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EDITORIAL

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# Editorial

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The Long-Term time series of Ecological Research (LTER) allow us to follow the evolution of the ecosystems over decadal scales to understand the driving processes behind their temporal variability in relation to local and global stressors.

LTER-Italy (http://www.lteritalia.it) network includes terrestrial, freshwater, transitional and marine sites where ecological research is regularly carried out on decadal scale with the involvement of numerous universities, scientific and technical institutions, as well as local authorities. Since 2006, LTER-Italy is part of LTER-Europe (http://www.lter-europe.net) and LTER-International (https://www.ilter.network) networks. LTER-Italy consists of 79 research sites belonging to 25 different areas (parent sites) distributed throughout the Country and also including extra-national sites in the Ross Sea (Antarctica) and in the Himalayas (Nepal).


**Figure 1.** Localisation of the LTER sites covered in this Special Issue. In the large panel, the Italian sites: terrestrial (brown), freshwater (light blue), transitional (green), marine (blue). In the inset: **A** Italy **B** Northern Europe **C** California (USA) **D** Ross Sea (Antarctica).

The present Special Issue entitled "*Italian Long-Term Ecological Research for understanding ecosystem diversity and functioning. Case studies from aquatic, terrestrial and transitional domains*" is the first published collection of studies performed at LTER-Italy sites which address the diversity and dynamics of ecosystems in different domains in response to natural and anthropogenic forcing. Eighteen papers in the volume present research carried out at 2 Antarctic and 16 Italian sites, one of which includes a comparative analysis with other International LTER sites in Northern Europe and USA (Figure 1 and Table 1). Two additional cross-domain papers address methodological and conceptual themes: Zilioli et al. (2019) tackle data management practices and interoperability for the monitoring of the Essential Biodiversity Variables in LTER-Italy; Ribera d'Alcalà (2019) compares terrestrial and marine ecosystems, highlighting their similarities and specific features in response to perturbations and climate change.

The studies focus on terrestrial (7 papers) and aquatic (11) domains, the latter including marine (7), transitional (3) and freshwater (1) ecosystems. The research sites span over a wide altitudinal range, from the mesopelagic ocean (-800 m) to the high-elevation mountain (2.800 m) and reflect the large diversity of the Italian territory and landscapes. The papers cover a broad range of topics, from biodiversity to biogeochemical fluxes, over time scales up to three decades. The different environments, organisms and processes are analysed with the common goal to discern the main modes

**Table 1.** List of the LTER sites covered in the papers of this Special Issue, with their names, DEIMS. ID (https://deims.org/docs/deimsid.html) and references, in the same order as they appear in the Index.

| LTER site name | DEIMS-ID | Special Issue reference papers |
|---|---|---|
| Appennino centrale: Gran Sasso d'Italia, Italy | https://deims.org/c0738b00-854c-418f-8d4f-69b03486e9fd | Petriccione and Bricca 2019 |
| Val Masino LOM1, Italy | https://deims.org/68a5673c-9172-48cc-88e5-b9408b203309 | Balestrini et al. 2019 |
| Istituto Scientifico Angelo Mosso (MOSSO), Italy | https://deims.org/17210eba-d832-4759-89fa-9ff127cbdf6e | Freppaz et al. 2019 |
| Gran Paradiso National Park, Italy | https://deims.org/e33c983a-19ad-4f40-a6fd-1210ee0b3a4b | Cerrato et al. 2019 |
| IT25 – Val Mazia/ Matschertal, Italy | https://deims.org/11696de6-0ab9-4c94-a06b-7ce40f56c964 | Steinwandter et al. 2019 |
| Foce Trigno-Marina di Petacciato (Campobasso), Italy | https://deims.org/1835cda2-b56d-400a-b413-ab5c74086dc5 | Marzialetti et al. 2019 |
| Foce Saccione-Bonifica Ramitelli (Campobasso), Italy | https://deims.org/088fe3af-c5bb-4cc8-b479-fe1ea6d5be80 | Marzialetti et al. 2019 |
| Montagna di Torricchio, Italy | https://deims.org/6b62feb2-61bf-47e1-b97f-0e909c408db8 | Chelli et al. 2019 |
| Lago Bidighinzu, Italy | https://deims.org/3707cf71-7e04-41e3-8afc-518b293f6c07 | Pulina et al. 2019 |
| Laguna di Venezia, Italy | https://deims.org/f7d94927-17be-4d3d-9810-e3c9bc91829c | Sfriso et al. 2019 |
| Mar Piccolo of Taranto, Italy | https://deims.org/ede24c6e-9cf2-4cf8-8bf7-36ba327403b4 | Petrocelli et al. 2019 |
| Sacca di Goro, Italy | https://deims.org/b7869194-b220-473a-b035-feeadfa21aba | Pitacco et al. 2019 |
| Valli di Comacchio, Italy | https://deims.org/70e1bc05-a03d-40fc-993d-0c61e524b177 | Pitacco et al. 2019 |
| LTER Marechiara, Italy | https://deims.org/0b87459a-da3c-45af-a3e1-cb1508519411 | Zingone et al. 2019 |
| Santa Barbara Coastal LTER, United States of America | https://deims.org/dbd399ed-9c26-4621-b479-7ab505c8aa35 | Kröncke et al. 2019 |
| Archipelago Research Institute, Finland (Seili LTER) | https://deims.org/9d4222a2-c50f-4fac-8b1d-3b685072b34d | Kröncke et al. 2019 |
| North Sea Benthos Observatory, Germany | https://deims.org/50946250-c0fa-41b0-a917-17d2a3992eee | Kröncke et al. 2019 |
| Golfo di Olbia, Italy | https://deims.org/3178d0fb-0789-4992-9c51-1ddb50b7e871 | Kröncke et al. 2019 |
| LTER Observatory HAUSGARTEN, Germany | https://deims.org/f6d9ed12-6bc1-47fb-8e81-ef24e9579596 | Kröncke et al. 2019 |
| Golfo di Trieste, Italy | https://deims.org/96969205-cfdf-41d8-979f-ff881ea8dc8b | Cerino et al. 2019; Monti-Birkenmeier et al. 2019; Franzo et al. 2019 |
| Mooring A: Southwestern Ross Sea, Ross Island, Antarctica | https://deims.org/86b6465c-b604-4efa-9145-0805f62216f4 | Chiarini et al. 2019; Azzaro et al. 2019 |
| Mooring B: North Central Ross Sea, Joides Basin, Antarctica | https://deims.org/1fb62b9c-4d5c-4f1f-8882-807032337de7 | Azzaro et al. 2019 |

