

Voices from the water: experience, knowledge, and emotions in long-term ecological research (LTER Italy)

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ABSTRACT

Based on the last decade of activities at the Italian Long-Term Ecological Research network (LTER-Italy), I describe and highlight here some major outcomes and challenges, by picturing different “voices”, which we are listening to and we are talking with. Organisms, ecosystems, methodologies, data, researchers, stakeholders and citizens: their voices – i.e., the information which we receive from them, and then interpret and, consequently, express – create our experience and knowledge, which we share with and convey to our contemporaries and future generations. One of the main narrator’s voices will be that of plankton: how we “listen” to them, describe and share long-term data and researches, also with the wide public. Through the “voices from the water” I will report and discuss experiences, which have been relevant also to open up the views on the role that science is challenged to play in a world of rapid change, characterized by complexity and contradictions. In particular I will consider: i) those voices coming from various LTER aquatic sites, mainly addressing the comparison among them; ii) how to make these voices most harmonized and audible through the open science approach; and iii) how to put the LTER voices in an effective dialogue with society. Finally, I will share some thoughts about the necessity and the possibility to open the purely scientific cognitive approach to other forms of knowledge, related to our intuition, feelings and empathy.

*If you are a poet, you will see clearly that there is a cloud floating in this sheet of paper.
Without a cloud, there will be no rain; without rain, the trees cannot grow; and without trees, we cannot make paper. (...)
If the cloud is not here, the sheet of paper cannot be here either. So we can say that the cloud and the paper inter-are. (...)
“To be” is to inter-be. We cannot just be by ourselves alone. We have to inter-be with every other thing.
(Tich Nath Han)*

INTRODUCTION

As human beings we realize our living immersed in networks of conversations, which we are not always aware of, that represent both a treasure and a danger. It is actually through the voices that we are listening to, and through the narratives we embrace, that we learn and reflect about the natural world and that we perceive our deep and vital interconnection with or separation from it. We should recognize, both as scientists and as citizens, that we can chose the story and the conversation we take part, because this shapes our responses to any crisis and challenge (Maturana and Davila, 2009).

In Long-Term Ecological Research (LTER) we are engaged in conversations with multiple actors: organisms, ecosystems, methodologies, data, other scientists, citizens, and other typologies of stakeholders, are some of the “voices” that we receive, interpret, and express, creating our experience and knowledge. At the same time, these voices shape and are influenced by our “inner world” - the psychological sphere defined by our emotions, thoughts, identities and beliefs – which is considered one of the main drivers of changes in our behaviour and values, enabling actions in uncertain or unprecedented situations (Wamsler and Brink, 2018; Ives *et al.*, 2018, 2019). Indeed, science is not only an individual intellectual or mental process: it is a collective, both organizational and institutional, practice driven by social dynamics. In this

pursuing practice, my and other authors’ perspectives indicate that the “inner world” is a necessary and positive player (Barbalet, 2002; Koppman *et al.*, 2015).

Grounding on the last decade activities of the Italian LTER network (LTER-Italy; www.lteritalia.it), I will review and report here some experiences, mainly focussing on those “voices from the water” that have been relevant and helpful to delineate my perspective on the role that Ecology (i.e., the branch of science which studies the interrelationships of organisms and their environments, in the complex interplay of functions and processes, information cycling, and cooperative and competitive dynamics) is challenged to play in a world of rapid change, characterized by socio-ecological conflicts and economic contradictions.

The one from plankton (Fig. 1) is the “voice” that I will primarily listen to, as that key ecological community of generally microscopic organisms floating in the waters of the Earth (Hensen, 1887; D’Alelio, 2020) is the main object of my study along the years. An Italian poet, Pierluigi Cappello (2013) writes: “*There are words without a body and words with a body. Freedom is a world without a body. Like soul. Like love. They need someone who lends them flesh, blood and boundaries to make them concrete*”. I like to picture that this is what we do with plankton: we lend our bodies and voices to make them become visible and real, appearing from the waters.

In particular, this paper describes and highlights

some major outcomes and challenges, in the form of the different voices, which we are listening to and we are conveying within and beyond our community, i.e., the one of scientists. In pursuing this aim, I will be: i) listening to the voices coming from the LTER aquatic sites, mainly addressing the comparison among them; ii) suggesting how to make these LTER voices more harmonized and audible through the open science approach; and, finally, iii) illustrating my perspective on how getting the LTER voices engaged in an effective dialogue with Society. In the end, I will share some thoughts about the chance, and necessity, to open the purely scientific cognitive approach to other forms of knowledge, integrating our inner world.

