2015 the awareness on urgent global environmental, political, and economic challenges has risen. Seventeen interlinked Sustainable Development Goals (SDGs) were proposed as a universal call to tackle poverty, reduce inequality, and protect the planet by 2030. Among all the SDGs, the SDG 11 suggests making cities and human settlements inclusive, safe, resilient, and sustainable. Indeed, the ever-growing urbanization and related impacts are undermining ecosystems and human health. In the context of the SDG 11, Green Infrastructures (GIs) represent a Nature Based Solution crucial to improve life quality of citizens. GIs can be defined as strategically planned networks of natural and semi-natural areas designed and managed to provide a wide range of Ecosystem Services (ESs) capable of improving human well-being in cities. In fact, GIs in urban areas provide multiple benefits to humans, such as climate mitigation, air quality improvement, and reduced runoff. In this study, we aimed to assess a set of regulating ESs generated by GIs in the city of Bolzano (Northern Italy). In particular, pollution removal, carbon sequestration, oxygen production, and avoided runoff were assessed. The generated ESs were assessed in all the five districts of the city, including about 12.000 trees. The i-Tree Eco software was used to perform urban and rural forestry analysis, assessing benefits they provide in both biophysical and monetary terms. The results of this study will increase the awareness on the important role GIs play in urban systems to improve human well-being, also informing policy-makers in charge of developing strategies to achieve impelling conservation actions and sustainability goals.

Disposable or refillable bottle? Life cycle assessment (LCA) of different common practices for water consumption

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Packaging plays an important role in our daily lives, especially when we buy goods in a retail or wholesale store. Nevertheless, that today's take-make-dispose society is one of the principal driver of global environmental change and ecosystems deterioration, raising concerns related to waste management. For example, plastics generate around 500 million tons of waste per year. Packaging reuse nowadays represents a major opportunity to reduce material use, therefore there is a fundamental change in the everyday attitude towards reusable systems. One of the sectors where these new trends have strongly influenced consumer is the consumption of drinking water. Indeed, many people are rejecting plastic beverage packaging in favour of other packaging materials that are seen as more sustainable. The aim of this study was to estimate and compare, by means of a Life Cycle Assessment (LCA), the environmental impacts associated with 1. the production of reusable bottles for drinking water made of different materials, namely glass, stainless steel, aluminium and plastic, and 2. their use over a hypothetical period of one year. The production and use of single-use plastic bottles over the same period was taken as a benchmark. Furthermore, each bottle was tested considering 1. daily bottle handwashing scenarios with and without soap, and 2. bi-daily bottle dishwashing scenarios. The LCA analysis, a standardized framework used to evaluate the impact of products, was performed using OpenLCA program with an Ecoinvent v.2.2. database and the ReCiPe midpoint (H) method. The results show that the production of disposable bottles generates less emissions than any other refillable bottles. The same conclusion can be drawn when considering the annual scenario where refillable bottles are hand-washed. Replacing it with dishwashing reduces emissions by around 99%, and this reduction could increase if the electricity is entirely supplied by renewable sources.

Environmental impact based on LCA analysis of cupped oyster (*Crassostrea gigas*) farming in the lagoon of Scardovari

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The aquaculture sector is becoming increasingly important in terms of world consumption, and it is therefore important to assess the economic and environmental aspects of this development. In particular, in Italy, where the production of molluscs such as clams (*Ruditapes* spp.) and mussels (*Mytilus* spp.) is already well-established, cupped oyster farming (*Crassostrea gigas*) is at its early-stage, even though valuable examples of oyster aquaculture is growing in several Italian regions. The purpose of the study was to assess the environmental impact of the oyster production facility located in the lagoon of Scardovari, in the North-East of Italy, where an innovative and unique shellfish farming system is applied. The analysis was carried out using the life cycle assessment (LCA) framework, by means of OpenLCA v.1.11 software. The functional unit has been established as 1 kg of fresh product, corresponding to about 10-12 oysters of commercial size. The system boundaries have been defined as a *gate-to-gate* from the seed purchase from France, to product packaging ready for selling. Based on LCA results, the environmental impact has been evaluated by means of the following categories: sea occupancy (measured as m^2*a), carbon footprint (measured as kg CO_2 eq), metal depletion (measured as kg Fe eq), and water depletion (measured as m^3). As an example, the major environmental hotspots related to oyster farming in Scardovari in terms of carbon footprint are the construction of the farming facility (0,206 kg CO_2 eq) and the material used for packaging (0,077 kg CO_2 eq). Further investigation will be focused on the adoption of alternatives to improve the overall sustainability.

Land use effects on plant communities in urban ecosystems

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The spatial configuration of urban landscapes, characterized by complex mosaics of fragmented patches subjected to different land uses, shapes biodiversity and, therefore, affects ecosystem stability and functioning.
The present study, carried out in the context of the PNRR MUR "National Centers" Member – CN_00000033 "National Biodiversity Future Center - NBFC", focuses on evaluating the effects of land use and fragmentation on the biodiversity of the herbaceous vegetation in urban contexts. Specifically, the structural and functional biodiversity was analysed, within the area of the University of Salerno (Southern Italy), along gradients of increasing distance from interfaces between different land use patches, such as pathways, lawns and tree rows. Taxa were identified at the species level, estimating their abundance through measures of number, dry mass and Braun-Blanquet cover, and functional traits, such as the biological form, chorological type and Ellenberg indices, were adopted in evaluating vegetation functional diversity. Data analysis relied on the derivation of synthetic structural and functional diversity indices, employed together with community composition and species abundances in ascertaining how land use and the margin effects drive the diversity of plant communities.
Overall, results show that land use differentially affects the structural and functional biodiversity of plant communities, both varying also in relation to the margin effect, even at scales in the order of few meters. Main drivers related to land use appear to be tree canopy shading and trampling/soil sealing, determining an abundance of terophytes in open and trampled spaces and a proportional increase in hemicryptophytes and chamaephytes under deciduous canopies. The association of several species to specific tree canopies may also explain changes in the chorological composition of communities and alterations in their dominance-diversity structures. Moving forward from the estimation of impacts to a proactive stance, our findings may also contribute to develop more sustainable urban planning approaches.

Forest, city and pollinators: supporting the pollination ecosystem service in urban settings within the National Biodiversity Future Center

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Pollinators are responsible of key ecosystem services and constitute a large proportion of biodiversity. They are facing progressive declines due to anthropogenic factors including the urbanization process, and it is timely to understand how to sustain pollinator populations in cities. Within the context of the National Biodiversity Future Center and its Spoke 5 devoted to urban biodiversity and forestation, I asked if a link exists between afforestation and pollinators within and around the urban areas. I found clear relationships between landscape configuration considering forest patch distribution and the wild bees found in urban and rural areas within Milan. Furthermore, withing the framework of the National Biodiversity Future Center, intensive research is being conducted on the relationship between green areas size and fragmentation and pollinators in six major Italian urban areas by looking at biodiversity patterns and plant-pollinator interactions. The results will inform strategies for preserving pollinators in urbanized landscapes. Moreover, activities for reinforcing pollinator populations through nutrition and nesting are being planned and will be applied in urbanized landscapes. Overall, the activities regarding pollinators and taking place within the Spoke 5 of the National Biodiversity Future Center will constitute a chance for understanding the relationship between green spaces, afforestation and pollinator biodiversity in cities.

Habitat suitability modeling for *Posidonia oceanica* distribution along the Ligurian coast

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Posidonia oceanica, an endemic seagrass of vital ecological and economic significance, forms extensive meadows along the Ligurian coast (NW Mediterranean). Comprehending the factors that influence the distribution of *Posidonia oceanica* meadows is crucial for effective conservation and management strategies. Therefore, the aim of this study was to develop a habitat suitability model to predict *Posidonia oceanica* distribution along the Ligurian coast.
A uniform grid of 142m x 142m squares was created to establish a standardized framework for analysis. Response variables were derived from the Atlas of Marine Habitats of Liguria updated in 2020, focusing on descriptors of *Posidonia oceanica* (i.e., *Posidonia oceanica* on sand, on rock, mosaic of *Posidonia oceanica* and dead matte). Explanatory variables included environmental factors (e.g., water temperature, salinity, seafloor type, depth) and both natural and human pressures (e.g., sewage outlets, ports, rivers, coastal defenses).
The Random Forest analysis, implemented using R software (v.4.2.0), was employed to model habitat suitability. Random Forest is an ensemble machine learning technique that constructs multiple decision trees and combines their predictions to generate robust and accurate results. The model was applied to the *P. oceanica* descriptors, both collectively and separately, revealing the main influential factors and their respective contributions to the presence of *P. oceanica.* The model outputs were visualized using QGIS software (v.3.22) and allowed to identify 1) areas with potentially optimal conditions for *P. oceanica* development and 2) variations in descriptors distribution.
This study provides valuable insights into the variables influencing the presence of *P. oceanica* and its different descriptors. The results can guide decision-makers and stakeholders in making informed choices regarding environmental management and conservation efforts. Additionally, the study offers knowledge into the most suitable areas for *P. oceanica* survival, supporting restoration initiatives.

Biodiversity associated with trees in urban areas: a pilot study in Milan to improve management practices supporting conservation in cities

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Greening urban areas is a major trend worldwide because of the need to create more sustainable and resilient cities. Trees constitute the main biological elements that compose the urban forest and their characteristics are fundamental to effectively support biodiversity and the provision of ecosystem services (ES) that depend on it. Despite their importance, the potential of trees to effectively support biodiversity is hindered by management practices and urban planning that often fail to incorporate ecological conservation principles. In addition, there is a lack of comprehensive knowledge regarding the entire community of organisms inhabiting trees, including their distribution and ecological needs. Consequently, we lack crucial information to adequately support conservation efforts. Here we present a study that aims to improve knowledge about biodiversity associated with trees and to test a sampling protocol. The study has been conducted in Milan, monitoring six trees for one year with a multi-taxon approach: bacteria, fungi, lichens and mosses, algae, invertebrates, and vertebrates. Sampling has been conducted both with traditional methods (entomological traps) and new techniques (microsoil eDNA). Traps and samples were positioned or collected at different heights of each tree (from the ground up to 33 meters) to cover the entire structure. Preliminary results allowed us to describe the biological community of each tree, and its vertical distribution, to highlight differences in terms of abundance and diversity for some groups related to tree height. The biological community heavily changed by season and we described the groups' turnover, a useful information for tree management. Further analyses are ongoing to deepen the species identification for different taxa and investigate patterns of distribution. The information derived from this study is currently shared with the municipality of Milan in order to be used to inform tree care professionals and policymakers and to raise citizens' awareness through divulgation events.

The role of secondary vegetation in the elevational distribution of tenebrionid beetles in Central Italy

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Vegetation tends to vary in a systematic fashion along elevational gradients, leading to the possibility of recognizing distinct vegetational belts, which are frequently used to describe and interpret elevational variations in biodiversity. However, anthropogenic changes, such as deforestation and grazing, can create landscapes dominated by grasslands in areas formerly occupied by forests, thus originating at intermediate elevations open habitats that mimic those of higher elevations (i.e., natural sky island grasslands). Because of a millenary history of human presence, the mountain landscapes of the Apennines have been profoundly altered, and the presence of secondary vegetation should be carefully considered when interpreting current biodiversity patterns along elevational gradients. The present research illustrates how the distribution of tenebrionids in Central Italy is profoundly influenced by the presence of secondary vegetation. To this end, classical schemes of vegetational belts proposed for the Apennines were modified into a scheme of main vegetation types that include secondary vegetations. For the 84 species and subspecies (hereafter species for simplicity) of tenebrionids occurring in the study area, the presence/absence in each belt was assessed. Species richness tended to decrease with elevation, but secondary vegetations were consistently richer than forests because of the prevalence of geophilous species in the study area. However, the proportion of geophilous and xylophilous species varied among belts, with geophilous species being prevalent in coastal, secondary, and natural high elevation vegetation, and xylophilous species in the natural forests. Relationships between belts outlined by similarities in tenebrionid composition indicated the presence of two main groups: one with forests and the other with natural and secondary grasslands, including sky island vegetation. Biogeographically, geophilous species prevailed among thermophilous tenebrionids with Mediterranean distributions, whereas xylophilous species prevailed among more mesophilous species distributed mainly in Europe. These results indicate that secondary vegetation facilitated Mediterranean, thermophilous species associated with open habitats.

Carbon stock evaluation in a Mediterranean mountainous area: the case of the Troodos massif, Cyprus

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The carbon storage potential of European habitats is among their most important Ecosystem Services. Studies which evaluate Organic Carbon (OC) stock based on field data collection are still few from the Mediterranean mountain landscapes. In this study, we aimed to quantify the OC stock in three pools, namely soil, aboveground biomass (AGB) and litter, within the Troodos National Park of Cyprus. A total 23 plots were investigated in the most representative habitats of the area: Pallas pine forest (*Pinus nigra subsp. pallasiana*), Pallas pine forest with *Quercus alnifolia*, *Pinus brutia* forest, and mixed forest of Pallas pine, *Pinus brutia* and *Quercus alnifolia*. For every plot we described the environmental features, collected soil samples until 40cm depth and litter by horizons, and measured the diameter at breast height and height of each tree. The OC stock in AGB was valuated using species and site specific allometric equations. Laboratory analyses were undertaken for soil (texture, pH, total N and C, bulk density) and litter samples (biomass, organic matter), thus the OC stock was quantified. The highest values of OC stock were in Pallas pine, *Pinus brutia* forest and *Quercus alnifolia* (14.8 kg/m^2), while the average total OC stock was 12 kg/m^2. The AGB had the highest values of OC stock, with an average of 7.5 kg/m^2, and litter stocked an average of 1.23 kg/m^2. Litter OC stock resulted positively correlated with elevation and tree basal area, whereas a positive correlation between soil and AGB stocks was found. Further research must be undertaken to determine the cause-effect relationship of these correlations, and to investigate the linkages between OC stock and other environmental features, such as rainfall regimes and temperature. This will aid in determining the key factors influencing OC stock in the Troodos area and facilitate the development of forecast models.

Urban landscape planning to enhance natural capital and mitigate land consumption

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Land is a non-renewable resource, and its temporary or permanent consumption can bring to land degradation due to its slow regeneration process. This means that spatial planning has to make the best use of land given that it is crucial for supporting economic activities and social capital. Several are the drivers of land consumption: for instance, population growth, economic development, and climate change. Under such circumstances, land use is putting increasing pressure on the natural system, mainly causing deforestation, landscape degradation, and biodiversity loss. in this context the aim of this research is to compare the past urban landscape trajectories and the future strategic landscape regeneration in three cities in the province of Lecce: Galatone, Lecce, and Nardò to highlight the importance of landscape change spatialization to detect the ecological meaning of land consumption in terms of natural capital flow loss. Since the urban plans of these three cities are at different implementation stages, it has been interesting to analyze the different strategies selected to guarantee the regeneration of natural capital and future sustainable development. According to the past trajectories, the three case studies have resulted more or less far from the Sustainable Development Goal 15.3 (Zero land consumption), but with the use of suitable indicators has been possible to plan and monitor the effectiveness of land consumption mitigation actions. The study has highlighted that it is not enough to quantify the amount of land consumption, but it is crucial to analyze it spatial connectivity, since it represents a risk of land consumption increasing, as well as to investigate what land consumption means ecologically.

Plant invasions on the coast: spatial-temporal features of iceplant and landscape dynamics in Mediterranean dunes

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Plant invasions significantly alter most ecosystems on the world and pose huge challenges for biodiversity monitoring, conservation and management. Multi-temporal landscape analysis is very promising for monitoring biological invasions, still its utilization supporting conservation on dynamic landscapes needs to be addressed.
This research aims to analyze the spatial-temporal characteristics of an invasive alien plant (IAP hereafter; *Carpobrotus* spp.) in relation with landscape pattern changes on Mediterranean coastal dunes. After producing detailed multi-temporal land cover maps, we described coastal dune mosaic changes through transition matrices. Then we addressed two questions: a) have the invaded patches changed in the last decade? (ii) how variations on invaded patches are linked with spatio-temporal changes?
Based on land cover and IAP maps we computed composition and configuration metrics and compared them over time by Mann Whitney test. For all pattern metrics we calculated the temporal delta values (pattern T_2-pattern T_1) and analyzed them by running machine learning algorithms followed by a Partial Dependence analysis.
The spatial-temporal characteristics of *Carpobrotus* spp. patches and the contextual landscape resulted linked over time. On coastal landscapes with stable seashore and increasing sealed surfaces, *Carpobrotus* spp. tend to substitute natural habitats. IAP pattern metrics tends to increase over time with a higher number of bigger and irregularly shaped patches in the recent data. On coastal tracts squeezed by erosion and soil sealing, *Carpobrotus* spp. cover declined overtime remaining narrowed on few, small, regularly shaped patches.
The proposed landscape approach allowed to effectively depict alien species dynamics on mosaics differently shaped by factors of change (e.g. seashore dynamics, urban sprawl) and produced important information useful for management planning on specific contexts.

Urban woods diversity in a small-medium city of an Italian inner area (Campobasso, Central Italy)

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The management and conservation of urban biodiversity is a major challenge. More than 50% of the world's population lives in cities, and urban biodiversity can be crucial to human well-being. Indeed, urban biodiversity provides multiple ecosystem services to society, such as mitigating heat waves, regulating stormwater during floods, and providing vital recreational space to support the mental, physical, and social well-being of residents.
In this context, the PNRR National Biodiversity Future Centre project, promoted by the Italian government, has identified "urban biodiversity" as a strategic research area and is implementing an Italian interdisciplinary group (Spoke 5: Urban Biodiversity), whose objectives include improving the current knowledge of biodiversity in Italian cities and providing new insights to protect and enhance nature in built up areas.
In this work we investigated the plant diversity of wooded areas across the urban-natural gradient in a small-medium town in the interior, i.e., the city of Campobasso. We sampled vascular plants on remnant semi-natural/natural forest patches in the Functional Urban Area of Campobasso (FUA) and analysed the spatial distribution of total woody species and of native vs. alien species. Vascular woody plants were sampled on 77 plots (10x10 m) placed according to a random stratified protocol, using remnant forest patches and the urban-natural gradient as strata.
A preliminary classification of the data revealed the presence of remnant *Quercus frainetto*, *Q. cerris* and *Q. pubescens* forest patches, including some in good condition despite their urban surroundings, as well as semi-natural patches dominated by the alien *Ailanthus altissima*, and their distribution varies along the urban-natural gradient.
This first recognition of natural forest biodiversity in the city provides a scientific basis for both: informing successful restoration of urban forest ecosystems and improving management actions, considering their main threats (e.g., fragmentation, non-native species pressure, urban heat island and climate change, pollution).

Macroecology of dung beetles in Italy

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Dung beetles are among the most iconic insects, being universally known for their trophic role. The Italian fauna of dung beetles includes about 170 species/subspecies (hereafter species for simplicity) of coprophagous Geotrupidae and Scarabaeidae (Scarabaeinae and Aphodiinae). Despite the availability of relatively good ecological and distributional data, there is no comprehensive study addressing dung beetle macroecology in Italy. We used data on dung beetle distribution in the Italian regions to investigate some macroecological patterns. Specifically, we tested if species richness decreased southwards (as expected according to the peninsula effect) or northwards (as expected if southern regions acted as important refugial centres during Pleistocene glacials). We also considered the effect of area (i.e., the species-area relationship), topographic complexity (expressed by the proportion of lowland, hilly and montane areas), and climate (temperature and precipitation) in explaining dung beetle richness. Finally, we used multivariate techniques to identify biotic relationships between regions. We found no clear latitudinal trend in species richness, which contrasts with both the peninsula effect and the possible role of southern areas as Pleistocene refuges, possibly because of large post-glacial movements. Species richness was weakly influenced by area, which suggests that environmental variables are more important than geographical constraints in shaping dung beetle communities. Precipitation was the most important climatic correlate of richness. This is consistent with the fact that about 60% of the considered species are Aphodiinae, which prefer humid climates since (differently from Scarabaeinae) they are unable to remove the dung, and hence need to exploit this resource before it dries. Sicily and Sardinia showed impoverished communities and appeared very isolated from the mainland regions, which were divided into two groups, corresponding to the Alpine and the Apennine areas. These results indicate the presence of distinct faunal groups, which reflect the current ecological setting and geological history of Italy.

New approaches for the evaluation of soil processes: the use of NMR spectroscopy

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Soil is a complex matrix that urges to be finely investigated and characterized in terms of amount and quality of soil organic matter (SOM), nutrient dynamics, composition and activities of the edaphic communities which are of great concern for regulating global carbon (C) cycle, nutrient budgets and biodiversity conservation. These ecological processes can change over time and be affected by different stressors, such as the increase of temperatures, alien species invasion or profound modifications due to the land-use and management. The application of nuclear magneticresonance (NMR) spectroscopy in ecological studies is a valid technique for exploring the chemical structure and dynamics of SOM processes and dynamics, detecting the molecular aspects thatmay drive different mechanisms and evaluate the change along soil profile in different ecosystems affected by specific anthropic and natural factors. The non-destructive solid-state ^{13}C cross- polarization-magic-angle-spinning (CPMS) NMR technique provides the molecular distribution of organic carbons in solids without extensive sample pre-treatment, whereas ^{1}H NMR spectroscopy detects chemical shifts due to hybridization of the atom to which the hydrogen is attached and electronic effects, in soluble fractions. Therefore, this technique allows to highlight the stable and labile compounds of SOM, C loss related to mineralization, and to predict the response of the edaphic communities for the efficacy of requalification policies such as afforestation or fertilization plans. The high input of aromatic-C to the mineral soil in the pine forests versus the relatively high input of aliphatic-C in the black locust forests or shrublands lead to the formation ofthicker organic layers that contribute to a greater C sequestration. Therefore, the afforestation with pine could favour long-term soil C storage. However, the use of NMR is still underestimated and it is desirable that this method is used in ecological studies, for its high sensitiveness and accuracy of results.

Wilderness is the prototype of Nature regardless of individual's connection to Nature. An empirical verification of the solastalgia effect.

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Background: Connectedness with Nature is a personality trait that influences our relationship with Nature. But Nature is not all the same. Wilderness is the original Nature, in relation to which human beings have evolved as a species, while domestic and urban Nature are relatively recent products of our interaction with the environment. Aim: The main purpose of this study is to verify whether the individual trait "connection to Nature" influences the perception of restoration, preference and familiarity for three types of Nature: wilderness, domesticated, urban. Results: Regardless of the level of connection to Nature, wilderness is always perceived as more restorative than domesticated or urban environment. Individuals with higher connectedness prefer wilderness more than others, but they recognize the restorative value of domesticated environments better than those with medium or low connectedness. Lower connected individuals tend to prefer domesticated environments, although wilderness is more familiar to them. Conclusions: This study shows that, despite our detachment from Nature, wilderness is the prototype of Nature and offers a plausible evolutionary explanation of solastalgia.

Biodiversity assessment on coastal areas aided by *Citizen Science* volunteers. An insight on the Italian Central Adriatic zone

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Coastal areas are complex, transitional and dynamic systems representing a hotspot of highly specialized biodiversity. Coasts are highly threatened (globally and in the Mediterranean) by multiple anthropogenic pressures, while their monitoring and management pose significant challenges. As coastal monitoring by traditional approaches requires costly field campaigns, often covering limited areas, the increase of *Citizen Science* applications and data collection activities may provide updated and cost effective tools for depicting biodiversity of these dynamic areas.
To increase the biodiversity knowledge on the Central Adriatic Italian coast across Molise and Abruzzo regions and to raise public awareness on the importance of coastal ecosystems, we implemented a *Citizen Science* (CS) program and developed the dedicated database "WCC-Wild Coast CASCADE" on iNaturalist platform (https://www.inaturalist.org/projects/wild-coast-cascade). iNaturalist is the most successful CS initiative addressed to data collection on biodiversity worldwide.
We present preliminary results of data collected through the WCC initiative from 2020 to 2022, which included both CS organized events and leisure time of individual citizens. In the analyses we retained only those records reaching the Research Grade and focusing on taxa of biodiversity conservation and management interest, i.e. a) species listed either VU, EN, or CR in IUCN Red List, both at global (www.redlist.org) and country level; b) species listed in annexes of the EU Habitat Directive 42/93/EC, c) diagnostic species for habitats listed in annex I the Habitat Directive 42/93/EC, d) non-native species, including those listed as Invasive Alien Species of Union Concern in the EU Regulation 1143/2014).
We downloaded 3784 observations collected across the study area on 742 species, with 81% of the Research Grade that were retained for further analyses. The highest number of observations were composed of Reptiles and Plants. We detected 19 species at risk according to the global IUCN Red List, 46 alien species (19 of fauna and 27 of plants), 4 species listed in HD annexes, and 52 diagnostics species of 14 habitats listed in the Habitat Directive.
Our findings underline the great potential CS for aiding coastal biodiversity monitoring and the sound management of biodiversity hotspots.

A case study of the public involvement in cetacean conservation at the "Ketos" citizen science centre (Taranto, Italy)

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Citizen science— the involvement of volunteers in science —is increasingly utilized in environmental research, providing benefits to scientific community, stakeholders and participants. In 2019, a Citizen Science centre called "Ketos- Centro Euromediterraneo del Mare e dei Cetacei" was realized in Taranto (South of Italy) by Jonian Dolphin Conservation (JDC), a scientific organization conducting research on cetaceans in the Gulf of Taranto (Northern Ionian Sea). Through its unique combination of specimen collections (mostly donated by National Research Council-Water Research Institute), nature-inspired art installations, high technological tools, scientific and public education expertise, Ketos bridged conservation science and education through citizen science. Indeed, on one hand Ketos is a research centre where sighting data acquired during JDC vessel-based surveys are analysed, on the other it is an educational centre characterized by a museum itinerary dedicated to cetaceans and marine local fauna, equipped with an ecology lab, an 8-stations virtual reality room, and a conference room. Thanks to numerous activities, workshops, meetings and cultural events, Ketos aims to raise citizen awareness on the importance of marine ecosystems conservation. During 2022, 6,000 students (120 schools) were involved in Ketos' educational programs. Moreover, 25 national and international interns and volunteers were hosted. Since January 2023, a land-based cetaceans monitoring protocol has been applied by Ketos' visitors supported by JDC biologists, increasing research data and knowledge on dolphins within the harbour area of Taranto. Indeed, 13 sightings of common bottlenose dolphin (*Tursiops truncatus*) occurred and several data about their behaviour and interaction with boats were collected. Thus, Ketos has become a cultural centre model in few years, fostering the development of knowledge on cetaceans for both scientific community and citizens. This model was also tested in Italy, Albania and Montenegro, through the Interreg-IPA CBC BioTourS project (co-funded by the European Union), achieving positive results.

Developing serious games for ecology teaching: how to put ecological principles in game format.

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Ecology is a complex discipline requiring solid knowledge of biology, chemistry and physics, a rigorous interdisciplinary approach but also advanced skills such as systems thinking and future scenarios building. In the Italian secondary school system, ecology is a marginal part of the subject "sciences", treated in the first two school years. It is addressed again in the subject "civic education", also in this case in a general way. However, a solid knowledge in ecology is the base for future citizens to deal with the coming climate challenges. Games were primarily used for entertainment but have recently been applied in formal and non-formal education, scientific exploration, health care, emergency management, urban planning, engineering, and politics. These are termed "serious games". Serious games can be effective didactic tools to introduce principles of ecology, to practise systemic approach and to exercise future scenarios building as a tool to face ecological challenges. The board game "*YouTopia - the ecosystem valley"* is a cooperative serious game developed by students and teachers to promote ecology learning and to put into practice sustainability principles. An accurate work was done to define expected educational outcomes and specific disciplinary contents. The main ecological features of the Alps and the concept of landscape as set of ecosystems and habitats were included in the board graphic. Concepts as trophic networks, ecological niches, nature-based solutions and allochthonous species were introduced by special cards. Key principles of systems thinking as causal connections and feedback loops as well as future scenario building were introduced through game mechanics. The output is a cooperative board game in which 6 players can build a new community in an ideal alpine valley, choose how to face climate change-related issues and anthropization side effects, paying attention to the balance between a flourishing economy and the related environmental impacts.

Learning about climate change and evolution through a board game

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Climate change is a very important topic at the moment, both for science and for the society as a whole. The effect of climatic changes on living species are mediated by a lot of different factors that may or may not play a role (e.g. fundamental niche of the species, reproductive strategy, generation time). While the overall complexity of this relationship is well understood by the scientific community, this is often not the case for the public.
We decided to create a free educational resource to explore the topic in a fun, simple but scientifically rigorous way. "Climate Change – the board game" (https://michelaleonardi.netsons.org/it/gioco-da-tavolo-sui-cambiamenti-climatici/) is a free print-and-play board game inspired on our research on how climatic changes affect animal species over long timescales.
In the game, the world is divided in four biomes (savanna, tropical forest, temperate forest, tundra), and the climate may change without warning modifying the distribution of the biomes. Each player is a species that can live in a given habitat. It has a genome with associated biological traits that, through mutations, allow it to adapt to different ones. Whenever the climate changes, the habitat may change too, and the species must react by migrating or adapting, or it goes extinct.
The board game explores complex scientific concepts such as adaptation, evolution, and extinction. It also highlights the difference between the current human-induced climate changes and to natural ones.
The game is available in four languages (Italian, English, Portuguese and Turkish) and can be played for free either in person (by downloading and printing the materials) or online through the dedicated website. It has been successfully used for outreach activities with schools in the University Museum of Zoology (Cambridge) and presented in several science festivals in Italy and the UK.

Can performing arts support environmental education? The case study of '*Can You Sea?*', an aerial and acrobatic performance about major Ocean threats

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The Ocean is increasingly under threat from several types of human activities, and is suffering dramatic loss and degradation of habitats and biodiversity. Unfortunately, societal perception of this situation is disproportionately low, because the affected systems are out of sight, as well as inadequately represented by media. In order to ensure the effective implementation of science-based solutions to restore marine ecosystems into global policies, society's relationship with the Ocean must change, and this requires adoption of participatory educational tools. Performing arts can represent innovative approaches to communicate complex issues and achieve societal changes, by creating an emotional connection that conveys new values and insights. Here we test the impact on all participants (performers, choreographers, scientists, audience…) of a physical/acrobatic theatre performance aimed at increasing awareness on major Ocean threats. A performance entitled '*Can You Sea?*' was co-created by choreographers and acrobats, researchers of marine ecology, biology and geology around the following themes: marine pollution (including nutrients, plastics, noise), over-fishing, bioinvasions and climate change. A scenography of polluted waters, ship propellers noise and bodies packed into narrow nets conveys an image of the sea that is anything but idyllic, showing the audience an evocative portrait of the destruction suffered by the Ocean. Physical performances are accompanied by audio recordings and short reads, written and executed by scientists, with the supervision of a community theatre researcher. Before/after questionnaires were designed to measure the performance impact and the level of engagement of the public and all participants.

A journey around a tree": preparing and setting up an exhibition as an opportunity for the environmental education

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The Research Unit of Landscape Ecology is carrying out a research (Habitat Trees: Home for biodiversity) that aims to survey the whole biodiversity associated with single urban trees. The research studies 6 mature trees (one for species: *Cedrus deodara, Magnolia grandiflora, Quercus robur, Platanus acerifolia, Pterocarya fraxinifolia e Tilia cordata*) in "Giardini Indro Montanelli" park in Milan. Giardini Montanelli is the oldest public urban park of Milan, and it is the location of the Municipal Museum of Natural History. As a dissemination action of this research, we aim to prepare an exhibition that will be open to the public in April 2024 in the rooms of the Museum. The theme of the exhibition is "A journey around a tree" and it will deal mainly with discovering trees as a home for different species of organisms that interact with each other and with the environment and humans.
The phase of the planning and preparation of the exhibition, before the exhibition itself, is an opportunity for the activities of environmental education of teachers. Here we will discuss ideas and activities that are or will be carried out. Trees remain the core of every educational project, but the paths can be different. Purely scientific, starting from the literature (books and stories by Calvino for example) or from art, or even intertwining the narrative planes. A preliminary survey shows quite well that children's books about trees explain better the complexity of trees as a habitat for several species than what is explained in primary school textbooks. The final purpose of the exhibition and of the educational projects linked to the exhibition is to improve the knowledge of trees and to make pupils and teachers more aware about the role of trees in supporting biodiversity and provide ecosystem services.

The Virtual Museum of Ecosystems

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The Virtual Museum of Ecosystems and Natural Environments (https://museoecosistemi.lifewatchitaly.eu) has been developed by the National Research Council of Italy (CNR) in the framework of the PON IR "LifeWatchPlus" e-science project PIR01_00028 funded by MIUR. This Virtual Museum represents a new approach to let citizens and students explore ecosystems in a virtual environment and it is a useful tool for science dissemination and education. The Museum is an interactive and innovative web-based tool for experiencing the complexity of ecosystems and for learning about their functioning, and it is offered as a tool for learning at school. It also aims to establish a multidisciplinary community composed of ecosystem researchers, teachers, students, science communicators and experts in ICT technologies aimed to enhance visualisation and e-learning. An overview on ecosystems and the environmental challenges for the future of biodiversity conservation is also provided, in order to lead visitors into a more comprehensive tour. Museum visitors can experience the real habitats through an immersive experience, by exploring 360° landscapes, where different points of interest give insights on species and ecosystem processes by storymaps, pictures, videos, interviews, texts and documents. Registered users will find tools for building "communities'' (e.g. school classes, interest groups), create their own works, share it with other members of the community, plan guided tours, plan on-line events and access virtual archives. Two interactive games stimulate visitors, in particular students, to understand the dynamic relationships between the different components of an ecosystem, and to ponder and be aware of the impact that some of our choices may have on the health of the ecosystem and humans alike.

Integrating ecology education in the context of urban green spaces: the experience of Bosco di Cancello Rotto (Bari, Italy)

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Urban green spaces are interesting outdoor laboratories for conducting research and biodiversity conservation actions, as well as for experimenting educational training and citizen science initiatives.
During 2022, a university educational training was carried out within "Bosco di Cancello Rotto", a public urban green area in Bari (Italy), managed through a participatory process involving citizens, associations and municipality administration. 15 students of the master's degree course "Analysis of Community and Ecological Systems" (University of Bari) were involved in sampling activities and data analysis aimed at investigating the multiple effects of local human disturbance on herbaceous vegetation. During lectures, students participated in a simulation of a research study commissioned by the managers of the green area, as a professional context useful for the training of students.
Vegetation was sampled in 12 stations affected by low (A), medium (B) or high (C) trampling disturbance. In each station, plant species coverage (%), and vegetation height (cm) were measured in three 1x1m plots. Several univariate and multivariate methods, and Gaussian species distribution model were applied to analyse differences along the disturbance gradient. A total of 27 species were identified in the study site. Significant differences in the median values of vegetation height were detected between sites with low and high trampling intensity ($p<0.001$). For 4 species, the distribution model allowed to identify species that are sensible or tolerant to trampling disturbance. Results were discussed by the students during the final examination, presenting their assessments to stakeholders. In addition, dissemination products (videos and slides) were developed after the end of the course, and they were presented within the "Apulian Biodiversity Week 2023".
This experience represents an opportunity of cooperation among researchers, associations, and students, where sustainable management of urban green areas is integrated with educational training in ecological disciplines.

Naturalistic illustration as a tool for public awareness raising on the presence of marine alien species: A.M.A. Adriatic Marine Aliens

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In recent decades the number of alien species in the Mediterranean Sea has increased rapidly, exceeding 1,000. Among the most important vectors of introduction are aquaculture and maritime traffic. The port of Ravenna is one of the most active ports in the Adriatic Sea, with navigable Candiano canal connecting the sea to the city of Ravenna. In the frame of the European ARMS program (ARMS-MBON) several alien species were detected along the canal. In 2022 different public awareness raising initiatives were taken to draw public attention on the presence of these species locally and problem of alien species introduction in general. The artist working on initiatives produced scientific illustrations of 16 alien species: 5 Arthropoda, 5 Mollusca, 3 Annelida, 2 Chordata and 1 Ctenofora. Illustrations were included in a booklet accompanied by information on their biological and ecological characteristics, distribution, and vectors of introduction in the Mediterranean. Web site containing the same information was created. A memory game with species illustrations on 20 x 20 cm polyvinyl plates was also produced. Booklet and memory game were presented to school children, youth and adult public during the European Researchers Night 2022. On the same event a questionnaire was distributed to assess the knowledge and perception of participants on marine alien species. More than 50 children played the memory game, and 100 persons answered the survey. Results show that more than half of the people (68%) know what alien species are, but perceptions about the pathways of introduction and impacts which these species have on environment and humans are underestimated. Many people consider alien species to be part of biodiversity, even though only 34% have a clear understanding of the concept of "biodiversity". Therefore, it emerges the need to include these topics in school programs and increase dissemination activities that involve citizens.

pastclim: a search engine for the climate of the past

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For decades, the scientific community has been aware that human activities are affecting the global climate, causing significant impacts on societies all over the world. This is why it is crucial to communicate this topic effectively.
When discussing how humans are changing the climate, deniers often argue that "Climate has always changed", meaning that what we are observing now is just part of a natural cycle. While it is true that the climate has shifted in the past, what makes the current situation different is the incredibly fast pace of change, much faster than anything we have seen in millions of years. However, explaining this can be tricky.
To tackle this challenge, we introduce pastclim: https://evolecolgroup.github.io/pastclim/index.html. It is a search engine for past climate data, spanning the last 5 million years. Natively, it is an R package offering easy access to paleoclimatic reconstructions for the whole world. Through simple functions, users can generate maps and graphs illustrating specific climatic variables for chosen regions and time periods. This invaluable tool can assist scientists in doing outreach, and help generate figures to be used in museums, and publications, comparing natural climate fluctuations with the ongoing human-induced changes.
We are now developing an online version for users unfamiliar with R. This interface, through a website, will enable anyone to generate the same outputs with just a few clicks, making the climate of the past accessible to a broader audience.