of temporal variability and to understand the causes of the observed modifications. The heterogeneity of the presented research activities mirrors the variety of ecological issues that need to be addressed to achieve proper environmental conservation and management practices.

For the terrestrial environment, papers in this Special Issue investigate the effects of climate variability and habitat use on the biological and biogeochemical components of ecosystems from the sea-level coasts to the peaks of the Alps in a variety of habitat types, such as forests, grasslands and dunes. Amongst the "sentinels" of environmental changes, the readers will find the high-elevation plants reported by Petriccione and Bricca (2019), which varied significantly in the species coverage, and the butterflies whose variations in species distribution and community composition was investigated by Cerrato et al. (2019). Carbon and nitrogen cycles are influenced by climatic drivers, as well as by the atmospheric inputs and the study of these elements in the soil and soil solution provides important data on the ecosystem functioning, as outlined by Freppaz et al. (2019) in the alpine tundra and by Balestrini et al. (2019) in a montane forest. Alien species invasions are another effect of habitat and climate alteration that can be monitored and modelled in the LTER network. An example is the study of Marzialetti et al. (2019), in which the authors provide a first exploratory analysis of the environmental characteristics promoting the rapid growth and development of *Acacia saligna* in Italian dune ecosystems and identify coastal areas as the main habitats that are affected by the invasive process. From a methodological point of view, Chelli et al. (2019) designed a monitoring system for the study of species richness and assemblage patterns over time, based on a probabilistic sampling scheme. LTER sites are also important for their contribution to biodiversity and biogeography knowledge, as demonstrated by the finding in South Tyrol of *Opetiopalpus sabulosus*, a beetle inhabiting steppe-like grasslands, which represents the first record of the species for the European Alps and Central Europe (Steinwandter et al. 2019).

Multiannual research in aquatic domains has revealed a remarkable interannual variability in different ecosystems, from temperate to polar latitudes. Different kinds of natural factors seem to have affected microbial processes (Franzo et al. 2019) and phytoplankton patterns (Cerino et al. 2019) in the north Adriatic Sea, as well as vertical particle fluxes (Chiarini et al. 2019) and microbial metabolism (Azzaro et al. 2019) in the Ross Sea (Antarctica). Conversely, decreased anthropogenic forcing was found to be responsible for the significant changes of phytoplankton in a eutrophic reservoir (Pulina et al. 2019) and of benthic macrophytes in a coastal embayment (Petrocelli et al. 2019). The long-term analysis of various ecosystem components has also proved to be useful to identify key variables that may allow environmental dynamics to be followed in view of possible future limitations of sampling or analytical efforts. This is the case of tintinnids for marine microzooplankton (Monti-Birkenmeier et al. 2019), taxonomic surrogates for benthic assemblages in transitional ecosystems (Pitacco et al. 2019) and nutrients, such as nitrites and reactive phosphorus for the trophic status of the Venice Lagoon (Sfriso et al. 2019). The value of LTER investigations, generally conducted at a single site, is further enhanced by expanding the spatial scale of the

observations in a comparative effort, which is especially useful for the prediction of future changes in marine systems in response to climate variability and ocean warming (Kröncke et al. 2019). Finally, besides the record of fluctuations and trends, long-term ecological research plays an invaluable role as an inspiration for other research, while the LTER sites can also be used as natural laboratories to test hypotheses and answer specific scientific questions. They can therefore have a primary role in the development of the knowledge of ecosystems much beyond the local scale (Zingone et al. 2019).

The content of this volume underlines and confirms how observations and analyses of ecological variables and processes at multiple scales are keys to understand important ecological relationships. Similar ecosystems can respond differently to identical changes in system drivers, depending on their inherent ecological structure and functioning, their history and spatial location within the territory and connections with adjacent ecosystems. The insights gained by this kind of research contribute to multiple aspects: from the formulation of general laws of ecology to the development of policies to face the Grand Challenges under Global Change at local, regional and planetary levels.

Before leaving the readers to enter the core of this Special Issue, we wish to express our gratitude to all colleagues who submitted manuscripts to this Special Issue and to the 51 reviewers for their time, attentive criticisms and constructive comments and suggestions. Our special thanks to Boriana Ovcharova, Managing Editor and the entire Editorial Office of *Nature Conservation* for their kind assistance and technical support.

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