VOICES FROM LTER-ITALY

LTER-Italy aquatic sites and plankton

The principal aim of LTER is understanding, analysing, and monitoring changes in ecosystem patterns and processes over extended periods of time, typically decades. LTER is prevalently organised in networks of sites and platforms, at the national (e.g., LTER-Italy), continental (e.g., European, LTER-Europe: <http://www.lter-europe.net/>) and global level (LTER-International, ILTER: www.ilter.network), where approaches and interpretations of ongoing ecological processes are developed (Mirtl *et al.*, 2018; Mollenhauer *et al.*, 2018), also with

the aim of creating a legacy of well-designed and documented knowledge for future generations.

Amongst the many papers that have been issued in the last decades about LTER research, networks and sites, I have been – and I still am – motivated by two of them, which are the voices providing me with both the knowledge and the language - words and metaphors - to convey it. Those seminal papers and their Authors are still influencing and nourishing my inner world as well, supporting my emotional perspective and my long-lasting bond with LTER.

The first paper was written by Magnuson (1990) and gifted me with the metaphor of “the invisible present”, which express powerfully the role of LTER in connecting the current environmental (both physical and biological) conditions to the past, in order to understand where we are and where we wish to move toward. In this paper, there is also a clear call for responsibility in LTER: the invisible present is actually defined as the time scale within which our responsibilities for the Earth are most evident since, within this time scale, ecosystems change during our lifetimes and the lifetimes of our children and our grandchildren. The second seminal paper was written by Peters (2010) and made me understand and appreciate the value of LTER sites, by bringing together their role along three different dimensions and ecological strategies: the long (long-term studies), the deep (short-term, pattern-process studies for deep understanding) and the broad (observation networks of sites for broad-scale patterns). The

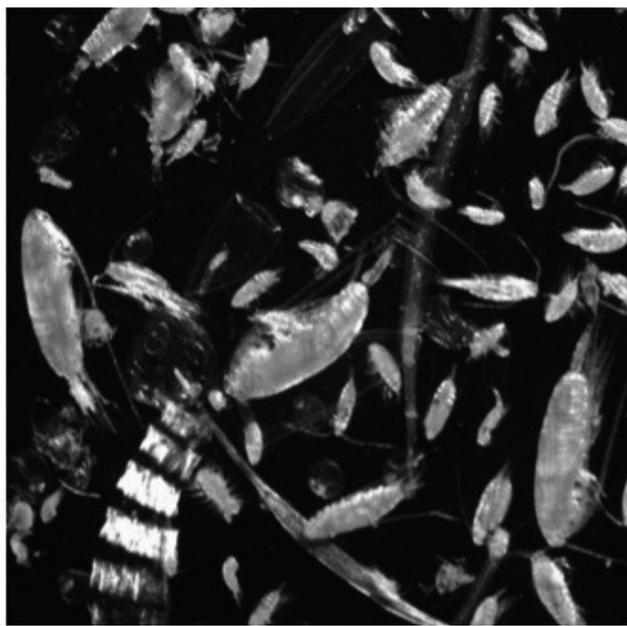
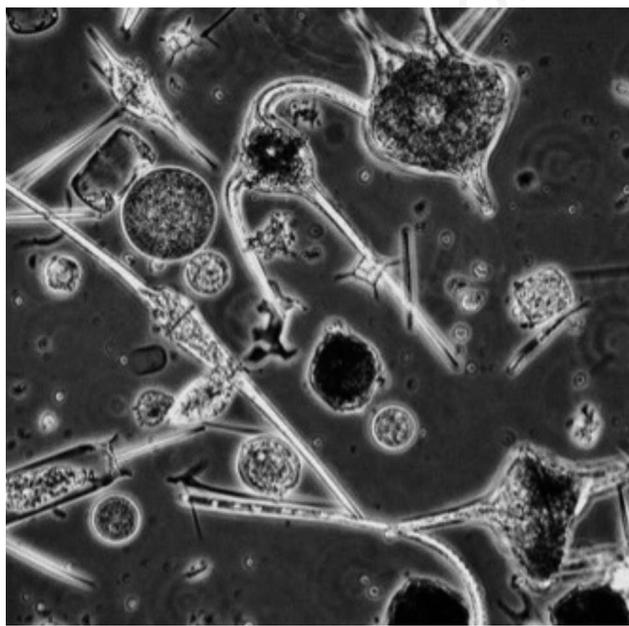


Fig. 1. Optic microscopy view of a mixed winter phytoplankton (left) and zooplankton (right) community gathered at the LTER site Gulf of Venice, Northern Adriatic Sea. Pictures courtesy of Stefania Finotto (phytoplankton), and Elisa Camatti and Marco Pansera (zooplankton).

process of construction and consolidation of the Italian LTER network, to which I contributed along with many other colleagues, have always been guided for me by the voices expressed by these two Authors, and have provided me the foundation of any further conceptual enrichment.