Young children focus more on baby animals than on non-living objects.

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Human-Nature relationship is a precious source, through which children can mature, evolve, investigate their subjectivity, get in touch with their own emotions and subsequently with those of other living beings, then finally pay attention to the preservation and protection of ecosystems. With this experimental study we have tried to investigate the hypothesis of biophilia in pre-school children. We proceed with a protocol where children (0-2 years and 3-5 years) play freely for 5-10 minutes and then, without warning, let in just one new guest: a pet, a remote-controlled car, a plant or a picture and time their reaction time to become aware of (to shift their attention to) the presence of the new guest. The objective of the experimental observations was to verify differences in the times of fascination (bottom-up attention) in contact with living (baby animals and plants) and non-living (animate and inanimate objects) creatures. We assume that baby animals shift children's attention more quickly and more frequently than non-living objects. And, among non-living objects, animated ones shift attention more than non-animated ones. We are therefore within Wilson's prediction (biophilia is "our innate tendency to focus on life and life-like forms and, in some cases, to associate emotionally with them") and, considering the age of the small experimenters, most likely it is an innate behaviour that reinforces the idea that biophilia is an evolutionary adaptation.

Enhancing attention restoration in adults through immersive experiences in aquatic landscapes

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It is widely recognized that contact with Nature has a positive impact on our mental well-being. However, quantifying these benefits is not always straightforward: psychological benefits are commonly assessed using subjective tools, and establishing a precise cognitive response associated with the feeling of well-being is difficult. Furthermore, existing research has primarily focused on the effects of terrestrial landscapes, such as forests and urban parks, neglecting other types of ecosystems. As a result, the potential of aquatic ecosystems and their landscapes for reconnecting people with Nature, and helping in mental fatigue relief, has been rarely evaluated. In this study, we present the results of an ecopsychology experiment that aimed to objectively measure the restorative value of a lagoon ecosystem in Italy. After assessing the participants' connectedness to Nature using psychometric scales, we administered a test that requires active and prolonged attention to quantitatively measure their attentional performance. Following this, the group engaged in an excursion along a trail, surrounded by the lagoon environment. At the conclusion of the excursion, we measured participants' scores on a second attention test to evaluate the possible effects of the immersive nature experience. Impressively, most participants exhibited improved performance on the attention test and completed the task significantly faster after the excursion with an average reduction of 47.2±35.0 seconds (21.7% less than the time taken for the test before the excursion, p-value<0.05). Moreover, participants assigned a higher restorative value to landscape views that included water than those without water. Our findings confirm the essential role of Nature in contributing to human mental well-being and suggest that spending time in coastal and lagoon ecosystems, with their distinctive elements, can significantly enhance efficiency for tasks requiring prolonged active attention while fostering relaxation and contemplation.

Threat, pressures and impact on the aquatic ecosystem in the Vallo della Lucania and Novi Velia area of Cilento region, southern Italy

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Anthropogenic activities (industry, agriculture, urban development) generate contaminants that can have a direct impact on the environment with a possible loss in the ecosystem services. These are mainly affected by land habitat and/or ecosystem structure alteration or by biogeochemical cycle changes. The Cilento region is a National Park that exhibits a territorial context with a combination of cottage industrial, domestic/touristic, and agricultural activities. Consequently, organic, inorganic, and emerging contaminants could be released into environment. The main goal of this study is to analyse anthropogenic pressures in this area and understand the impacts on water quality. In particular, we studied the Alento River catchment, situated in Vallo della Lucania and Novi Velia municipalities, that represents an interesting case study due to its integrated system of storage dams and high biodiversity, by evaluating the main hazard posed by pesticides, fertilizers, metals and microplastics.
GIS analysis was used to integrate available territorial and environmental data to select sampling areas to be seasonally monitored. Water and sediment matrices were characterized by chemical analyses, and by a battery of ecotoxicological tests with organisms from different trophic levels (bacteria, algae and crustaceans). All results were integrated to obtain a Toxicity Battery Index (TBI). In addition, we evaluate chronic effects, by developing a *Daphnia magna* tailored test with sediments. In depth analysis of microplastic occurrence in sediments and associated risk was carried out. Preliminary findings showed, only for some sites, moderate levels of ecotoxicological risk and the hazard posed by metal mixtures highlighting the essential role of integrated assessments in achieving a comprehensive evaluation of water quality. Moreover, the comparison of TBI and Hazard Index allowed evidencing the contribution of diverse contaminants to the overall observed effects. Such evaluation is necessary to estimate the areas at greatest environmental risk and define the correct control and monitoring plans.

Investigating anthropogenic disturbance across a hierarchical progression of ecological system complexities – insights from low-frequency magnetic fields

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The multiple feedback mechanisms involved in complex systems modulate the propagation of stresses through the hierarchical progression of ecological systems, yielding adaptive dynamics and unpredictable outcomes, ultimately making its study a highly non-trivial task. This is especially true when the mechanistic understanding of stress-response relationships is still rudimentary, as in the case of oscillating magnetic field (MF) interactions with ecological systems, where the responses may depend on frequency, intensity, phase and time of exposure.
With a view to shedding light on these interactions, we focused on natural low frequency MFs potentially interfered by anthropogenic MFs, *i.e.* the first mode of the Schumann resonances (7.83 Hz), studying the effects of varying intensities and exposure times on multiple levels of ecological organization, purposefully choosing the analytical targets in relation to system properties. In particular, effects were investigated at the level of organism, focusing on animal behavioral ecology and plant ecophysiology and development, of population, analyzing seed recruitment and germination kinetics, and of ecosystem, investigating organic matter decomposition by soil microbial community. System responses were studied under controlled conditions in order to highlight potentially small effects, using exposure devices and settings purposefully developed and chosen according to finite element modelling analyses.
Preliminary results highlight the presence of invariant responses across different levels of organization, with MF eliciting clearer dynamics to the varying field intensity (7.5 µT, 15 µT, 30 µT) at short exposure times (15' in respect to 30' and 60'), especially at the population and ecosystem levels. Considering the interaction between the artificial and the natural MFs, differing in field intensities and phases, findings can be explained in terms of intermediate disturbance. Overall, our research demonstrates the coupling between low frequency magnetic fields and the functioning of ecological systems at different levels of complexity, with responses modulated by interfering anthropogenic fields.

Temporal pattern of diseases prevalence in Thudufushi Island, Maldives: 2010-2022

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Coral reefs are lately suffering a fast decline in biodiversity due to the coupled effect of climate change and diseases outbreaks, which in recent decades have been reported with higher frequency and shorter intervals. Few studies have been conducted on coral diseases in the Maldives and in few locations. Moreover, these studies were not able to assess a temporal trend in the coral disease dynamic. In this context, we investigated the change in the distribution, prevalence, and host range of four diseases, namely Black Band Disease (BBD), Brown Band disease (BrB), Skeletal Eroding Band (SEB) and White Syndrome (WS), during the last twelve years (2010-2022) in the reef system around Thudufushi island. The overall disease prevalence in the island increased in the last twelve years for all the diseases, with exception of Brown Band disease; the Skeletal Eroding Band disease had a severe increase in prevalence in the 2010 with respect to 2022. The overall coral disease prevalence is approximately ~ 2 %, which highlighted an increase of about 0.7% from the 2010 . Colonies affected by diseases were found in all the transects and sites, with the east site mostly affected and SEB disease the most prevalent disease in all the investigated sites. The affected colonies belong to 13 genera, with *Psammocora* genus showing the highest overall mean disease prevalence. This study depicted a temporal trend in disease prevalence. It calls for a dedicated national monitoring protocols to better understand and predict future coral disease dynamics at regional scales.

Evaluation of sublethal toxicological effects of two fungicides used in vineyards on *Apis mellifera*

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The main pesticides used in vineyards are copper-based and Folpet active principle fungicides. In these areas, *Apis mellifera,* collecting the morning dew from vine leaves and using sugar from the grapes, are very likely to come into contact with these contaminants. Climate change can even exacerbate these effects due to the increasing periods of drought. The lethal effects of pesticide active principles are tested for commercial use approval, while the sublethal effects of pesticide's final commercial formulations are scarcely investigated. This study investigated the sublethal effects of the fungicides Fantic® (Folpet-based) and Ramedit® (cymoxanil+copper-based) alone and in combination on honeybees. A multi-biomarker approach was applied to test neurotoxicity (AChE, CaE), metabolic alterations (ALP, GST) and immunotoxicity (LYS). A laboratory experiment was carried out with the fungicides alone and in combination, as well as a beehive monitoring in vineyards before and after the treatments with the two fungicides. The pesticide interaction model applied showed that the mixture of the two fungicides had subadditive effects. The laboratory experiment showed induction of GST activity in all treatments, except the mixture at the lowest concentrations. The ALP activity showed a decrease compared to the control. An increase in LYS activity was found in the groups exposed to Fantic®, to the lower concentration of Ramedit® and the mixtures. The monitoring study showed no esterase inhibition in honeybees sampled during and after the treatment of the vineyards with Fantic® and Ramedit®, compared to those sampled before. Metabolic alterations and effects on the immune system (decrease in LYS activity) were found in bees sampled during the vineyard treatments. This study confirms the need to deeply investigate the sublethal effects of commercial pesticides, in particular those used in vineyards, to protect wild and farmed pollinators.

The hidden consequences of Lithophaga lithophaga (Linnaeus, 1758) illegal fishery

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The illegal fishery of the date mussel Lithophaga lithophaga is one of the most destructive practices for the carbonatic rocky subtidal substrates of several areas across the Mediterranean Sea. Once the date mussel is fished, there is no evidence of full recovery of the disturbed habitat since several decades are necessary for the date mussels to regrowth after their harvesting. Understanding the functional consequences of the loss of this species from kilometers of rocky coasts is critical to fully understand the ecological consequences of this illegal fishery and to design appropriate restoration interventions. We carried out a manipulative experiment to assess if the presence of L. lithophaga can affect the recovery of benthic assemblages, possibly also driving the development of a distinct epilithic microbial communities. We scraped the substrate removing epibenthic assemblages from 50x50 cm replicated plots (three conditions: L. lithophaga still present, L. lithophaga previously removed by the fishery, control plots). The recolonization of sessile species was assessed with photographic sampling. Preliminary results show a significant effect of the presence of L. lithophaga on the epibenthic recovery immediately after manipulation, in terms of benthic recovery. As far as the microbial community, we sampled collecting 5 replicates of sediment for each condition. After the DNA extraction, samples were sequenced targeting V3-V4 regions of the 16S rRNA gene. Preliminary results from bioinformatic analyses showed statistically significant differences in the composition and patterns of variability among conditions (presence/absence of date mussels) independently from the sampling site. Results support the hypothesis that the removal of the date mussels at regional scale translates into critical ecological changes not only for the epibenthic component but also for the associated microbioma with further, undervalued, functional consequences on ecosystem recovery.

First evidence of microplastic pollution in water, sediments and macroinvertebrates in Mediterranean wetlands in south-west Spain

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Microplastics (MPs) in aquatic habitats are a global concern due to their ubiquity, persistence and effects on biodiversity and ecosystem functioning. Yet many studies on MPs focused on marine or freshwaters (rivers and lakes) systems while studies on wetlands are scarcely addressed. Wetlands play key roles in supporting biodiversity and are considered as nature-based solutions to address global challenges (e.g. climate change and water pollution). Nonetheless, they continue to suffer persistent pressures that threaten their biodiversity and functioning. Emergent contaminants, such MPs are expected to add further stress to these systems.
In this study, we examined the microplastic contamination across 11 sites (7 located within protected wetlands) in Andalusia (south-west Spain). These sites have varying distances from potential sources of contamination (i.e. landfills). Some of them are used as roosting or nesting sites by birds (i.e. gulls and white storks) with well-known implications in the plastic transfer from landfills to wetlands.
First, we estimated MPs concentration in water, sediments and macroinvertebrates and then we characterized polymers with Raman spectroscopy. We also applied generalized mixing linear models (GLMM) to evaluate the contribution of landfills proximity, site protection and bird presence (gulls or white storks) to MPs accumulation.
We found that MPs (mostly fibers) were present in all studied sites and compartments, but macroinvertebrates showed the higher contamination. Polyvinyl chloride (PVC) was the most frequent polymer in water, Polyethylene (PP) in sediment and Polystyrene (PS) in macroinvertebrates. We also found that MPs concentration in macroinvertebrates was lower in protected site, and depended on the proximity to landfills e.g. macroinvertebrates in wetlands closest to landfills showed more MPs contamination.

Multi-level approach to evaluate the toxicity of polylactic acid (PLA) and polybutylene adipate terephthalate (PBAT) microplastics in *Daphnia magna*

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The inappropriate disposal of plastic waste and its accumulation in the environment raised a worrisome concern for ecosystems, pushing the society to look for sustainable solutions, including the transition from the use of fossil-based plastics to bioplastics. Similarly, to fossil-based plastics, at their end-life bioplastic objects have the same probability to enter and contaminate the ecosystems, as well as to generate microplastics (MPs). However, to date there is a dearth of information concerning the hazard for organisms due to the exposure to microplastics originated from the degradation of bioplastics. The aim of this study was to investigate the potential adverse effects induced by the exposure to MPs from bioplastic objects made of polylactic acid (PLA) and polybutylene adipate terephthalate (PBAT) towards the cladoceran *Daphnia magna*. MPs were obtained from PLA-based disposable knifes and PBAT-based shopping bags. Organisms were exposed for 21-days to three concentrations (0.125 µg/mL, 1.25 µg/mL, 12.5 µg/mL) of PLA-MPs and PBAT-MPs. A multi-level approach was performed to investigate adverse effects at different levels of the biological hierarchy, from sub-individual (*i.e.*, biochemical) to individual level (*i.e.*, growth rate and behavior). At biochemical level the onset of oxidative stress (*i.e.*, activity of antioxidant and detoxification enzymes, lipid peroxidation) was explored. Modulations in proteins, carbohydrates and lipids content, as well as in the total caloric content, were also investigated. Changes in growth rate, swimming activity and reproductive efforts were investigated to assess effects at individual level. Our results showed that the exposure to MPs made of bioplastics induced effects at sub-individual and individual levels, suggesting the necessity to study in depth the potential toxicity of these polymers.

Evaluating the impacts of sediment flushing operations in alpine streams with benthic macroinvertebrates

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Damming is a common and widespread cause of ecological impairment for alpine streams. The management of the impounded sediment is one of the major issues associated with dams and its evacuation downstream still represents the most cost-effective strategy. Thus, sediment flushing operations act as an acute flux and an intense deposition of fine sediment on the riverbed with dramatic ecological consequences on both aquatic habitat and biota, and cascade effects on the food webs and ecosystem functionality. Although the negative effects of fine sediment on aquatic biota have been widely recognized in scientific literature, specific biomonitoring indices related to this type of disturbance are still rare. In this contribution, the Siltation Index for LoTic EcoSystems (hereafter SILTES) is illustrated and tested for assessing the impacts of fine sedimentation based on benthic macroinvertebrate communities. SILTES is a multimetric index that varies from 0 (most impaired condition) and 1 (pristine condition) and combines both taxonomic and functional metrics, namely the total taxon richness, EPT richness and the abundance of macroinvertebrates preferring coarse mineral substrates and fast-flowing water. Data from three independent case studies on sediment flushing operations, ranging from the Cottian to the Rhaetian Alps, were used to test the performance of SILTES index. Our results show that SILTES index is more effective than generic indices in detecting the negative effects of fine sediment deposition associated with such operations. Results of these works provide useful tools for biomonitoring the effects of man-induced siltation in streams and contribute to improve our diagnostic ability concerning stressor-specific alterations.

Mega-fires in the Mediterranean Sea: an exploratory study of indirect effects on rocky reef communities in Sardinia Island (Italy)

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Scale, frequency, and intensity of Mediterranean wildfires have increased in the last few years due to climate change. In Summer 2021, a mega-fire extending approximatively 20.000 ha broke out in central-western Sardinia (Italy). Secondary-order effects were expected in intertidal and shallow rocky habitats along the coast, as a consequence of winter floodings depositing ashes mixed to sediment and debris into the sea. Firstly, the concentration of organic matter, nutrients and metals as well as additional basic physicochemical parameters were analyzed from sediment and water collected along two rivers and at their estuaries. To evaluate how flooding affected intertidal and shallow reef communities, we applied a hierarchical design, where three localities inside and two localities outside the impacted area were sampled before and after the flooding. In each location, we sampled 5-15 replicated plots at each of two sites, hundreds of meters apart. Sea water turbidity was measured in continuum with dataloggers at 5 meters depth in each site. We investigated (a) the patterns of variability of macroalgal community structure at 0- and 3-5-meters depth; (b) sea urchin population structure (abundance and size frequency) at 3-5 meters depth. Finally, (c) we measured the recovery capacity of intertidal marine forests formed by *Ericaria crinita* and *E. amentacea* in plots where macroalgal canopy was removed before flooding, by comparing them with forests and algal turfs at the same sites. Results on the effects of the wildfire after 16 months highlighted significant recovery of intertidal *Ericaria* spp. and an increase of sea urchin recruitment in the subtidal. This megafire provided an extra source of nutrients (natural fertilization) for the benthic community in a high oligotrophic system.

Interactive effects of light pollution and man-made structures on intertidal benthic assemblages

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Several coastal areas worldwide are exposed to light pollution (Artificial Light at Night - ALAN) as a consequence of coastal development and urbanization. Along the coast, ALAN is often related to the presence of man-made structures, built to support human activities and enhance coastal protection. A few studies have focused on the interaction of artificial structures and ALAN on biological assemblages, despite these two anthropogenic pressures having individually been recognized as important drivers of changes in biodiversity. We asked how the presence of artificial breakwaters and ALAN from streetlamps might impact intertidal benthic assemblages. Our hypothesis was that artificially lit and naturally dark areas were characterized by different benthic assemblages and that these differences would change between natural rocky shores and breakwaters. Along the Mediterranean French Riviera, we selected 4 locations where the coastline was characterized either by natural rocky shores or breakwaters, all including both lit and dark areas. We sampled two lit and two unlit areas in each location during two consecutive new moon periods in summer 2022. Macroalgal cover was estimated non-destructively using quadrats (20x20cm) and benthic assemblages (macroalgae and epifauna) were collected by scraping 6 cm diameter surfaces, brought to the laboratory and deep-frozen until sorting and identification to the family level. Epifauna density and macroalgal percentage cover data were analyzed by means of multivariate generalized linear models. Despite some degrees of temporal variability, results showed that the interaction between habitat (natural *vs.* artificial) and ALAN was significant in determining different benthic assemblages and that the differences between lit and dark conditions were generally larger in artificial than in natural habitats. Furthermore, results from the epifauna suggested the importance of a good taxonomic resolution (family rather than class level) to get important information on ALAN effects.

Fate and effects of pharmaceutical micropollutants in Lake Como in a winter scenario (4- Stress singoli e multipli su ecosistemi acquatici e terrestri a diverse scale di indagine)

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According to the EU watch list, micropollutants are identified as contaminants of emerging concern (CECs), widespread in the ecosystems. Among them, pharmaceuticals received considerable attention given their worldwide use, presence in the aquatic ecosystems and the changing legislation such the EU Zero Pollution action plan and the EU Green Deal. Fox example, Lake Como provides valuable ecosystem services (i.e., drinking water, irrigation water, etc.). In this study, a surface water model (Dyna Model) was used to evaluate the fate of 42 pharmaceuticals using lake Como as a case study, following their environmental path in two wastewater treatment plants (Como and Chiasso WWTPs), in the receiving water bodies river Cosia and Breggia and Lake Como at three depths (Como town basin) and in two drinking water fountains in Como. The results of the study report the environmental presence of several compounds included in the EU Watch List, giving a snapshot of the pollution state. Results showed a decrease of pharmaceutical concentrations from WWTPs to the Lake. The most important pharmaceutical (in terms of lake concentrations) was diclofenac, while other important contributors were carbamazepine and its metabolite, and clarithromycin. An Environmental Risk assessment was performed comparing measured concentrations to PNEC. Toxic Units (TUs) were also calculated to evaluate the risk of chemical mixtures. It was shown that risk for the ecosystem is substantially negligible with exception of the river tracts receiving wastewater output. Model simulation allowed to evaluate the chemical residence time in the Como basin of Lake Como and the role of WWTP discharge vs. incoming water flows in regulating concentrations and therefore the potential ecological risk.

Assessing the occurrence of Phthalic Acid Esters (PAEs) and Pharmaceutical and personal care products (PPCPs) in Mediterranean key anthozoan species

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Over the last decades, the biodiversity of the Mediterranean Sea has experienced rapid decline due to climate change and human activities. Marine heat waves, mass mortality events, and increasing pollution in coastal areas, particularly from plastics and emerging contaminants (ECs) are among the most significant threats, problem that has become even more pronounced in the aftermath of the recent pandemic.
In this context, the present work aimed to assess, for the first time, the occurrence of phthalic acid esters (PAEs) and pharmaceutical and personal care products (PPCPs) in four key species of Mediterranean benthic community: *Cladocora caespitosa*, *Eunicella cavolini*, *Madracis pharensis*, and *Parazoanthus axinellae*. For PAEs and PPCPs determination in the coral tissue solid phase microextraction (SPME) and liquid chromatography couple to tandem mass spectrometry (LC- MS/MS) were performed. All the specimens were found to be contaminated with at least one type of ECs over the quantification limit. The PAEs displayed an average concentration of 17.23 ± 11.39 ng/g with a maximum value of 44.17 ng/g, while the PPCPs average concentration was 25.89 ± 16.99 ng/g with a maximum value of 57.49 ng/g. The most abundant were DBP (10.35 ± 5.59 ng/g) and ketoprofen (16.97 ± 17.05 ng/g) respectively. Interestingly, they were found in higher concentrations in the same species, *P. axinellae*, suggesting a higher susceptibility to adsorb both contaminants. Furthermore, the other three species demonstrated an adsorption capacity two-fold lower, possibly due to varying environmental conditions related to depth, currents, and shelter, which exposed them differently to the contaminants.
Given the crucial role of these species in forming the habitat of benthic communities along the Mediterranean coastal environment, it is important to investigate the potential human impact in the form of PAEs and PPCPs more thoroughly.

Go with the flow: the drift of plastics in the Mediterranean Sea

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Plastic debris is the most abundant fraction of marine litter, constituting a pervasive threat with no spatio-temporal borders. Marine litter monitoring, management and reduction are goals of several legislations; nevertheless, our understanding of plastic fluxes, pathways and fate is still incomplete. The aim of this study was to characterize the spatio-temporal v ariability of plastic Floating Marine Macro Litter (FMML) dispersion from fine-scale field data observed along the Palermo-Tunis route (FLT Med Monitoring Network, ISPRA). Moreover, we wanted to explore the potential plastic pollution in Mediterranean Marine Protected Areas and Fisheries Restricted Areas (MPAs and FRAs).

Particle 3-dimensional high resolution tracking simulations were performed using the Ichthyop/Roms3D Lagrangian model based on data collected between 2017 and 2019. The 3-dimesional plastic particles frequencies were calculated for each 10 m depth section to define their distribution and temporal diffusion along the water column. Results were used also to assess the potential pollution pressure by plastic FMML in Mediterranean MPAs and FRAs calculating a seasonal vulnerability index (V).

2,552 plastic objects were used as particles for the modelling exercise. After a year, they travelled for long distances covering large areas. The same pattern of particles sinking depths was observed without significant yearly differences. For the first 200 days, over 80% of particles were concentrated up to 5 m depth, distributing over the entire water column after this time. Malta and Sicilian MPAs were the main areas under pressure all year-round, although plastics reached also the North Mediterranean Sea. MPAs and FRAs vulnerability changed accordingly to seasons, with a higher number of vulnerable MPAs found during summer. FRA_1 and FRA_2 resulted the most potentially at risk, especially during winter and spring.

The study strongly supported the need to use field-based data in Lagrangian models to quantify the realistic 3-dimensional plastic pressure at different spatial scales.

First data on the reproductive migration of *A. anguilla* in the North-Adriatic area, in a climate change scenario.

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The European eel (*Anguilla anguilla*) is a threatened species in its entire range, included as "critically endangered" in the lists of IUCN, and in the Red List of freshwater fish, European Commission. The main global threats to the species are attributed to the illegal fishing of juveniles, the loss of habitat, the presence of dams, and the general lack of information and attention for conservation.
With the LIFEEL project "*Urgent measures in the Eastern Mediterranean for the long-term conservation of European eel*" it was possible to monitor the start of the reproductive migration of the *A. anguilla* in the North Adriatic area, contributing to the updating of the first data on the migratory behaviour of the species, and in relation to climate change.
The migratory activities were investigated in the period 2021--2023 through the application of an indirect monitoring system (tagging-recapture) with T-BAR ANCHOR TAGS markers, and direct telemetric monitoring system (sonic tracking; emitters-receivers, 69 Hz).
Of the total of 1424 animals released with tags in the migration phase, the recaptures of 18 specimens were reported, 3 specimens 120 km and 15 days from the release site. Of the total of 99 released specimens equipped with sonar emitters, 12 were detected by the receiver system at a range of 35 km and 15 days after release. The results obtained showed a common migration behaviour of the *A. anguilla* specimens in both monitoring campaigns. The detection of the specimens always took place on the same day at a maximum time distance of 25 minutes from the first detection to the last, at a distance from the coast between 0.7 and 1.5 miles, in a postponed time period of 2 months compared to the natural period of reproductive migration for the northern Adriatic.

Thermal preconditioning delays coral bleaching in the coral *Pocillopora damicornis* by triggering antioxidant response and cellular protection pathways.

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Coral reefs worldwide are declining due to high sea surface temperatures causing coral bleaching, that is the breaking of the symbiosis between the coral polyps and the unicellular algae Symbiodinaceae hosted in their tissues. Since Symbiodinaceae algae provide most of the energy needed by coral colonies, the fate of a bleached coral is probably its death. Recent studies are focusing on novel strategies to prevent coral bleaching. Amongst them, thermal preconditioning, i.e. subjecting corals to sub-lethal temperature prior to heat stress, has shown promising results in slowing coral bleaching. However, the cellular mechanisms involved in conferring an increased heat tolerance by thermal preconditioning are still unknown. In this study, we showed that thermal preconditioning on the coral *Pocillopora damicornis* delayed negative effects of heat stress inducing bleaching. Thermal preconditioning was performed by exposing the coral colonies to the sub-lethal temperature of 28°C for one week after which thermal stress was applied at 31°C for another 7 days. We assessed coral bleaching through the analysis of the Symbiodinaceae density and taxonomical identification and the chlorophyll concentration (Chl). Moreover, we compared the expression of Heat shock protein 70 (Hsp70) a molecular chaperone involved in cell protein protection, the activity of three antioxidant enzymes such as superoxide dismutase, catalase, and glutathione peroxidase and the lipid peroxidation in preconditioned, non-preconditioned and control coral colonies of *P. damicornis.* Our results showed that Chl concentration and symbiont density were higher in preconditioned corals compared to non-preconditioned corals. In addition, no difference in Symbiodinaceae identity was observed. Moreover, preconditioned corals had higher antioxidant enzymes activity and higher expression of Hsp70 compared to non-preconditioned colonies. These findings suggests that thermal preconditioning delayed coral bleaching in *P. damicornis* by mitigating oxidative stress and maintaining cellular homeostasis and highlighted the possible role of thermal precondition as useful mechanism to enhance thermal resistance of coral colonies used worldwide in coral restoration projects.

Ecotoxicity of End-of-Life Tire particles: a view on *non*-conventional plastics

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Tires are considered a source of (micro)plastics, originated by the abrasion at the asphalt interface, and, only in Europe, about 3.4 million tons of these materials reach the end-of-life every year. The so-called End-of-Life Tires (ELTs) represent a special waste, potentially recycled or re-used in floor mats or in rubberized asphalts to reduce the traffic noise. The aim of this study was the evaluation of chronic toxicity induced by leachates of both ELT granule (Gr; 0.8 < size < 2.5 mm) and powder (Pw < 0.8 mm) on *Danio rerio* embryos. We performed the exposure to 0.1, 1 and 10 mg/L of leachates from 0 to 120 h post fertilization (hpf). The toxicity was evaluated through an integrated approach of biomarkers, transcriptomics and proteomics. We observed a significant increase ($p < 0.05$) in swimming activity and heart rate in specimens exposed to Pd leachates. In addition, the activity of detoxifying enzymes ethoxyresorufin-O-deethylase (EROD) and glutathione-S-transferase (GST) showed a significant ($p < 0.05$) modulation after the treatments, probably due to the released chemicals by ELTs. In the same way, proteomics highlighted the modulation of many (more than 100) proteins by Pw leachates and a lower modulation by Gr. Impacted proteins were involved in the metabolism of aromatic and nitrogen compounds, derived from traffic activity or used during the tire production. Obtained results suggest that the toxicity of ELTs is associated to the release of chemicals in the leachates, with a highest toxicity of Pw than Gr. However, considering the high tested concentrations, chosen to identify the mechanism of actions of ELTs, other investigations are needed to clarify the toxicity of selected materials, whose recycling is a fundamental process to reduce their environmental impacts.

The invasive blue crab *Callinectes sapidus* tolerance to salinity: mapping suitable habitats for management measures at local scale

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The blue crab *Callinectes sapidus* is one of the most invasive species in the Mediterranean, occupying a wide variety of habitats (e.g. lagoons, saltmarshes, coastal habitats, estuaries, etc.). Salinity plays a key role in the blue crab's life cycle, since copulation between males and females takes place in desalinated areas, and fertilized females migrate to the sea (salinity > 30) to release planktonic larvae that develop at sea. To determine the effect of salinity on the basal metabolism of blue crabs, experiments were carried out under controlled conditions. Blue crabs were collected from the Biguglia Lagoon (Corsica, France), and 13 salinities were tested ranging from 0 to 65 psu. Mortality rates were measured over 4 days of exposure to different salinities. The basal metabolism of *C. sapidus* increased between S = 5 and S = 20 before decreasing until the crabs died at S = 65. The salinity optimum was observed at S = 20. No differences were observed between males and females. In terms of mortality, individuals survived only 18 ± 6 h (S = 0), survived for > 4 days between S = 5 and S = 45. Beyond that, survival decreased: 72 ± 52 h (S = 50), 35 ± 56 h (S = 60) and 6 ± 3 h (S = 65). Based on metabolic rates, Salinity Habitat Suitability (SHS) maps were performed on current and futures conditions in the Mediterranean Sea. The marine habitat did not show suitable salinity habitats for *C. sapidus* except in estuaries and river mouths. In contrast, at the Biguglia Lagoon scale, salinity showed marked differences and fragmentation of the habitat along a north-south gradient. Sensitive areas for the species were identified to implement population control measures. These study was funded by the *Premio Luigi e Francesca Brusarosco 2022.*

Carbon loss from *Pinus halepensis* Mill. woodland affected by wildfire

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Forest ecosystems play a crucial role in mitigating climate change by storing carbon (C) mainly in plant biomass and soil. This stored C is under severe threat also due to the increasing frequency and severity of wildfires, resulting in massive CO_2 emissions in the atmosphere.
This study aimed to evaluate the effect of a wildfire that occurred in 2017 in an Aleppo pine woodland, within the Special Area of Conservation (SAC) IT9130006-Pinewoods of the Ionian Arch, on the C loss from the soil (mineral and organic layers) and the pines tree biomass.
In 2021, in still different sites for burn severity *i.e.*, low (LSB), medium (MSB) and high (HBS) burn severity, and in an unburnt control site, we collected samples of soil organic layers and mineral soil (0-10 cm) to determine organic C stock. In addition, the basal area of the live and dead pines was determined as a proxy for above-ground biomass (AGB) and to evaluate the C stock of the tree layer. Four years post-fire, the C stock (Mg ha^{-1}) showed a decrease as a function of burn severity. In MSB and HSB, the C stock of the soil organic layers was completely lost along with a sharp decrease in biomass C stored in the trees. In contrast, there was no C loss from the mineral soil layer. Our study resulted in an estimate of approximately 330 Mg of organic C lost from trees (310 Mg) and soil organic layer (20 Mg) from the entire burnt area and potentially transferred to the atmosphere. This amount may have been only partially offset by the C sequestration from herbaceous plants grown after the fire, especially in MSB and HSB. Fire prevention is hereafter mandatory to ensure the post- fire vegetation regrowth and to start storing C back in this ecosystem.

Soil resource as affected by different grazing management

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Grazing is the most extensive land use on the planet, occupying about 25% of land surface of the Earth. It could negatively impact the soil resource by altering its physical, chemical and biological properties and affecting its ability to provide key ecosystem services. Voisin rational grazing (VRG), worldwide applied in several grazing areas, could be a viable alternative to traditional grazing, as it could ensure a better balance in soil-plant-animal systems. VGR consists of fencing an area into several plots among which the animals are moved regularly, allowing soil and vegetation to recover between grazing intervals. This study evaluated, for the first time in Italy, the effects of VGR on soil biological, physical and chemical properties in a Southern Italy sheep grazing area.

Experimental design included a traditional grazing area (TG) and a VGR area, the latter divided into several plots, in each of which animals remained for 1-2 days. VRG area also included un-grazed plots. Within experimental area, we sampled soil in plots left by sheep from 10-14 days or from 77-

79 days, respectively, after one (VGR-I) or two (VGR-II) grazing shifts, in the un-grazed plot (UG) and in the traditional grazing area (TG). Soil samples were analyzed for microbial biomass, activity (soil potential respiration, N-mineralization and nitrification) and genetic bacterial diversity (as richness and Shannon index) and for water content, water-holding capacity, bulk density, pH, total and extractable soil organic C and mineral nitrogen content.

Results showed that application of VGR in plots did not cause adverse effects on soil compared with to UG plot, even a few days after the sheep left the plots. Indeed, slight positive effects were recorded on some soil properties compared to TG area. Further studies are needed to verify this trend over a longer period, including different areas and different livestock types.

Seasonal variations more than plant cover and fire drive soil nutrient balance

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Soil degradation is a human-induced process that compromises the functioning of terrestrial ecosystems. One of the main effects of soil degradation is the organic matter loss with consequences on soil nutrient balance. As nutrient balance is a proxy of soil quality and drives microbial activity, its maintaining is necessary. In Mediterranean areas, soil nutrient balance depends not only on climatic conditions and plant cover, but also on fire frequency and intensity. In this concern, to increase the current understanding of nutrient dynamics, the aim of the research was to assess the impact of seasonality, plant cover and fires on soil nutrient balance and consequent microbial activity. The study area is located in the Vesuvius National Park where in 2017 a wildfire occurred. Soil (0 – 10 cm) sampling was performed in Fall 2020 and Spring 2021 at 12 unburnt sites covered by trees (T_UB) and 12 unburnt covered by shrubs (S_UB), at 12 burnt sites covered by trees (T_B) and 12 burnt sites covered by shrubs (S_B). The C:N, C:P, N:P, N:K, P:K ratios were calculated to evaluate soil nutrient balance. Moreover, bacterial (Eub) and fungal (fungi) biomasses, microbial respiration, hydrolase (HA), dehydrogenase (DHA), β-glucosidase (β-glu) and urease (U) activities were evaluated. The non-metric multidimensional scaling (NMDS) highlighted a clear separation ($p<0.05$) of sites according to seasonal variation. In Fall, unburnt soils covered by trees separated ($p<0.05$) from the remaining soils; in Spring, unburnt and burnt soils covered by trees clearly separated by unburnt and burnt soils covered by shrubs. Soil nutrient balance affected soil microbial biomass and activity mainly in Fall regardless of plant cover and fire occurrence. In conclusion, soil nutrient balance as well as microbial biomass and activity were controlled by microclimatic conditions more than plant cover and fire.

Multiple threats to freshwater biodiversity in Central Italy detected through environmental DNA

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Biodiversity studies were revolutionized in the last decades by the development of environmental DNA (eDNA)-based approaches, that have been proven efficient in supporting traditional species monitoring. We implemented an innovative multi-species monitoring protocol aimed at the rapid detection of species occurring in freshwater bodies of Central Italy. The target taxa included some main threats to native biodiversity represented by six alien invasive species included in the EU regulation 1143/2014 (i.e., *Dreissena polymorpha, Orconectes limosus, Procambarus clarkii*, *Pseudorasbora parva, Lithobates catesbeianus, Trachemys scripta*), a transfaunated fish (*Padogobius martensi)*, and the pathogen a fungus *Batrachochytrium dendrobatidis*. Three liters of water were collected and filtered on 0.22 µm Millipore membrane using a vacuum pump, with two-time replicates (2021 and 2022) at 52 freshwater sites located in protected areas, Natura 2000 sites, or in the regional ecological networks (REL). DNA was extracted from filters using the Soil kit DNeasy PowerSoil Pro kit (Qiagen) and then amplified through quantitative PCR (qPCR) assay Species specific probes were validated *in silico*, *in vitro* (i.e., on positive tissue samples) and the operational environment (i.e., water eDNA extracts with confirmed occurrence of the target species). From one to three species were found at 22 sites over 52. All species except *Trachemys scripta* were detected at least at one sampling site, with detection rate ranging from 0.3% to 77% of sites. *Dreissena polymorpha* and *Padogobius martensi* showed the highest rates of detection (44% and 77% respectively), whereas *Lithobates catesbeianus* and *Batrachochytrium dendrobatidis* were detected at only one site (10% and 5% detection rate). Outcomes are discussed in terms of early warning and threats to specific endangered taxa.

Short-term microplastic exposure triggers cellular damage through oxidative stress in the soft coral *Coelogorgia palmosa.*

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Microplastics are a persistent and ubiquitous source of pollution in the marine environment, representing a severe threat to tropical coral reefs. The effect of microplastic on reef-building (hard) corals have been documented (interference with normal digestion process, polyp retraction, oxidative stress, impairment of the photosynthetic machinery, bleaching). However, the impact of microplastic on soft corals, the second most abundant benthos of tropical reefs, remains to be thoroughly studied.
In this work, we analysed the effects of a short-term microplastic exposure on the cellular physiology of the soft coral *Coelogorgia palmosa*. We found that samples exposed to > 50 mg L^{-1} of microplastic showed significant increase in the activities of the antioxidant enzymes: glutathione reductase, catalase, and superoxide dismutase, suggesting a raise in oxidative stress. Furthermore, exposure to microplastic increased lipid peroxidation, indicating oxidative damage. Overall, our results show that similar to hard corals, microplastic ingestion causes oxidative stress and cellular damage in soft corals. Our study provides a first assessment of physiological effects of microplastic exposure on the soft coral, *Coelogorgia palmosa*, highlighting the need for further investigations about these contaminants and their influence on marine benthic fauna. Such information is crucial to understand how different reef organisms respond to microplastic pollution and who the ecological winners or losers will be in an increasingly polluted marine environment.

How does plastic pollution influence primary productivity of large rivers? A study in the Lower Mekong River

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Once introduced into aquatic ecosystems, plastic debris undergoes rapid biofouling, resulting in the formation of a man-made ecosystem known as the 'plastisphere.' This plastisphere comprises various microbial communities, including bacteria, single-celled algae, and fungi. The impact of these plastic substrates and their associated epiplastic community on ecological processes and biogeochemical cycles has been largely overlooked. Although limited evidence exists, it has revealed potential processes that could affect ecological functioning. To address this knowledge gap, we conducted a study investigating the microalgal and bacterial communities thriving on plastic debris collected from three rivers in the Lower Mekong River Basin (Cambodia). We incubated different plastic polymers for 30 days and characterised the plastisphere community by high-throughput Illumina sequencing of the hypervariable V5−V6 regions of 16S rRNA gene and the V4-V5 hypervariable region of the 18S rRNA. We assessed chlorophyll-a concentration as an indicator of autotrophic organism biomass and examined the effects on ecosystem production (gross, respiration, and net) by measuring oxygen dynamics in light-dark bottle incubations. Additionally, we monitored changes in the chemical species of nitrogen, phosphorus, and organic carbon. Our findings revealed limited growth of the microalgal community and a dominance of the bacterial one, with populations predominantly consisting of organisms from the families Nocardiaceae, Comamonadaceae, and Rhodobacteraceae. We also identified the presence of potential bacterial pathogens. Across all sites, we observed the dominance of net bacterial heterotrophic activity, which led to a reduction in dissolved oxygen levels. These results suggest that plastic debris can have far-reaching effects, potentially altering metabolic traits within aquatic ecosystems.

Are the water-soluble polymers a new emerging concern? An integrated approach to evaluate their chronic effects on zebrafish embryos

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Water-soluble polymers (WSPs) represent a new class of emerging contaminants whose widespread use in several applications (detergents, single-use products, pharmaceuticals, personal care products and pesticides) inevitably facilitates their release into the environment. Despite their wide production and use, their environmental presence and concentration are still unknown and their behaviour in the environment and impact on the ecosystem remains unclear.
For this reason, the aim of this study was to evaluate the toxicity induced by three concentrations (1 µg/L, 0.5 mg/L and 1 mg/L) of the most commonly used WSPs (the polyvinylpyrrolidone (PVP), polyacrylic acid (PAA) and polyethylene glycol (PEG)) on *D. rerio* embryos exposed from 0 to 120 hours post fertilization –(hpf). As acute effects, we evaluated the daily mortality, while for the assessment of the chronic toxicity, we evaluated the alteration in the swimming performance, the heart rate, and a suite of biomarkers of oxidative stress. Besides, more in-depth measurements as proteomics have been assessed on the organisms exposed to the highest concentration of all the three WSPs (1mg/L) to investigate the effects at deeper level of the biological complexity and to define the possible mechanism of action of these WSPs.
The results regarding *D. rerio* locomotor performance, underlined PVP as the most effective WSP, since all the concentrations affected behavioural parameters as the total distance moved, the mean velocity and the mean mobility, while PAA seemed the less effective WSP. Even proteomics results confirmed PVP as the most harmful tested WSP for zebrafish embryos, as it modulated a greater number of proteins than the other two compounds, as well as determined significant variations in several endpoints as heart rate and the activity of antioxidants enzymes, confirming the suggested toxicity scale PVP>PEG>>PAA.

Occurrence of cocaine and its main metabolite in a Brazil coastal zone and sublethal effects of benzoylecgonine on the oyster *Crassostrea brasiliana*

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Many studies have identified the occurrence of cocaine (COC) and its main metabolite, benzoylecgonine (BE) in aquatic matrices in all continents, even the Antarctic. Brazil is considered a traffic route of cocaine to Europe and a large consumer of this drug. The input of those substances in the ecosystem may be a risk to the biota. The present study determined environmental concentrations of COC and BE in a subtropical coastal zone (São Vicente, Brazil) and exposed specimens of an oyster (*Crassostrea brasiliana*) to ecologically relevant concentrations of BE. Superficial water samples were collected and analyzed by LC/MS-MS. To evaluate the sublethal effects caused by BE, specimens of the oyster *C. brasiliana* were exposed for 7 days to three concentrations of the main metabolite of cocaine (0.02, 0.2 and 2 $\mu g.L^{-1}$) and two controls (water and solvent) in controlled laboratory conditions (photoperiod, salinity, dissolved oxygen and pH). Gills, digestive glands, muscle and hemolymph were collected and analyzed after 2, 4 and 7 days of exposure. DNA damage, lipid peroxidation (LPO), neurotoxicity effects (ChE) and lysosomal membrane stability (LMS) were evaluated. COC and BE were identified and quantified in all sampling sites. Cocaine ranged from 1.41 to 3.66 $ng.L^{-1}$ and benzoylecgonine concentrations ranged from 8.89 to 18.6 $ng.L^{-1}$. It was observed a significant decrease LMS between the treatments of BE and the two controls. It was not observed neurotoxicity effects or lipid peroxidation in the tested oysters. Although, it was observed an increase in DNA damage in the digestive glands of oysters exposed to BE compared to the controls. Our results suggested that the daily input of illicit drugs in aquatic ecosystems must be considered a threat to non-target organisms since BE may cause cytogenotoxic effects in a bivalve.

Soils of the Vesuvius National Park are highly resilient to fire: implication for conservation management.

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Fire dramatically changes the ground layer of Mediterranean vegetation in the short term, but the system is highly resilient and quickly recovers the pre-fire state. Soil conditions can be widely affected by fire passage depending on its intensity. The impacts of fire on soils are well known; by contrast, the dynamics to recover the physical, chemical and biological soil conditions are not yet fully clarified and can vary according to the pre-fire state and plant community. In the present research, the recovery of soils within the Vesuvius National Park (S-W Italy) after four years since fire passage was evaluated by the comparison of paired burnt and unburnt sites across four plant communities (*Quercus ilex* L. forests, *Pinus pinea* L. plantations, *Robinia pseudoacacia* L. stands and low Mediterranean maquis). Soil abiotic (bulk density, pH, moisture, organic matter, C and N contents) and biological (bacterial and fungal biomasses, microbial respiration, enzymatic activities and microarthropod richness and diversity) properties were measured, on three replicates, at each site using standard protocols. Results showed a recover of the pre-fire soil properties at all the tested conditions, clearly indicating high resilience of the local soils at relatively short term. The range of soil properties were linked to the plant community which however cannot fully explain the variability observed in some conditions, particularly in soils covered by *ilex* L. and *R. pseudoacacia* L. The multivariate ordination provided a more reliable picture of the studied soils. Accordingly, a subset of soils covered by *H. oak* L. and characterized by high chemical quality, microbiological diversity and functionality was highlighted as an important management target for conservation purpose; whereas, the remaining soils covered by *Q. ilex* L., not differing from soils covered by *R. pseudoacacia* L., could be more prone to invasion eventually fostered by fire.

Understanding the role of predicted acidification conditions on *Posidonia oceanica* seedling development

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As a result of the anthropogenic emissions, ocean acidification has been consistently evidenced to have profound impacts on marine biota, from single individual organisms to habitat-forming species. The effects of future increased pCO_2 conditions on seagrasses have received some attention worldwide, but the available evidence gained, however, is not always consistent. Moreover, responses of early life stages as seedlings are poorly understood. This study aimed at evaluating how projected Mediterranean Sea acidification under moderate-case and worst-case scenarios affect the survival, and then the morphological and biochemical development of *Posidonia oceanica* seedlings through a long-term field experiment along a natural low pH gradient in Vulcano Island (Aeolian Islands). Future ocean conditions seem to constrain the morphological development of seedlings: high pCO_2 exposures caused an initial increase in the degree of saturation of fatty acids in leaves and then improved the fatty acid adjustment increasing unsaturation levels in leaves (but not in seeds), suggesting a nutritional compound translocation. Results also suggested a *P. oceanica* structural components remodelling which may counteract the effects of ocean acidification but would not enhance seagrass seedling productivity. Overall, this study evidenced that seagrass responses to ocean acidification are not unidirectional and could depend upon species, in-situ characteristics and plant portion analysed. The need of further *in-situ* research, in combination with manipulative laboratory experiments that consider wider duration of exposure and range of pH conditions is needed to identify acclimation responses of *P. oceanica* seedlings to an incoming acidified Mediterranean Sea.

Molecular biomarkers to evaluate multiple stress to anthropogenic contaminants in fin whale and striped dolphin from the Ligurian Sea

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The fin whale (*Balaenoptera physalus*) and striped dolphin (*Stenella coeruleoalba*) living in the North-western Mediterranean Sea share an habitat exposed to multiple threats (e.g. marine litter, legacy and emerging contaminants, habitat disruption, maritime traffic). Being long-living and top predator species and species of ecological importance, it is necessary to evaluate their health status of wild populations to drive conservation measures. Molecular biomarkers based on the quantification of mRNA levels, as early warning signal, have been evaluated on skin biopsies of free-ranging fin whales (n=17) and striped dolphins (n=22) samples in the Pelagos Sanctuary. A set of genes involved in different biological processes, from energy metabolism alteration (e.g. FABP4, THRa, THRb, GR, PPARA) to exposure to endocrine disruptors and legacy and emerging contaminants (e.g. AhR, CYP1a, ER1, PPARG) have been evaluated by droplet digital PCR. The expression of the target genes has been analyzed to evaluate the interspecific differences in the response to stress, the intersexual differences due to the different ability of accumulating contaminants and according to the levels of phthalate esters (PAEs) measured in the blubber of the same individuals. The results show different expression profiles in the two species and a correlation among the PAEs load and the molecular up- and down regulation of the target genes. This study underline the need to evaluate a multiple set of diagnostic signal to have a more comprehensive picture of the exposure to anthropogenic stress of cetacean wild populations.

Microplastic retention in European flat oyster (*Ostrea edulis*): comparison between Adriatic and Tyrrhenian productive areas.

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Oyster farming produces seafood with high appreciated organoleptic properties. Indeed, as filter feeders, oysters consume phytoplankton and organic matter naturally available in the environment, making their production one of the most sustainable in terms of carbon recycling and sequestration. Nevertheless, due to their trophic ecology (based on passive and non-selective filtration of huge water volumes) oysters are highly susceptible to environmental stressors derived from anthropogenic activities. These organisms can retain microplastics (MPs) being considered as bioindicators of water-column contamination which represents a potential risk for human consumption. In this scenario, the aim of this study was to assess and compare the levels of MP retention in the European flat oyster (*Ostrea edulis*) from two different productive areas, one located in the Adriatic Sea and the other in the Tyrrhenian Sea. Potassium hydroxide at low temperature (25°C) was employed for the digestion protocol in order to avoid any damage to the integrity of the ingested MPs and the digestion efficiency resulted always higher than 96% (tissue dry weight/digested tissue dry weight). Further, the ingested MPs were soundly identified at a fluorescence stereomicroscope, after staining with Nile Red (NR). This technique allowed the comparison between MP retention in two different size class oysters from two distinct sea basins in terms of quantity (n. of MPs/gr dry weight; n. of MPs/individual) and characteristics (size and shape).

Does size matter? Seed screening trial to identify best-performing genotypes in *Posidonia oceanica*

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Posidonia oceanica is endemic to the Mediterranean basin, where it forms extensive monospecific meadows. Rapid environmental changes are causing irreversible regression of these valuable ecosystems, which highlights the need for immediate and effective actions, including strategies to increase their resilience to current and future stressors. Identifying best performing genotypes through phenotypes screening trials and manipulative selection experiments may be useful for increasing transplantation success and genetic variation of restored populations. Specifically, seed size and weight (s/w) are important traits for plant evolution and improvement. In this study we developed a simple and rapid visual and laboratory screening protocol on *P. oceanica* seeds to investigate if seed s/w are synthetic traits to identify genotypes with different heat tolerance (tolerant vs sensitive). For this purpose, *P. oceanica* seeds were individually weighed to classify them into two categories (small: below 33 percentiles and large: 67-100 percentile) and then germinated under common conditions. 5-month old seedlings were exposed to a thermal stress (31°C) for six weeks and their fitness, growth, survival and photochemical efficiency were analysed to test our hypothesis. In addition, at the end of the exposure, a subset of the seedlings was returned to control, non-stressful conditions for two weeks in order to determine their resilience. Preliminary results showed a high resistance of the younger life stages of *P. oceanica* to prolonged exposure to elevated seawater temperatures as evidenced by the very low mortality rate in seedlings belonging to both seed sizes. Despite this, differences in the fitness traits and biomass fractions of the two sizes were observed. This work represents the first attempt to define a screening test for identifying *P. oceanica* genotypes with significant tolerance to heat-stress, which can then be used in the future to improve performance under field stress conditions.

Intraspecific cell size variability in the marine diatom *Chaetoceros affinis* along a nutrient gradient

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The role of interspecific variability on the functioning of phytoplankton communities along environmental gradients has been well studied, while today still too little is known about the role of intraspecific variability, which may occur at an inter- and/or intragenotypic level.
Nine different genotypes of *Chaetoceros affinis* were incubated under different nitrate concentrations: first altogether and with another stably coexisting species, the coccolitophore *Emiliania huxleyi*, through a long-term community experiment (199 days); then individually, through a short-term plasticity experiment (7 days). A significant intraspecific variability in cell size of *Chaetoceros affinis* was detected in both the experiments. According to a trait-based perspective, while no correspondence was observed among the cell size and nitrate concentrations at the intergenotypic level, the biggest cells were detected at the highest nitrate concentrations at the intragenotipic level in the community experiment in the long-term. This drove an increase in *C. affinis* mean cell size and total biomass along the nitrate gradient. In the plasticity experiment, significant differences in cell size along the nitrate gradient determined important variations in cellular nutrient content and stoichiometry at both the inter- and intragenotypic level.
This work provides new findings on the intraspecific variability in phytoplankton morpho-functional traits and underlines the importance of considering this when phytoplankton responses to environmental changes are investigated.

Recovery of soil microarthropod community after six years since fire

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Fires frequently disturb the stability of terrestrial ecosystems in the Mediterranean basin. Microarthropod distribution in soil is linked to spatial heterogeneity of surface and to soil properties. Fires impact soil microarthropod community directly changing their biomasses and indirectly modifying the post-fire soil conditions. The studies about the capability of microarthropod community to recover the pre-fire state highlight controversial information as their dependence to the overall environmental characteristics. The present research aimed to evaluate the probable recovery of microarthropod community in burnt soils covered by *Quercus ilex* L. (holm oak). In order to achieve the aim, the microarthropods, extracted by soil cores, were identified and described for taxonomical attributes such as density, richness, diversity (H), evenness (E) and for functional traits such as body length, mouthpart type, pigmentation, presence of eyes and QBS-ar index. The soil cores were collected at six forest stands, 3 before (BF) and 3 after 3 (3y-AF) and 6 years (6y-AF) since fire. The results highlight that 9, 6 and 7 taxa of microarthropods were found in BF, 3y-AF and 6y-AF, respectively. Acarina and Collembola were the most abundant taxa in all soils. In burnt soils, the abundance of Acarina increased and that of Collembola decreased, as compared to unburnt soils. Coleoptera larvae, Diplopoda, Pauropoda and Symphyla disappeared in 3y-AF and recolonized in 6y-AF. Microarthropod density, richness and diversity increased in 3y-AF and in 6y-AF came back to the values in BF. In 3y-AF, the abundances of small microarthropods decreased and those of chewing, pigmented and with eye presence increased but, in 6y-AF they came back to the values in BF. It can be concluded that microarthropod community resulted stressed by fire after three years, but they recover the initial state after six years.

Characterization and variability of morpho-functional traits from two strains of a bloom-forming Anabaenopsis under varying nutrient conditions.

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Climate change is one of the main stressor facing aquatic ecosystems in recent years. The overlap of climate change with other factors, such as eutrophication, can have cascading consequences on each trophic level. Additionally, the direct or indirect consequences of the abovementioned stressors can favor the development of noxious phytoplankton species impacting the functioning of ecosystems and the provision of ecosystem goods and services. To increase knowledge on noxious phytoplankton species which are favored by exceptional climatic conditions and influenced by nutrient variability in Mediterranean transitional ecosystems, we conducted a growth experiment using two strains of Anabaenopsis (Cyanobacteria) from Santa Giusta Lagoon (Oristano Gulf, Mediterranean Sea). Selected morpho-functional traits were determined at the end of the experiment in 5 treatments with varying phosphorous and nitrogen concentrations. The two strains showed similar growth rates in each treatment. Both strains showed significantly higher growth rates in the Control and significantly lower growth rates in treatments with the most diluted phosphorus. Selected morphological traits showed significant differences between strains in each treatment. However, the two strains showed similar responses to treatments, i.e. the trichome morphological traits did not vary in the treatments whereas cell morphological traits in the Control were significantly different respect to nutrient-modified treatments. The intra-strain plasticity was greater for some of the traits and it was strain-specific for trichomes. Instead, cell plasticity was concordant between strains, i.e. lower plasticity for cell volumes and greater plasticity for length:width cell ratio. The observed results added further information on the Anabaenopsis ecology. More broadly, they constitute a useful base for further studies on the morpho-functional variability of phytoplankton. In fact, these aspects are now recognized as crucial in understanding the functioning of communities and ecosystems along environmental gradients.

Plastic monitoring in four rivers of Northern Italy: comparison between water and sediments

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Plastic pollution represents an emerging global problem and the continental area massively contribute (80 %) to the Ocean plastic impact. For these reasons, this study aimed to monitor the presence of plastics in both water and sediments of four tributaries of Po River (Ticino, Adda, Oglio and Mincio) also investigating the role of sediment composition, as grain size, water content and organic matter, in plastic retention. Samplings were performed in triplicate and floating plastics in water matrix were collected using plankton nets with 100 µm mesh, while sediment samples were obtained with a Van Veen grab. After plastic extraction with hypersaline solutions (sodium chloride for floating plastics and zinc chloride for sediments), the detected particles were quantified and characterized in terms of shape, size, colour and polymer, using a Fourier Transform Infrared Microscope System (µFT-IR). The main results highlighted a higher contamination in sediments than in water for all considered rivers, with significant differences ($p < 0.05$), in terms of plastic content, between water and sediments of Adda and Oglio river. In detail, we observed a predominant domestic contamination by polyester fibers in both water and sediments of Ticino and Adda, as well as in sediments of Oglio River. A different situation was obtained in both water and sediments of Mincio, as well as in Oglio water, where industrial polystyrene pellets were massively detected. Based on the obtained results, the sediments were the most contaminated matrices by plastics, probably due to the settlement of synthetic particle associated to their retention on the bottom of water body, while the water monitoring represents only an instantaneous picture of the performed sampling. However, no significant covariation was found between the number of plastics in sediments and the measured grain size.

Connectivity analysis of European hake spawning grounds under climate change scenarios

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The identification of connectivity hotspots in the marine environment provides important insights into the spatial distribution, dispersal, settlement, and development of the first life stages of many pelagic and demersal species in the ocean. In a scenario of climate change, mutating environmental conditions can alter these connections, resulting in modifications in the dispersal patterns of marine species. Understanding the potential consequences of these modifications is key to sustainable fisheries management. In this work, we carried out a connectivity analysis for the European hake (*Merluccius merluccius*) in the waters of the Adriatic and Ionian seas to explore the seascape connectivity of the species within the basin. Starting from Hake's juveniles density distribution generated with MEDITS data in the context of the Seawise Project (Horizon 2020), we ran backwards Lagrangian simulations to reconstruct spawning grounds and forward simulations to build a connectivity matrix. Then, we evaluated a set of network metrics to assess the role of different portions of the study area in the dispersal of early life stages. We ran three distinct simulations in as many time periods, representing respectively the current situation (2010-2019), near future (2040-2049) and far future (2090-2099), the latter two under two climate change scenarios (RCP4.5, RCP8.5). The results of our analysis show dense connectivity hotspots in the Adriatic Sea, with interesting differences on both latitudinal and longitudinal scale. We show that this methodology can provide insights into the spatial dynamics of demersal marine species and how changing environmental variables may affect their distribution in the future.

Impact of PCB re-emission from a contaminated agricultural area on terrestrial food chain biomagnification

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In the last few decades there has been a considerable interest in the management of chemicals to protect human health and ecosystems. Many directives and regulations have been issued at global, national, and regional level to reduce hazardous chemicals usage and emissions in the environment. More than twenty years ago, the Stockholm Convention entered into force to reduce and/or eliminate the discharge of Persistent Organic Pollutants (POPs), including Polychlorinated Biphenyls (PCBs). These chemicals were produced and used in many countries up to the early 1980s as dielectric fluids in capacitors and transformers, sealants, waxes, dedusting agents, printing inks, etc., and were then banned due to their persistent, bioaccumulative and toxic properties. Recently, global monitoring campaigns demonstrated that PCB concentrations in air are decreasing in most of the selected sampling sites, confirming the effectiveness of chemical regulation efforts. However, PCB re-emission from secondary sources (i.e., soils and landfills) still drives the current PCB air burdens in areas adjacent to contaminated sites, resulting in steady and/or slowly declining air concentrations. The aim of this study was to investigate the temporal variability of PCB air concentrations in the National Priority Site SIN Brescia-Caffaro. Here, more than 100 ha of agricultural fields were contaminated by the activities of Caffaro s.p.a that produced PCBs from 1930 to 1984. Leaf samples of several species were collected in 2013 and 2022 and used as passive air samplers. Data were compared to those measured in 2007 in the same area with a high-volume sampler and finally use to model PCB biomagnification in an agricultural (grass $\rightarrow$ cow) and in a wildlife (grass $\rightarrow$ birds $\rightarrow$ mammals) food chain. No significant PCB concentration reductions appeared in the last 15 years and the measured levels (thousands of pg/m^3) represent an important source for PCB grass uptake and subsequent biomagnification.

Focus on the Bramble Shark *Echinorhinus brucus* conservation status and first evaluation of possible sub-species presence

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The IUCN red list is constantly updated in relation to fishing pressure and climate change and new marine species are added to it. Despite conservation researchers are working hard to implement knowledge about them, the biology, ethology, reproduction, distribution or genetic structure of many species are still scattered. *Echinorhinus brucus* is a deep benthic shark evaluated as endangered species on which little information is available, particularly about its genetic variability. *Echinorhinus brucus* belongs to the Echinorhinidae family and its sister species is *Echinorhinus cookei.* The main morphological diagnostic character for these two species is the presence of denticles with different shape and pattern on derma. In 2014 in the Venezuelan Caribbean Sea, a shark identified as *E. brucus* by genetic markers presented intermediate denticles characteristics. Some COI sequences were downloaded from Bold System and five and four sequences attributed respectively to *E. brucus* and *E. cookei*. They were aligned with ClustalW and three phylogenetic analyses were conducted. The first one was a Maximum Likelihood analysis handled with default parameters, other two were Bayesian analyses handled respectively with relaxed and strict model. Apparently, Atlantic *E. brucus* sequences did not cluster with Indian *E. brucus* sequences and all analyses showed a similar topology, supported by high value nodes (more than 85%). On the contrary, Indian sequences clustered with *E. cookei* sequences and ML analysis shows a small distance between them. Our results confirm how still poorly known is the variability into *E. brucus* species and in Echinorhinidae family. In fact, despite the few individuals sequenced and only one genetic marker available, the evolutionary history of this group is controversial, suggesting that more data should be investigated for this species.

Life history traits responses of the lesser spotted dogfish S*cyliorhinus canicula* across a gradient of fishing disturbance

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The lesser spotted dogfish, *Scyliorhinus canicula*, is a demersal elasmobranch species widespread across the Mediterranean Sea, Northeastern Atlantic Ocean, North Sea and Irish Sea. Different populations may present different life history traits in response to various source of local and global disturbance. It is then crucial to study every population single-handedly to disentangle their ecological role and to assess their condition within the inhabited ecosystems. *S. canicula* is here reported as a relevant component of the bycatch fraction, accidentally caught by trawlers operating in the Central Mediterranean Sea, off the Southern Sicilian coasts, across the fishing ground encompassing Portopalo di Capo Passero and Malta. Even though the species is still poorly studied and not much is known about the biological information and ecological role of this population on both local and basin level. The lack of knowledge specifically salient in consideration of the high fishing pressure exerted on the study area, may generate concern to which our preliminary collation of evidence attempts to reply. The species seems to be quite resilient to the high fishing pressure, as recorded off the Iberian coasts in the Western Mediterranean, our evidence from life history traits (*i.e.* condition, diet and maturity indices) will be useful to build the missing knowledge baseline salient to address future monitoring and management plan and to complete the patchwork of this species into the Mediterranean basin.

Fuel exhaust PTEs and PAHs accumulation in coastal marine primary producers and their potential transfer along trophic webs

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Potentially toxic elements (PTEs) and polycyclic aromatic hydrocarbons (PAHs) are persistent and ubiquitous pollutants in marine ecosystems, where their sources are primarily represented by local fuel exhausts and inputs from the coastline, and where they tend to preferentially accumulate in sediments and biota. Indeed, the capability of several organisms, especially primary producers, to accumulate PTEs and PAHs from the environment, allows the transfer of such contaminants through trophic webs and, in several cases, their biomagnification. These outcomes have been consistently viewed as a major environmental and human health concern, due to PTE and PAH toxicity and their effects on biodiversity and ecosystem functioning.

To evaluate the potential input to marine trophic webs of both PTEs and PAHs mainly deriving from fuel exhausts (Fe, Cu and Zn, and phenanthrene and benzo(a)pyrene, respectively), we preliminarily investigated their distribution in sediments and in the main benthic producers, collected from six sites of the Cilento coast (southern Italy) differing in anthropogenic pressure. Over 57 species observed (1 Cyanobacteria, 16 Chlorophyta, 29 Rhodophyta, 9 Heterokontophyta, 2 Embryophyta), 18 species were analyzed (1 Cyanobacteria, 4 Chlorophyta, 6 Rhodophyta, 6 Heterokontophyta, 1 Embryophyta), according to their availability and abundance. Notwithstanding the different uptake mechanisms and phylogenetic position, the analyzed taxa showed comparable concentration ranges for most of the analyzed pollutants. Except for Fe, with the highest concentrations in sediments, all the contaminants were preferentially accumulated in the biota with concentrations up to one order of magnitude higher than those observed in sediments. In particular, the obtained results highlighted potentially hazardous concentrations, in relation to their availability to higher trophic levels, of Cu and Zn in Embryophyta, of phenanthrene in Heterokontophyta and of benzo(a)pyrene in Cyanobacteria, Rhodophyta, Heterokontophyta and Embryophyta.

Development of a new predictive index for estimating the potential effects caused by multiple stressors on coastal marine ecosystems.

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The potential effects resulting from climate-related impact drivers (e.g., heatwaves) and non-climate-related drivers (e.g., dredging) on protected habitats in the coastal marine environment of the Mediterranean Sea can be analyzed in detail through the use of an integrated approach that combines the results of numerical models and species-specific stressor tolerance curves obtained from ad-hoc mechanistic laboratory experiments. Specifically, the disturbance caused by increasing temperature and turbidity on the endemic Mediterranean *Posidonia oceanica* and coralligenous habitats adjacent to the port of Civitavecchia (located on the western coast of Italy) was analyzed. To assess the potential effects on these habitats, a new synthetic index called the MATTE (Multistressor hAbiTaT indEx) was developed, which takes into account the results of hydrodynamic models (SHYFEM) and sediment transport models (DELFT3D-WAQ), as well as the temperature and turbidity tolerance of the analyzed habitats. Low values of the index indicate a high probability of habitat regression due to global warming or unsustainable coastal activities (lack of mitigation measures such as an Early Warning System). Within the Renovate project, which is based on an ecosystem approach for compensation and mitigation actions in the coastal marine environment, the MATTE index was used to analyze the effects of dredging activities for the expansion of the port of Civitavecchia, as well as to differentiate the impacts on the same habitats caused by heatwaves affecting this coastal stretch. This index will contribute to the development of early warning systems and the design and implementation of risk assessment and management plans in coastal areas.

Thermal performance of *Holothuria tubulosa* (Gmelin, 1788), a suitable novel resource for Mediterranean aquaculture in a climate change context.

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Worldwide sea surface temperatures are continuously rising due to global warming, with drastic effects on the prevailing ecosystems. This is especially true for the Mediterranean Sea, considered a climate change hotspot, meaning it is exceptionally sensitive to the rising concentrations of greenhouse gases. Simultaneously overfishing is jeopardising natural fish stocks worldwide, with the Mediterranean Sea and North Atlantic representing the most drastic consequences. Integrated Multi-Trophic Aquaculture (IMTA), lining up with United Nations Sustainable Development Goals, promotes new advances in modern aquaculture. The concept is to create a simplified version of an ecosystem with its key components of different trophic levels to have the circulation of nutrients and prevent any nutrients and waste products to accumulate. Sea cucumbers are good candidates being deposit feeders capable of ingesting and processing organic byproducts, with a high market value. However, very often the choice of one species respect to another is mainly subject to individual performances. Given that temperature is the main factor driving biological processes, energy flows and biochemical reactions, this represent the main focus when studying individual performances. Here, accordingly, specimens of the sea cucumber *Holothuria tubulosa* were sampled to investigate their thermal performance and limits using respiration rates as a proxy of individual metabolism, testing 14 different temperatures, in a window between 8°C and 34°C. Experimental results identified a left-skewed curve, with a T_{opt} at 28.83 °C and a CT_{max} at 35.74 °C, classifying *H. tubulosa* as a thermo-tolerant species, living in the Mediterranean Sea near-to or below its thermal optimum. Specially in a context of climate change, information on species thermal thresholds may result as essential to feed mechanistic models aimed at evaluating the effect of a changing environment on species' Life History traits and their individual performances in an IMTA context.

Development of a behavioral test in the terrestrial oligochaetes *Eisenia* exposed to Per and poly fluoro alkyl substances (PFAS)

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Behavioral tests are considered a promising tool for ecological risk assessment and environmental toxicology. Their use can reveal direct effects on the nervous systems or sensory organs caused by different type of pollutant or mixtures. In recent years, successful behavioral ecotoxicological tests have been carried out on earthworms, indicating that the methodological approach may result particularly effective with this group of invertebrates. The avoidance behavior of earthworms is recognized as a valuable endpoint in the assessment of soil quality. The primary objective of this study was to standardize a behavior test using multiple locomotion variables to assess the behavior of earthworms (*Eisenia fetida*). The test aimed to evaluate the impact of three alternative PFAS congeners (HFPO-DA, PF4MOBA, PF3MOPrA) and PFOA, serving as a benchmark, across a concentration range of 0.6-229 microM through OECD Test No 207 contact exposure. The locomotion variables, including escape time, path length, speed, global activity, and immobility rate, were analyzed to investigate potential effects on earthworm behavior. Results indicate a significant impact of PFAS congeners on earthworm locomotion, with noteworthy dynamics observed for GenX and PFOA during the escape test, measuring the ability to withdraw from stressful situations. Compared to the well-known avoidance test, the behavior test employed in this study offers advantages by avoiding the limitations associated with the assessment of substance repellency. Instead, it provides a comprehensive evaluation of the earthworms' responses, avoiding potential biases related to intolerance or idiosyncrasy towards specific substances introduced into the soil. This behavior test holds promise as a valuable tool for assessing the behavioral effects of PFAS exposure in earthworms. The outcomes of this study hold promising implications for the development and standardization of a behavior test designed to assess neurotoxicity in terrestrial oligochaetes. And shed light on the suitability of utilizing earthworms as bio-indicators for neurotoxicity testing.

PFAS in *Parus major* eggs from different areas of Nord-East Italy

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Per- and polyfluoroalkyl substances (PFAS) are anthropogenic pollutants globally distributed. PFAS have raised increasing concerns in recent decades due to their persistence in the environment and toxicity to human and wildlife, birds included. Although some PFAS are regulated, the presence of their precursors and alternatives in the environment requires frequent monitoring. Wild birds are considered efficient sentinels of environmental contamination and bird eggs have been proven to be a good monitoring tool for assessing the presence and exposure to PFAS.
The aim of this study was to evaluate the PFAS levels in great tit (*Parus major*) eggs from areas characterized by different anthropogenic impacts. Therefore, during 2021 and 2022, great tit eggs were sampled from nest boxes installed in agricultural, urban and wooded areas of Nord Eastern Italy far from known contaminated sites. Eggs were freeze-dried and the extraction was performed by sonication with ACN/water mixture enhanced by salting out and acidification; extracts were purified on HybridSPE-Phospholipid to remove matrix suppression effects by phospholipids. Legacy and emerging PFAS were analysed by ultra-high performance liquid chromatography coupled with high resolution mass spectrometry (UHPLC-Q-Orbitrap).
The results allow matching anthropogenic impacts and levels of contamination, as well as to determine anthropogenic background levels due to diffusive pollution.

Graphene-Related Materials (GRMs) behaviour in reconstituted and natural freshwaters systems: when dispersion stability matters

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Thanks to their unique physicochemical properties, GRMs application in many innovative fields is rapidly increasing. The resulting widespread availability of GRMs-containing products could lead to unintended release of GRMs during their life-cycle with unknown consequences for the environment. GRMs dispersed in aqueous media tend to agglomerate and settle, changing their bioavailability. Therefore, this work aims to evaluate the environmental fate of GRMs by studying GRMs Dispersions Stability (GDS) in reconstituted and natural freshwaters. Turbiscan and Utermöhl sedimentation chambers were used to evaluate sedimentation and flow cytometric analysis (FCM) was used for agglomeration. The following factors affecting GDS were tested: particle (*i*) composition and (*ii*) concentration, (*iii*) medium composition, and (*iv*) presence of freshwater algae (*Raphidocelis subcapitata*). The effects of (*i*)-(*ii*) were tested using dispersions of few-layers graphene (FLG), graphene oxide (GO), and reduced GO (rGO) at 4-50 mg L^{-1}. The effect of (*iii*) was tested by comparing the GDS in distilled water, 5 commercial mineral waters with different ionic content, OECD TG201 medium enriched with Suwannee River Natural Organic Matter (SRNOM), and natural freshwaters from 9 water bodies in Friuli Venezia Giulia (NE Italy). Our results showed that FLG exhibited the fastest sedimentation rate, whereas GO was the most stable, independently of (*ii*). Regarding (*iii*), dispersions in media with high ionic content showed increased GRMs agglomeration and sedimentation. SRNOM especially increased the GDS of GO dispersions. Preliminary analyses on natural freshwaters revealed a decreased GDS in comparison to distilled water. Finally, (*iv*) had a negative effect on GDS by increasing the GRMs (hetero)-agglomeration. These novel GDS data will help to predict the fate of GRMs in freshwater environments and the behaviour of GRMs during standard ecotoxicological tests, an important factor for the correct interpretation of results and for a good implementation of current test guidelines and guidance documents.