The LTER-Italy network has been established in 2006, year that marks its official affiliation to ILTER (i.e., the ‘International’ LTER network). The story of LTER-Italy has been driven by professional collaboration and friendship, with many events and memories that promoted the long-lasting connection within this wide community. In the past 15 years, the development of LTER-Italy has been tightly connected with that of LTER-Europe, even more now that the European network has entered a new phase, while developing the eLTER Research Infrastructure (eLTER RI) as a formally recognised ESFRI Research Infrastructure, since 2018. LTER-Italy currently consists of 79 research sites, organized in 25 parent sites (i.e., made by multiple research sites), managed and coordinated by public research institutions, universities, and environmental agencies. The sites represent the main ecosystem ty-

pologies of Italy: they include terrestrial, freshwater, transitional and coastal marine environments, giving the network a marked interdisciplinary brand.

Forty sites, i.e. more than half of the total LTER-Italy sites, are aquatic (Tab. 1). They are distributed along the whole Peninsula and they include the most common Italian lake typologies (large and deep subalpine lakes, small and shallow mountain lakes and reservoirs), the main Italian lagoons and relevant marine coastal ecosystems. Long-term series of data on plankton (phyto-and/or zooplankton) dynamics have been collected during the last forty years at most LTER-Italy aquatic sites, providing an invaluable empirical and rigorous knowledge for the sustainable management of aquatic resources, considering that in the last decades most aquatic ecosystems in Italy have undergone significant ecological changes.

The voices from LTER-Italy aquatic sites – from the large subalpine lakes to mountain and artificial lakes, from lagoons to marine coastal ecosystems – were gathered and compared by 54 Authors in a first, and unique until now, synoptic and trans-domain overview of plank-

Tab. 1. List of the LTER-Italy aquatic sites involved in the papers cited in the text and/or in the *Cammini* LTER initiative. For the full list of the LTER-Italy aquatic sites see: www.lteritalia.it

LTER-Italy Parent Site	LTER-Italy Research site	Ecosystem typology	Morabito <i>et al.</i> , 2018	Rogora <i>et al.</i> , 2018	Zingone <i>et al.</i> , 2019	Tanentzap <i>et al.</i> , 2020	Pilotto <i>et al.</i> , 2020	<i>Cammini</i> LTER
Lake Ecosystem of Sardinia	Lake Bidighinzu	Artificial lake	X				X	
Lake Ecosystem of Sardinia	Lake Sos-Canales	Artificial lake	X					
Southern Alpine lakes	Lake Como	Deep subalpine lake	X					
Southern Alpine lakes	Lake Garda	Deep subalpine lake	X					X
Southern Alpine lakes	Lake Iseo	Deep subalpine lake	X					
Southern Alpine lakes	Lake Maggiore	Deep subalpine lake	X			X		X
Southern Alpine lakes	Lake Orta	Deep subalpine lake	X					
Mountain lakes	Lago Anterselva	Alpine lake					X	
Mountain lakes	Lago piccolo di Monticoli	Alpine lake					X	
Mountain lakes	Lake Paione Superiore	Alpine lake		X				X
Mountain lakes	Lake Paione Inferiore	Alpine lake		X				X
Mountain lakes	Lake Santo Parmense	Appennine lake	X	X				
Mountain lakes	Lake Scuro Parmense	Appennine lake	X	X				
Mountain lakes	Lake Tovel	Alpine lake	X					X
-	Lake Trasimeno	Shallow lake	X					
Lagoons of Salento	Alimini	Coastal lagoon	X					
Lagoons of Salento	Aquatina	Coastal lagoon	X					
Marine Ecosystems of Sardinia	Lagoon of Cabras	Coastal lagoon	X					
-	Mar Piccolo of Taranto	Coastal lagoon	X					X
-	Lagoon of Venice	Coastal lagoon	X				X	X
Gulf of Naples	Marechiarra	Mediterranean Shelf and sea	X		X			X
Marine Ecosystems of Sardinia	Gulf of Olbia	Mediterranean Shelf and sea	X					
Northern Adriatic Sea	Gulf of Trieste	Mediterranean Shelf and sea	X					X
Northern Adriatic Sea	Gulf of Venice	Mediterranean Shelf and sea	X				X	X
Ligurian Sea	Portofino Promontory	Mediterranean Shelf and sea	X					
Northern Adriatic Sea	Senigallia-Susak transect	Mediterranean Shelf and sea	X					