Offshore wind farm development: a preliminary study on potential environmental impacts at the Island of Pantelleria

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Wind power is one of the fastest growing, most mature and most cost-competitive renewable energy technology. Nevertheless, even in locations with favourable conditions for wind integration, factors such as restrictive regulation, social unacceptance, as well as concerns about landscape alteration or negative impacts on ecosystems and biodiversity, hinder the deployment of new wind power plants. Thus, in order to facilitate the spread of this emerging energy technology, one of the objectives of the Wind In My Backyard project is to understand and find ways to assess the cumulative environmental impact of offshore wind farm (OWF) in Europe. To carry out assessment of OWF localised impacts, Pantelleria Island was selected as one of the pilot cases. Pantelleria is a small volcanic island with high potential for variable renewable energy production due to its location in one of the windiest Italian areas. The present ongoing study is divided into two phases; during the first phase data on Good Environmental Status quality descriptors included in the Marine Strategy Framework Directive (2008/56/EC) have been collected and reported in georeferenced maps. During the second phase levels of impact expected from the OWF developments will be evaluated and mapped. The results of the first phase will be reported, showing the extent to which OWF installations in the pilot area may affect particularly vulnerable marine species (e.g. marine mammals, sea turtles, seabirds) and pre-existing anthropogenic activities such as shipping and fishing. The second phase of the study will allow us to bring together all the information we have collected and to produce a comprehensive assessment map of the study area to estimate the potential impact of the OWF. Consideration will also be given to how environmental decision-making and management, including mitigation and adaptation measures, can support the coexistence of OWF, the natural environment and anthropic activities.

Macroplastic contamination on different hiking trails in the Stelvio National Park

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Plastics are synthetic organic polymers playing an irreplaceable role in everyday life. However, their massive use has often led to improper management and disposal and, consequently, to their widespread accumulation in the environment. Plastic items of both macroscopic (i.e., macroplastic) and microscopic (i.e., microplastic) size are commonly found in any ecosystems, including aquatic and terrestrial ones, as well as in remote areas such as high-mountain, glacier and polar ecosystems. However, the information on the presence, distribution and sources of plastic contamination in high-mountain areas is limited. The present work aims at investigating the distribution of macroplastics along some hiking trails in the Stelvio National Park (Northern Italy). In August 2021, macroplastics were sampled along 8 transects grouped in two different categories depending on the amount of tourists (i.e., high-frequentation and low-frequentation trails). The collected macroplastics were categorized according to their weight, size, type and polymer composition. Macroplastics were detected on all the transects for a total number of 289 macroplastics. As expected, the abundance of macroplastics decreased as the distance increased from the starting point of the trail. Contrary to our expectations, no difference in abundance of macroplastics was found between high-frequentation and low-frequentation trails. The most of macroplastics were attributable to food packaging and mountain equipment. According to the polymer composition of the identified items, polyolefin such as polyethylene (PE), polystyrene (PS) and polypropylene (PP) were the most abundant polymers contaminating hiking trails. These results suggest that the presence of macroplastics on mountain trails is mainly due to their voluntary or inadvertent release of the hikers visiting the park every year.

Adaptive mechanisms to emerging contaminants by aquatic organisms from brackish ecosystems

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In the recent years, great concern has raised on the ecological impact caused by the discharge of a variety of pollutants into the environment. In particular, due to their widespread use, plastics are widely released into the aquatic environment, where they undergo degradation processes leading to the generation of microplastics (MPs), highly persistent and hazardous to biota. Among the different ecosystems, the aquatic environments, and particularly the brackish ones, appear to be highly sensitive to the release and accumulation of MPs. Therefore, the biological impact of polystyrene MPs, one of the most common MPs detectable in aquatic environments, was herein assessed on gills and posterior adductor muscle (PAM) of mussel *Mytilus galloprovincialis*, a filterfeeder species of high ecological and commercial relevance from brackish areas, by a short-term exposure of 3 days. After measuring the differential time-dependent uptake and accumulation of MPs in the two selected mussel tissues, their related biological effects were evaluated by a multibiomarker approach, including histological, biochemical and metabolomic tools, at three daily sampling times (24 h, T24; 48 h, T48; 72 h, T72). A MP-induced time-dependent hemocyte infiltration was detected, especially on gills, as well as alteration of several biological pathways (i.e., antioxidant defence system, osmoregulation, cholinergic neurotransmission and energy metabolism) as adaptive mechanisms to MP insult triggered in mussels. Therefore, the results achieved to date point out the ability of aquatic mussels to elicit early biological responses when challenged by MPs already at the initial phase of exposure, enabling a deeper knowledge of the cellular pathways involved during the interaction with this class of emerging contaminants. Overall, all these findings provide useful information for a better preservation of these peculiar brackish ecosystems.

Effects of altered nutrient conditions on the physiological performance of the endangered *Fucus virsoides*

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Fucus virsoides J. Agardh is a glacial relict endemic to the Adriatic and the sole representative of the genus in the Mediterranean region. Once widespread from northwestern Italy to southern Albania, this intertidal species has experienced a dramatic decline in recent decades due to the cumulative impact of multiple stressors. Accordingly, with only a few remaining populations, *F. virsoides* has been classified as Endangered by UNEP and it is threatened with extinction.
The reduction in phosphorus (P) loading from its primary freshwater source, coupled with the implementation of Italian legislation, has resulted in an increased ratio between nitrates and phosphates in the area (N:P ratio). This has led towards oligotrophic conditions, which might be unfavorable for the macrophytes metabolism. In the Gulf of Trieste, the last population of *F. virsoides* is located at Marina Julia (Gorizia, Italy), where it faces a wide range of extreme conditions. To investigate the effects of nutrient conditions on physiological traits, we queried the EMODnet database for historical nutrient data in the region and selected different N:P ratios to cultivate fronds of *F. virsoides* in controlled mesocosms. A two-week experiment was conducted, in which we measured chlorophyll fluorescence every four days to assess photosynthetic performance in vivo. In addition, we used photo-respirometry techniques to record the metabolic rates of *F. virsoides*, under both light and dark conditions.

Neurotoxic Effects of Legacy and Alternative PFAS on Earthworm Neural Systems

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New generation Per and polyfluoroalkyl substances (PFAS) often contain one or more ether groups in their chemical structure to reduce persistence in the environment and potential bioaccumulation in biota. However, very little is known about their toxicological properties, which is why they are also referred to as "poor data" PFAS.This study investigated the neurotoxic effects of PFAS on earthworm neural systems, with potential implications for the human nervous system (NCS). Utilizing four PFAS congeners (PFOA, GenX, PF4MOBA, PF3MOPrA) across a concentration range of 0.6-229 microM, we assessed the impact on the main inhibitory and excitatory neural pathways in *Eisenia foetida* muscles which are known to express genuine gaba-a and nicotinic acetylcholine receptors. Neurotransmitter levels were measured in SN10 tissue extracts by means of High-resolution LC-MS/MS analysis in a Thermo Scientific Vanquish UHPLC system coupled to a Q-Exactive mass spectrometer interfaced with a heated electrospray ionization source and a hybrid quadrupole-orbitrap mass analyzer. The mass spectral data for quantitation were acquired in PRM mode according to an inclusion list. Our results showed that GenX, as well as PFOA affected the level of gaba-a at both low and high concentration levels (respectively 0.6 and 229 microM) and in same time increased those of acetylcholine. GenX also affected the level of serotonin and PFOA those of its precursor tryptophan. PF4MOBA showed similar results, but they were not always significant at all concentrations. Acetylcholinesterase activity (AChE) was consistent with results found for the neurotransmitter being inhibited by the three compounds. The full set of molecules (nearly 50) is currently ongoing and will complete the big picture of PFAS neurotoxicity in oligochaetes. Our findings clearly demonstrated a significant impact of these PFAS compounds on the earthworm neural systems. Moreover, the study provides valuable insights into the potential harmfulness of these compounds on the human NCS, suggesting the importance of considering PFAS as emerging neurotoxicants. These results contribute to the understanding of PFAS neurotoxicity and its potential effects on broader ecological and human health perspectives, warranting further research and consideration within the neuroscience community.

Soil microbial community functions across different land use types in the area of Matese National Park

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The different land uses are the result of the interaction between anthropogenic activities and natural factors. Stresses related to land-use can reduce the capability of ecosystems to sustain soil health, leading to a decrease in soil biodiversity and a degradation of soil ecological functions. The aim of the work was to evaluate the response of soil microbial community potential functions to different land uses. Therefore, we choose adjacent areas in the Matese National Park under different land uses: forest, crop and pasture. Water content, pH, organic matter content and enzymatic activities (hydrolase, β-glucosidase, phosphatase and β-glucosaminidase, arylsulfatase, laccase) have been analysed on topsoil samples. The results show lower values of enzymatic activities in disturbed soils than in undisturbed forest soil: β-glucosaminidase and arylsulfatase activity significantly differ among land uses with values in crop<pasture<forest soils; while phosphatase and laccase was significantly lower only in crop respect to forest soil. Higher soil enzyme activity in pasture and forest can be attributable not only to the positive impacts of vegetation but also to the lack of soil tillage. Agricultural management practices constantly disturb the soil and the removal of the litter layer limits the supply of substrate for the microorganisms, thus reducing the enzymatic activities. Soil biological and biochemical properties are sensitive to environmental stress and can be used as an indicator of the impact of land use on soil health.

Presence of pharmaceuticals and other emerging contaminants in different substrates used in agriculture as fertilizer

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Sewage sludge is a typical by-product of our society, and its reuse in agriculture is potentially an ideal solution for its disposal. The application of sludge and other biosolids on overexploited agricultural land can bring great benefits due to their content of organic carbon, nitrogen, phosphorus and micronutrients. However, great attention must be paid to their potential adverse effects due to the presence of several classes of emerging contaminants (ECs), such as pharmaceuticals, including antibiotics, personal care products and perfluoroalkyl compounds. Several ECs coming from people's daily life, agricultural and industrial activities are detected in wastewater and sludge. The aim of this study was to investigate the presence of about 40 ECs in different substrates (sewage sludge, compost, digestate, pig and cow manure) and to assess whether their application in agriculture poses a threat to the terrestrial ecosystem and human health. This was done by analysing ECs presence in earthworms (*Eisenia andrei*) and lettuces (*Lactuca sativa*) grown in soil mixtures containing the different substrates. The analysis of the ECs was performed by liquid chromatography-tandem mass spectrometry (HPLC-MS/MS). The results showed different profiles of contamination in the different substrates investigated, with prevalence of fluoroquinolones, antibiotics for human use, in sewage sludge and of veterinary antibiotics in manure. Some antibiotics and plasticizers were found in *Lactuca sativa*. The input of ECs into agricultural lands through the application of these substrates can create a stressful condition to the terrestrial ecosystems. Particularly, the presence of antibiotics promotes the spread of antibiotic resistance, a serious threat for human health. This study improved information on ECs presence in sludge and manure and on uptake in lettuce with the overall goal to convert a potentially risky practice such as the application of biosolids in agriculture into a safe process of circular economy.

Can macroplastics affect riparian vegetation blooming and pollination? First observations from a temperate South-European River

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Since plastics are a growing global concern that persists in nature, they threaten ecosystem conservation and human health. Although research on plastics focused on marine and freshwater ecosystems, riverine and riparian habitats received less attention notwithstanding rivers are major carriers of plastics to the sea. As interactions between plastics and biota or ecosystem services remain neglected, our achievement was a first attempt to assess the effects of macroplastics on riparian vegetation and the ecosystem service of pollination. Here, (i) while investigating macroplastics entrapped by riparian vegetation, (ii) we propose the new field observation of the flower's coverage by macroplastics. Then, (iii) we indirectly assessed the possible interaction between macroplastic litter and the ecosystem service of pollination. Finally, (iv) we performed a meta-analysis search to understand better how many studies were carried out on this topic. To achieve our aim, surveys of riverine macroplastic litter entrapped in riparian vegetation were carried out in the urban tract of the Aniene River. To assess if pollination was possibly reduced by macroplastics covering flowers, we observed the visitation of pollinators on flowers. Overall, we observed that flowers of riparian vegetation were covered by macroplastics, preventing them from being pollinated by insects, and successful pollination was potentially reduced to 81.4% by a factor of 18.6%. Our research highlights for the first time that macroplastics on vegetation indicate a new stress to plant reproduction, reducing blooming (i.e., flowering or flower production) and potentially pollination. These recent observations urge new studies to evaluate how macroplastic litter accumulates and might affect ecosystem services in long-term research. Given that most global food crops depend on pollination by insects, crops, and fruits (e.g., coffee, cocoa, apples), our findings could be of particular concern as pollination in agricultural crops and riverine habitats is central to human welfare as ecosystem service.

Unravelling the actual role of soil-drilling engineers at a continental scale: biogeography of earthworms across European agroecosystems

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The resources that we can obtain from the soil are huge and more and more studies are involving the soil biome itself. Earthworms play a key role in its maintenance by grazing activity and active soil engineering are making goods and services available aboveground. Hence, understanding their distribution based on ecological and geographical factors could be useful to better assess soil sustainability and edaphic responses to intensive agriculture and climate change

Among the issues on which researchers are most focused, there are the patterns of distribution of earthworms globally, or in any case wider, considering pedoclimatic conditions. Therefore, the aims of the following study are: analysing the relationships of biodiversity and earthworm abundance according to FAO soil types and different soil management systems; underlining the relationship in terms of biodiversity and abundance of earthworms on longitudinal and latitudinal gradients in different European sites; evaluating how overlooked the environmental legal provisions of the 2030 Agenda are and how critical their implementation for the Green Deal is.

We show here the extent to which environmental factors have an impact on the community composition and the distribution of earthworms in Europe. As a matter of fact, the excessive use of pesticides and fertilizers lead to an increase of earthworms' abundance, while tillage can lead to a reduction of earthworms in annual croplands, but not in perennial croplands. Differently, geographical factors do not explain their distribution variation aside of a weak negative linear correlation between biomass and latitude in sites with intensive pesticide use, and a positive linear correlation among abundance and longitude/latitude in sites without pesticide use.

Thermal performance of the purple sea urchin *Paracentrotus lividus* (Lamarck, 1816).

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Climate change generates side-effects with direct and indirect ecological repercussions that are often difficult to predict. Among main ecological side-effects at local level, community compositional shift is one among the most difficult to predict. An example is the case of the shift from a seagrass-dominated to an algae-dominated state where multiple effects due to climate and local biotic interaction factors such as grazing due to the sea urchin's action usually drive the transition from high- to low complexity habitats. While this kind of shift is well-investigated in the Mediterranean Sea, mechanisms driving it are less known as those driven by functional traits dealing with the species-specific thermal performances. Temperature indeed drives all activities at individual level including the strong link between metabolism and feeding (grazing) rates. Thus, investigating the species-specific thermal window of grazers involved in the ecosystem shifts illustrate the role of temperature in ecological processes, increasing our ability to predict ecosystem shifts under current increasing temperature. Here, thermal tolerance of purple sea urchin *Paracentrotus lividus* was investigated and specimens of *P. lividus* were sampled from Sicilian subtidal sites and 19 different temperatures, between 8°C and 37°C, were tested, using respiration rates as a proxy of individual metabolism. *P. lividus* showed a left-skewed curve, with a T_{opt} at 29°C, classifying *P. lividus* as a thermo-tolerant species, by now living in the Mediterranean Sea very often near-to or over the measured thermal optimum. Such a basal functional information may result crucial when assessing and predicting the role of grazers in reversing the ecosystem state as provides the extent of the thermal field of action of grazers under the current increasing temperature of water masses in the Mediterranean Sea.

Immunotoxic Effects of Legacy and Next-Generation PFAS on Earthworms: Insights for Environmental Regulation and Health Assessment

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Emerging pollutants, including per- and polyfluoroalkyl substances (PFAS), pose serious hazards to the environment and ecosystems due to their persistence, potential carcinogenicity, and high bioaccumulation rate. PFAS are detected in various environmental matrices, underscoring their mobility and persistence in the environment. Earthworms, especially *Eisenia fetida*, are widely used as bio-indicators of soil contamination in standardized laboratory and field tests, making them ideal for assessing the effects of PFAS exposure. This study aimed to investigate the impact of four different PFAS congeners, including legacy PFAS PFOA and three perfluoroether carboxylic acids (GenX, PF4MOBA, PF3MOPrA), on immune system cells (coelomocytes) of sexually mature earthworms. The exposure range was 0.6-229 microM, and the contact test followed OECD Test No 207 guidelines for 72 hours to assess immunotoxic effects. To characterize immunotoxic responses, we evaluated morphometric alterations (Area, Perimeter, and AP-ratio) of coelomocytes, hemocyte oxidative burst, and RNA relative abundances of antimicrobial peptide lysein, lumbricin and celomic cytolytic factor-1 (ccf-1). A combination of microscopy (including fluorescence microscopy), cytofluorometry, and molecular techniques facilitated the assessments. The results revealed a significant impact of PFAS congeners on both cell-mediated and humoral innate immune functions in earthworms. Most notably, there was a drastic decrease in the number of immunocompetent cells (amoebocytes) showing oxidative burst, accompanied by changes in morphological parameters of these cells, particularly in response to the alternative congeners. The gene expression data also suggested potential impairment of immune-related responses in earthworms exposed to perfluoroether compounds.These findings contribute to a deeper understanding of the mode of action of legacy and next-generation PFAS compounds and have implications for potential regulatory measures at national and European levels. This study sheds light on the immunotoxic effects of PFAS exposure in earthworms, supporting further research to protect ecological health and contribute to the advancement of environmental regulations.

Inside the wood: new data on marine borer from the central Mediterranean Sea

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In the marine environment, associations among species of different taxa are quite frequent. The most abundant ones concern mutualistic relationships, with one of the most emblematic examples in the associations among cleaner fishes and their hosts. In marine and brackish waters, we can find several species of invertebrates that burrow into wood, damaging it. These species are known as "marine borer" and belong to the phyla Mollusca and Crustacea. In particular, they include species of xylotrophic organisms such as Bivalvia (Teredinidae and Pholadidae), Isopoda (Limnoriidae and Sphaeromatidae), and Amphipoda (Cheluridae). In European waters, the most common wood-boring bivalves belong to the Teredinidae family; while wood-boring Crustacea belong to the Limnoriidae and Cheluridae families. The presence of Teredinidae, commonly known as "shipworms", can cause heavy economic damage on maritime structures. Recent studies estimated that in Europe the economic loss due to their activities is of the order of millions of euros per year. In this study we present preliminary data on different marine borer species, with particular emphasis on Teredinidae and associated fauna, essentially composed by Isopoda (Limnoriidae) and Amphipoda (Cheluridae). Specimens were obtained from wood pieces collected in two different areas of the central and southern Ionian coast of Sicily: Catania and Marzamemi. A quali-quantitative analysis was conducted and they emerged clear differences: the associated wood species collected at Catania were four (belonging to the following taxa: Teredinidae, Limnoriidae, Cheluridae and Copepoda), versus the only species of Teredinidae collected at Marzamemi. The study of ecological factors and spatio-temporal variations determining the community associated to wood is of fundamental importance to open new scenario and potential tools for biological monitoring. For example, the species composition, abundance and time of colonization among different areas could be used as a tool to indicate specific ecological and anthropogenic conditions of water masses quality.

Physical and molecular impact of environmentally relevant microplastic exposure on thermally challenged *Pocillopora damicornis* (Cnidaria, Scleractinia)

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Microplastic pollution is an emerging threat to coral reefs, which are already challenged by global warming. It has been demonstrated that scleractinian corals ingest microplastics. However, little is known about the egestion of microplastics by corals and how microplastics impair corals at physiological and molecular levels. In addition, the effects of microplastic pollution, at current *in situ* concentrations combined with thermal stress, on these organisms are poorly studied. In this study, the combined effects of these two environmental threats, on *Pocillopora damicornis,* an ecologically important reef-building species, was investigated. *Pocillopora damicornis* colonies were exposed to different concentrations of polyethylene microbeads; (1) an environmentally relevant level (1 mg/L) and (2) a high concentration (10 mg/L) which represents a possible future microplastic concentration. *Pocillopora damicornis* was exposed to these two microplastic concentrations for 72 hours at ambient temperature (25 °C) and at an elevated temperature (30 °C). Results show that at the environmentally relevant microplastic concentration, microplastic beads adhered to *P. damicornis* colonies, were ingested, but were also egested by the colonies. Thermally stressed colonies egested more microplastic beads at high microplastic exposure. At both experimental microplastic concentrations used, no increase in physical signs of stress was observed after 72 hours of exposure whether in thermally stressed or non-thermally stressed coral colonies. However, at cellular and molecular level, stress responses were observed. Exposure of thermally stressed *P. damicornis* colonies to the environmentally relevant microplastic concentration led to coral bleaching, as indicated by a significant decrease in chlorophyll (*a*, c_2) and Symbiodiniaceae density. An increase in oxidative damage and expression of stress response genes, *hsp70* and *cas3* was also observed. Results suggest that thermally challenged coral colonies were more impacted by microplastics compared to non-thermally stressed colonies. This study highlights that while mitigating ocean warming remains of uttermost importance to conserve coral reefs, managing the emergence of new threats such as microplastic pollution is also essential.

Perfluoroalkyl substances (PFASs) in food webs: a state-of-the-art review

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Perfluoroalkyl substances (PFASs) are emerging contaminants that have been introduced by anthropogenic activities since the 1950's. PFASs are persistent in the environment and can be subdivided in short-chained and long-chain congeners; the latter have raised considerable attention in the last decade, since they have been repeatedly indicated to accumulate in food webs. In this review, we searched the published literature on long- and short-chained PFASs with a focus on their transfer in trophic networks. We aimed at summarizing the available information on the different behavior of congeners, identifying at the same time potential geographical bias and knowledge voids in the type (e.g., grazing/detrital, or marine/freshwater/terrestrial) of food webs investigated. The results confirmed that long-chained PFASs have a higher rate of bioaccumulation and bio-magnification in living organisms. Most of the studies were carried out in aquatic ecosystems (marine, and to a minor extent freshwater), where bioaccumulation has been demonstrated for only a reduced set of long-chained PFAS congeners. In general, research efforts have been performed mainly in polar and temperate regions, while very little is known for tropical regions, where their peculiar climatic regime and other environmental factors might play a role in regulating the transfer of these contaminants in trophic networks. Terrestrial ecosystems are still under-explored and information about PFAS dynamics in their food webs is limited and patchy. In conclusion, our review identified a number of important aspects that have remained to date overlooked or inadequately explored, prompting for additional and more systematic investigations focused on the tropho-dynamics of these emerging contaminants and in particular of short-chained PFASs.

Thermal performance and thresholds of the interaction between the sea anemone *Paranemonia cinerea* and *Cymodocea nodosa* in a Mediterranean coastal lagoon.

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Biotic interactions drive key ecological and evolutionary processes and mediate ecosystem responses to climate change. At the same time, climate change can alter the direction, the frequency and the intensity of biotic interactions. The purpose of the current study is to measure the thermal tolerance limits as a proxy of functional response of major elements of a lagoon benthic community. Specifically, here we measured the joint thermal performances of two Mediterranean lagoon interacting species complex: the structuring phanerogam *Cymodocea nodosa* and its epiphyte, the sea anemone *Paranemonia cinerea* in mutualistic association with the zooxanthellae *Symbiodinium*. Respiration rate, oxygen production and photosynthetic performance traits were used as proxy of metabolism and were measured at 14 different temperatures (from 8°C to 36°C). *Cymodocea nodosa* Thermal Performance Curve (TPC) showed a wide thermal window with an optimum temperature at 27.5°C and an upper critical limit (CTmax) over 40 °C, highlighting the potential ability of the species to acclimate and adapt to increasing temperature scenarios. *Paranemonia cinerea* TPC showed a left skewed trend (typical of a warm-tolerant species), with a thermal optimum identified around 31°C with a metabolic peak (CTmax) at 36.5°C. Along with the change of metabolic traits, a change in the morphological traits (bleaching and mucus production) was measured around 32 °C showing a stressful response after the optimum. *Symbiodinium* instead had a lower optimum and CTmax (28.6°C and 31.1°C respectively) with a decrease of photosynthetic performance at higher temperature (i.e. an impairment of symbiotic photosynthesis function) which was coupled with a bleaching phenomenon. Understanding the complex interplay between climate and biotic interactions is crucial to predict how ecosystems will respond to the fast rates of current warming and how biotic interactions may change over time.

Integrating GIS mapping and water quality assessment: An ecohydrology perspective

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The interlinkage between hydrological processes and water-related ecosystem services represents a fertile research area much needed to counteract the effects of an increasing climate instability and related threats to human and ecosystem health. The Ecohydrology framework combines the study of the ecological relationships among living organisms and their physical environment with hydrological concerns about water quality, quantity, location and timing. In this study, we apply an ecohydrology perspective to assess water quality in the upper part of the Ofanto river basin (Campania region, Southern Italy). In particular, a territorial survey was firstly conducted by collecting and integrating GIS data and thematic maps, also identifying potential sources of contamination. Subsequently, chemical-physical, microbiological, and ecotoxicological analyses were conducted to characterize water and sediment quality of the watercourses receiving discharges from wastewater treatment plants as well as runoff from agricultural lands. The chemical analysis showed a good water quality, complying with regulatory limits, while the microbiological analysis revealed high values of faecal indicators. Ecotoxicological tests were performed using a battery of assays with organisms belonging to different trophic levels: bacteria (*Vibrio fischeri*), algae (*Raphidocelis subcapitata*), and crustaceans (*Daphnia magna*). The ecotoxicological assessment identified biostimulation and toxic effects in both water and sediment. Results highlighted how this type of integrated assessments are much needed for a comprehensive assessment of water quality to determine the suitability of water use for recreational and irrigation purposes.

The resilience of the bioconstructor *Lithophyllum stictiforme* to mechanicaldamage under the current and future climate scenario

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Marine benthic habitats in coastal areas are increasingly impacted by local and global stressors. Their combined effects may act synergistically or antagonistically influencing all types of marine communities and unequally impact habitat-forming species such as Crustose Coralline Algae (CCA) that are ubiquitous component in many benthic habitats and play a crucial ecological role by contributing significantly to their structural complexity and diversity. Taking advantage of the natural temperature differences between two depths (35 and 15 m) during water stratification period and considering them proxies of two climate scenarios (current and future), a manipulative field transplant experiment was conducted to examine the combined effects of a mechanical damage and warming on a crucial foundation species of the Mediterranean Sea, the CCA *Lithophyllum stictiforme*. A significant effect between mechanical damage and warming on the growth angle of the thalli was detected while no interactive effects on the other biological traits ofthese algae were observed. Overall, our findings highlight a good response to both stressors considered, especially to warming while mechanical damage reduces algal growth in both scenariosconsidered. These results confirm the key role of the management in benthic habitat protection in both current and future climate scenarios.

First characterization of potentially noxious marine epiphytic Cyanobacteria in Sardinia

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Temperature increase due to climate change and the nutrient anthropic input are causing significant changes in coastal marine areas. These new conditions have been proven to be particularly favorable for Cyanobacteria and reports on their development are increasingly frequent even in pelagic and benthic marine ecosystems. Several recent studies are focusing on marine epiphytic Cyanobacteria, identifying new species forming extensive blooms and discovering numerous secondary metabolites, including some powerful toxins that can be bioaccumulate and transferred via aquatic food webs also to terrestrial biota. Following reports of poisoning in dogs at beach areas in Sardinia (Torregrande beach, north-western coast) we hypothesized a potential role of epiphytic Cyanobacteria in these events. This study started with a preliminary sampling in September 2021, with a second sampling conducted in September 2022. During the samplings, *Cymodocea nodosa* bundles were taken from the first meters from the shore. Subsamples observed under the inverted microscope revealed a dense cover of filamentous Cyanobacteria on leaves and sheaths. Individual filaments were then isolated and cultured. The 2022 isolations in solid medium SWBG11 allowed the culturing of a strain that was maintained in salinity conditions of 38 PSU, with a temperature of 22±1°C, under a light:night cycle of 12:12 and an irradiance of 100 µmol photons $m^{-2}s^{-1}$. The culture belonged to Oscillatoriales and preliminary data were obtained for morphology and genetic, representing the first information on this topic from Sardinian coasts. Further future investigations will concern the determination of toxins to verify the hypothesis of a link between the poisonings of dogs recorded in Torregrande beach and the role of marine epiphytic Cyanobacteria.

Enzymatic Responses in *Eisenia fetida* Exposed to PerFluoroEther Carboxylic Acids (PFECA) and Perfluorooctanoic Acid (PFOA) via OECD Contact Test No. 207: Insights into Oxidative Stress, Neurotoxicity, and Immune Response

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PerFluoroEther Carboxylic acids (PFECA) such as GenX, have gained attention as potential alternatives to legacy perfluorooctanoic acid (PFOA) due to their distinct properties useful in industrial processes such as emulsion catalysis of polytetrafluoroethylene resins. This study investigated the enzymatic activities in *Eisenia fetida* exposed to three alternative PerFluoroEther Carboxylic acids (PFECA) and Perfluorooctanoic Acid (PFOA) using OECD Contact Test No. 207. The enzymes studied in earthworm tissues were Catalase, Cu/Zn Superoxide Dismutase (SOD), Acetylcholinesterase (Ache), and Phenol Oxidase. The findings revealed significant differences in enzymatic responses. Catalase activity was induced by all PFECA, indicating potential antioxidant response activation. In contrast, PFOA did not elicit a similar response. PFECA exposure led to SOD inhibition, suggesting possible neurotoxic effects, while PFOA had no impact on SOD activity. PFOA, GenX and MOBA inhibited Ache at low levels, raising concerns about potential neurotoxicity. Phenol Oxidase activity was inhibited by all PFECA, while PFOA exhibited more complex dynamics, implying diverse immune responses according to the dose level. These results provide valuable insights into the varying toxicological effects of PFECA and PFOA on oxidative stress, neurotoxicity, and immune responses in *Eisenia fetida*. Understanding these mechanisms is crucial for assessing the suitability of these compounds as substitutes for legacy PFAS and for promoting environmental sustainability.

Microplastics act a metal carrier in soils and plants

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Microplastics (MPs), as solid contaminants similar in size and shape to soil particles, exert effects on soil. They modify the bioavailability of crucial elements impacting microbial activity as well as plant growth and physiology. The research aimed to evaluate the effects of two types (biodegradable: B-MPs; un-biodegradable: NB-MPs) of MPs at different concentrations (0.5, 1 and 2% d.w.) on: i) element bioaccumulation and translocation from soil to spinach (*Spinacia oleracea* L.); ii) plant stress responses. To achieve the aims, mesocosm trials were set up using 35 pots where MPs and soil were mixed and spinach were grown. Al, Ca, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, V and Zn were measured in soils (as availability), roots and leaves. Then, element translocation and bioaccumulation factors (BF and TF) were calculated. Moreover, the integrative biological responses (IBR) was calculated considering the microbial respiration and enzymatic activities. To assess the plant stress responses, the expression of catalase (CAT) and ascorbate peroxidase (APX) was evaluated. The findings highlighted that, according to the MP concentrations, the highest Fe, Pb and Zn availabilities were measured in NB-MPs soil, and the highest Cu and Mn availabilities in B-MPs soil. The highest IBR values were calculated for 2%-NB-MPs. BF values for roots were higher than 1 in all treatments and for leaves were lower than 1 for Ca and Pb in all treatments, for Cu and Mn in B-MPs, and for Fe in NB-MPs. TF values were lower than 1 for Al, Ca, Cr, Fe, Pb and V in all treatments, and for Cu in B-MPs. CAT and APX were more expressed in NB-MPs treatments. In conclusion, element bioaccumulation was highlighted for all elements and treatments, whereas translocation was limited to K, Mg, Mn, Na, Ni and Zn. Spinach grown on NB-MPs showed highest stress response.

The potential role of Mater-Bi in mussel-farming

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Aquaculture activities use many plastic materials, from equipment for the different stages of farming to the packaging of the final products. However, poor management of facilities and extreme weather events can release these materials into the environment, constituting a threat to marine biodiversity. The present study aims at evaluating the replacement of polypropylene socks (PP) with a biodegradable and compostable bioplastic, the Mater-Bi (MB; Novamont S.p.A., Italy) in a mussel farming located in the Mar Piccolo of Taranto (Italy). To compare the behavior of MB to that of PP along the production cycle of *Mytilus galloprovincialis*, we studied i) surface chemical alteration, ii) microbial colonization, iii) mussel's biomass, and iv) macrofaunal community associated with mussels. In October 2021, MB and PP socks were deployed in the study area, and samples from each type of plastic were collected monthly. Chemical analyses were performed by Fourier transform infrared spectroscopy (FT-IR) and microbiological analyses were carried out to investigate the microbial colonization of PP and MB by coupling molecular and culture-dependent approaches. Moreover, the biometric parameters and the weight of individuals were recorded seasonally to assess the mussel biomass, the macrofaunal community was identified and divided into the main taxa through taxonomic keys. FT-IR analysis did not show evident alterations in both plastics, while microbiological analysis indicated a clear diversification of colonization on PP and MB. Regarding the study of biomass and macrofaunal community, our results showed that PP socks are preferred by organisms for early colonization, but then MB socks seem a better substrate to grow faster in size. In conclusion, the use of MB could be a good alternative to reduce the impact of PP socks in the marine ecosystem, but further studies and long observation times are needed to understand the potential and sustainability of MB in mussel farming.

Use of *Donax trunculus* (Linnaeus, 1758) for the assessment of gadolinium presence along Italian sandy coasts

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Rare Earth Elements (REEs) play a fundamental role in the development of innovative technologies, representing a crucial resource for modern industry. Among REEs, gadolinium (Gd) is a promising tool for many applications, from technological (display screens, hybrid vehicles) to medicine field (magnetic resonance imaging contrast agent). Since the presence of gadolinium has been documented in marine ecosystems in several countries, and negative effects on biota have been observed, an evaluation of the levels of this emerging contaminant should be carried out in the Mediterranean basin. From this assumption, the present study aimed to investigate the presence of Gd in 8 sites along the sandy coasts of the Adriatic, Tyrrhenian, and Ionian Seas through water and sediment samples, as well as the accumulation of this pollutant in the bivalve mollusk *Donax trunculus* (Linnaeus, 1758). This species was selected because, in addition to possessing all the characteristics of a suitable biomodel, it is also widely distributed throughout the Mediterranean basin. Juvenile (<2 cm) and adult (>2 cm) individuals of *D. trunculus* were sampled throughout the basin, in addition to water and sediment samples, and analyzed by ICP-MS. The results showed that Gd was present in all sampled sites. Stations located on the Adriatic coast were significantly more polluted than those on the Ionian and Tyrrhenian coasts. No significant difference in accumulation capacity was found between juveniles and adults, indicating that even at small sizes, *D. trunculus* can accumulate a considerable amount of Gd. A positive correlation was found between Gd values in sediment and those in the studied bivalves, demonstrating that *D. trunculus* was an excellent biomodel for this study. In conclusion, this study represents the first investigation of Gd pollution in sandy habitats in the literature and aims to stimulate further research in these characteristic environments along the Italian coasts.

Ecotoxicological evaluation of biogenic matrices for agricultural application, using the earthworm *Eisenia fetida* and zebrafish embryos

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The use of biogenic matrices as fertilizers and amendments is considered a good solution to improve soil properties and resilience. Nevertheless, there is a growing concern on their potential hazard to ecosystems and human health, due to the presence of toxic chemicals either hydrophobic and hydrophilic. In this scenario, this study aimed to evaluate the ecotoxicity of two organic fertilizers as sewage sludge (SS) and defecation gypsum (DG), using the earthworm *Eisenia fetida* and zebrafish (*Danio rerio*) embryos. We tested acute toxicity of either whole matrices and elutriates. In addition, sub-lethal effects were investigated applying a multi-biomarker suite related to cytotoxicity, oxidative stress, neurotoxicity, energetic metabolism and behavioral alterations. Moreover, the effects on reproduction was assessed in earthworms.
Both matrices caused 100% mortality of earthworms upon acute exposure to quantities representative of those applied as organic fertilizers according to current Italian practices. Upon dilution 1:5 with LUFA 2.1 control soil, cytotoxicity was found in hemocytes, but not oxidative stress. At this dilution, only DG affected acetylcholinesterase activities. At dilution 1:10 no effects were observed on the reproduction. Concerning the effects on zebrafish, the exposure to elutriates induced lethality and some embryonic defects in 50% of the organisms at dilutions above 1:40. No effect was observed on swimming performance and on oxidative stress biomarkers. Instead, an increase of basal oxygen consumption and total respiration rate was measured in embryos exposed to DG with respect to controls.
Our study highlights how ecotoxicity could provide relevant information in terms of ecological hazards posed by substrates intended for agricultural applications on terrestrial and aquatic species and the importance to combine acute assays with sub-lethal endpoints. The integration of our data with results related of chemical characterization, will provide an overall and representative view of the real effect of these matrices.

Sediment and bottom water eDNA metabarcoding to support coastal management

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Ocean sprawl and climate change exacerbate coastal erosion and flooding, resulting in habitat loss and decreasing biodiversity. To counteract these threats, different coastal defence tools have been developed, with an increasing emphasis on nature-based solutions. However, tracking the impacts of these interventions on marine benthic organisms requires appropriate sampling designs and timely investigation methods due to the dynamic nature of coastal environments. Environmental DNA metabarcoding is a promising, non-invasive, and quick technique to monitor community changes. Here, environmental DNA COI-based metabarcoding data from sediment and bottom water samples were used to characterize benthic communities at three sites along the Emilia-Romagna coast differing in the topology of coastal defence actions (from no defences to groynes and low-crested barriers) and to evaluate the effectiveness of the two sampling matrices in detecting local biodiversity. The findings revealed significant differences in the structure of the benthic communities depending on site, sample type (i.e., sediment versus bottom water), and their interaction. The three sites differ in abiotic characteristic affecting the community composition. Lido di Dante and Riccione showed higher species diversity due to the new type of substrata provided by the hard defence structure, while Foce del Bevano showed the presence of species typical of low impacted areas. Bottom water, hosting more traces of pelagic and nektonic species, showed significantly different species composition compared to sediment samples, suggesting the need to consider both matrices in coastal monitoring.

Temporary ponds (TPs): research, conservation and vulnerability of a disappearing ecosystem

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Temporary Ponds (TPs) are unusual and peculiar habitats seasonally flooded, with a short aquatic phase. In light of the ongoing freshwater biodiversity crisis, detailed knowledge regarding the current conservation status of TPs is urgently required. Diatoms are a useful ecological tool that, studies the water quality under natural conditions. They allow understanding the ecological status and predicting what may occur in natural ponds after pollution, water crisis and other anthropogenic or natural disturbances. In this study, conducted within "The Presidential Estate of Castelporziano", a protected area in Central Italy, 169 temporary and permanent ponds were taken into consideration. The project includes pond status assessment and monitoring work, macroinvertebrates community characterization, hydroperiod monitoring and diatom community turnover rating; ecological comparison between temporary and permanent ponds is also included. Over six months of samplings, we found that about 30% of TP surveyed in the 1990's is now completely dry, although the bearings were taken during the wet season. Despite the premise, about 10% of the ponds were new generation, not existing during the last samplings; climate change is strong affecting the lifetime of temporary ponds, reducing the life of some and generating others.

Evidence of eutrophication and average high oxygenation emerges from the presence of species like *Nitzschia palea*, *Achnanthidium eutrophilum*; the large TPs biodiversity was represented by Copepod, Cladocera, Dytiscidae for macroinvertebrates, and *Gomphonema, Navicula, Nitzschia* for diatoms. Although the minor abundances, *Lepidurus* spp. and *Chirocephalus* spp. show high frequencies through the surveyed ponds. These results represent a new database useful for further comparisons and discussions on the climate change effects on TPs. The research contributes to anthropogenic and natural impact on APs studies, increase awareness on conservation of this neglected habitats and highlight the usefulness of diatoms as bioindicators.

How extreme climatic events threaten the larval settlement and survival of theendemic Mediterranean coral *Astroides calycularis*

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Climate change is heavily impacting natural ecosystems altering their structure and functioning andcausing a great loss of biodiversity. Extreme weather events such as marine heat waves (MHW) or severe storms are increasing in frequency and intensity over the last century, causing strong and growing impacts on marine ecosystems. They may impact organisms performance and fitness, affecting their reproductive ability and success, as well as the survival of the first viable life stages. It is particularly worrying when affecting vulnerable species presenting long-life cycles with slow growth rates and limited dispersal ability, as happens to anthozoans communities from coralligenous and pre-coralligenous habitats. The larval stage is one of the most important phases in sessile organisms life cycle since it allows and ensures the maintenance of local populations and the dispersal of the species. Here, we studied the effect of multiple climatic stressors (increasing temperature and decreasing salinity) on the larval stage of one of the most threatened endemic colonial coral in the Mediterranean Sea, the scleractinian *Astroides calycularis*, recently involved in several mass mortality events. Manipulative experiments were performed to measure larvae individual metabolism response (respiration rate) and settlement and mortality rates to three different treatments: temperature spike (1 day), MHW (5 days) and the interaction between MHWand salinity decrease. Increasing intensity and duration of disturbance, as well as the interaction ofstressors exacerbated larvae performance, settlement and survival ability. In the current scenarios of changing environmental conditions, studying and knowing the response of the early life stages is crucial to understanding population dynamics changes and the potential consequences on communities structure and ecosystems functioning.

Sediment eutrophication mitigation using a benthic living bioreactor: the sea cucumber *Holothuria tubulosa* Gmelin 1788

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Due to their bioturbation ability and large thermal tolerance, sea cucumbers are candidates for mitigating benthic eutrophication under sea warming conditions. To provide insights on this, specimens of *Holothuria tubulosa* Gmelin, 1788, acclimated at 20, 24, 28, 30 and 32°C and starved for 72h, were let to feed on coastal sediments for five days, during which feces were continuously removed. A set of mesocosms without sea cucumbers was used to estimate natural organic matter (OM) decay during the experiment. OM ingestion rates, once subtracted its natural decay, were calculated as the difference between estimated OM contents in each mesocosm before the feeding phase and that remaining at the end of the experiment, added to the amount of feces produced. Assimilation rates were estimated as the difference between the ingestion rate and the daily feces production.
Whichever the organic compound and at all temperatures, daily ingestion and assimilation rates (normalized per wet weight of the specimen) were negatively correlated with the specimens' size, suggesting that the smallest ones would be most effective in removing OM. At all temperatures, sea cucumbers ingested significant amounts of biopolymeric C, with the highest rates (0.23 mg C d^{-1} $w.w.^{-1}$ of sea cucumber) observed at 24°C. Percentage of assimilated organic carbon over the ingested one increased with increasing temperature, saturating (100%) at temperatures >30°C. While lipids were assimilated at all temperatures, protein and carbohydrate assimilation differed among temperatures, with the former not being assimilated at 20°C and the latter not being assimilated at 28° and 32°C.
We conclude that the possible use of *H. tubulosa* as a bioremediator of benthic eutrophication must be calibrated in terms of either specimens' size (with preference for a multitude of small animals) and, at the different temperatures, of the relative availability of protein and carbohydrate substrates.

Marine Ecosystem Restoration (MARES): approaches and challenges to reverse the biodiversity loss across the Italian seas

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Within the UN Decade on "Ecosystem Restoration" and Mission Board on Healthy Oceans, Seas, Coastal and Inland Waters "Mission Starfish 2030: Restore our Ocean and Waters by 2030", restoration is a key action in the EU Biodiversity Strategy for 2030. Italian seas' biodiversity will be on the path to recovery by 2030 for the benefit of the environment, society, and economy. Recently researchers developed standardised protocols for restoring a suite of degraded marine ecosystems under different socio-ecological settings, analysing along implications across Italian seas. Within the National Biodiversity Future Center, a scalability plan will be developed, based on innovative solutions and commitments for adoption of large-scale restoration to i) allow the upscaling of marine restoration; ii) provide the restoration potential of priority ecosystems and iii) support sustainable and effective restoration activities in the long term, to make possible biodiversity resilience. Cross-sectoral collaborations (research, society, public, private sector) are necessary for the integration between social-ecological restoration priorities and Blue Economy. A next generation capacity will raise through the development of training promoting marine restoration as a science-based management solution. The results will contribute to the goals and targets of the Global Biodiversity Framework, EU 2030 Agenda for Sustainable Development, and EU Nature Restoration Law.

Does ecological restoration work?

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The need to address long-standing impacts of human activities on natural ecosystems is growing. Besides protection, ecological restoration represents an alternative option for helping degraded ecosystems recover. Ecological restoration, indeed, has become an essential component of the EU's vision and strategy for biodiversity conservation, emphasizing the value of restoring biodiversity as a crucial step in mitigating the effects of climate change, improving ecosystem resilience , enhancing ecosystem services and, ultimately, humans' health and well-being. Despite this, the effective success of the restoration actions implemented in to date is still a matter of debate. Neither, a consensus has been reached about which are the main drivers leading to successful results of restoration. To provide robust science-based insights on these still debated issues, we conducted a global literature review, without time restrictions, and used meta-analytical techniques to identify key variables in the success or failure of ecological restoration in four different realms. A total of 349 different papers on field restoration actions were included in the analysis, producing 7543 case studies among terrestrial, freshwater, transitional and marine water habitats in the last 30 years. Significant successful restoration outputs were observed just in terrestrial habitats. Restoration methods are positively related to restoration efficiency in all realms except for the marine habitats, for which the highest heterogeneity in techniques emerged. Measured response variables have significant relationships with the success or failure of ecological restoration for terrestrial, freshwater and transition waters at either population or ecosystem levels. Conversely, in marine habitats, any of the potentially determining tested variables apparently ensures the positive outcome of restoration. Our results provide a new vision of strengths and weaknesses in the current ecological restoration actions in a global context, and may assist ecologists and practitioners in performing more successful ecological restoration actions to improve ecosystems management.

Can thermal anomalies impair the restoration of *Cystoseira s.l.* forests?

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Healthy rocky coasts of the Mediterranean Sea are dominated by macroalgal forests formed by brown algae of the *Cystoseira s.l*. group. These species provide important ecosystem services, contributing to coastal primary production and nutrient cycling, providing food, shelter, nurseries, and habitat for many other species. *Cystoseira s.l.* populations in the Mediterranean are suffering a large-scale regression mainly due to anthropic impacts, including coastline urbanization, habitat loss, overfishing, climate change and the increase of occurrence and severity of extreme events.
In the last decade, efforts have started to be implemented to restore *Cystoseira s.l.* using both *in-situ* (positioning of seed bags to locally enhance recruitment) and *ex-situ* (outplanting juveniles cultured in the lab on tiles) techniques.
Large variability in phenology and reproductive potential of donor populations has been experienced because of climate anomalies, potentially affecting also restoration efforts. During 2022, several *ex-situ* restoration efforts were implemented for *Ericaria amentacea*, a species thriving in the intertidal. Fertile apices have been collected in several locations along Italian coasts (Ionian Sea: Brucoli in Sicily; Tyrrhenian Sea: Capri in Campania and Ligurian Sea: Bogliasco in Liguria) in May/July, when the species is known to achieve sexual maturation.
The success of the culture phase was significantly lower compared to the previous years: reproductive structures were not well developed, the released zygotes were fewer and less vital, juvenile percent cover on tiles and survival rate were extremely low.
A very anomalous thermal condition was observed in 2022, in the donor sites with thermal anomalies exceeding climatological means of 4.3°C and heatwave events lasting up to 78 days.
The extreme thermal anomalies recorded may have been the main cause of the failure of *Ericaria amentacea* culture success, suggesting that climate change related effects represent one of the main threats not only to the welfare of marine ecosystems but also to their restoration.

From population genomic connectivity to restoration of marine animal forests

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Organisms forming marine animal forests are considered ecosystems engineer due to their complex three-dimensional structure, hosting most of the biodiversity in benthic ecosystems and being essential for ecosystem functioning. Despite their ecological significance, marine forests are threatened by various human-related stressors. As such, it is fundamental to quantify the declines of these ecosystems and their resilience to disturbances, and genetic connectivity can provide valuable insight into the processes of population maintenance and replenishment following environmental fluctuations. Data on genetic connectivity can inform conservation and restoration strategies to enhance population resilience and originate new ecological corridors that may strengthen the recovery of neighboring populations. Nevertheless, genetic connectivity is not always included in the latest restoration activity plans. Here we present how genetic connectivity data was used in three anthozoan species (*Savalia savaglia*, *Parazoanthus axinellae*, *Antipathella subpinnata*) to increase the knowledge on reproductive behavior within each species, to resolve phylogenomic disparities within taxonomically problematic groups (i.e. Slender and Stocky morphotypes within the *P. axinellae* species complex), and to understand which populations could serve as a potential source of genetic diversity for adjacent populations. Then, we present a roadmap in which this information is used to develop an innovative and sustainable protocol for marine animal forests restoration, monitoring, and conservation.

Cystoseira s.l. forest restoration: advancements, challenges, and future perspectives

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The field of marine restoration has made notable advancements in recent years and this trend is expected to accelerate during the UN Decade of Restoration (2021-2030). While some countries have gained sound experience in kelp restoration, the scientific understanding and practical implementation of such efforts are still at an early stage for Mediterranean fucoids. Efforts to restore macroalgae lag behind those of other marine ecosystems and are often limited to small-scale academic experiments of short duration, highlighting the need for further research.

Recently, the increasing threat and observed decline of *Cystoseira s.l.* populations, together with the availability of funding, have stimulated interest in these macroalgae and led to a large number of projects, although concrete restoration initiatives remain rare. Nevertheless, the attempts made and recent studies have yielded valuable insights from both failures and successes in selecting suitable sites, species/populations, and restoration protocols.

However, the urgency of restoration efforts is compounded by the challenges posed by climate change, which also affect their feasibility. Both natural and restored populations face similar threats, including thermal anomalies and storm surges, along with disruptions to their biological cycles. Therefore, it may no longer be viable or advisable to restore the same species or populations where they once occurred.

By using knowledge from ongoing restoration efforts and recognizing the challenges of climate change and scaling up, we can establish a path to a more efficient, cost-effective and sustainable approach to conserving and restoring these crucial ecosystems.

Macroalgal canopy contributes to the early colonization of vermetid reef-builder on artificial substrates

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Intertidal algal canopies represent valuable biogenic refugia for benthic organisms, controlling the microclimate on the underneath surface and modulating the effect of physical and biological disturbances in the infralittoral zone and are considered natural-based solutions for coastal conservation and restoration.
Here, we investigate the effect of the macroalgal canopy on the colonization success of the central-Mediterranean vermetid reef-builder *Dendropoma cristatum* (Biondi 1859) on artificial substrates produced for reef restoration. During June 2022, twenty-four artificial geopolymer discs (8 cm in diameter) produced by 3-D technology have been placed on the outer rim of a natural reef, along the NW coast of Sicily. Half of the tiles were anchored within patches of the algal canopy, the other half was placed outside the patches, to control the canopy effect on the vermetid colonization.
After thirty-five days the tiles were collected, photographed and the number of vermetids on each substrate was counted under the microscope. On average, a significantly higher number of settlers was found on the substrates placed underneath the canopy compared to the controls, and respectively: 87.75 ± 24.02 (mean ± SE) and 64.5 ± 22 settlers/disc ($p<0.05$).
This study reveals that the presence of a macroalgal canopy has a positive effect on the early colonization of the reef-builder *D. cristatum* on artificial substrates. This could be explained by a different microclimate underneath the canopy which may provide more suitable conditions for the initial vermetid colonization (e.g., by sheltering the new settlers from the direct sun radiation, lowering temperature peaks, preventing desiccation stress, buffering predation pressure and wave energy), promoting the achievement of vermetid colonised units which may be transferred to other reefs for repopulation purposes. Certainly, the mechanisms which justify this positive interaction between the macroalgal canopy and the juvenile vermetids need to be further explored, also considering a wider temporal scale after the reef-builder settlement.

Metabolic functional traits as a tool to monitoring and predict the restoration success of structuring habitat species

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Restoration of degraded ecosystems presents a critical challenge for conservation ecologists and practitioners, drawing increased attention in recent years due to the rising threat of interacting stressors leading to biodiversity loss. One of the key challenges in restoration ecology is predicting the success of restoration efforts, especially in terms of ecosystem functioning and the subsequent recovery of the ecosystem services provided by the restored species. *Posidonia oceanica* (L.) Delile is an endemic Mediterranean seagrass that forms extensive continuous meadows providing crucial ecosystem services, currently threatened by the interacting effects of anthropogenic stressors and changing environmental conditions. Given its socioeconomic and ecological values, this seagrass has become a primary target habitats for restoration actions in the Mediterranean Sea. Monitoring plans for the restoration of *P. oceanica* typically rely on indicators such as seagrass coverage, density, growth, and reproduction rates. Integrating metabolic proxies (e.g. respiration rate, gross and net primary production) to monitor seagrass functioning would contribute to quickly assess ecological functioning, performance, stability, and, consequently, the success of the restoration action. Here we report the results of a mesocosm experiment designed to assess the functional responses of *P. oceanica* in terms of respiration rate, gross and net primary production, and photosynthetic performance traits under the combined action of temperature and turbidity. Main outcomes highlight a rapid and significant stressful effect of interacting stressors on *P. oceanica*'s performance, with the intensity and duration of disturbances playing a key role in the species' response. Using functional trait-based information may contribute to provide feasible indications to better predict the success of restoration and conservation efforts for key habitats.

RENOVATE Project: ecosystem based approach for compensation and mitigation actions in marine environment

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Coastal areas are characterized by the presence of relevant ecosystems that often are affected by the development of coastal infrastructures. This situation generates conflicts between human activities and natural ecosystems conservation, as well as by ongoing climate change impacts. Specifically, along the Latium region, the expansion of the Civitavecchia port requires the necessity of specific compensation measures trough marine habitat restoration and mitigation activities. RENOVATE project was developed to design and implement compensation and mitigation measures based on an ecosystem-based approach. The project concept focuses on the restoration of habitat 1120* and 1170 in order to recover the lost ecological functions and ecosystem services. The activities of the RENOVATE project will last 10 years to ensure the recovery of the loss of ecosystem services through interventions spatially distributed and controllable over time to have greater guarantees of success and potentially greater compensation than the impact of coastal infrastructure. In order to develop this approach, it is necessary to implement an integrated observing system and operational modelling at regional scale, to contribute to: the development of an early warning system for extreme events, dredging and avoidance of potential impacts; the implementation of ecological compensation measures to restore ecosystem services; the siting and implementation of Nature Based Solutions; the monitoring of the ecosystem services recovery during 10 years.

Effects of protection on sea urchin predator dynamics. A case study of the Tavolara - Punta Coda Cavallo Marine Protected Area

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Assessing the effects of protection on the demographic dynamics of fish populations is crucial for effective marine conservation planning. In Mediterranean rocky reef ecosystems, marine protected areas (MPAs) can be effective in reversing negative ecosystem-wide consequences of excessive fishing on sea urchin predators. Grazing pressure in the absence of top-down control, in fact, can determine the switch from ecosystems characterized by forests of erect macroalgae and high biodiversity to barrens dominated by encrusting algae at low levels of biodiversity, with a net loss of ecosystem functions and services. We analysed the abundance series of four fish predators of sea urchins (*Diplodus sargus*, *D. vulgaris*, *Coris julis* and *Thalassoma pavo*) obtained via underwater visual census between 2005-2021 in the MPA of Tavolara - Punta Coda Cavallo (NE Sardinia). Data were collected at locations characterized by different protection levels (zone A, B, C) and at control sites outside the MPA. Our results highlight rather rapid and lasting effects of full protection on the density, biomass and size of the analysed fish species. Partially protected zones (B and C) do not seem to differ from unprotected ones in terms of density, while some small but statistically significant differences have been observed in terms of biomass. Estimated mortality rates for commercially important species appear significantly higher in unprotected zones than in the fully protected zone (A), further confirming the effectiveness of protection. The densities achieved by sea urchin predators under full protection are considered sufficient to effectively control sea urchin populations. Therefore, there are chances that the positive effects of protection extend to macroalgal forests, although further field research is needed to support this hypothesis.

Patella ferruginea restoration in the supralittoral transition zone: a cost-benefit assessment from Nature perspective

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The ferruginous limpet Patella ferruginea is a western Mediterranean endemic invertebrate considered severely threatened according to Directive 92/43/EEC and in "risk of extinction" according to the Barcelona Convention (UNEP/MAP-SPA/RAC, 2018). Therefore, in the last decades of the XX century some restocking attempts have been realised while, between 2016-2021, the ReLife project (LIFE15 NAT/IT/000771) was launched to reintroduce ferruginous limpet within 3 Marine Protected Areas (MPAs) in Liguria, North Western Italy. Recently the European Commission's has proposed the Nature Restoration Law (Procedure 2022/0195/COD), that foresees at least 20% of the EU's land and sea areas to be restored by 2030 and all ecosystems by 2050. According to the law, even if restoration practices are cost-effective, they require investments and costs to be compensated and Member States must select appropriate methods to determine which, how and when stakeholders must be involved in compensation. The costs incurred are not only financial, but also biophysical, since restoration interventions require the use of resources (e.g. water, fuels) in order to be performed. These biophysical costs should be included in the compensation amounts. For this purpose the procedure sketched in the context of EAMPA and the EU INTERREG MARITIME GIREPAM projects for the realisation of an integrated (ecological and economic) balance for MPAs was tailored and applied to restoration actions. First of all, the natural capital of the 3 restored sites (Cala dell'Oro-Portofino MPA, Montenero-Cinque Terre MPA and Isola di Bergeggi MPA) was assessed before P. ferruginea reintroduction and after, considering different reintroduction scenarios. Then, the biophysical costs for reintroduction were assessed to calculate the net benefit of the restoration activity. Using this approach, the reintroduction cost of Patella ferruginea along the Liguria coast was evaluated and a natural capital increase of the supralittoral zone between 18'769 and 46'622 em€ was assessed.

Advancing Coralligenous restoration: an ex-situ approach for cultivating *Lithophyllum stictiforme*

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Crustose coralline algae (CCAs) are widespread foundation species that contribute to the structural complexity of marine ecosystems. CCAs are known to trigger settlement and metamorphosis in a variety of invertebrate larvae, such as corals and gorgonians, exhibiting species specificity. Consequently, they can facilitate the recovery of such organisms by acting as selective primary substrates. Specifically, *Lithophyllum stictiforme* (Areschoug) Hauck has been shown to favor the settlement of *Eunicella singularis* (Esper, 1791) and *Paramuricea clavata* (Risso, 1827). In this study, we tested the feasibility of cultivating *L. stictiforme* sporelings in mesocosms with enriched artificial medium using an orthogonal experimental design. Small thallus fragments with fertile conceptacles were collected at a depth of 28 m (Costa Paradiso, northern Sardinia). To optimize the survival and growth of *L. stictiforme* spores, we investigate two light intensities (40 and 160 µmol photons m-2s^{-1}) and two temperatures (14 and 20 °C): the lower light and temperature settings were chosen to simulate sampling site conditions, while the higher light and temperature settings were tested as potential growth promoters.

Following sporulation induction, spore settlement, growth, and survival were estimated through photographic sampling over a two-week period. Calcification was analyzed by Scanning Electron Microscopy coupled with Energy Dispersive Spectroscopy (SEM-EDS). The results showed that sporelings had higher survival rates under low light and high temperature conditions, which also promoted the growth of germinal discs. Regardless of the experimental conditions, germination discs showed an enhanced calcification with a lower Mg/Ca ratio in the peripheral cells, while the central ones were more weakly calcified. Sporelings grown in low light condition had a higher percentage of Ca2+ in their Mg-calcite cell walls, conferring them with improved hardness and resistance to dissolution.

Disentangling the effects of translocation, light irradiance, depth origin and thermocline deepening on the gross biochemical composition of *Posidonia oceanica*

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The current sea surface warming is pushing the summer thermocline to move deeper and deeper. This phenomenon, exacerbated during marine heat waves, can cause mass mortality events of deep benthic species, and it is also expected to affect seagrass survival. Deep-living ecotypes of the seagrass *Posidonia oceanica* (L.) Delile 1803 are less tolerant and more prone to the putatively detrimental effects of environmental change. In the framework of the project MAHRES (PRIN, Call 2017), in order to investigate the potential effects of a thermocline deepening on seagrasses, we carried out a manipulative experiment in Cyprus (E-Mediterranean Sea) to identify and disentangle the effects of light irradiance (and temperature), origin depth and the translocation on the gross biochemical composition of *P. oceanica* leaves. Seagrass shoots were collected at 31 m and transplanted at 12 m under and without a shading net, put in place to simulate either deep light conditions (at 31 m) or a shallow high-light habitat. Samples were collected before and after 7 and 11 weeks, and analyzed in terms of total protein, water-soluble carbohydrates, and total lipid contents. In all treatments the contribution of water-soluble carbohydrates increased with time, whereas total lipid contributions increased in shallow shoots and decreased in the deep ones. Protein contributions did not show clear patterns, though increased in shoots translocated at the same original light conditions but decreased when exposed to either higher or lower light irradiance. Our results indicate that the biochemical composition of shallow and deep seagrass cuttings respond differently to environmental change. Moreover, although responses to cross-depth translocation and the deepening of the thermocline had only minor effects, we suggest that the restoration of seagrass beds should be carried out with propagules originating from the same depth range.

Are algae worthy of restoration? The *Ericaria amentacea* case

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Cystoseira sensu lato species are recognized for their ecological importance as keystone and ecosystem engineers, contributing to the hosting and maintenance of biodiversity. They are classified as endangered species and are protected because of their vulnerability (SPA/BD, Barcelona Convention, COM/2009/0585/FIN). Due to their sensitivity, some species of *Cystoseira s.l.* are used as indicators of the environmental quality in Mediterranean coastal waters (2000/60/EC). Among them, *Ericaria amentacea* that forms dense stands in rocky intertidal habitats, is particulary vulnerable to natural environmental disturbances (e.g., hydrodynamics, tidal excursion) and human pressures (e.g., trampling, bathing, dumping). Along several Mediterranean coasts, the continuous belts formed by this species have either declined to sporadic patches or have been replaced by other assemblages. Consequently, *E. amentacea* has become the focus of recent environmental restoration projects.
This study focused on *E. amentacea* forests in Liguria (Pontetto and Portofino) and Sicily (Ciclopi Islands). The project aimed to quantify the differences in biophysical and monetary value during two periods of the algae's phenological cycle (autumn and summer) and determine the environmental cost of its restoration.
The results showed a significant difference between the two phenological periods, with summer values being approximately 2.5 times higher than autumn ones. This difference can be explained by the natural phenological cycle of *E. amentacea,* whereby during autumn it loses part of the fronds produced in spring. In the natural capital theory, thalli branches represent environmental flows, while the cauloid (the semi-perennial part of *E. amentacea*) represents the natural capital. Additionally, the costs of restoration were assessed, resulting in an increase in *E. amentacea* forests generation costs by over 90%, thereby highlighting the need for active conservation efforts.

Threshold's hunters: how a functional trait-based restoration addresses the restoration's success in a changing sea

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Ecological restoration deals with the restoring species composition of pre-disturbance communities through the reintroduction of native species and/or facilitating the recolonization on degraded sites. The main goal of restoration programmes are not the transplanting actions *per se*, only the first practical phase based on engineering techniques, but to increase the ecosystem functioning rate thanks to the increase of the local abundance/density of the restored species that in turn is expected to increase i) the associated resident biodiversity, and ii) the recovery of ecosystem services (e.g. carbon sequestration, climate regulation, ecotourism etc.). While to date there is a robust theory based on functional traits, only few studies exploit their ecological power to increase our mechanistic understanding on how the performance of a target species changes over the range of environmental and competitive conditions experienced at local level, and how this links to the ecological community functional thresholds. Studying this link improves predictive ability on whether target restored species and communities can flourish under new conditions of "restored" sites, up to their definitive establishment, although living in a variable and changing world. Also, functional thresholds are crucial to predict whether density of target species and their associated communities are able to increase biomass and the structural complexity in new sites. And not only, they are the sole way to individuate early signals of restoration success. Here, we show how functional traits can be useful in addressing all phases of restoration, from the siting to the monitoring of the success, and then we show new experimental methods based on community metabolism analysis to assist practitioners in ascertain the recovery of most ecological functions supporting ecosystem services. Through case studies dealing with marine foundations species, spanning different stressor's conditions and sites, we will show how to incorporate functional trait's theory to address restoration measures.

Simulated thermocline deepening: how do *Posidonia oceanica* shoots adapt to different light and temperature conditions?

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A future deepening of the thermocline, correlated to the rising temperature, has been predicted in the Mediterranean Sea and the effects on seagrass performance need to be investigated. This study was carried out in Konnos Bay, Cyprus: the effect of a simulated thermocline deepening on the seagrass *Posidonia oceanica* was investigated through a manipulative field experiment that also allowed testing the effects of the irradiance, origin depth and translocation. *P. oceanica* shoots were collected from 31 m of depth and transplanted at 12 m under a shading net (simulating the 31 m light conditions and therefore the effect of the thermocline), and at 12 m without shading net (testing the effect of the light irradiance). Shoots from 12 m and from 31 m were also translocated at the same depth of origin to test the translocation effect. Morphological (number of leaves, leaf area, leaf necrosis) and physiological (growth rate) variables were considered. Results highlighted an effect of the thermocline deepening and origin depth effects with an increase of leaf necrosis, while a translocation effect was found through a decrease in the leaf area. No differences in shoot growth rate due to treatments were found and it is important to highlight that no mortality was recorded. Overall, there is evidence of a morphological and physiological acclimation of *P. oceanica* cuttings in coping with future thermocline conditions, and results may contribute to the knowledge related to restoration efforts, as they corroborate the hypothesis that in restoration actions using shoots of the same depth of the receiving meadow might be more successful than using shoots from meadows of different depths.

Are Nature-based Solutions useful for the ecological recovery of degraded environments without a proper scale-based study?

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It is expected a significant increase in the variability of global temperatures for the next decades with a rise in the intensity and frequency of extreme weather events. Due to its transitional location between arid and temperate regions, the Mediterranean area is among the most susceptible areas to climate change. Under these conditions, plants will be exposed to high leaf transpiration and, in turn, will react by closing the stomata, reducing thus photosynthesis rates. Exposure to this long-lasting aridity leads to reduced primary production, growth rates and regeneration ability. Since 2000, a series of European projects focussed on the ecological restoration of degraded Mediterranean ecosystems have been performed by introducing Nature-based Solutions (NBS). However, some NBS applications did not give a real recovery but rather an insufficient requalification of the degraded environments. Here, the authors analyse the failing causes and propose a method named top-down and bottom-up approach that makes the complementarity between local-scale monitoring and large-scale observation possible. The bottom-up approach supplies information by using in-field measurements such as gas exchanges aiming to quantify carbon and water fluxes at leaf-to-canopy levels. The top-down approach provides the use of data collected through instrumental processing (eddy-covariance-based C flow) and remote sensing, which are useful for regional and global scale studies. The Nestos delta (Greece) is a significant study area that has been considered for a reafforestation aiming to recover the riparian forests growing along the Nestos River. This NBS realised at the beginning of 2000 is gone progressively to deterioration throughout a not programmed flooding regulation, nullifying de facto the reafforestation effort. The top-down and bottom-up approach has been applied to quantify the water flows and water balance of the Nestos ecosystem during the LIFE projects PRIMED and NewLife4Drylands and to clarify the deterioration causes, proposing a new NBS.

Combining passive and active restoration to rehabilitate a historically polluted marine site

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Passive and active restoration approaches have been considered as different alternatives to achieve the ecological restoration of a degraded site. This false dichotomy has been overcome in terrestrial ecosystems, for which several restoration approaches have been applied within the same restoration project, creating a continuum of interventions. In the marine environment, the passive-active combined approach is less studied. Here, we tested the possibility of actively restoring a macroalgal population in a historically polluted industrial site, subjected to decadal passive restoration (i.e., unassisted, or spontaneous recovery following cessation of industrial activity), in the Mediterranean Sea. Recently, it has been demonstrated that in this site, there is no longer any sign of the historical contamination or impact on benthic fauna, therefore environmental conditions are indistinguishable from surrounding areas. We used artificial breakwater barriers in the site to restore a population of the brown algae *Gongolaria barbata*. The intervention was conducted applying an *in situ* recruitment approach and a complementary action using cages to exclude the herbivores. The *G. barbata* recruits were transplanted on the artificial reefs and after they reached the maximum growth inside the cages, one cage was opened and another one was completely removed to also test the grazing pressure. The associated benthic assemblages were also analysed in terms of meio- and macrofaunal abundance and diversity. At least, over a relatively short period (6 months), the use of the cages represents a useful tool to let the macroalgae grow enough to counterbalance the herbivory pressure. The associated fauna below the macroalgae was characterized by a different taxonomic composition when compared to controls (i.e., artificial reefs without the macroalgae), particularly considering the rare taxa. In conclusion, the combination of passive and active restoration can be considered a useful approach to restore marine sites degraded by historical industrial activities.

Short-term recovery dynamics of fish assemblage following *Posidonia oceanica* restoration.

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Seagrasses provide a wide range of ecosystem services but are now in global decline due to human activities. Restoration is considered a viable strategy to accelerate recovery and increase the resilience of seagrass ecosystems by re-establishing ecosystem functionality. This study aimed to assess the recovery dynamics of the fish assemblages to a *Posidonia oceanica* transplantation intervention carried out in December 2021 in the Gulf of Palermo (Italy). Using biodegradable anchoring supports, more than 22,000 *P. oceanica* shoots from a donor meadow were transplanted onto a dead matte substrate, covering a total area of 1,200 m^2. Fish assemblages associated with the transplanted *P. oceanica* were monitored by underwater visual censuses every four months for one year and compared with a reference meadow (donor meadow) and an unvegetated site characterized by dead matte only. The fish assemblage in the transplanted area showed signs of recovery, indicating a rapid improvement in habitat provisioning function. More specifically, the fish assemblage was more similar between the transplanted and donor meadows than between them and the unvegetated site. In addition, the increase in similarity between vegetated sites over time was mainly due to the increase in abundance of seagrass-associated fish (i.e., labrids and sparids) in the transplanted meadow. Furthermore, fish diversity and species richness increased throughout seasons, from winter when the transplantation took place, to late summer, and this increase was greater in the transplanted meadows than in the other sites. Although long-term monitoring is considered to be of paramount importance in assessing the effects of seagrass transplantation interventions, this study has shown that the first signs of recovery of the fish assemblages associated with transplanted meadows are already perceptible in the first year after transplantation, demonstrating that some recovery dynamics may be evident even in the short term.

How can seagrass restoration success be evaluated? Insights from marine soundscape and fish biophony

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Lately, restoration strategies have been employed to enhance the recovery of *Posidonia oceanica* meadows, since the integrity of this ecosystem has been threatened by anthropogenic disturbances and large-scale loss have been reported in the Mediterranean Sea. Habitat restoration success has been evaluated by the short-term persistence of the foundation species after initial transplantation (e.g., plant survival and growth). However, successful plant responses do not necessarily reflect the recovery of the ecosystem biodiversity and functions. Recently, soundscapes (the spatial, temporal and frequency attribute of ambient sound and the types of sound sources characterizing it) have been related to different habitat conditions and community structures. Thus, the effectiveness of a restoration action could lead to acoustic restoration and soundscape ecology may represent an important component of restoration monitoring. Here, we evaluated the effect of *P. oceanica* restoration on acoustic community, using passive acoustic monitoring devices, and we tested whether habitat restoration is accompanied by a restored soundscape. Acoustic recordings from degraded (dead matte), reference and restored meadows were collected one year after a restoration opera (7000 m^2) in Sardinia. Soundscapes of each habitat were examined using both spectral analysis and counts of calls, based on a catalogue of fish sounds from the Mediterranean Sea. Acoustic richness was higher in reference and restored meadows, which were dominated by sounds associated to *Scorpaena* spp. Acoustic abundance and sound pressure level (SPL, dB re: 1µPa-rms) in the frequency band related to fish calls (0.7-2 kHz) were both higher in restored and reference meadows compared to dead matte, while the SPL in the frequency band associated to invertebrate sounds (2-11 kHz) was higher in restored meadow. These results showed that meadow restoration may lead to the recovery of soundscape and the associated community, suggesting that acoustic monitoring can provide complementary information to evaluate seagrass restoration success.

Sustainable sea urchin (*Paracentrotus lividus)* aquaculture to enhance the recovery of disturbed seabed.

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Sea urchins are considered among the most efficient grazers in benthic marine habitats and their ecological role has been increasingly documented. In the Mediterranean Sea, *Paracentrotus lividus* can shape the distribution patterns of benthic communities of the shallow rocky substrates, often driving the transition from macroalgal beds to barrens, characterized by lower complexity and diversity. Sea urchin culling has been proposed to reduce subtidal barren grounds. However, in the last twenty years, this species has also suffered from an intense overexploitation, leading to a relevant decreased density across the Mediterranean Sea. Sea urchin aquaculture might represent a potential sustainable solution to mitigate the negative impact on *P. lividus* and meet market demand.
This study aimed to assess the somatic and gonadal growth of *P. lividus* over a 5-month period in a recirculating aquaculture system (RAS). Following circular economy principles, two alternative sustainable diets were formulated using vegetable (carrot) and fish (anchovies) processing by- products at different concentrations (D50 and D100), comparing the effects respect to a control diet represented by a commercial pellet. D50 and the control diet yielded the highest results in terms of somatic growth rate (SGR), especially for the smallest size class of sea urchins. Gonadosomatic index (GSI), shows no significant differences ($p>0.05$) between treatments in the largest size class. However, in the smallest size class fed with the D100, the GSI was significantly lower than the other two diets. These findings show that *P. lividus* during its life cycle have different trophic requirements and food energy allocation. The study also demonstrated the effectiveness of utilizing anchovy and carrots by-products as sustainable alternative feeds for the growth of *P. lividus*. This emphasizes the potential of sea urchin aquaculture as a sustainable approach to decrease the pressure on *Paracentrotus*, allowing its recovery, while meeting market demand.

Monitoring the effects of the environmental management of a eutrophic lagoon in the Po delta two years after the end of the LIFE AGREE project

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Since the 1990s, the Gorino lagoon, the eastern zone of the Sacca di Goro, has been characterised by a progressive marinization with the consequent loss of brackish habitats. The LIFE AGREE project (coAstal laGoon long teRm managEmEnt, LIFE13 NAT/IT/000115, 2014-2020) aimed at restoring the salinity gradients typical of the lagoon environments by means of hydraulic interventions (e.g., permanent opening of a navigation basin, building a sluice gate) improving the circulation between the lagoon and the Po River branch.