ton dynamics, based mainly on published studies, but also checked and complemented with unpublished information (Morabito *et al.*, 2018). This paper is indissolubly associated to the figure of Giuseppe Morabito, who, during the paper drafting, passed away for a sudden upsurge of the illness that hit him some years before. Giuseppe was a strong and much appreciated voice in phytoplankton ecology, both in Italy and abroad. But, above all, he was a friend for most of us. The “voice” of Giuseppe, both the remembrance of its tone and laughs and the ecological conceptualization it brought to us, accompanied us for many months following his death and it was crystalized in our paper.

In the article by Morabito *et al.* (2018), a general conceptual framework was achieved, connecting the large and small scales in a chain of events embracing the whole ‘aquatic continuum’, where the plankton responses appear to depend mainly on the trophic state of the ecosystems and on the strength of the local anthropogenic disturbance. Actually, the long-term patterns were linked to a variety of factors, differently identified in: i) the physical and meteorological conditions; ii) the combination of bottom-up and top-down controlling factors; iii) the progressive improvement of wastewater treatment; and iv) the contemporary decrease of precipitations and nutrient loading from inflowing rivers. Besides, the marked increase in water temperature over the last decades was a trait shared by many Italian marine and freshwater environments: these results concur to confirm the significant warming of marine ecosystems and largest lakes, in line with the outcome of measurements recorded at the global scale.

Some of the voices of LTER-Italy aquatic sites (Tab. 1) joined the ones coming from the terrestrial sites, in two cross-domain studies conducted at the European level (Rogora *et al.*, 2018; Pilotto *et al.*, 2020). The first of these studies (Rogora *et al.*, 2018) offers a comprehensive overview and synthesis on the effects of climate change in different mountain ecosystems, considering several LTER sites, both terrestrial and freshwater (lakes and streams), distributed along the Apennines (Italy) and the Alps (Italy, Switzerland and Austria). Rogora *et al.* (2018) focus on the change in vegetation cover and carbon uptake, on the alteration of biogeochemical cycles in soils and water, and on the change in phenology and biological diversity in mountain ecosystems; data showed varying levels of effects in response to climate change, which has a prevalent indirect impact, resulting from multiple interactions. For instance, the interannual variability in the duration of the snow cover appeared to play a key role, affecting nutrient cycles both in soils and in surface waters and influencing the biological communities as well.

The second cross-site study mentioned herein (Pilotto *et al.*, 2020) is a meta-analysis of multidecadal biodiver-

sity series in Europe, aiming to fully understand the patterns of local biodiversity change and the discrepancies between local and global biodiversity trends. The study considers 161 long-term series from 115 marine, freshwater and terrestrial sites, mostly belonging to LTER-Europe, in 21 European countries, covering nine biogeographic regions, three realms and eight taxonomic groups. This wide scale, long-term study showed that a significant heterogeneity in the degree and direction of change in biodiversity metrics (i.e., the criteria used to ‘measure’ the level of biodiversity) exists at the continental spatial scale, demonstrating that biodiversity changes at local scale are often complex and cannot be easily generalized.

Going back to the three ecological strategies described by Peters (2010), the papers by Morabito *et al.* (2018), Rogora *et al.* (2018) and Pilotto *et al.* (2020) are examples of the “long” and the “broad”, which both represent essential components of the LTER networks and of eLTER-RI, i.e., the wide scale systematic coverage of major terrestrial and aquatic environments, which can provide a whole-system multi-scale approach for comparative ecological analysis (Mirtl *et al.*, 2018).

Amongst the LTER-Italy aquatic sites, there are also many examples of the “deep”, meant as the development of different kinds of specific research questions and complementary studies, emerging from the long-term observations, and which provide valuable interpretative tools that enhance the informative significance of the long-term series themselves. I report here only two examples for all, concerning the LTER site MareChiara (LTER-MC) in the Gulf of Naples (Zingone *et al.*, 2019) and the Lake Maggiore (Tanentzap *et al.*, 2020), two iconic LTER sites as for the coastal marine environments and the large lakes, respectively (Fig. 2).