The results of ex-post monitoring actions have confirmed that the works carried out and the management decisions taken as part of the LIFE project have led to a significant short-term improvement of the environmental conditions in the entire lagoon. The increased freshwater inflow allowed a rebalancing of the salinity gradients, and, despite the increased nutrient input, summer anoxia was avoided due to more active self-depuration processes resulting from the partial recovery of the reed beds. The post-LIFE programme is the continuation of the ex-post monitoring performed during the LIFE project, with the aim of verifying the medium- and long-term effects of the hydraulic interventions to define a management plan of the lagoon in line with the Water Framework Directive. Monitoring actions from April to December 2022 showed that the improvement in the ecological quality of the Gorino lagoon is consolidating. The lower salinity conditions and the recovery of *P. australis* stands contributed to a more efficient removal of nutrient loads, preventing the accumulation of organic matter and the consequent risk of hypoxic/anoxic events. In conclusion, following the implementation of the project management measures, the dramatic anoxic and dystrophic crises that affected parts of the lagoon in the past no longer occurred, despite the worsening of extreme summer conditions due to climate change, such as the elevated temperatures recorded in June-July 2022.

Structural and functional analysis of the Palo Laziale Forest. Integrative approaches for supporting ecological restoration activities.

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Mediterranean forests are among the ecosystems most susceptible to climate change, which can affect vegetation's functional and structural properties.
The establishment of stress conditions in the vegetation favours the emergence and spread of pathogens as it occurred in the Palo Laziale Mediterranean Forest. This area has been recognized as a CIS and since 2017 has been included in the LIFE PRIMED project focused on a series of ecological restoration interventions. Representative vegetation species were *Quercus cerris, Fraxinus angustifolia ssp. oxycarpa, Phillyrea latifolia,* and *Pistacia lentiscu*s. Structural and functional trait measurements were conducted on these species during the spring and summer months of 2022, aiming to define what plant species were useful to restore degraded areas of the Palo Laziale Forest. The allometric measurements allowed the estimation of above-ground biomass (1.38 tC/ha, AGB). The integration of AGB with diametric class distribution data confirmed the occurrence of secondary succession in the degraded forest. *Q. cerris* exhibited good resilience to the drought stress conditions showing Leaf Area Index (LAI=1.96 m² leaf area/m² soil) and Specific Leaf Area (SLA=13.7 mm² leaf area/mg dry weight) comparable to those reported in the literature under the absence of drought stress. These parameters were also calculated, for the first time in Italy, in *F. angustifolia ssp*. (LAI=2.80 m² leaf area/m² soil and SLA=9.6 mm² leaf area/mg dry weight). The CO_2 in the biomass of the degraded wood was quantified as 5.25 tCO_2/ha, pointing out a good C sink of the site. Finally, the analysis of these indicators will be useful for an appropriate monitoring strategy to verify the effectiveness of the ecological restoration interventions in progress.

Role of nursery habitats in sustaining trophic relay processes in a Mediterranean coastal lagoon

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In coastal lagoons, saltmarsh habitats play an important nursery role for several invertebrate and vertebrate species, which take advantage of abundant trophic resources and sheltered conditions of these environments. Fish species using such nurseries actively export the energy gained towards adjacent habitats, connecting confined sites with the rest of the lagoonal habitats and eventually the sea, through the process that has been described by the "trophic relay" model. Here, we assessed three confined saltmarsh habitats of the Venice Lagoon with the aim to investigate their ecological role as nurseries and to estimate the trophic pathways sustaining the most abundant fish species that contributes to the trophic relay. Sampling of fish community and potential prey was performed from spring to autumn 2019, in two sites of each saltmarsh: the intertidal creek and the saltmarsh outer edge. Fish assemblages were composed by two resident and two marine migrant species in all habitats. Juveniles of *Chelon ramada* showed the highest abundance among marine migrants and particularly within the intertidal creek, hence it was chosen as target species for this study. Results of stomach content and carbon and nitrogen stable isotope analysis showed the important contribution of hyperbenthos in spring and diatoms in summer, soon after the peak of microphytobenthos biomass. While no relevant differences emerged between the intertidal creek and the outer edge through stable isotope analysis, stomach contents revealed that hyperbenthos was mainly foraged at the outer edge and diatoms were mainly foraged within the creek. Overall, these outcomes i) highlight the importance of the trophic role of nursery habitats in sustaining fish species that consistently use these habitats before migrating towards adjacent systems, hence exerting trophic relay processes; ii) suggest the importance of *C. ramada* as elective fish species involved in such processes in the Venice Lagoon.

Preliminary results on conservation status of coralligenous bioconstructions withinthree MPAs of Tyrrhenian Sea.

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Mediterranean coralligenous bioconstructions result from the accumulation of carbonatic skeletons of many sciaphilic species. These assemblages are considered biodiversity hot spots andtherefore are protected by European and national lows. Thus, monitoring activities of their conservation status is of primary importance. Within tree Marine Protected Areas (Punta Campanella - PC, Santa Maria di Castellabate - SMC andCosta degli Infreschi e della Masseta – CIM) the conservation status of coralligenous bioconstructions was assessed by the STAndaRdize coralligenous protocol (STAR: ISPRA 191/2020). STAR includes the itegrated evaluation of three indexes: ESCA, focused on biocenotic aspects, COARSE, on landscaping and ISLA, on species sensitivity levels (SL). 270 pictures, taken between 33 and 37 meters depth by scuba divers, were examined.

Statistical analyses were performed on cover percentage matrix, and differences among MPAs (p <0.001) and sites (p < 0.05) were detected. The taxa/morphological groups that better contribute to dissimilarities are: algal felt (SL=1), encrusting calcareous rhodophyta (SL=4), cylindrical erect ochrophyta (SL=6) and *Eunicella cavolini* (SL=10). Within PC 26 taxa/morphological groups were detected and ESCA ranges between 0.64 and 0.91, COARSE between 1.07 and 1.27 and ISLA between 0.36 and 0.47. Within SMC 20 taxa/morphological groups were detected and ESCA rangesbetween 0.43 and 0.55, COARSE between 0.51 and 0.95 and ISLA between 0.31 and 0.37. Within CIM 28 taxa/morphological groups were detected and ESCA ranges between 0.49 and 0.81, COARSEbetween 1.40 and 1.44 and ISLA between 0.35 and 0.41. Higher ESCA values in PC show that coralligenous bioconstructions are better structured, followed by those of CIM and of SMC, where lower values have been found. Low values of COARSE and ISLA in all the MPAs suggest that conservation actions should be increased. Indeed, most of taxa/morphological groups that better contribute to distinguish bioconstructions among MPAs show high values of SL.

Population dynamics and isotopic niche of *Callinectes sapidus* in a Mediterranean hyperaline coastal marine ecosystem, the Stagnone di Marsala.

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Biological invasions are globally acknowledged as one of the major threats to biodiversity, hence it is deemed urgent understanding the effects of invasive species on recipient ecosystems, and the possible impacts on the invaded community. Here, we investigated the population of the invasive Atlantic blue crab *Callinectes sapidus* that has recently established in Sicily, in the Stagnone di Marsala (Italy), with the aim to assess its population dynamics and trophic role within such invaded area. Firstly, we investigated the population structure and its seasonal dynamics. Thereafter, estimation of the isotopic niche and trophic position was conducted by comparing *C. sapidus* with two autochthonous brachyurans, *Carcinus aestuarii* and *Eriphia verrucosa,* in order to assess potential trophic overlap with other crabs. Results showed a seasonal trend of the blue crab's abundance, and a heterogeneous distribution of males and females in this basin. Moreover, despite the low abundance compared to other Mediterranean areas, this study showed how this species is largely capable to establish and reproduce in habitats where environmental characteristics (*e.g.*, salinity) are different from those experienced in the native environment as well in other areas to date invaded. Isotopic niche results confirmed the highly opportunistic behaviour of the blue crab, and its high trophic flexibility even within a relatively small basin such as the Stagnone di Marsala. Furthermore, the comparison among the three brachyurans species suggested a clear repartition of the trophic niche, given by exploitation of different food sources and diverse trophic habits. Overall, these findings indicate an expansion of the environments that this species is able to colonise, and a repartition of isotopic niche with other brachyurans, providing important information to perform projection of its future distribution, useful to better understand its ecological role in invaded areas.

The concept and application of individual home-range.

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There are a few key ecological concepts which are not fully operational since they are not clearly defined in space, time or space & time windows. Home range is one of these concepts. Even though it can be clearly defined, as the spatial area required by an individual to satisfy its overall needs over the life cycle, the operationality and comparability of the concept of home range can be hindered due to the complexity of individual behavior, such as sociality, and life cycle, as well as the absence of a standardized individual tracking system for most, if not all, species. Thus, the concept of home range can only be fully operational and comparable when the temporal and spatial scales are appropriately defined, based on the specific scientific questions being addressed. Here, we present a few study cases, covering both terrestrial and aquatic species, at local and global scale, using field and laboratory data to analyze the actual concept consistent with the data used, which allows assessment of home-range size and gives insights into the underlying mechanisms. When the spatial area required by an individual to satisfy its overall needs is contextualized to the competitive interactions between individuals of the same or different species, a time frame and an individual tracking system can be adapted to describe and analyze the spatial extent where interactions occur as well as the resource-mediated interaction among individuals. As all interactions occur in space, a proper, modular, definition of home range seems suitable to assign a spatial extent to intra and interspecific interactions among competing individuals.

Biodiversity can enhance above and belowground functioning via phenological mechanisms

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It is often argued that biodiversity enhances ecosystem functioning when species with complementary niches allow biological communities to capture resources more efficiently or by the presence of one dominant species. Yet, the role of community phenology as a measure of temporal niche breadth has rarely been explored. Moreover, plant phenology is typically assessed aboveground, and less is known about the phenology of belowground processes or they are affected by biological diversity. We measured plant (plant height and greenness) and soil (root growth and detritivore feeding activity) processes as proxies of biological activity every two weeks for one year in an experimental grassland, where plant diversity ranges from monocultures to 60-species mixtures. We tested how plant diversity and climatic factors predict the phenology of aboveground-belowground activity during spring, summer, and winter. In the growing season, peak plant height preceded greenness. Root production started right after leaf senescence and continued throughout the winter. Detritivores were active throughout the year but with high variability, with peaks in summer and late fall. Plant diversity effects on biological activity were present throughout the whole year, but their magnitude and/or changed. Surprisingly, plant species richness showed constant positive effects on root production, even during winter, when aboveground plant organs are dormant. With this, we show that diversity has effects on the community earlier than the start of the growing season. Soil temperature and moisture also showed strong effects on above-belowground activity throughout the year. In some cases, plant diversity affected the climatic variables, evidencing indirect effects of diversity on ecosystem functioning. By providing fine-resolution within-year data, we show fundamental differences in the phenological patterns of shoots, roots, and soil fauna activity, stressing the role of plant diversity in modulating plant-soil interdependence and ecosystem functioning.

A crucial heart pulses within complex Antarctic food webs

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The Ross Sea (Antarctica) is considered a biodiversity hotspot. Nevertheless, mechanisms underlying the persistence of complex Antarctic food webs are poorly understood, hindering predictions of the effects of climate change on Antarctic communities and associated ecosystem services. Based on isotopic data and Bayesian mixing models, we investigated changes in complex food webs following seasonal sea-ice breakup and associated resource inputs in the Ross Sea. We hypothesized that niche partitioning and foraging optimization by consumers would lead to stable and efficient food webs. While the food web simplified after sea-ice break up, observed complexity was too high to achieve local stability both before and after break up. Hence, in order to investigate stability mechanisms in such complex communities, we focused on the Most Important Energy Pathway (MIEP) supporting each species, i.e. we selected the strongest trophic link for each consumer species. On average, MIEPs delivered nearly the 40% of the assimilated diet, with the contribution of sympagic algae and plankton increasing after sea-ice break up. Notably, MIEPs involved a very small percentage of food chains (3% and 8% before and after sea-ice break up respectively), which were evenly distributed on diverse basal resources and were shorter than the remaining food chains in the web. This produced a highly modular and efficient structure characterized by low levels of niche overlap among consumers. Our results unveil the presence of a simple, stable, and efficient heart pulsing within complex Antarctic food webs, providing crucial insights into persistence mechanisms of complex ecological communities. The diversity and timing of resource inputs, coupled with consumer foraging optimization, were key factors in promoting food web stability. These findings can help predict how Antarctic food webs will restructure in response to changes in resource inputs under climate change scenarios, enhancing biodiversity conservation and management in the Ross Sea MPA.

Fish invasions in inland waters: synergy between competition and habitat simplification in Lake Bracciano.

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Non-native fish invasions are among the main causes of biodiversity loss and impairment of ecosystem structure and functioning in freshwaters. Invaders may have direct impacts through predation and competition, and indirect impacts through cascading effects along the trophic chains. The ecological factors that allow alien species to establish in receiving ecosystems can be extremely complex and difficult to understand. Coupling the competitive interactions between invasive and native species with the habitat simplification due to anthropic impacts may be one key to understanding the mechanisms underlying the success of alien species. We investigated, by means of carbon and nitrogen stable isotope analysis, the trophic niche of three alien species (*Pseudorasbora parva*, *Lepomis gibbosus* and *Gambusia holbrooki*) and a native species (*Salaria fluviatilis*) in three littoral areas of Lake Bracciano differing for habitat complexity. The results of this study show that environmental complexity is the main driver in shaping the isotopic niches of the studied species. The degree of niche overlap increased with the simplification of the habitat, and it was highest at the site with the highest degree of anthropization. *Lepomis gibbosus* was the species with the highest trophic plasticity and, where environmental complexity was higher, its niche was completely separated from other species. On the other hand, the native *S. fluviatilis* did not shift its niche between sites. Overall, we observed a decrease in the community metrics (Carbon Range, Nitrogen Range, Total Area and Centroid Distance) with the reduction of the habitat complexity. In conclusion, this study highlights a greater competitive pressure of alien species (showing high trophic plasticity) on autochthonous species in areas subject to habitat simplification. Therefore, maintaining high levels of habitat heterogeneity is of fundamental importance to limit the effect of alien species on native species such as *Salaria fluviatilis*.

Effects of simulated heatwaves on sedimentary organic matter quantity, biochemical composition and turnover in a Mediterranean coastal lagoon

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Heatwaves (HWs) frequency and intensity in the Mediterranean Sea are increasing and their effects on aquatic communities are well known. Nonetheless, HWs impacts on coastal lagoons biogeochemistry are less known. To cope with this gap of knowledge, within the project eINS - Ecosystem of Innovation for Next Generation Sardinia (CUP F53C22000430001- MUR Grant Assignment Decree No. 1056), we conducted a manipulative experiment in mesocosm. Lagoon sediments (Santa Gilla Lagoon, Sardinia) were exposed to simulated heatwaves, that led the sediments acclimated at 21°C to reach (in 5 days) 25, 29 and 33°C, corresponding to +4, +8 and +12°C T anomalies. After another 5 days of exposure, sediments were analyzed in terms of biochemical composition and degradation rates. Biopolymeric C contents declined in reference sediments (by -6%) and sediments exposed to +4°C (-20%), +8°C (-26%) and +12°C (by -19%) anomalies. Contents of all biochemical compounds, but carbohydrates, decreased in either reference or treated sediments, though with patterns varying across T anomalies. The largest drop was observed at +8°C for proteins (-24%), and at +12°C for carbohydrates (-29%), lipids (-28%), and phytopigments (-51°). Aminopeptidase (LEU) and β-glucosidase (BETA) activities decreased in reference and treated sediments, with maximum drops for LEU in reference sediments and sediments exposed to the +15°C anomaly (both -51%). BETA activities showed the maximum drop (-50%) at +4°C. C turnover time increased (+93%) more in reference than treated sediments (+21-64%). The exposure to HWs determined a major modification of the sedimentary organic matter biochemical composition, with sediments exposed at +12°C clearly segregated from all other treatments. Since the trophic status of sediments depends upon quantity, composition and degradation rates of organic matter, we contend that, though with differences among T anomalies, HWs can have detrimental short-term consequences on the food availability for coastal lagoon benthic consumers.

Structure and dynamics of the phytoplankton assemblages in the Northwestern Adriatic Sea: 2008–2019 time series data

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Marine phytoplankton is responsible for nearly half of the photosynthetic fixation of CO_2 and, subsequently, for generating various biomolecules such as carbohydrates, proteins and lipids. Moreover, it represents the first level of the ocean food web. Due to the fundamental ecological role of phytoplankton, the main aim of this study was to assess whether the phytoplankton assemblage structure variations in time and space could be influenced by environmental forcings. Time series data (2008–2019) of phytoplankton assemblage structure in two coastal sites of the Northwestern Adriatic Sea was investigated and, for both stations, physico-chemical and biological parameters, including surface seawater samples, were recorded by a CTD multiparametric probe monthly. Phytoplankton identification and quantification by light microscopy, chlorophyll *a* (Chl *a*) and dissolved inorganic nutrients determinations were performed in sub-samples. From our results, diatom species such as *Skeletonema marinoi*, *Thalassionema nitzschioides*, *Dactyliosolen fragilissimus*, and undetermined Dinophyceae, showed a non-random pattern in the binary time series. S. *marinoi* was more frequent in winter and early spring, whereas *T. nitzschioides* showed an opposite pattern with high frequency in late spring and summer. This was due by a clear and almost regular 12-month period cycle; while the *D. fragilissimus* deviation from randomness was caused by the long-term trend of this species time series, as this diatom appeared more frequently since 2016. In conclusion, it was shown that in the Northwestern Adriatic Sea, phytoplankton assemblage structure was likely driven by seasonal and environmental factors. Since phytoplankton is considered a good proxy for quantifying environmental changes due to its rapid turnover and response to environmental changes, the study of time series assemblage structure may be crucial to move towards water quality targets, as required by both the European Water Framework Directive and Marine Strategy Framework Directive.

An ecological model to analyze and control the dynamics of a leafminer pest (*Tuta absoluta*) on tomato (*Solanum lycopersicum)*

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The South American insect *Tuta absoluta* is a key leaf-mining pest for tomato plants (*Solanum lycopersicum*) and it is gaining attention worldwide because of its devastating effects on yield. In the last 15 years, *T. absoluta* was in fact able to invade and rapidly expand into most of the European and African countries. All current estimates indicate growing dangers for its potential spread into all key tomato-growing regions. Despite the major importance of this pest at the global scale, the few models available to date have mainly focused on the developmental dynamics of *T. absoluta* at the individual-, rather than population- or even community- (*i.e.*, plant-pest) level. Here we propose and discuss the functioning of a first ecological, process-based mathematical model accounting for the interdependent dynamics of a population of the herbivorous insect *T. absoluta* and of the tomato plants it feeds on. Our model explicitly and causally incorporates the effects of water and nutrients availability, as well as of temperature, on the growth of insects and plants populations. After having calibrated the model on empirical evidence and available data, we found it can qualitatively reproduce several of the observed patterns. Given the mechanistic nature of our modelling approach, the framework was eventually used to analyze the combined effects of different temperatures and fertilization/irrigation (fertigation) management policies on (i) the tomato yield, and (ii) the health of the whole production system. Top-down control practices (*i.e.*, biocontrol) were finally contrasted to bottom-up (fertigation) actions so as to quantitatively discuss effectiveness and trade-offs of a portfolio of management policies.

Mediterranean beaches and oceanic paradigms: insights from communities inhabiting different supralittoral substrates.

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Among ecological paradigms for sandy beaches at global level, the Habitat Harshness Hypothesis (HHH) predicts a decrease in species number of resident organisms and of their interactions under conditions of increasing exposure to the energy of incoming waves, paired with coarse substrate. However, hypotheses are based on oceanic sites, microtidal and located in the Southern hemisphere. Furthermore, most information about beach communities is built on its semiterrestrial component, tied to the presence of water -or water saturation- of the substrate. In this context, Mediterranean beaches represent outliers, as they lack typical oceanic waves, and are characterized by higher patchiness of substrates. They offer therefore an occasion to test overall paradigms. To this aim, six pocket beaches on the Northern shore of Crete, aligned along a coastal stretch of 8 km, were selected based on their substrate: sand, mixed coarse, banquette and cobbles. A monthly sampling over a year allowed to gather data of 1) abiotic basic metrics such as beach width, beach face slope, mean grain size, and 2) community diversity, reaching species-level discrimination and traits discrimination related to “air breathers” and “water breathers”, two co-occurrent components along the emersed littoral of a beach. The nMDS ordering indicated a more homogeneous distribution of the “water breathers” (global R = 0.666) across substrates, while the “air breathers” are discriminated against the different substrates (global R = 0.077). Results point at the fact that the abiotic constraints defined for oceanic sandy beaches better apply to the “water breathers” from fine-medium sand, while the variety of sandy beaches includes other substrata which are not as limiting as foreseen by the HHH but are characterized by different “air breathers” components.

Native vs. introduced sabellids in the Faro Lake (Messina): Does a competition exist?

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Competition with invasive species is cause of decline and even extinction of endemic species, both in continental and marine environments. In Mediterranean, the Indo-Pacific polychaete *Branchiomma boholense* (Grube, 1878), is an interesting case study. This invasive sabellid in 2007 reached the Natural Reserve of Capo Peloro Lagoon North-Eastern Sicily, settling in the Faro Lake. *B. boholense*, despite being a sessile hard-bottom species, rapidly spread in the soft bottoms, already colonized by infaunal and semi-infaunal sabellids, i.e., the alleged Lessepsian *Branchiomma luctuosum* (Grube, 1870), the native *Acromegalomma lanigerum* (Grube, 1846), and the endemic *Myxicola cosentini* (Putignano et al. 2023), the latter formerly reported as *Myxicola* sp.. Starting from the first evidence of an ongoing invasive process, the population density of *B. boholense* and other sabellid species was evaluated during Spring 2012, 2013, 2016 and 2019, by counting all specimens of each sabellid species present in sixteen stations, each of 100m^2 surface.
To test the time effect on the possible competition relationships, we performed a generalized linear model (GLM) for repeated measures which provides analysis of variance when the same measurement is made several times on each subject. We used time as a within-subject effect factor and the between-group effect (status: indigenous/endemic vs. introduced/naturalized) for the selected times. Repeated measure ANOVA, taking the cross-product status-time into account, showed a highly significant difference between the sampling events ($F=6.24$, $DF=7$, $P=0.012$). Moreover, only the interaction of time and status effect was significant, as status effect and time exhibited a $P>0.14$.
Results demonstrated that a trait-driven competition occurred between couples of species characterized by similar tentacle crowns, i.e., the native *A. lanigerum* vs. the naturalized *B. luctuosum*, as well as the endemic *M. cosentini* vs. the invasive *B. boholense*. Moreover, the two non-native species showed a similar interannual trend.

Temperature and predation pressure interactively affect from population- to community-level ontogenetic metabolic scaling of aquatic organisms

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According to the metabolic theory of ecology, metabolic rate, an important indicator of the pace of life, varies with body mass and temperature as a result of internal physical constraints. However, various ecological factors may also affect metabolic rate and its scaling with body mass. Although reports of such effects on metabolic scaling usually focus on single factors, the possibility of significant interactive effects between multiple factors requires further study. We show that the effect of temperature on the ontogenetic scaling of resting metabolic rate depends critically on habitat differences in predation regime for: i. freshwater and lagoon amphipod population, ii. marine invasive mussel population, and iii. freshwater macroinvertebrate communities. Increasing temperature tends to cause decreases in the metabolic scaling exponent (slope) at population- and community-level in systems with predation pressure. Accordingly, the temperature sensitivity of metabolic rate is not only size-specific, but also its relationship to body size shifts dramatically in response to predation pressure. Our results demonstrate a complex interaction among metabolic rate, body mass, temperature and predation regime from individual- to community-level of aquatic organisms. The intraspecific scaling of metabolic rate with body mass and temperature is not merely the result of physical constraints related to internal body design and biochemical kinetics, but rather is ecologically sensitive and evolutionarily malleable.

Pinna nobilis dead shells as a receptacle of a diverse and rich mollusc community. Acase study from the northern Adriatic Sea

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Pinna nobilis is the largest endemic bivalve of the Mediterranean Sea that plays key ecological roles in coastal ecosystems. As a suspension feeder, it facilitates the transfer of energy and matter from the water column to the sediment, promoting benthic-pelagic coupling and benefiting infaunal communities. In addition, the fan mussel is considered as an ecosystem engineer and catalyst for enhancing local biodiversity by creating new suitable substrates and providing shelter for a diverse epibenthic community. Recently, *P.nobilis* has experienced an epidemic mass mortality that broughtit close to the brink of local extinction in several Mediterranean regions, including the northern Adriatic Sea and the Gulf of Trieste. Despite this significant loss, the numerous empty shells of *P. nobilis*, that remained intact and firmly anchored in the sediment, continued to serve as substrate giving rise to complex 3D-structures that harbour and thrive rich and diverse benthic communities.The aim of this study is to evaluate the persistence of the ecological role of empty *P. nobilis* shells as biodiversity enhancers by investigating the associated epibenthic community. As an initial step, the study conducted a structural analysis of mollusc community living associated with *P. nobilis* shells collected from four different sites in the Gulf of Trieste. A total of 96 mollusc species characteristic of both infralittoral and sublittoral hard and soft bottoms, were identified in thirteendead specimens of the fan mussel. In addition, significantly high diversity metrics were observed, suggesting that a rich mollusc community inhabits both the outer surface and inner cavities of the fan mussel shells, and that the shells now freed from the animal may also host some soft-bottom mollusc species. These findings confirm that the role of the bivalve as an island of biodiversity persists after the death of the animal.

Large-scale spatial variation in the structure of lotic food webs in Ohio (USA).

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There is a pressing need to better understand the spatial dynamics of trophic networks, and how they adapt their structure to local environmental conditions as well as to global scale pressures such as climate warming. However, studies on the spatial variation of highly-resolved food webs are to date relatively rare and mostly focused on marine environments. Here we analyzed a huge data set that we made available in the Dryad repository including information on the fish assemblages characterizing lotic environments of different order located throughout the State of Ohio, USA for a total of 2051 sampling sites. The set, originally reporting the common names of the sampled taxa, data on their abundance and individual body size, together with information on sampling procedures, was updated by including Linnaean taxonomic nomenclature and made spatially explicit and GIS-ready. By including the trophic level of fish taxa as recorded in FishBase, the set was used for estimating cumulative trophic indices and investigate their spatial co-variation with taxonomic or functional diversity indicators from a whole-state to a single-basin or -reach scale. Furthermore, a binary matrix representing the meta food web for the whole Ohio State was constructed after completing the set with information from FishBase and other scientific references on fish potential vegetal and animal prey. This allowed, by sub-sampling the Ohio meta-food web, the estimation of descriptive structural metrics at the level of single sampling site and an in-depth scrutiny of their spatial variability. The possibility of further increasing the resolution of the network by including e.g., data on the occurrence of invertebrate preys available from external sources, e.g, PREDICTS, GBIF, US EPA is discussed, together with sampling pitfalls of the adopted methodological approach.

Functional diversity of invertebrate communities associated with Pacific oysters' (*Magallana gigas*) aggregations in the Mediterranean Sea

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Pacific oysters (*Magallana gigas*) are important ecosystem engineers, which modify habitats influencing local biodiversity. However, functional roles of the species associated with their aggregations in the Mediterranean Sea are overlooked. Research of functional traits of benthic communities can often reveal more information on their ecology compared to classical taxonomic approaches. In this study, we accessed spatial and temporal patterns in functional diversity of invertebrate communities associated with wild and farmed Pacific oysters in the Northern Adriatic Sea. Life modalities of five life traits (Bioturbation, Body size, Feeding habit, Larval development and Adult mobility) were assigned to each of the 103 recorded taxa, using fuzzy coding procedure. In general, most of the analysed species were sessile, superficial modifiers, suspension/filter feeders and predators, with body size of 10-50 mm and direct and planktotrophic development. This functional composition was mostly due to the high diversity and abundance of Annelids and Arthropods. Higher diversity of functional traits and an increase of individuals of small dimensions was observed in autumn period, particularly within farmed oysters. Observed trends will be related with habitat characteristics. Our research revealed lack of knowledge regarding life trait features of numerous species and suggests that more basic studies should be done to provide information on functional characteristics of benthic organisms.

Functional traits mediate the response of spiders to urbanization

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The conversion of natural and rural land into urban areas, i.e. urbanization, affects all ecosystem components, with multifaceted repercussions on biodiversity. The investigation of the ecological dynamics occurring in urban ecosystems represents a lively and debated topic in urban ecology and evidence in literature suggests that functional traits play a key role in mediating species response to urbanization. To gain more insights into this topic, we developed a specific study designed to investigate the urban-driven selective processes acting on ground-dwelling arthropods in Torino (NW-Italy). By using ground spiders as model organisms, we provide evidence that the process of urbanization correlates with a strong decline of spider diversity and abundance, in parallel with a filtering effect on functional traits, i.e. body size, dispersal capacity and trophic behavior. More specifically, by combining taxonomic and functional patterns of spider communities along the urbanization gradient we unraveled that different selective mechanisms, namely environmental filtering and dispersal barriers, act on biotic communities in urban habitats. Such selective process was evident also on the intraspecific body size variation of three spider species differing in their dispersal behavior, with stronger environmental selection on the sedentary species. Overall, by combining the results obtained at community and population level, we outline the role of functional traits as key elements in mediating species response to urbanization in spiders.

Does survival of *Paracentrotus lividus* recruits depend on predator size and habitattype?

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Sea urchin harvest in Sardinia has been so intense in the last two decades that their populations have drastically regressed and concerns have arisen about the effectiveness of harvest restrictions.According to the theory of phase transition in shallow rocky reefs between vegetated and barren habitats, sea urchin recruitment, a key process structuring population, seems hampered by some stabilizing feedbacks despite sea urchin harvest has quit. To shed a light on predation effects on seaurchins recruits, a 27-day field experiment was conducted using exclusion cages (40x40x40 cm, 1 cm in mesh size) in barren and turf substrates, that differ in micro predator assemblages. At this aim, 672 recruits (1.1 ± 0.02 cm in size) reared under control conditions were positioned in groups of 42 in each experimental unit (n=4). Predator exclusion had a significant effect regardless the substrate, since a higher number of recruits was found under cages both in turf and barren. However, the results showed that the size of survived recruits was larger in turf than in barren, as in the former substrate micropredation has reduced the abundance of the smallest recruits, highlighting that predator size affects differently the size of the survived recruits depending on the substrate. Overall, these results provide valuable information addressing actions to restock sea urchin populations in overharvested areas and studies on habitat stability mechanisms.

Urbanization drives changes in foliage-dwelling spider communities

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Urbanization is one of the major human-induced global changes, being responsible for several biotic and abiotic environmental alterations at both local and landscape scale, such as habitat fragmentation, temperature increase, pollution and changes in resource availability. Although evidence in literature highlighted negative effects on the diversity of several arthropod communities, little is known about the response of foliage-dwelling spiders.

To fill this gap, in this research, we investigated the diversity patterns of foliage-dwelling spiders across an urbanization gradient in the city of Torino (NW-Italy). A total of 32 sites have been selected across nine urban parks, from the city centre to the suburban areas, and in a natural park next to the city. Foliage-dwelling spiders were sampled with the beating tray method during autumn 2022. Overall, the results show that communities sampled in the most urbanized sites are composed by a filtered subset of the communities sampled in the low-urbanized sites. By applying GLMMs, we demonstrated that species richness, abundance and the number of foraging guilds significantly decrease at increasing values of urbanization. In terms of feeding groups, we detected a shift towards ambush hunter strategies as a possible result of the functional homogenization due to habitat simplification.

Overall, our results demonstrate that urbanization exerts a strong filtering effect on foliage dwelling spider communities. Since spiders are predators exerting a significant top-down control on invertebrate communities, changes in their species composition may have strong repercussions on lower trophic levels, and as such impact ecosystem goods and services. Looking ahead, we have plans to integrate data collected during the spring season allowing us to gain a more comprehensive understanding of the fluctuations and patterns that occur within these urban ecosystems throughout the year.

Toward benthic health in mussel productive areas: evaluation of sea cucumbers as extractive species in Multitrophic-Integrated Aquaculture with mussels *Mytilus galloprovincialis*

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Multitrophic Integrated Aquaculture (IMTA) is a production system based on the exploitation of the existing trophic interactions in ecological communities for the rearing of commercial species from different trophic levels. IMTA of mussels and holothurians is highly attractive since both these organisms have high economic value and fundamental environmental role. Mussel farming is one of the most widespread industrial shellfish production, while sea cucumber aquaculture is a growing aquaculture sector because of overexploitation of natural stocks. Mussel and sea cucumber co-culture does not need external food input, resulting in an eco-friendly protein source production. Mussels are filter-feeders feeding on natural primary production and produce a consistent organic matter input in nearby areas that could be an attractive food source for deposit-feeder sea cucumbers. They ingest sediment and organic material, playing an important role in nutrient cycling and energy flow. Hence, the aim of the present study was to evaluate the culture of four Mediterranean sea cucumbers (*Holothuria tubulosa*, *H. polii, H. mammata* and *H. Sanctori*) when integrated as extractive species in mussel (*Mytilus galloprovincialis*) productive plants. The IMTA experiment was carried out in a long-line mussel farm in Gaeta (Tyrrhenian Sea) between 2022 and 2023. Sea cucumber Subadults were placed in seabed cages beneath the mussel farm for six months and sea cucumber ability to use mussel waste as trophic source was evaluated in terms of survivorship and somatic growth. Results highlighted different responses, with *H. tubulosa* and *H. mammata* presenting the best overall performance, followed by and *H. sanctori*, while *H. polii* presented the poorest compatibility with mussel co-culture. Findings confirmed the value of combining mussels and holothurians in a multitrophic and eco-sustainable production system, but also highlighted that these species have different trophic ecology and culture requirements despite belonging to the same trophic level.

Mediterranean coastal landscapes and moth diversity: does dune zonation matter?

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Moth communities play key roles in ecosystem functioning. While moth larvae have strong links with their host plants, the adults are usually generalist pollinators. The relationships between moths and vegetation have been explored in many ecosystems worldwide, but little is known from Mediterranean coastal dunes. We analysed moth and plant diversity in an Adriatic Long-term Ecological Research Network site (LTER-IT20) in Central Italy. Plant and moth sampling were conducted on the shifting dunes and on the backdunes along transects placed perpendicularly to the seashore. Moths were collected every 15 days using light traps (UV LEDs) for one year (December 2021 - November 2022). Vegetation was sampled with a random stratified protocol using 4m x 4m plots. For both moths and vascular plants, we compared differences in community structure between shifting dunes and backdunes, and used multivariate analyses to explore the association between moths and vegetation zonation. Overall, we collected 1,587 moths belonging to 171 species, with Noctuidae and Geometridae being the most represented families (with 71 and 35 species, respectively). Moth diversity was slightly higher on the backdunes than on the shifting dunes. We found a high beta-diversity between the two zones, with 20% of the species exclusive of the shifting dunes, and 30% limited to the backdunes. Plant communities showed a clear zonation, with a high turnover in species richness between the two zones. Shifting dunes were characterised by the presence of oligophagous moth species feeding on Poaceae (e.g. *Euxoa segnilis* and *Mythimna riparia*), whereas species feeding on plants of Mediterranean macchia (e.g. *Zebeeba falsalis*) exclusively occurred on the backdunes. The high number of moth species associated with specific zones of the dune and their potential role as pollinators highlight the importance of dune vegetation integrity in maintaining multi-taxa biodiversity in coastal ecosystems in the Mediterranean.

The Invasive Seaweed *Caulerpa cylidracea* as a potential New Trophic Resource in the Mediterranean Sea

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Biological invasions represent one of the greatest threats to biodiversity and ecosystem functioning, competing with native species and altering invaded habitats. The Mediterranean basin is relatively rich in species, but its coasts are densely populated and its living resources deeply-exploited. As a consequence of such a long history of exploitation, the basin is exposed to different human pressures, whose combination ultimately leads to multiple effects on marine ecosystems, further amplified by ongoing warming under climate change. The tropical *Caulerpa cylindracea* Sonder, is a non-indigenous invasive seaweed in the Mediterranean Sea, widely distributed in the coastal habitats, which ultimately affects marine biodiversity and ecosystem functioning. Here, a systematic literature analysis on the consumption of the invasive *C. cylindracea* by Mediterranean native and non-indigenous species is provided, focusing on the pros and cons for the native communities and human health. The present research aims to resume knowledge and provide tools to manage the presence of the invasive seaweed *C. cylindracea* in the Mediterranean Sea, encouraging an ecosystem-based approach to the management of the ecological, economic, and social effects of the successful expansion of this alga.

Scaling of space use behavior with body mass and metabolic rate across temperature levels

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Elucidating the underlying mechanisms behind variations of animal space and resource use is crucial to pinpoint the relevant ecological phenomena. Organism's traits related to its energy requirements might be central in explaining behavioral variation, as the ultimate goal of a forager is to fulfill its energy requirements. However, it has remained poorly understood to what extent individual energy requirement determines the behavioral patterns. Here we aimed to assess how behavioral patterns in use of space and resource in a patchy environment, are influenced by the foragers' metabolic rate and its main determinants i.e. body mass and temperature. We tested the individual behavioural patterns and metabolic rates of a model organism, the amphipod *Gammarus insensibilis*, across a range of body masses and temperatures. Our result showed that body mass and temperature exert a major influence on foraging decisions and space use behaviour via their effects on metabolic rates. Individual cumulative space use was found to scale allometrically with body mass and exponentially with temperature, with patch giving-up time falling as body mass and temperature increased. Moreover, cumulative space use scaled isometrically with SMR, and patch giving-up time characterized by negative SMR dependence. Remarkably, we found that SMR had greater predictive power for behavioural patterns than body mass and temperature combined. Our findings regarding the mechanistic relationship between behavioural patterns and metabolic rate across body mass and temperature shed light on higher-order energy-based ecological processes, with implications in the face of climate change.