The paper by Zingone *et al.* (2019) explicitly addresses how the LTER local site, specifically, the LTER-MareChiara programme conducted with sampling 2 miles off downtown Naples, proved to be relevant not only to trace plankton changes at different scales and under different environmental conditions across three decades, but this effort set a natural laboratory up, which has become a source of many inspiring voices for complementary research widening considerably the knowledge of the planktonic organisms and of the whole ecosystem functioning. A high number of phytoplankton species has been uncovered (both with microscopy-detailed taxonomic studies and biomolecular approaches), elucidating also the role of ‘crypticity’ in shaping natural diversity; the different phases in the life cycles of individual species have been finely described, with a consequent improvement of our ability to interpret seasonal and biogeographical patterns.

At the other side of the ‘salinity border’, the long-time

series of Lake Maggiore was used to thoroughly assess how the warming lake temperatures, up to 2 C, might have restructured the pelagic food webs from 1981 to 2008 (Tanentzap *et al.*, 2020). This paper addressed the thermal responses of the different trophic levels, associating temperatures with population dynamics, an issue whose evidence remain scarce in nature. As the lake warmed, the food web shifted, in terms of numerical abundance, towards predators occupying middle trophic positions, strengthening the top-down structuring of the food web.

All the above-mentioned valuable studies addressed the plankton ecology and/or the functioning of ecosystem and their changes with the well-established cognitive approach, where we – as human beings in our role of scientists – observe the environment. Field activities, critical data analysis and discussion, writing up the results: these, well-motivated and conscious, actions are all necessary and enjoyable activities taken by our rational mind, which allow obtaining valuable knowledge and objectively based information on how ecosystems work and change.

However, I guess that we all have experienced another type of knowledge of the sites we are studying, based on different qualities that are connected with our emotions

and with a peculiar kind of perception, which deeply bond us with Nature, beyond scientific and rationale knowledge and words. This brings us to what is called “Affective Ecology” (Barbiero, 2011 and 2017), a new discipline grounded on Ecology and dealing, indeed, with our connecting with Nature. Affective Ecology is epistemologically founded on two scientific hypotheses: the biophilia (Wilson, 1984), which manifests the innate learning rules evolved in the human species to connect and govern our relationship with Nature; and the theory of multiple intelligence (Gardner, 1983), which individuate different manifestations of human intelligence, one of which can be defined as naturalist intelligence (Gardner, 1999).

In the scientific papers we write, there is usually (and understandably) virtually no place for an exploration of affective ecology and the qualities it brings, since these latter are considered to be just subjective impressions of our own, suitable for poetry perhaps, but not for a ‘business-as-usual’ approach to science. Instead, cognitive Ecology and Affective Ecology can act in synergy within one another, thus giving rise to a virtuous circle: on the one hand, establishing an affective connection with the natural world stimulates the desire to know nature at a



Fig. 2. LTER – Plankton sampling activities at the LTER sites MC - Gulf of Naples (left) and Lake Maggiore (right). Pictures courtesy of Maria Grazia Mazzocchi and Gabriele Tartari, respectively.

deeper level; conversely, a deeper ecological knowledge may stimulate a more intimate relationship between nature and the mankind (Harding, 2011).

Are the LTER-Italy “voices” harmonized and open?

Based on the cross-site studies presented above, two major interconnected issues appear as shared at the European and global levels (Mirtl *et al.*, 2018): i) the heterogeneity of long-term series, for what concerns series lengths, survey schemes, and methodologies; and ii) the inadequate accessibility and availability of the dataset, which frequently lack appropriate data management plans and sharing procedures. These issues stem intrinsically from the most frequent establishment process of national networks at the European level, including the Italian one, which were mainly driven by bottom-up efforts, i.e., making the best use of the existing long-term ecological activities and facilities, without any prior harmonization and agreement around data management procedures and policies.

At the global and European levels both aspects are tackled with different tools and initiatives, namely by the adoption of: i) the Ecological Metadata Language (EML, Michener *et al.*, 1997) as a common metadata language (Vanderbilt *et al.*, 2010); ii) the Environmental Thesaurus (EnvThes, <http://vocabs.ceh.ac.uk/evn/tbl/envthes.evn>; Schentz *et al.*, 2013), which provide a common and stable semantic backbone for documenting research products; and iii) the Dynamic Ecological Information Management System – Site and Dataset Registry (DEIMS-SDR), a research and monitoring site registry (<https://www.deims.org/>; Wohner *et al.*, 2019) that allows describing and identifying in situ sites and facilities (stations, sensors, datasets, persons), generating persistent, unique and resolvable identifiers for each site, and also documenting associated data linked to each site. Besides, a core set of biotic and abiotic variables is under definition, for better comparisons across spatial scales and increase of the usage of LTER data, based on the already existing frameworks and approaches at the global level (Haase, 2018). These core set of recommended variables consider and link, currently, both the Ecosystem Integrity Framework (Mueller, 2005) and the Essential Biodiversity Variables (EBV; Pereira *et al.*, 2013), within an integrated approach to be applied to terrestrial, freshwater, transitional and marine ecosystems. This approach could support holistic ecosystem research, ensuring that individual sites cover the most important features of ecosystems, promoting the comparability and interoperability of data between different sites and monitoring networks, and contributing to harmonize field research globally.

To this respect, Zilioli *et al.* (2019) tested the level of maturity of LTER-Italy at contributing to the EBVs’ framework by i) investigating how many and which cat-

egories of LTER sites currently provide datasets suitable for measuring the two EBVs “Species Distribution” and “Species Abundance”; and ii) mining the information which is structured and publicly shared by site managers through DEIMS-SDR. Through this analysis, a first overview of EBVs monitored in LTER-Italy and the corresponding data management practices has been provided, as well as an assessment of the interoperability of the network with respect to other research organisations. The study evidenced a documented capacity to provide essential measures through the information system DEIMS-SDR, but at the same time the need to support the community and to optimise the EBVs’ information retrieval to improve the assessment and hence the effectiveness of LTER as an observing system.

The technical, cultural and social aspects of data sharing are considered as crucial in ILTER, which thoroughly address them with a general and full agreement, in principle, on open data at the global scale (Vanderbilt *et al.*, 2015; Vanderbilt and Gaiser, 2017; Shin *et al.*, 2019). However, putting the open science principles into practice is still an issue in many of the national member networks and at the local level, calling for the development of practical case studies. One of them has been recently carried out in the LTER-Italy framework: it regarded the release, with open access, of a long term marine dataset of water quality and plankton data collected in the Northern Adriatic Sea, in 50 years, from 1965 to 2015 (<http://doi.org/10.5281/zenodo.3516717>; Aciri *et al.*, 2019, 2020). This goal was achieved by embracing an open vision extended to the whole research lifecycle (Minelli *et al.*, 2018a, 2018b): from research idea to results and data, from metadata to methods and software. Open science actually involves a broad and comprehensive view, for making the various research steps accessible, reusable, and understandable.

Besides the most technical aspects, which can be found in the above-cited papers and that are not reported here, I wish to stress the cultural and human ones, which connected the LTER voices beyond time and space. Indeed, a heterogeneous working group, made by field ecologists and data management scientists as well as by retired researchers, worked together since the beginning and along the whole process, with the goal of sharing and harmonizing also the different experiences, needs, and points of view, and of demonstrating that a change of vision is possible, from “publishing as soon as possible” to “sharing and collaborating” (Moedas, 2015). All the LTER-Italy scientists involved agreed with open science and they were willing to know better what open science actually could imply in practical terms. Uncertainty to openly share the data was mainly due to the concern of getting proper acknowledgments to the data producers and about the extra time needed to accomplish the whole process,

which was seen as a further workload, difficult to hold up. Moreover, the opportunities of publishing datasets and data-papers were also poorly known and considered with scepticism, mainly for the low impacts on the professional careers. Actually, indexing published datasets on Web of Science and the practice of data papers is quite a new one, which needs still to enter in the publication habits.

Working side by side in this multidisciplinary group allowed to express and examine honestly all the difficulties encountered, trying to find together the possible solutions and including, as essential parts and outcomes of the process itself, also the cultural resistances and practical challenges. The whole process required sharing, in a concrete and pragmatic way, visions, tools, and languages. One of the unexpected products was, for instance, a glossary (Scovacricchi, 2020) initially started as a joke after each meeting, containing all the terms and acronyms that were used in the informatics field and were not understandable by field researchers. This glossary has been then organized, transformed into a report, openly accessible (<http://doi.org/10.5281/zenodo.4302115>), to be exploited as a tool to learn and share terminologies that often could hamper the integration between different expertise.