Trophic and behavioural traits influence mercury accumulation in fish naturally exposed to low pH conditions in a Mediterranean shallow CO_2 vent.

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Ocean acidification is not an isolated threat to marine organisms, as it may act in combination with other stressors (*e.g.* warming, hypoxia, pollution). Shallow CO_2 volcanic vents, in particular, provide an opportunity to study trace element bioaccumulation processes as a natural spill out of trace elements takes place in these areas and their bioavailability is favoured by the low pH and Eh conditions. In this study, we investigated the influence of trophic and behavioural traits on the bioaccumulation patterns of total mercury (THg) in coastal fish associated with *Cymodocea nodosa* seagrass meadows exposed to the naturally acidified conditions of the Island of Vulcano (Aeolian Archipelago, Italy). To this end, sediment and macrophytes together with fifteen fish species belonging to different trophic guilds and habitat use categories (from highly mobile to sedentary fish) were compared for THg concentrations under high pCO_2/low pH (vent) and ambient pH conditions. Spatially localised contamination close to the CO_2 vent resulted in a clear accumulation of THg in benthic primary producers. In fish, although the response was species-specific, higher THg levels were found in low-mobile benthic fish from the vent than in reference sites but not in highly mobile shoaling fish, reflecting the influence of local benthic pathways and restricted movements and habitat use on THg accumulation and trophic transfer. General linear mixed models revealed that THg levels increased more across trophic levels at the vent than at reference sites, suggesting higher rates of bioaccumulation and biomagnification in the former. These results suggest that in future acidified and polluted seas an increase in bioaccumulation and biomagnification of trace elements can be expected.

Modelling interference between vectors of non-persistently transmitted plant viruses to identify effective control strategies

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Aphids are the primary vector of plant viruses. Transient aphids, which probe several plants per day, are considered to be the principal vectors of non-persistently transmitted (NPT) viruses. However, resident aphids, which can complete their life cycle on a single host and are affected by agronomic practices, can transmit NPT viruses as well. Moreover, they can interfere both directly and indirectly with transient aphids, eventually shaping plant disease dynamics. By means of an epidemiological model, originally accounting for ecological principles and agronomic practices, we explore the consequences of fertilization and irrigation, pesticide deployment and roguing of infected plants on the spread of viral diseases in crops. Our results indicate that the spread of NPT viruses can be *i*) both reduced or increased by fertilization and irrigation, depending on whether the interference is direct or indirect; *ii*) counter-intuitively increased by pesticide application and *iii*) reduced by roguing infected plants. We show that a better understanding of vectors' interactions would enhance our understanding of disease transmission, supporting the development of disease management strategies.

Do invasive species survive better in Mediterranean Sea? Case study on metabolic scaling changes of invasive mussel Brachidontes pharaonis in relation to temperature and predation

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A common belief is that body mass scaling of metabolic rate results chiefly from intrinsic body-design constraints. However, several studies have shown that multiple ecological factors affect metabolic scaling. The mechanistic basis of these effects is largely unknown. Here, we explore whether abiotic and biotic environmental factors have interactive effects on invasive mussel's metabolic scaling. To address this question, we studied the simultaneous effects of temperature and predator cues on the ontogenetic metabolic scaling of lessepsian invasive mussel species (Brachidontes pharaonis) in the Mediterranean Sea. We assessed effects of phenotypic plasticity on metabolic scaling by exposing the mussels to experimental conditions with and without predator cues (the blue crab Callinectes sapidus) at multiple temperatures. Temperature interacts significantly with predator cues to affect metabolic scaling. Our results suggest that metabolic scaling is highly malleable in response to short-term acclimation. The interactive effects of temperature and predators show the importance of studying effects of global warming in realistic ecological contexts. Our study expands how environmental and biotic factors interact to affect physiological processes that drive the invasive species distribution range in the Mediterranean Sea.

Assessing and managing toxic phytoplanktonic *Dinophysis* species in aquaculture areas of north-western Adriatic Sea

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Harmful algal blooms (HABs) are a natural phenomenon occurring in all aquatic environments characterized by relatively fast proliferation of toxic phytoplankton. The frequency and intensity of HAB events are increasing in response to global warming and other climate change conditions, with consequences to environment and shellfish safety. During these events, shellfish may accumulate high concentrations of natural toxins and remain contaminated and unsafe for human consumption, jeopardizing shellfish farming. It becomes necessary to develop proactive strategies to predict the environmental changes, HAB formation, and shellfish contamination to anticipate and mitigate these negative impacts. Diarrhetic shellfish toxins (DST) are produced by toxic dinoflagellate *Dinophysis* spp. DSP (diarrhetic shellfish poisoning) toxins are frequently responsible for seafood contamination along NW Adriatic coasts, causing recurrent shellfish farm closures. When toxin accumulation exceeds the regulatory limit, the production is stopped until toxin values return to safe levels. This represents huge economic losses to the aquaculture sector. This project aims to analyse data from the Northern Western Adriatic survey activity. *Dinophysis* spp. abundances and okadaic acid events from 1999 to 2022 were analysed to look for inter-annual trends and seasonality. It also aims to evaluate the use of a molecular qPCR assay for the quantification of *Dinophysis* spp. in aquaculture sites. The preliminary data analysis pointed out a decreasing trend in both *Dinophysis* spp. abundance and toxic events. Moreover, the investigation conducted on seasonal occurrence showed *Dinophysis* spp. higher abundances in late spring-early summer and in late autumn, while higher toxicity of the mussels was registered from late summer through winter. Time series data and environmental parameters analysis will aim to support forecasting HAB formation and shellfish contamination to anticipate and mitigate negative impacts through proper actions in terms of production management, stock distribution or storage, and reducing production waste and economic losses.

An integrated approach for coastal habitat monitoring based on innovative spatial surveying technologies and ecosystem functioning measurements.

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Climate change and human activities threaten the health of the world's oceans. Among marine ecosystems around the world, those on the coasts of the Mediterranean Sea (e.g., seagrass meadows) are particularly threatened. Accurate information about the spatial distribution and functioning of coastal habitats is essential towards effective management of anthropogenic pressures to guarantee the conservation of environmental resources and ecosystem services. In this perspective, the use of innovative technologies may assist the improvement of monitoring methods focused on the spatial distribution (e.g., Unmanned surface vehicles - USVs, and remote operated technologies – ROVs) and functioning (e.g., respirometric benthic chambers) of key coastal habitats. Here, we report the results of habitat distribution using an integrated approach which involves the use of USV and ROV technologies and field measurements of the metabolic functioning of the main key structuring habitat (i.e., *Posidonia oceanica*) along the coast of Civitavecchia (Northern Latium, Italy). The integration of spatial and functional information coming from this novel approach may significantly contribute to the improvement of management and conservation actions plans on key and vulnerable habitats under the current and future climate change scenarios. This work was performed as part of the RENOVATE project, financed by the Port System Authority of the Northern-Central Tyrrhenian Sea.

Butterfly diversity patterns across dune ecotones in the Adriatic coast

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Butterflies offer a sound model for monitoring biodiversity in different ecosystems, yet little is known about spatial patterns of butterfly diversity in coastal dune. We explored the relation between butterfly and vegetation diversity in dune mosaics in an Adriatic Long-term Ecological Research Network site (LTER-IT20) in Central Italy. Butterfly and vascular plant communities were sampled along three transects placed perpendicularly to the seashore following the LTER protocol. Butterflies were sampled every 15 days (April 2022- October 2022) using entomological nets, whereas vascular plants were sampled using a random stratified protocol during spring 2022. We compared butterfly and plant communities diversity on shifting dunes and backdunes (EC- habitats) by using diversity indexes and rank abundance curves. We also explored the association between butterfly species and dune habitats by two-way multivariate classification. We counted 92 butterfly individuals, belonging to 18 species. Butterfly diversity was significantly higher on the backdunes than on the shifting dunes. The rank abundance curves followed a geometric series model, which is typical of harsh environments with simple communities dominated by few species. Three butterfly species occurred exclusively on the shifting dunes and seven on the backdunes, whereas the other ten did not show any clear habitat preference. We registered 71 species of vascular plants, belonging to 28 families, with Poaceae, Asteraceae and Fabaceae being the most abundant ones. Plant distribution responded to a steep zonation, with a high species turnover due to the presence of species exclusive of one of the two habitats. Correlation between plant and butterfly diversity was higher for entomophilous plant species (which are rare in the study system) and lower for the more abundant anemophilous ones. Our results provide evidence of the importance of coastal dune mosaics for preserving plant and insect biodiversity, and the importance of their interspecific relations for assuring ecosystem functions.

Seagrass meadows in the brackish ecosystem of "Oriented Natural Reserve Laghetti di Marinello" (ME)

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The Oriented Natural Reserve "Laghetti di Marinello", located in the north-eastern coast of Sicily, southern Tyrrhenian Sea, includes a highly dynamic coastal brackish system, characterized by both rapid spit accretion and erosion processes. As coastal lagoon, it is a priority habitat of community interest (Directive 92/43/ECC; Annex I, code 1150*), whose floristic characteristics have not been exhaustively investigated yet. In fact, although seagrass species have been reported in the past, nothing is known about their distribution and interaction.

Our investigation testified that meadows of *Cymodocea nodosa* (Ucria) Asch. and *Ruppia* spp. occur in all ponds but occupying two fairly distinct vegetation belts. Moreover, the occurrence of *Halophila stipulacea* (Forssk.) Asch. in Lago Porto Vecchio has been confirmed, associated with *Cymodocea nodosa* and *Caulerpa cylindracea* Sonder. Patches of *C. cylindracea* associated with seagrasses also widely occur, except for the Lago Mergolo, where *C. cylindracea* is absent.

In conclusion, the occurrence of well-established seagrass meadows in different species associations, despite the occurrence of non-indigenous seaweeds, notably implements the ecological value of this protected environment. The need of specific valorization actions is suggested.

The role of the trophic phenotypes as a functional trait of species in the complex architecture of Antarctic benthic biodiversity

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In Antarctica, the food resource availability is regulated by the seasonal sea-ice dynamics, which is undergoing variations due to climate change. To understand the effects of these variations on the Antarctic benthic biodiversity, the diets of two keystone benthic consumers, the scallop *Adamussium colbeki* and the sea-urchin *Sterechinus neumayeri*, were studied before and after the sea-ice breakup through the C and N stable isotope analysis. Bayesian isotopic mixing models were used for the diet quantification of the single individuals considered as trophic-functional units in the web. Then, the diet of the single populations was obtained including the trophic choice of all individuals to highlight the intrapopulation variability in the resource use. The results were compared with the diet based on the average N and C signatures of the populations. The detailed diet of the two species populations showed high intrapopulation diet partitioning compared with the classical approach to diet reconstruction based on average C and N signatures.

The scallop exploited sympagic algae both in period of high availability (as fresh material) and in period of scarce availability (stored in the sediments). The sea-urchin shifted from a strictly herbivorous to a detritivorous diet when the resource became limiting. During the same period a highly significant relationship between the nitrogen isotope signature and the mean biomass (expressed in grams) of the trophic-functional units of the two species was found. Specifically, the higher the weight, the lower the trophic level occupied by the scallop, while the higher the trophic level occupied by the sea-urchin. The intrapopulation niche partitioning by size of individuals can be a strategy adopted by the two abundant Antarctic populations to limit intra- and inter-specific interference when the resources are limiting, and thus to increase their stability. Our results suggest the importance of considering the diet of individuals, as species functional trait, in food web models to obtain detailed information on the structure and stability of communities as well as useful information for biodiversity management.

Importance of mesopelagic prey and effects of the lunar cycle on the diet composition of swordfish (*Xiphias gladius*) in the central Mediterranean Sea.

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Mesopelagic organisms play a critical role in the marine food web, transferring energy from lower to higher trophic levels and linking deep-sea to surface layers through vertical diel migrations. This study highlights the importance of mesopelagic organisms, in particular cephalopods, in the diet ofswordfish (*Xiphias gladius*) in the central Mediterranean. A total of 133 individuals (size: 100–220 cm LJFL) were collected. Qualitative and quantitative analyses of the diet composition were performed and feeding strategy was assessed. Overall, 55 prey taxa were identified and the most represented were teleosts (19 families and 34 species) and cephalopods (14 families and 19 species).Swordfish mainly consumed mesopelagic cephalopods (constituting about 70% of its diet). The percentage index of relative importance (%IRI) revealed that the cephalopod *Todarodes sagittatus* (%IRI = 48.17), *Ancistroteuthis lichensteinii* (%IRI = 23.14), *Heteroteuthis dispar* (%IRI = 10.23) and *Ommastrephes caroli* (%IRI = 6.70) were the most important prey items. Among mesopelagic fishes, the silver scabbardfish and barracudinas were frequently ingested, particularly *Lepidopus caudatus*(% F = 19.66), *Sudis hyalina* (%F = 19.66) and *Lestidiops sphyraenoides* (%F = 11.97). Ommastrephidae, Onychoteuthidae, Sepiolidae and Paralepididae were the main familiesresponsible for the dissimilarity in the swordfish diet composition in relation to some lunar phases of the moon cycle. This study provides information on the role of mesopelagic cephalopods and fishes in the trophic ecology of swordfish, highlighting that these prey items are key species in the diet of this large predator.

Paleolimnological analyses in the Balma Lakes (Northwestern Italy): classic and new proxies to understand changes in flood regimes in alpine ecosystems

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Alpine lakes are remote and pristine ecosystems, hosting communities shaped by severe environmental conditions and showing simple structures, low diversity and simplified trophic webs. Paleolimnological analyses of subfossil communities are commonly used to reconstruct past environmental changes, especially in relation to impacts due to human activities. The effects of flood events in mountains are of particular interest: due global warming, the increase in frequency of extreme precipitations has been observed also in the European Alps, but interpretation and understanding of these events are often difficult in mountain areas, due to their complex topography.

In the present study, we carried out paleolimnological analyses in two alpine lakes in Western Alps (Balma Lakes, Piedmont, Italy), with the aim to investigate temporal changes in subfossil assemblages, in relation to flood events due to the variation of precipitation regimes. The lakes are placed in the same geographical area, but they differ in shape, altitude, and morphological characteristics of the catchments. We analyze chironomid assemblages, commonly studied in paleolimnological reconstructions, and testate amoebae communities, which are still poorly studied in alpine lakes. Chemical characterizations of core profiles were also performed. Our results highlighted significant changes in the analyzed communities and allowed to identify different time periods related to variations in pluvial/drought events of the last 2000 years. Despite they are placed in the same area, the analyzed lakes showed a different history, due to morphological differences in basin morphology. Moreover, the effect due to fish introduction was analyzed, representing a possible bias in environmental evaluations of paleolimnological datasets. Historical and natural archives provided by lacustrine sediments represent an interesting sources of information to better understand past and future evolution of flood and precipitation events and their effects on communities of alpine lakes, which are "early warning systems" for the main mountain area.

Global warming is promoting the rapid invasion of the mountain hare (*Lepus timidus*) range by the European hare (*Lepus europaeus*) in the Alps

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The mountain hare (*Lepus timidus*) is a boreo-alpine species with unfavourable conservation status in the Alps. Climate change seems to impact the species through two interconnected and additive mechanisms. Being adapted to the cold climate, the species probably suffered from the temperature increase over the last decades. Secondly, warmer temperatures promote a rise in altitude of the European hare's (*Lepus europaeus*) with an increased risk of hybridisation and competition.

We investigated the distributional pattern of hare species in the Orco Valley (Gran Paradiso National Park, Western Alps) with genetic techniques based on mtDNA and resampling the same locations after 12 years (2009-2021). We searched for faecal pellets in 47 locations along 250m-transects. The species and sex of collected samples were determined through mtDNA analysis. Locations with mountain hares decreased from 25 (2009) to 14 (2021), while European hares increased from 5 to 9. In 6 locations, individuals of the two species and of different sexes coexisted, thus suggesting a potential for hybridisation. In 2009 the mountain hares were numerically dominant at every altitude (four quartiles between 1544-3010m). In 2021, the European hare dominated at 1544-1889m and 1890-2269m, and the mountain hare was exclusive only at 2471-3010m. The mountain hare dominated only in pioneer vegetation and rocky areas, while European hares were more common in woodlands, shrubs, and alpine meadows.

Our data support the hypothesis of a retreat of the mountain hare to high elevations, where the species is now restricted to a very narrow, high-altitude strip, and an expansion of the European hare, probably favoured by climate change. The considerable spatial overlap suggests that the European-mountain hare system could evolve towards a complete admixture situation with a high risk of hybridisation. Conservation measures should mitigate climate change effects and appropriately manage European hare populations.

The impact of the wolf (*Canis lupus*) on livestock activities in mountain pastures: the case of Piedmont

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Wolf (*Canis lupus*) is a protected species by national and international laws considered extincted in Italy in '70s. Since 1992s, the wolf underwent a natural expansion from the Italian Apennines population to the south-western Alps, even settling recently in hilly and lowland areas. The latest monitoring report estimated in Piedmont, in 2020/2021, the presence of 81 wolf reproductive units (68 packs and 13 couples). The Alpine area is an important connection site for wolves population and since the natural return of the species occurs mainly in rural and mountainous areas, the interactions between the predator and pasturing livestock represent one of the main sources of conflict between wolf and human activities.

The Piedmont region has a large high grazing areas and every year thousands of animals (cattle, sheep and goats predominantly) move to the Piedmontese alpine pastures. In territories where the wolf has disappeared, farmers have lost the habit of coexisting with him; with its return, they are forced to adapt quickly by employing tools and modifying farm management to protect livestock and to prevent attacks. Conflict mitigation is a keys points of the two LIFE project dedicated to the wolf on the Alps, LIFE WolfAlps project (2013-18) and the current LIFE WolfAlps EU project (LIFE18 NAT/IT/000972), with a particular interest in protecting a non-intensive and high-quality pastoralism as an ecological and economic value of priority interest for the territory.

The aim of this work is to analyse the data relating to depredations and grazing in Piedmont in the last decades to assess the impact of the wolf presence. Although several evaluations have already been done, this analysis could be useful to define more effective prevention actions to minimize the conflicts as well as to enhance the conservation of habitats linked to pastures.

Ecological assessment and contaminants input in high-mountain lakes from Alps

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Mountain environments and in particular high-mountain lakes are perceived to be among the most natural and esthetically attractive areas in Europe leading to a general concern for their protection. Alpine lakes are remote and extreme ecosystems undergoing harsh climatic conditions and are characterized by low resilience to disturbances. Oligotrophic conditions, UV radiation intensity, extreme temperatures allow the dwelling of a few dominant but well-adapted species. Global and local anthropogenic pressures, such as pollutants from lowland emission sources, climate change, tourism and mountain farming may threat primeval condition disturbing the physiology of organisms inhabiting the mountain lakes. Metals and microplastics are pro-oxidants exerting oxidative stress via ROS boost hence triggering critical changes in cellular detoxification pathways. Herein we quantify the degree of anthropogenic impact in two high-mountain lakes, Balma (Cottian Alps) and Dimon (Carnic Alps), of northwest Italy during the ice-free season lasting only for few months, from mid-June to late October. Occurrence of microplastic and trace elements (As, Cd, Cr, Cu, Fe, Hg, Pb, Ni, Se, and Zn) were investigated in tissues of brook trout (*Salvelinus fontinalis,* Balma Lake) and bullhead (*Cottus gobio*, Dimon Lake). Oxidative stress biomarkers (e.g. metallothionein, superoxide dismutase, catalase, glutathione peroxidase, glutathione reductase, and glutathione S-transferase) were assessed for the same tissues. The findings highlighted MPs contamination in Balma Lake, whereas metals bioaccumulation was almost similar for both fish species and lakes. Chemical-physical parameters of water and certain metals influenced changes in levels of oxidative stress biomarker in the analysed tissues. Oxidative stress biomarkers along with contaminants bioaccumulation may be informative tools in assessing health of fish species and mountain lakes. Thereby these findings may contribute to an awareness of the extent and potential severity of chemical contamination in extreme ecosystems like mountain lakes.

CO_2 fluxes in Alpine ecosystems: measurements and models from the Gran Paradiso National Park, western Italian Alps.

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High mountains are sentinels of climate change as modifications are manifesting at faster pace than in the surrounding lowlands. In particular, whether future Alpine ecosystems will be carbon sinks or sources depends on a complex suite of processes that primarily affect carbon dioxide (CO_2) fluxes at the soil-vegetation-atmosphere interface. Such processes encompass several space and time scales and involve many different ecosystem components, making future projections difficult. The first step to overcome such model uncertainties is to identify the drivers of CO_2 fluxes and the expected biological responses to climate change, soil moisture variations and modification in land use. To this aim, we study CO_2 emission and uptake in the Alpine Critical Zone (CZ), the surface layer of the Earth that extends from the top of the vegetation canopy to the bedrock, where 'rocks meet life'. Since 2017, IGG-CNR manages a CZ Observatory located at the Nivolet Plain (in the Gran Paradiso National Park, western Italian Alps) that is equipped with portable flux chambers, automated chambers, and an eddy covariance tower. At the same site, sensors for the measurement of meteoclimatic variables are also installed and surveys of ecological descriptors are periodically performed. Comparing different measurement methods and estimating multi regression models based on these data allowed us to identify the main flux drivers and the flux dynamics at different scales. Hence, using an ensemble of studies, we built a framework to explore the response of the CZ to the changes in environmental conditions.

Making high-resolution microclimate information collaborative: a VRE approach to soil temperature in high mountains and glacier forelands

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Landscapes nearby glaciers are disproportionally affected by climate change. Microclimate variations can modulate the impacts of global warming on proglacial ecosystems and their biodiversity. In a recent publication, we used near-subsurface soil temperatures in 175 stations from polar, equatorial and alpine glacier forelands to generate high-resolution temperature reconstructions and assess spatial variability in microclimate change between 2001 and 2020. We found that temporal changes in microclimate were tightly linked to broad-scale conditions, but the rate of local warming showed great spatial heterogeneity. Warming was faster nearby glaciers and during the warm season, associated to a stronger extension of the snow-free season. Still, most of the fine-scale spatial variability of microclimate is one-to-ten times larger than the temporal change experienced during the past 20 years, indicating the potential for microclimate to buffer climate change, possibly allowing organisms to withstand, at least temporarily, the effects of warming. Here we want to make available the microclimate model for a broader audience, aiming at a collaborative approach to microclimate research. The approach advocated here is based on a "Virtual Research Environment" (VRE), that is, a virtual place where participants can share data, analysis methods, modelling techniques and knowledge. Using open platforms (e.g., D4Science) and in the spirit of the European Research Infrastructure LifeWatch ERIC, we are currently working in the large PNRR ITINERIS infrastructure project to build a VRE on Critical Zone (CZ-VRE), with a focus on mountain ecosystems. Integrating the model presented here in the CZ-VRE will allow researchers to obtain high-resolution (~30 m) information on soil temperature in their own study areas and/or timeframes of interest, increasing our knowledge on the effect of microclimate changes on ecosystems. At the same time, the feedbacks and data received by the users will provide a fundamental source of information for further model evaluation and refinement.

Occurrence of Persistent Organic Pollutants in brook trout (*Salvelinus fontinalis*) from two high-mountain lakes (Cottian Alps)

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Remote mountain lakes, whether found at high altitudes, usually appear to be in pristine condition. However, recent research indicates that even the most remote lakes are impacted by atmospherically transported pollutants. Indeed, high-mountain ecosystems are areas of regional convergence of atmospheric pollutants: due to their high elevation, mountains intercept the flux of chemicals coming from the lowland. Moreover, the deposition of volatile compounds by condensation is favored by the lower temperature at the summit compared to the valley bottom. Generally, pollutant monitoring data in high-mountain lakes are currently incomplete, with many regions and substances having been only poorly investigated. Thus, in this study we evaluated the occurrence of 41 Persistent Organic Pollutants (POPs) by GC-Orbitrap applying the ROIMCR chemometric approach in specimens of brook trout (*Salvelinus fontinalis*) from two high mountain lakes (Balma Lakes) located in northwest Italy (Cottian Alps). POPs considered in this study were: polychlorobiphenyls-PCBs (7), organochlorine compounds-OCPs (26) and polybrominated diphenyl ethers-PBDEs (8) which are included in the Stockholm Convention. Results revealed that fish muscle contained mainly hexachlorobenzene, pentachlorobenzene, hexachlorobutadiene, methoxychlor, p,p'-dichlorodiphenyldichloroethylene, PCB-101, PCB-118, PCB-138, PCB-153 and PCB-180 at concentrations ranging from 0.01 ng/g to 2.5 ng/g wet weight (w.w.). Although the POPs concentrations in fish muscle were quite low, the vulnerability of high-mountain lakes to their toxic effects has to be expected due to the harsh environmental conditions, the organism's traits, the insular position of mountain lakes and a lower species richness with increasing altitudes. To verify this suggestion and expand the existing knowledge, it is necessary that future studies combine a more holistic pollution monitoring with exposure modelling and links to biological effects.

PIT-tagged Italian riffle dace (*Telestes muticellus*) movement and behaviour in a small mountain stream

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Worldwide, there is a widespread decline in biodiversity within freshwater ecosystems. Therefore, to safeguard fish populations from human-induced threats, it is crucial to understand the ecology and habitat utilisation of these systems. However, there is a significant lack of scientific knowledge regarding the habitat preferences and movement patterns of numerous fish species, especially small and endemic ones. In pursuit of this knowledge, our research focused on investigating the habitat use and movement behaviour of the Italian riffle dace (*Telestes muticellus*) within a small high-gradient stream in the Apennines region for over one year. We used PIT telemetry (Passive Integrated Transponder) to track the movements and habitat preferences of individual fish, according to our previous experimental findings that revealed no significant increase in mortality and high tag retention rates related to this tagging methodology. In the field, preliminary data suggest that Italian riffle dace primarily inhabits pool habitats within the available stream habitats. While many fish remained in close proximity to their capture/release sites, a few individuals displayed movements spanning several hundreds of meters. We did not observe any evidence of directed spawning migration, possibly attributable to the consistent range of habitats and substrates available in the studied stream. However, during periods of drought, the majority of fish residing in the intermittent river section were able to survive by migrating upstream to perennially watered reaches.

Potential epidemiological risks of downwind exposure to airborne pathogens from thawing Siberian permafrost

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Permafrost is known to harbor metabolically active microbes, including potentially harmful pathogens that have survived up to thousands of years under relatively stable, yet extreme environmental conditions. Fast-rising temperatures, especially in Arctic and Subarctic regions have led to the degradation of permafrost. The most impacted areas are those experiencing thermokarst landslides, the so-called Retrogressive Thaw Slumps (RTSs), where ice- and organic matter-rich permafrost collapses, directly exposing increasing extents of ice to the atmosphere. Aim of this research is to assess the potential geographical extent of regions at risk from aerosolized microbes released from Siberian RTSs and dispersed by wind currents. We use a Lagrangian approach to follow the trajectories of particles released in the atmosphere from RTSs using HYSPLIT, a software developed by NOAA to track the path of substances transported through air. The obtained maps can be considered as proxies of the epidemiological hazard for relevant host populations that may enter into contact with potential pathogens. In terms of exposure, we use distribution maps of hosts, such as crops, livestock, or humans. Crossing the hazard and the exposure maps, we obtain a trustable indicator for the potential epidemiological risk. Finally, we hierarchically rank risk locations using a Pareto analysis on a multi-objective space. Maps resulting from our analyses reveal that pathogens could provide hazard in different biomes, from pristine boreal wetlands to cities. Furthermore, our Pareto-analysis highlights that also cities at mid-latitudes are ranked at high risk. Given the increasing rates of permafrost thawing and the consequent resulting risks in environments that are distant from the polar regions, our study strongly suggests the need for (1) an improved monitoring network of RTSs, (2) a better characterization of the pathosphere of permafrost, and (3) a continuing analysis of the dispersal patterns of those pathogens potentially reaching host populations affecting humanity.

Climate change adaptation through the assessment of ecosystem services and related human perception in Alpine highlands

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The ongoing climatic changes are increasingly harming ecosystems and human well-being in Alpine areas. Increasing temperatures and reduced snow precipitations are the main causes for glaciers retreating and permafrost melting at high altitudes, leading to the progressive loss of water availability with relevant impacts on aquatic ecosystems. With aim to develop integrated adaptation measures across sectors (environmental, landscape, cultural, socio-economic domains) for the Trentino Province, an ecosystem services-based approach was applied. First, a questionnaire survey was carried out to investigate and rank ecosystem services according to stakeholders' and citizens perception. Then, on this basis, we selected a set of the most important ecosystem services for their quantification, both in biophysical and monetary terms, according the System of Environmental-Economic Accounting - Ecosystem Accounting (SEEA EA) framework. The results underline that role of aquatic environments, such as glaciers, springs, lakes, streams and peatlands, as well as the potential effects of climate change on their ecological functions and services. Cultural services, particularly those deriving from non-direct uses of ecosystems, remains poorly studied and need to be considered into adaptation measures. The assessment of ecosystem services represents a key approach to include environmental conservation and socio-economic development into adaptation measures, thus guarantying the reaching of sustainable goals.

Alien climbers: results of the MIREN protocol for monitoring invasive alien plants along an elevation gradient in the central Apennines.

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Invasive alien plants (IAPs) are one of the most serious threats to biodiversity. Mountain ecosystems may show some resistance to biological invasions due to their unique ecological characteristics, but global change might change this, markedly in the Mediterranean regions. In particular, the presence of anthropogenic infrastructure, such as paved roads, may provide preferred routes for access and dispersal of IAPs along elevation gradients. Here we aimed to test how the ecological characteristics and the level of disturbance of the native plant community may affect both the presence and abundance of IAPs along road corridors in the central Apennines.

We applied the MIREN protocol to monitor IAPs in three central Apennine massifs (Maiella, Gran Sasso and Terminillo). The protocol includes vegetation sampling along roads in 20 plots placed every 100 m of elevation. Each plot was further divided into 2 sub-plots of 50 x 2 m: one next to the road and the other 50 m from the road. We then used community-weighted values of Ecological Indicator Values for Europe together with Disturbance Indicator Values as predictors of IAP presence and abundance in a machine learning classification and regression framework.

Preliminary results showed that above an elevation of 1300 m, the presence of IAPs was essentially nil. Focusing on the range between 500 and 1300 m, our analyses showed that IAP presence in the community was favoured by proximity to the road and was related to soil disturbance and a more thermophilic native community. In contrast, abundance of IAPs was mainly related to high grazing pressure and a more nitrophilic community.

These preliminary results provide a benchmark on the current situation of biological invasion in the central Apennine massif, with an ecological perspective on which factors related to native communities can favour the presence and abundance of IAPs in the future.

Evaluation of soil carbon stock within the framework of EU Biodiversity strategy for 2030

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The EU Biodiversity Strategy for 2030 established the target to increase the share of land area under strict protection (i.e., without human intervention) from the current 3% to at least 10%. Forests can contribute to mitigate CO_2 increase in atmosphere owing to the large above and below ground biomass and C stocks. However, the C storage capability is strongly linked with habitats features and therefore can vary within each biogeographical region and among forest types and age. The goal of this ongoing study is to investigate the role of natural rewilding of abandoned agricultural land on soil C carbon stock changes (above- and below-ground) and biodiversity along the secondary succession. Quantifying this phenomenon along a latitudinal gradient in Italy, and clarifying its relationships with taxonomic and functional biodiversity at different levels, is one of Task 4.2.1 objectives of the Spoke 4 within the National Biodiversity Future Centre (NBFC). A space-for-time approach is applied to identify and date the land cover transition, as well as the main stages of the secondary succession, to reconstruct replicated chronosequences in undisturbed protected areas. At each site a detailed inventory of C stocks in the different pools as well as a detailed characterization of soil physical, chemical and biological properties and microbial, micro-fauna and understorey plant diversity is done. Preliminary results for the northernmost site (Taipana, UD) show that C storage in standing trees increases with stand age, with 22±2, 27±3, 33±1 and 44±5 tC ha^{-1} recorded in stand of 20, 21-45, 46-70, and > 70 years, respectively. Under the perspective of Nature Based Solution for climate change mitigation, this outcome, although preliminary, confirms the study expectations and highlights the role of forest rewilding as particularly promising among the tools to consider for fulfilling the 2030 Biodiversity goals.

Occurrence of microplastics in water, sediment, and fish in high-mountain lakes from Alps

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Microplastics (MPs) have been found in remote ecosystems such as the Arctic polar regions, high-mountain lakes, and glaciers via atmospheric transport and deposition. Due to their low density, MPs are lifted by wind currents into the upper layers of the atmosphere and then deposited by snowfall or rainfall in high-mountain ecosystems. Recently, it was proposed the use of high-mountain lakes as indicators of MPs pollution. With this study we wanted to determine whether MPs can be found only in abiotic compartments (water and sediment) or also in aquatic organisms such fish (*Salvelinus fontinalis*). The study site was two high-mountain lakes (Upper and Lower Lake Balma) located in the western Alps (Italy). No MPs were found in water samples, whereas the mean MPs in sediment samples was 1.33 ± 0.67 items/m^3 and 1.75 ± 0.62 items/m^3 in Lower and Upper Lake Balma, respectively. The mean number of MPs items found in the gastrointestinal tract (GIT) of fish was considerably higher in specimens from the Lower (0.45 items/g GIT) than in those from the Upper Lake (0.20 items/g GIT). There was a negative relationship between fish size (weight and age) and MPs abundance in the GIT of fish, indicating that young fish accumulated more MP items probably due to the high prey ingestion rate compared to adults. The same MPs color (blue, white, black), shape (fibers and fragments), and chemical type (polypropylene and polyethylene) were found in both sediment and fish of both lakes. Our findings suggest the use of *S. fontinalis* as an indicator of MP pollution in high-mountain lakes. Further studies are needed to better understand the sources and the effects of MPs in these remote ecosystems.

Vegetation dynamics in the Gran Paradiso National Park through a remote sensing-based approach

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Climate change and human activities are widely recognized as the main driving forces of vegetation dynamics. Vegetation significantly affects the global material and energy flows, as well as carbon balance and climate stability at different spatiotemporal scales by changing the rates of plant photosynthesis, respiration, and soil organic carbon decomposition. In this context, alpine areas are facing deep changes as a result of the progressive abandonment of traditional agro-sylvo-pastoral practices, further exacerbated by climate change. Gran Paradiso National Park, established in 1922, represents a peculiar observatory because of the wide availability of studies conducted and data collected over time, although not continuous in time and space. Some questions still remain unanswered, such as the changes that have taken place and their timing at the landscape scale. The availability of long-term, high-resolution satellite remote sensing data has made it easier to obtain accurate information that can be used to study the role of vegetation, especially in remote and inaccessible areas, with high temporal and spatial resolution. This study, which is currently ongoing, aims at studying vegetation dynamics through a remote sensing approach. Time series of vegetation distribution maps will be extracted from Landsat satellite data. This will be achieved through the implementation of a land cover classification algorithm based on machine learning methods, which aims to take advantage of all the information that can be extracted from satellite images and available auxiliary data related to the distribution of plant communities. Subsequently, change maps will reveal the mechanisms of terrestrial ecosystem behavior, predicting future vegetation growth and, thus, informing environmental management and policies.

The pigment:chl ratio as a functional trait in the study of phytoplankton community in transitional environments

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The trait-based approach is a useful tool in the study of phytoplankton community structure and dynamics, especially at the face of the ongoing climate warming and the increased human pressures affecting marine coastal areas. The rapid response of phytoplankton communities to environmental fluctuations makes this compartment among the most important ecological indicators in marine ecosystems, allowing to analyze both the short time space scales and the scales describing the seasonal dynamics. The presence of photosynthetic pigments capable of harvesting most of wavelengths of light available in aquatic environments has allowed these small organisms to colonize a high diversity of habitats. Given the pigmentary spectra composition of different lineage and the capability of cells to adjust these spectra in relation to environmental stressors, pigments can be seen as an important functional trait. This is of course important also in defining the space time dynamics of the forcing factors affecting different environmental context. This research frame has been addressed in two different extreme environments: a dismissed Mediterranean saltwork on the central Tyrrhenian coast, and the western sector of the Ross Sea (Antarctica).