Finally, I wish to emphasize the contribution to LTER studies provided by retired researchers, who revealed to be extremely precious, for the knowledge they owned about the oldest data, which they gathered personally, and for their unaltered memories, tightly connected with personal stories, which were reviving the data from the past. Thanks to them, we became more aware of the human dimension behind the dataset and of the crucial importance of fostering open science also for allowing the creation of links among the past, the present and the future. This brings us back to the paper by Magnuson (1990) and to his call for the responsibility in LTER studies: transmitting openly the data and knowledge, inspired by the vision of continuity across generation, can actually move us from a pure cognitive experience to an enlivening and rewarding one.

LTER-Italy voices in dialogue with society

There is a wide and growing recognition that the environment must be viewed and studied as a social-ecological system, where ecological research becomes also a cultural process, not only a scientific one (Haberl *et al.*, 2006). The integration of social sciences in LTER networks is a recognized priority (Singh *et al.*, 2013; Mirtl *et al.*, 2018, Dick *et al.*, 2018): socio-ecological research is conducted worldwide in LTER networks, aiming at involving a broad stakeholder community in measurements in the co-design of investigation practices and also in the definition of research priorities (Haberl *et al.*, 2006; Mauz *et al.*, 2012; Dick *et al.*, 2018). The LTER networks may therefore represent an appropriate and suitable context

where new and different forms of communication and public participation and engagement could be experimented, sharing the voices of LTER with the civil society in a mutual relationship. Indeed, ecosystem and biodiversity too often remain abstractions and conceptualizations, unless new methodologies in science communication and education are developed, with new voices and words able to convey different perceptions, embedded in the language, in the culture, and in the daily experiences (Monbiot, 2017; Gray and Colucci Gray, 2018).

Aiming at making the public more familiar with the different LTER ecosystems and with the LTER vision and aims, LTER-Italy researchers planned and realized, from 2015 to 2019, the informal science-communication initiative called *Cammini* LTER (D'Alelio *et al.*, 2016; Bergami *et al.*, 2018; L'Astorina *et al.*, 2018a; Pugnetti *et al.*, 2019). During *Cammini*, researches “walked, cycled and kayaked” along itineraries, which connected two or more LTER sites, creating a physical and visible movement of researchers towards and with citizens, sharing informal events and communication activities, in close relationship and cooperation with the territories crossed, which were quite heterogeneous in size (from big towns to small villages) and audience (from school children to elderly people, from lay people to territorial managers, such as foresters, ecological and alpine guards, local environmental associations). Thirteen trails were realized in 5 years, most of them involving LTER aquatic sites (Tab. 1; Bergami *et al.*, 2018) and letting spread the voice of plankton in very different context, across seas, lagoons, lakes, and also on the land.

The initiatives realized in the trails covered most of the communication typologies mentioned in the literature (Bergami *et al.*, 2018; L'Astorina *et al.*, 2018b; Pugnetti *et al.*, 2019). The science communication system can be, indeed, compared somehow to an ecosystem (Davies and Horst 2016), where various communication practices co-exist, occupying diverse and self-consistent niches, all quite interconnected. In the *Cammini*, traditional (e.g., press releases, public conferences, tweets and post on the social networks, reports on blogs) and experimental (Fig. 3; e.g., sharing of the LTER activities at the sites, with samplings of the different ecosystems' components and microscopy sessions of plankton and benthos) activities were carried out along each trail, aiming at highlighting the relevance of LTER in the territories crossed and the role of the institutions involved. To these activities, more participative and inclusive initiatives were added, such as those of citizen science (Criscuolo *et al.*, 2018a, 2018b), the Bioblotz (Petriccione, 2018) and the Sea Futuring Tours (Fig. 3; L'Astorina *et al.*, 2018c). These lasts consist in a new form of public engagement, aimed at fostering awareness and responsibility towards the surrounding environment, the sea in this case: secondary school students

of Naples and Taranto were invited and guided, through different cognitive and sensorial experiences, to imagine the future of the sea they lived by, the Gulf of Naples and the Mar Piccolo.

The multifaceted communication activities and methods experienced during *Cammini* reveals the heterogeneity of expertise, interests and expectations of LTER scientists: i) experience new languages to make science most accessible and attractive; ii) activate synergies between expert and local knowledge in a mutual exchange; and iii) recover or strengthen the emotional and affective link with our work and with the natural environment.