Resistance in extreme habitats is an ancestral character in bdelloid rotifers

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Bdelloid rotifers are microscopic invertebrates found in any habitat, from temperate latitudes to the areas of the planet that are at the extreme values of environmental parameters allowing life, like Antarctica or the Atacama Desert. They have colonized any habitat where liquid water is temporarily available, including terrestrial environments such as soils, mosses, and lichens, tolerating desiccation and other types of stress such as high doses of ionizing radiation (IR). It was hypothesized that bdelloid desiccation and radiation resistance may be attributed to their potential ability to repair DNA double-strand breaks (DSBs). Here, these properties are investigated and compared among nine bdelloid species collected from both mild and harsh habitats, addressing the correlation between the ability of bdelloid rotifers to survive desiccation and their capacity to repair massive DNA breakage in a phylogenetically explicit context. All tested bdelloid species are able to withstand high doses of ionizing radiation, up to 1000 Gy, without experiencing any negative effects on their survival. However, the fertility of two desiccation-sensitive species, *Rotaria macrura* and *Rotaria rotatoria*, was more severely impacted by radiation than that of desiccation-resistant species. Surprisingly, the radioresistance of desiccation-resistant species is not related to features of their original habitat. Indeed, bdelloids isolated from Atacama Desert or Antarctica were not characterized by a higher radioresistance than species found in more temperate environments. Tolerance to desiccation and radiation are supported as ancestral features of bdelloid rotifers, with a group of species of the genus *Rotaria* having lost this trait, potentially after colonizing permanent water habitats in their evolutionary history.

Nitrogen isotopes: a tool for reconstructing past and present nutrient cycling and anthropogenic ecosystem perturbations in the Ross Sea, Antarctica

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The Southern Ocean plays a pivotal role in regulating the global carbon cycle and Earth's climate. Multiple lines of evidence suggest that large changes are already occurring in the Southern Ocean biogeochemical cycles. However, available data is scarce and limited to the past few decades of observations, hindering our ability to disentangle the effects of natural variability from anthropogenic activity. Nitrogen isotopes ($\delta^{15}N$) are an established tool to reconstruct nutrient cycling dynamics and ecosystem changes in polar regions, but their application in the past is limited by poor preservation and diagenetic effects on organic matter. Preliminary data indicates that the nitrogen (N) isotope composition of proteins trapped with the skeletal carbonate of Antarctic cold-water corals (CB-$\delta^{15}N$) in the Ross Sea holds great potential to reconstruct Southern Ocean's overturning circulation and ocean's biological pump efficiency beyond the temporal extent of instrumental records. The reliability of this novel proxy relies on solid calibration to particulate organic matter (POM)-$\delta^{15}N$ and seawater nitrate (NO_3^-)-$\delta^{15}N$. In such a perspective, three decades of deployment of oceanographic moorings in the Ross Sea region by the Italian Programma Nazionale di Ricerche in Antartide (PNRA) offers a unique multipurpose resource by providing a long-term high resolution archive of the biogeochemical dynamics of this important region, which can also be used to calibrate Ross Sea deep sea corals CB-$\delta^{15}N$ to the particulate organic upon which the corals feed. Here, we present the first $\delta^{15}N$ results on deep sea corals from Iselin Bank in the Ross Sea as well as species-specific zooplankton and particulate organic matter $\delta^{15}N$ analyses from Ross Sea moorings samples.

Relating intraspecific trait variation to subterranean adaptation: a case study in volcanic habitats

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Being characterized by the absence of light, low food availability and thermal stability, subterranean habitats exert strong selective pressure on living organisms, leading to specific morphological adaptations, such as depigmentation, reduced eye development, and longer appendices. However, whether these morphological traits show differences across individuals of the same species is largely unknown. To gain more insights into this topic, we conducted an extensive field investigation from 2020 to 2022 in multiple lava caves on Mount Etna, where we examined the ecological preferences and intraspecific body size variation of *Duvalius hartigi* (Coleoptera: Carabidae, Trechinae), a subterranean endemic species. First, we performed a Species Distribution Model based on the bioclimatic data from 22 sites where the species was present. The model revealed a strong preference for colder and wetter sites. Additionally, regression models applied at the local level highlighted the major effect of the cave microclimatic stability on the abundance of *D. hartigi* and a positive preference for caves developing in older volcanic substrate. Based on these results, we related morphological traits measured in at least five male individuals from each site to cave temperature and volcanic substrate age. Our analysis revealed a significant positive correlation between body size (i.e., length of the pronotum) and cave temperature, with larger individuals in sites at lower temperatures, which are preferred by the species. At the same time, troglomorphic features (i.e., antennae elongation), exhibited a significant positive relationship with volcanic substrate age. This result implies that caves developing in older volcanic substrates may provide more favorable environments for subterranean species compared to younger lava caves, possibly due to increased surface coverage that ensures the establishment of subterranean-like environmental conditions. Further studies addressing the population genetics of this cave dwelling beetle are required to shed light on the evolutionary process leading to adaptation in subterranean habitats.

Potential *in situ* biodegration of microplastics and persistent pesticides in Antarctic soil microbiomes

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The Antarctic continent is one of the most pristine and vulnerable ecosystems. However, the Antarctic coasts are affected by the contamination of several chemical agents, and plastic waste. Plastics, especially in the microplastic form (particles ≤5 mm in size), such as polyethylene (PE), can enhance their harmful capacity by absorbing hydrophobic toxic compounds, as organochlorine pesticides and dichloro-diphenyl-drichloroethane (DDT), representing a joint pollution problem. General mechanisms of the potential biodegradation of synthetic plastic waste and pesticides have been based on microbes isolated in pure culture. In order to evaluate the potential *in situ* bioremediation of microplastics and other chemical compounds, the aim of this work was to detect bacterial genes related to the degradation of PE and DDT in soils samples collected from ice-free, coastal areas of Livingston and King George Islands, using molecular and bioinformatic tools, based on 100 assembled metagenomic genomes (MAG). In details, α/β hydrolases and *alk*B, encoding for the alkane monooxygenase, were related to the potential initial stage of degradation of PE, and genes codifying for catechol 1,2-dioxygenase (*cat*A), catechol 2,3-dioxygenase (*xyl*E), gamma-hexachlorocyclohexane dehydrochlorinase (*lin*A) and haloalkane dehalogenase (*lin*B) were related to the biodegradation of DDT. Genes related to α/β hydrolases were common to all samples, whereas sequences of *alk*B were not detected in samples without animal influence, suggesting that marine pinnipeds and seabirds can act as vectors of PE microplastics from sea to land. Genes involved in DDT degradation were retrieved in all samples and were mainly represented by *lin*B, followed by *xyl*E, *cat*A, and *lin*A in sites inhabited by pinnipeds and birds. Considering that marine mammals and birds can transport polyethylene microplastics, it can be inferred that they can also act as vectors of DDT. The developed analytic tool could be used for future investigations to monitor and/or compare the potential *in situ* bioremediation of PE microplastics and DDT in different geographical areas.

Changes in microbial community and weathering of Polyethylene terephthalate (PET) film in cryoconite sediment

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In recent years plastics emerged as novel contaminants in glacier ecosystems. Both macro- and microplastics were detected on high-mountain and in polar glaciers. Once on the glacier, plastic can experience weathering processes through photolysis, hydrolysis, and biodegradation. However, no information is currently available on the degradation of plastics in glacier ecosystems. The aim of the present study was to qualitatively and quantitatively investigate the processes of plastic weathering in supraglacial environments. A series of different microcosms were prepared in both light and dark, sterile and not sterile conditions, including 14 µm thin Polyethylene terephthalate (PET) square-shaped film into cryoconite sediment. These microcosms were set up to evaluate the effect of photodegradation, microbial degradation and changes in microbial community over 6 months of exposure under controlled laboratory conditions. After 2, 4 and 6 months, the colonization and the changes in microbial communities, as well as potential signs of degradation of PET film were investigated. Already after two months from the beginning of the experiment, an enrichment of the microbial community was observed on the PET film included in the cryoconite sediment under both light and dark conditions, showing a significant variation over the time. The main orders of microbial community on PET film were Desulfomonadales, Selenomonadales and Caulobacterales, while the main genera were *Rhodococcus* and *Alpinimonas* (order Actinomycetales), *Geobacter* (Desulfuromonadales), *Psychrosinus* (Selenomonadales), *Niabella* (Sphingobacteriales), *Brevundimonas* (Caulobacterales), and *Clostridium IV* (Clostridiales). Our results showed a selection of microbial communities resulting in a specific biofilm colonizing the PET film. Lastly, chemical analyses showed signs of chemical degradation in terms of changes in intensity of some bonds and decrease in molecular weight of PET. Our experiment represent a first attempt to shed light on the biological weathering of the so-called "plastisphere" in supraglacial environments.

Shifts in the taxonomic composition of microbial communities associated with *Anemonia viridis* (Cnidaria, Anthozoa) species tentacles along a natural pH gradient

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Environments characterized by acidified pH conditions and increasing CO2 concentration select for the establishment of more resistant organisms as anemones, which may thrive under ocean acidification conditions. Interestingly, sea anemones are known for their capacity to buffer intracellular pH conditions, even when exposed to low seawater pHs, suggesting that overall physiology may not be strongly affected by ocean acidification. Here, the pH gradient deriving from volcanic activity at a shallow hydrothermal vent in the Levante Bay (Vulcano Island, Italy) was taken into consideration to investigate the effects of ocean acidification on the microbial communities associated with the tentacles of *Anemonia viridis* (Cnidaria, Anthozoa) collected at different pH conditions. Microbial enzymatic activities (leucine aminopeptidase, LAP; beta-glucosidase, GLU; alkaline phosphatase, AP) within anemone tissues were investigated by using fluorogenic substrates. High values of LAP enzymatic activities (from 74 and 67 mmol g−1 h−1) were detected in anemone tentacles in more acidified sites. Results from advanced generation sequencing techniques showed an overall microbial community dominated by *Proteobacteria*, followed by *Bacteroiodota*. Some differences in the taxonomic composition of symbionts were detected with a general decrease in biodiversity from less to more acidified sites. Some microbial taxa, i.e. *Planctomycetota*, *Firmicutes* and *Desulfobacterota* were less represented in anemones from most acidified sites. The characterization of the *A. viridis* symbionts was useful to provide deeper understanding of the holobiont response and its acclimation mechanism to naturally acidified environmental conditions.

Colonization and initial degradation of plastics by thermophilic, hydrocarbon-utilizing bacilli from shallow hydrothermal vents

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Plastics abundance and pollution impacts in the marine environment represent a serious concern for human and environmental health. Since petroleum-derived substances are made of different types of stable and recalcitrant materials, plastics occur as suspended on the sea surface or accumulated in the sediments. Moreover, especially in microplastic form, plastics can act as carrier of different toxic compounds, enhancing their harmful potentials. As derived from fossil fuels, plastic fragments in aquatic environments are rapidly colonized by a diverse microbial community, which can expect to be dominated by hydrocarbon degrading bacteria.

Bacillus and *Geobacillus* constitute common bacterial genera inhabiting shallow hydrothermal marine vents of Eolian Islands (Italy), as demonstrated in our previous studies and by the isolation of thermophilic and thermotolerant species, which are known to thrive in similar extreme environments. The common occurrence of hydrocarbons in emitted fluids from the vents suggest they can offer a rich source of unexplored hydrocarbon-utilizing microorganisms also able to degrade xenobiotics. In this study, we investigated the ability of thermophilic, hydrocarbon-utilizing bacilli to colonize plastics fragments of polyethylene (PET), polystyrene (PS) and polyvinyl chloride (PVC), as the most worldwide produced and released in the ocean. After 48h incubation, *Bacillus* sp. B3-72, *B. licheniformis* B3-15 and *B. horneckiae* SBP3 were able to adhere efficiently on PS, PET and PVC fragments, and to form stable biofilm. Subsequently to the initial bacterial adhesion, greatly depending on complex interactions between surfaces, and the biofilm development, bacteria exhibited more degradative potential than their free-living counterpart. As assessed by spectroscopic analyses, strains SBP3 and B3-15 were able to modify the chemical structure of PET more efficiently than PVC and PS after six days incubation. Together with the weight reduction (~20%) of the polymers, our results support the hypothesis that these strains are able to initially degrade PET, PS and PVC in short time. Therefore, these strains could be proposed to mitigate environmental pollution caused by plastics.

Resistance and Resilience of Microalgal Mat Dominated by *Amphora* spp. in an Arsenic-Rich Saltmarsh Pond

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Marine microalgae, mainly diatoms, are essential members of phytoplankton communities and they are also able to colonize submerged artificial and natural surfaces, contributing to the benthic microbial biomass. To cope with several environmental stresses, including strong variations in temperature and high concentration of heavy metals, diatoms developed several resistance strategies.

In this study, a microalgal mat sample was collected from the centre of Lake *Mergolo della Tonnara* (Oliveri-Tindari Lagoon, Italy), characterized by shallow depth, cold emission of gases and high arsenic content of supposed hydrothermal origins, to evaluate: i) the microbial composition, ii) the resistance ability of selected isolates to arsenite (As^{III}) and arsenate (As^{V}) (25 ppm) in F/2 medium, under 100 µmol photons m^{-2} s^{-1} illumination conditions. As assessed by 18S rRNA gene sequencing, the mat was dominated by members of the genus *Amphora,* and predominant species were affiliated (99% similarity) with *A. coffeaeformis, A. capitellata* and *A. montana.* Three isolates, representative of each species, were more resistant to As^{V} than the more toxic As^{III}. In the presence of arsenic, each strain exhibited different ability to form biofilm on glass surfaces, being *A. coffeaeformis* the most active in the presence of As^{V}, and *A. montana* with As^{III}. Photosynthetic pigment levels (chl *a* and chl *c*) were different in each biofilm. Specifically, in the presence of As^{V}, both pigments increased in *A. coffeaeformis,* whereas high levels of chl *a* were observed in *A. capitellata* and *A. montana*, indicating a species-specific response to arsenic stresses.

Our results suggest that *Amphora* represent the principal primary producers in the Lake Mergolo microalgal mat, adopting biofilm production by secretion of exopolysaccharides as a resistance strategy to survive stresses. Moreover, *Amphora* spp. possess genetic and physiological adaptation, *i.e.*, changing in photosynthetic pigment levels, as fast response to cope arsenic stresses.

Luminescent Bacteria associated with rare deep-sea species from Sicilian Waters(Mediterranean Sea)

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Bioluminescent marine bacteria are a fascinating group of microorganisms that possess the uniqueability to emit light. This phenomenon, known as bioluminescence, has captured the attention of scientists and researchers due to its intriguing biological and ecological implications. Bioluminescent bacteria are found abundantly in various marine environments, including surface waters, deep-sea regions, and symbiotic associations. While extensive research has been conducted on bioluminescent bacteria from well-known organisms, the investigation of such bacteria in rare deep-sea species remains limited. The study was aimed at assessing the presence of bioluminescent bacteria in rare deep-sea species and evaluating their potential use in biotechnology. Overall, 11 specimens of three different mesopelagic species (*Coelorinchus caelorhincus*, *Hymenocephalus italicus* , *Nezumia sclerorhynchus*) were collected by bottom trawling in the Gulf of Patty (Strait of Messina) and were used for the isolation of luminescent bacteria from ventral photophore (all species) and anal ventral photophore (only for *Hymenocephalus italicus*). The isolation of bioluminescent bacteria was carried out on glycerol- supplemented medium (Sea Water Complete, SWC) and then phylogenetically characterized by amplification and sequencing of 16S rRNA gene. A total of 13 bacterial strains were isolated. The isolates showed high similarity (>98%) to the GenBank next relatives *Photobacterium phosphoreum* and *Photobacterium leiognathi*. The biotechnological potential of isolates was investigated by performing preliminary screening for esterase and EPS production. On the total of isolates, the 8% was positive to the screening procedure.

In conclusion, this study unveils the presence of bioluminescent bacteria within rare deep-sea species, assessing the presence of *Photobacterium* spp. members in close association with them. Future research should focus the specific mechanisms involved in their bioluminescence and optimizing their performance for various biotechnological applications.

Diversity of prokaryotic communities associated with benthic invertebrates inhabiting the hydrothermal area located in the Gulf of Patti, Tyrrhenian Sea

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Marine hydrothermal systems are extreme environments characterized by harsh chemical and physical conditions such as very high temperatures, high concentrations of CO_2 and H_2S, and low pH. Although considered prohibitive for any form of life until few years ago, recently several hydrothermal systems have been proven hotspot of biodiversity. Microbe–invertebrate associations, widespread in marine environment, have a pivotal ecological role in marine ecosystems, by facilitating the survival of symbionts even in the presence of harsh conditions. For this reason, the study of such relationships could provide interesting insights for the comprehension of ecological dynamics in peculiar habitats. Within the project Project MARINE HAZARD (PON03PE_00203), three invertebrate species (the molluscs *Spondylus gaederopus* and *Pseudochama gryphina* and the sponge *Crambe crambe*) collected in the hydrothermal area of the Gulf of Patti, in the Tyrrhenian side of NE Sicily (southern Italy) were used to investigate their microbiome. The associated prokaryotic communities were related to those retrieved in sediment samples. Microbial community diversity was investigated by next generation sequencing (NGS) after DNA extraction and amplification with standard universal primers. Results from advanced generation sequencing techniques showed an overall microbial community dominated by Proteobacteria in all samples, followed by Bacteroiodota in sediment samples. Higher abundance of Cyanobacteria and Planctomycetota were detected in association with the sponge *Crambe crambe* and *Pseudochama gryphina* individuals. At family level, AEGEAN-169 marine group, Amoebophilaceae and Blattabacteriaceae were more abundant in the sponge individuals, while Arcobacteraceae and the group AB1 were highly represented in *Spondylus gaederopus* specimens. Sediment microbial communities were better represented by members of Bdellovibrionaceae and Arcobacteraceae. The characterization of the prokaryotic symbionts was useful to highlight specie- specific differences and to elucidate the influence of hydrothermal conditions.

Preliminary observations on the microbial communities of an extreme hydrologicalsystem: the Bayelva River catchment (Western Svalbard, High Arctic Norway)

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Glacier melting results in the mobilization-transport of microorganisms, along with organic/ inorganic compounds and solid particles, stored since a long time via meltwaters. In this context, the Bayelva catchment (79°N 12°E, Svalbard Islands, High Arctic Norway) is a crucial site for establishing the links between microbial communities and hydrology dynamics in the Svalbard glaciers. Two field campaigns were carried out in spring and summer 2022 in the Bayelva River catchment, from its glaciers (i.e., Austre and Vestre Brøggerbreen) and periglacial/proglacial systems up to the fjord, in a marine sector significantly affected by the river. Flowrates at the Bayelva River section close to the fjord varied between 2 and 9 m^3/s in June. Glacier snowpack, glacial meltwater, groundwater, river and fjord water were collected. Samples were analysed for culturable heterotrophic bacteria and total prokaryotes, microbial enzymatic activities (leucin aminopeptidase, LAP, beta-glucosidase, GLU, alkaline phosphatase, AP), and total chlorophyll-a. Prokaryotic abundance was quite low in snowpack (10^3 cells/ml of melted snow), but it increased in river and fjord water. Prokaryotes were predominantly coccus-shaped and appeared as individual cells or aggregates. Viable counts, differing among the used culture media, were in the order of 10^2CFUs/ml, with lower values in snow than in the other analyzed samples. The lowest enzymatic activities were recorded in snow samples, with higher LAP than GLU and AP values. Mean chlorophyll-a concentration was higher in seawater (0.5 mg/m^3) compared to the river (0.1 mg/m^3),where the greatest variability was observed. This study provided preliminary data useful to quantify the microbial biomass mobilization and its transfer from the investigated glacial system to the Kongsfjorden.

Bacterial isolates from plastic fragments retrieved in a High Arctic pond (Ny-Ålesund, Svalbard Islands)

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Plastic production has increased significantly in recent decades, thanks to its durability, wide use, and low cost. Plastics can end up in freshwater habitats where they would build up and endure for years, becoming the substrate for the development of complex microbial biofilm, playing a pivotal role in organic matter utilization and energy supply to the food web. Unfortunately, plastics have reached also remote areas, such as the Ny-Ålesund Research Village in the High Arctic, causing alterations in the biological diversity. In the framework of two different research projects, both aimed at exploring the microbial diversity of Arctic freshwater systems, researchers in the field stumbled upon a clear macroplastic pollution in the Goose Pond, a small pond close to the coastline. Twelve different typologies of macroplastics (from duct tape scraps to Styrofoam bits) were aseptically collected and preliminary analysed for the attached bacterial communities. More than 150 bacterial isolates were tested for biofilm formation, enzyme production (e.g., esterases and lipase), antibiotic susceptibility, and then taxonomically identified by the 16S rRNA gene sequencing. No evident differences were observed between the cultivable bacterial communities attached to different typologies of macroplastics. *Shewanella* and *Pseudomonas* members were probably the main responsible for biofilm formation on the plastic fragments. A number of potential fish and human pathogens were isolated (e.g., *Aeromonas salmonicida* and *Flavobacterium branchiarum*), indicating the plastics as possible carriers of allochtonous bacterial species, often dangerous to biota. Isolates of marine origin (e.g., *Sporosarcina aquimarina*, *Psychrobacter nivimaris*, *Planococcus maritimus*) probably had been dropped off by aquatic birds visiting the pond. Finally, some isolates were closely related to species involved in the degradation of plastics and aromatic hydrocarbons or in the production of bioemulsifiers. This work contributes to our knowledge about the yet underexplored plastisphere in Arctic freshwaters.

A novel acidophilic, CO_2 sequestering *Tetradesmus sp.* M42 (*Chlorophyta*) as potential natural indicator of high CO_2 concentration in acidified aquatic environments

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In recent years, the atmospheric concentration of CO_2 has increased dramatically due to greenhouse gas emissions by human activities and industrialization, causing climate change and acidification of water bodies. Due to their exceptional ability to capture CO_2, microalgae can be helpful in reducing its concentration in aquatic ecosystems.

In this study, we evaluated the ability of the newly isolated acidophilic microalgal strain M42, to sequester CO_2 at different pH conditions, when cultivated in BG11 medium at 25 °C, under continuous illumination at a light intensity of 100 µmol photons m^{-2} s^{-1} and continuously bubbled with atmospheric air (approx. 0.04% CO_2). As resulted by the phenotypic and genotypic (18S rRNA gene sequencing) investigations, strain M42 was related to the family of *Scenedesmaceae* (*Chlorophyta*) affiliated to *Tetradesmus* sp. (98.8% similarity), widely distributed in aquatic environments. Strain M42 was able to grow over a wide range of pH values (from 4 to 10) with an optimal pH value of 5, and its productivity ranged from 0.160 (pH=10) to 0.821 (pH=5) g L^{-1} d^{-1}. Furthermore, the highest CO_2 fixation rate was 1.51 g L^{-1} d^{-1} at pH 5. CO_2 fixation rate of M42 strain was higher than its closest phylogenetic relatives, *Tetradesmus* strains UJEA_AD and SJTU-3, (sixfold and tenfold, respectively). Interestingly, the CO_2 fixation rate of M42 was also higher than that of the most efficient *Scenedesmus obtusiusculus* (0.970 g L^{-1} d^{-1}).

Possessing high growth rates and considerable consumption of CO_2 *per* day, the acidophilic M42 could be used as indicator of high CO_2 concentration in acidified aquatic environments, such as those present in heavily anthropized and industrialized areas.

Evidence for a chemoautotrophically supported invertebrate community in a subterranean ecosystem

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The deep sections of the gypsum karst system of the Monte Conca sinkhole (Sicily, Italy) harbor a diverse invertebrate community, suggesting the existence of a complex food web associated with sulfidic pools and chemoautotrophic microbial activity. To gain insights into this unique biological assemblage, we conducted a study investigating the species composition of the invertebrate community and their trophic interactions. We discovered a well-structured biological assemblage comprising both subterranean specialized and non-specialized species, encompassing all trophic levels. Notably, the community exhibited higher diversity within the sulfidic habitat rather than non-sulfidic ones. In particular, when analysing trophic interactions with stable isotopic analysis, we highlighted the presence of a significant chemoautotrophic contribution by the microbial communities to the local food web, particularly during the dry season when the organic input from the surface is limited. Samples of invertebrates collected in the sulfidic habitat were isotopically lighter in carbon ($\delta^{13}C$ = –41.08 to –25.26‰) than the one collected in the non-sulfidic habitat ($\delta^{13}C$ = –10.64 to –25.34‰). Differences among the two habitats in terms of $\delta^{13}C$ values were statistically significant confirming a clear separation of the two habitats, at least during the dry period. However, potential threats to the entire ecosystem arise during the wet season when large volumes of water flood the cave due to local agricultural activities or extreme precipitation events, inhibiting the local autotrophic production and threatening the conservation of the entire ecosystem

Mercury concentration and microbial communities in Arctic snow, a unique ecological niche.

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Snow covers about 35% of the Earth's surface during the year and represents one of the most important climatic and ecological systems. It is a physically, chemically, and biologically dynamic system. Mercury (Hg) can be emitted both by anthropogenic processes and naturally from land surfaces. Once released, due to its long atmospheric residence time, Hg undergoes long-range transport and arrives in remote regions such as the Arctic, where it is deposited. Atmospheric Hg is principally deposited onto the cryosphere before entering hydrological systems. The abundance of microorganisms in the snow varies, ranging from 10^2 cells/ml of melted snow in the South Pole up to 10^5 cells/ml in high mountain and Arctic snow. Microorganisms in the snow from polar regions were also analyzed for their metabolic activity and their production of molecules of interest. This research aimed at surveying Hg pollution level, assessing bacterial community activity in the snow, and isolating biotechnologically interesting bacteria for bioremediation potential. Our preliminary results underline that the snow is an interesting and unique ecosystem, especially in terms of bacterial composition and activity. Very relevant results were obtained in intermediate snow deposition layers, where the concentrations of chlorophyll-a and enzymatic activities were the highest ones. The microbial activities detected in the snow were comparable to (and in some cases higher than) those retrieved in previous studies. An increase in Hg concentration was observed in the snow along the depth of snow accumulation, probably due to an increase in snow density, therefore the mercury concentrations found were indicative of pristine recently fallen snow. Finally, Hg-tolerant bacterial strains have been isolated. Further analyses are needed, with some of them that are in progress, especially for the evaluation and quantification of the presence of *mer* genes.

Towards a sustainable touristic use of show caves

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The touristic use of caves causes multiple environmental alterations to the subterranean ecosystem, having potential effects on all components, from the atmosphere to lithosphere, hydrosphere, and biosphere. The sustainable touristic use of show caves is thus crucial to preserve the equilibrium of their ecosystems and requires the implementation of monitoring and management programs aiming at their conservation. To achieve this goal, we created a literature-based dataset from 289 papers published over the last 30 years and selected through a systematic literature survey of an initial set of more than 1,000 scientific papers relative to the knowledge on the ecological status of 265 show caves worldwide. We extracted and analysed the data provided in these selected papers with the Driver-Pressure-State-Impact-Response (DPSIR) causal model, which we applied to the four compartments of the subterranean ecosystem, namely atmosphere, lithosphere, hydrosphere and biosphere. This approach allowed us to establish simple causal relations among human pressures and their consequent impacts on the subterranean ecosystem and to identify integrated responses to mitigate the impacts. Our research highlighted that contamination by alien microorganisms and atmospheric physical and chemical changes represent the most alarming impacts due to their effects encompassing all ecosystem components. Most of the management actions directly address these impacts, while the potential use of broader measures is often overlooked. Based on these results, we provide a roadmap for a scientifically-sound sustainable use of show caves.

Benthic foraminiferal seasonal responses to environmental gradient variations in Kongsfjorden (Svalbard)

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In polar fjords, glacial meltwater and associated high sediment loads generate strong environmental gradients due to increased water column stratification and surface turbidity, which, ultimately, affect primary production. Spatial and seasonal variations in glacial inputs (from very fine silt to coarse gravel) resulting in burial of benthic ecosystems, lead to faunal biozonation and changes in sediment biogeochemistry, from tidewater glacier fronts to the outer fjord area.

To characterize the seasonal and spatial effects of environmental gradients upon benthic realms in a polar fjord, a study of living benthic foraminiferal was conducted in Kongsfjorden. During two oceanographic campaigns (May and August 2021), sediments were sampled from 4 stations along a transect from the Kronebreen glacier front to about 10 km away. Along with foraminifera diversity, abundance and vertical distribution, other environmental parameters were investigated such as sediment grain size, organic matter content and water mass distribution.

In May, the water column was well mixed throughout the fjord, and the environmental gradient was mainly driven by the organic matter content in the sediment, with a strong increase of biopolymeric carbon (BPC) and phytopigments from the glacier front to distal locations. In August, the water column stratification with surface turbidity induced a lowering of organic matter content in the sediment near the glacier front. In both seasons, we observed the same biozonations of foraminiferal communities, with higher abundances in summer than in spring, due to higher food supply. The vertical distribution of the specimens was different in the two seasons, reflecting both biogeochemical microhabitat distribution along the transect and seasonal differences in sediment supply from the glacier.

These findings support the use of foraminifera to monitor the effects of ongoing climate change on the benthic ecosystems of Arctic fjords and to reconstruct glacier front positions in the past.

Conservation measures for benthic suspension feeders: protected and neglected Marine Animal Forests

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Marine macrobenthic communities can provide three-dimensional environments that substantially increase the complexity of otherwise bare sedimentary bottoms, thereby providing habitat to a number of additional associated species, and ultimately resulting in biodiversity hotspots. Marine Animal Forests (MAFs) encompass some of the most important marine benthic habitats into which diversified sessile suspension feeders like anthozoans, sponges, bryozoans, corals, sea pens, ascidians, tube worms, and bivalves occur. Such mix of sessile species raises unique structures and supports important ecosystem functions. In the last decades, some MAFs have been object of international conventions, EU directives, and national policies to address human-induced disturbances. Effective conservation, monitoring, and restoration actions require summarizing the available information to include MAFs in conservation plans. In the present research, the main international policies for the protection of coastal and marine fauna were screened in order to provide a list of protected species occurring in Mediterranean MAFs. These international normative documents include the Washington Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Convention on the Conservation of European Wildlife and Habitats (Bern Convention), The Habitats Directive, the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA/BD Protocol) of the Barcelona Convention and the International Union for Conservation of Nature (IUCN) Red List of Threatened Species. Reporting the status of the MAF species that should be considered in management and conservation measures will be crucial for by policy-makers, as well as for mitigating current and future impacts on these unique marine environments.

Antarctic sponges *Haliclona (Rhizoniera) dancoi* (Topsent, 1901) and *Haliclona scotti*(Kirkpatrick, 1907) from the Thetys Bay (Terra Nova Bay, Antarctica): associated bacterial communities *vs* pollutant accumulation

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Despite their remoteness, polar regions are reached by pollutants emitted at lower latitudes due to long-range transport mechanisms. Pollution events can also occur at local scale following increasingresearch and tourism activities. Sponges are extremely efficient filter feeders. This ability makes them excellent accumulation systems and important sentinels for pollution, also in remote areas. Sponges also represent important habitats for a community of associated (micro)organisms, and investigations on Antarctic sponge-associated bacteria are increasing in the last years. To find a glue between pollution level and bacterial communities in sponge mesohyl, this work aims at both investigating pollutant (i.e., polycyclic aromatic hydrocarbons, PAHs, polychlorinated biphenyls, PCBs, and heavy metals, HM) concentration by chemical analyses and estimating microbial community taxonomic composition by 16S rRNA gene metabarcoding approach in two Antarctic sponge species, i.e. *Haliclona (Rhizoniera) dancoi* (Topsent, 1901) and *Haliclona scotti* (Kirkpatrick, 1907) inhabiting two sites within the Thetys Bay (Terra Nova Bay, Ross Sea). Abiotic matrices (i.e., water and sediment) were also analyzed. Some HMs (e.g., Hg, Ni, Zn and Cd), almost all tested PAHsand PCB congeners were more concentrated in the sponge mesohyl than in sediment. The associated bacterial community was dominated by bacterial phyla frequently found in marine environments of polar regions, but the diversity indices highlighted a higher alpha-diversity compared with previous studies. Distinct bacterial communities occurred in the biotic and abiotic investigated matrices, suggesting a high specificity of the sponge-associated communities. *Actinomycetota*, *Acidobacteriota*, *Planctomyceota*, and *Bacteroidota* were negatively correlated with low chlorinated PCBs. Obtained results suggest that Antarctic sponges could be an excellent sentinel of environmental pollution and that differences among the bacterial communities may be site-driven and dependent on relationships between bacteria and pollutant concentration in the benthic hosts.

What is a healthy soil? A search for biological indicators for soil functions and carbon storage.

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"Soil health" has been defined as "the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals and humans, and connects agricultural and soil science to policy, stakeholder needs and sustainable supply-chain management". Soils have to sustain very different ecosystem services, such as carbon sequestration and nutrient storage, water purification, maintenance of soil structure and below- and aboveground biodiversity, among others. The European Parliament notes that over 60% of European soils are unhealthy and that our soils are further degrading due to unsustainable management of the land. According to the EU Biodiversity Strategy for 2030, healthy soils have become of geo-strategic importance and it is essential to step up efforts to protect soil fertility, reduce soil erosion and increase soil organic matter by adopting sustainable soil management practices. It is further stated that by 2050 all EU soils should be healthy. Therefore significant progress is needed to restore degraded soils, define the conditions for good ecological status, and improve the monitoring of soil health. BUT how can we restore degraded soils? What are conditions for good ecological soil status? Are there universal biological indicators of soil health? According to the EU Mission #8: "improve soil literacy in society", I will explain some basic mechanisms of soil recovery after restoration and why it is so challenging to identify biological indicators for "good soil status".

Digital democratization for the ecological transition: from Industry 4.0 to Nature 4.0

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Digital twin technology is currently widely used in Industry 4.0. However, via technological innovation and gains, it is rapidly entering into new application fields including Earth's ecosystems. The European Commission considers the development of high precision Earth's digital models one of the pillars of the European Green Deal and Digital Strategy and launched in 2021 "Destination Earth" with the goal to deliver the first two digital twins on extreme natural events and climate change adaptation by 2024. There are up to date no digital twins yet for forests which could deliver new insights on biogeochemical cycles, their responses to climate changes and their interactions with wildlife and the human activities. New sensors with wireless capabilities (IoT) are today available to investigate single trees physiological endpoints such as: transpiration, biomass growth and phenology and several others are recently developed for wildlife sound detection, volatile organic compounds detection and forest fires early warning system. A process of democratization of such technologies (low cost – mass deployment) is greatly needed to address complex interactions of climate changes on tree species physiology at unprecedented scale of monitoring (from 1 hour to seasonal and interannual scales) to elucidate triggers, physiological thresholds, and complex legacy effects of climate on trees potential declines or die-backs. A technological transition to Nature4.0 which could include a democratization approach with low-cost technologies, together with increasing high performance computing and AI applications could lead a new wave of ecological frontier science stimulating also new academic curricula and a new young generation of ecology researchers.

The global climate challenge: how to rewet 2 million ha of drained peatland per year?

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Although peatlands contain worldwide more carbon than all forest biomass combined, their importance has long been overlooked. Drained primarily for agriculture and forestry, peatlands emit over two gigatonnes of CO2 equivalent per year. This means that 0.3% of the Earth's land area is responsible for a disproportionate 5% of anthropogenic greenhouse gas emissions. To meet the Paris climate targets, all natural peatlands must remain wet, all drained peatlands must be rewetted, and productive peatland use should only take place under wet conditions.
The greatest challenge lies with the agricultural peatlands. Until now, rewetting has mostly implied them being taken out of productive use. But we will no longer be able to afford this comprehensively. The development and implementation of wet production methods ("paludiculture") is urgently needed.
The advantages of wet peatland use are so great that one may wonder why paludiculture is not implemented quickly and across the board. However, paludiculture suffers from the historical heritage of 10,000 years of "dry" agriculture. Paludiculture generally implies a redesign of the entire production and value chain: from crop selection, technology, infrastructure and logistics, products, promotion, to education, training and research, and this takes time. Payments for ecosystem services - especially carbon credits - can serve as a transitional strategy towards the full implementation of paludiculture.

Peatlands must be wet: For the peatland, for the land, for the climate, forever!

Adaptation to Climate Change, Water, and Ecological Winners and Losers

Kirk Winemiller
Texas A&M University, USA

Climate change has happened, is happening and will continue, and many effects on ecological systems already are apparent. This talk will explore these effects with regards to aquatic ecosystems. Initial evidence indicates many systems lack the capacity to resist effects of climate change, with some shifting to altered states, even as some species exhibit evolutionary potential for adaptation to changing conditions. The capacity of nature and society for resilience to climate change is currently unknown.

Is the 30% solution necessary or sufficient?

Stuart Pimm
Duke University, Saving Nature www.savingnature.org, USA

At COP15, many nations approved the "30-30 solution — protect 30% of the land and oceans by 2023. I ask: is the 30% solution necessary or sufficient?

The current state of play is that human actions drive species to extinction about a thousand times faster than they diversify through evolution. Extinctions are primarily in areas — hotspots — where high levels of habitat loss collide with concentrations of species with small geographical ranges. The principal means of preventing species extinctions is the creation of protected areas. Most are in remote places, too hot, too dry, or too cold for human habitation. Generally, these places have few vulnerable species. Despite this, the fraction of small-ranged species protected is substantially larger than one would expect. The conservation community has done an excellent job of protection. Will expanding the protected area network to 30% improve things? Not if it's business as usual, for more land will not equate to more species. In protecting more areas, quality matters, not quantity. Importantly, many protected areas are small and isolated. To maximise effectiveness, we must restore fragmented landscapes, allowing the remnant populations to connect and species to move in response to a heating climate.

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Sostenibilità ecologica : scienza, scenari e partecipazione

2023