Cammini can be considered as a part of a long-lasting tradition, where walking is considered the most intimate way to engage with the landscape, offering privileged insights and knowledge into both places and self (Solnit, 2000), reinforcing the connection with the natural environment (Maturana and Varela, 1998; Varela *et al.*, 1991).

In the physical gesture of “opening to the world” with the body and the senses (Le Breton, 2000), most researchers left behind, not only symbolically, the comfort zone they were used to (e.g. the desks, the laboratories, the mental schemes, the thematic congresses) to experiment informal and not mediated communication modalities, activating empathy with the people and places and overcoming the sense of separation and distance that often characterize the relations between science and society (L’Astorina *et al.*, 2018a).

CONCLUSIVE MUSINGS

In this paper I evidenced some crucial aspects of LTER-Italy activities at the aquatic sites, with emphasis on plankton, which guiding voice brought me to deal different issues that have been - and still are - at stake in the current development of the national network and of



Fig. 3. Examples of activities carried out during *Cammini* LTER. Upper panel: scientist sharing with the public the sampling activities at the LTER mountain site Lake Paione Inferiore. Lower panel: secondary school students engaged in the Sea Futuring Tours at the LTER site Gulf of Naples, gathering and analysing materials to imagine possible futures for the sea. Pictures courtesy of Antonio Bergamino.

eLTER-RI, at the European level: i) the relevance of wide scale comparative ecological analysis at different sites across ecological domains; ii) the possibility to develop specific research questions and complementary studies emerging from the long term observations at the LTER sites; iii) the necessity to deal with methods and data heterogeneity, by identifying harmonizing frameworks and fostering open science; and iv) the possibility to find and pursue a change in our vision of the relations between science and society, starting with different ways of communicating, in an open and empathic way. Most of these aspects are an expression of our scientific and cognitive approach to ecosystem study and they are all necessary to gaining knowledge and information on how ecosystems work and change through time.

In this conclusive musings I wish to make a step further, emphasizing some voices that are much overlooked, and which whisper that the LTER sites could be also the starting point where develop a deep connection with Nature, entering in what is called the “soul of the place” (Harding, 2011): places in which one may spend time getting to know them intimately with intuition and feeling, whilst using the rational mind to find out about their ecology and about how humans have interacted with these places over the years. The age we live in is characterized by uncertainties, complexity and by crucial environmental and societal challenges (Millennium Ecosystem Assessment, 2005): according to many scholars, it is necessary, more than ever, to embrace a shift of perspectives for a transformative change (Leiserowitz *et al.*, 2005; Ericson *et al.*, 2014), which requires the elaboration of a deep and broadened form of subjectivity, in which humans identify also with non-humans, allowing to suspend the illusion of separateness (Naess, 1984; 1995; Carvalho, 2014; Geiger *et al.*, 2018; Eisenstein, 2018).

Indeed, as evidenced by an increasing number of studies, scientific knowledge, new technology or governance alone cannot resolve the current ecological crisis and global sustainability challenges (Wamsler and Brink, 2018). They also require a broader cultural change and new approaches (Esbjörn-Hargens and Zimmermann, 2009; Dhiman and Marques, 2016; Wamsler and Brink 2018) that integrate in every ecological study and action an inner dimension, which include emotions, identities and values (Buchanan and Kern, 2017; Hedlund-de Witt, 2011; Ives *et al.*, 2018, 2019). The inner world has been largely disregarded in scientific studies, but it is gaining increasing momentum in parallel scientific fields, such as neuroscience, ecopsychology and education. Within this context, some contemplative practices, such as meditation, have been proved to be crucial to open pathways (Mayer and Frantz, 2004; Panno, *et al.*, 2017; Geiger *et al.*, 2018; Wamsler, 2018), which could enable an expansion of empathy to include non-human subjects or, as in-

spiringly David Abrams (1997) calls them, the “more than human world”.

I decided not by chance to start this paper citing a famous sentence of the Buddhist monk Tich Nath Han, whose practices and insights aim at fostering the awareness of interconnectedness and “inter-being” (Carvalho, 2014), since he expresses in a poetical and vibrant way the deep interconnections that are at the foundation of any ecological and LTER study: interconnections among human beings, in a long chain that links the past to the present and to the future through LTER studies, and among us humans and non-human beings that surround us, in intertwined and mutually dependent functions and processes (Abrams, 1997).

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