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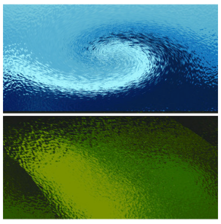

VIEW POINT

The Italian Long-Term Ecosystem Research (LTER-Italy) network: results, opportunities, and challenges for coastal transitional ecosystems

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Abstract

1 - The Long-Term Ecosystem Research (LTER) network, now a global reality, was founded on a combination of long-term ecological studies, short-term experiments, and comparisons among sites and eco-domains.

2 - The LTER-Italy network was officially established as a formal member of the LTER international network in 2006, following a wider on-going process in Europe; it currently consists of 22 sites representing the main ecosystem typologies of Italy. Four coastal transitional ecosystem sites are included in the LTER-Italy network: on the northern Peninsula, these include the Venice Lagoon and the lagoons of the Po River Delta, which are characterized by a temperate climate and the influence of tides; and in the southern sector, these include the coastal ecosystems of Sardinia and the Mar Piccolo of Taranto, which are characterized by a Mediterranean climate and the absence of sensible tides.

3 - In this paper, we present and discuss three main issues: (1) the LTER-International and LTER-Europe context, emphasising the most practical issues and activities that must be addressed for the effective organization and maintenance of LTER networks; (2) the history, structure, and perspectives of the national LTER-Italy network; and (3) the opportunities, strengths, and weaknesses related to participation of the LTER-Italy network in the study of coastal transitional ecosystems.

Keywords: LTER-Italy, coastal transitional ecosystems, Venice Lagoon, Po River Delta, Sardinia costal ecosystems, Mar Piccolo of Taranto.

Introduction: The LTER network

The Long-Term Ecological Research (LTER) network gathers and analyses multi-decadal ecological observations so as to provide an appropriate temporal context for minimising misinterpretations in our efforts for understanding and managing ecological issues and concerns. LTER observations are critical for detecting meaningful ecological shifts and assessing whether ecological changes are due to human or natural causes. Data from the LTER networks are useful for identifying thresholds in the normal range of multiple states of an ecosystem and for estimating the probabilities of moving from states of higher to more degraded biological quality. The LTER data are particularly important for the identification of temporal trends, as many ecological processes develop at temporal scales that are longer than have typically been considered in traditional short-term ecological research studies (Parr *et al.*, 2002). LTER may have different connotations, according to the local objectives of monitoring studies, but the time scales of observations should be consistent with the time scales of phenomena under investigation so as to distinguish signals related to ecological change from those of background noise. The LTER network is critical for challenging existing ecological paradigms and scientific dogmas, for testing ecological theories on the organizing principles of ecosystems and biological communities, and for understanding the dynamics, variability, and resilience of communities and the processes of community dynamics. The LTER approach should be coordinated with both palaeoecological studies and future forecasting models and scenarios. However, it owns a meaningful and self-consistent value as it comprises and represents the time scale within which our responsibilities for the Planet are most manifest: within this time scale, ecosystems change during our lifetimes and the ones of our children and grandchildren (Magnuson, 1990).

Although LTER is recognized as a key ecological discipline, it is among the main victims of funding shortages—grant-funded projects with actual long-term perspectives are extremely rare. Moreover, because of the frequent imbalance between energy investment in LTER and its actual scientific yields, LTER is generally not a suitable basis for solid scientific curricula; thus, LTER is often not attractive to researchers and research institutions (Wolfe *et al.*, 1987; Duarte *et al.*, 1992; Vogt *et al.*, 1997). Thus, LTER is predominantly the result of the personal determination and vision of individual scientists. In addition, the pioneering collection of long-term ecological data has often been initiated to answer applied questions, as for example in the case of continuous plankton recording experiments (Richardson *et al.*, 2006) that began in 1925 with the goal of mapping oceanic plankton distributions in relation to fisheries, but has also proved invaluable in addressing many new ecological questions, including community responses to ocean warming (Kirby *et al.*, 2007). Pioneering LTER studies have demonstrated the value of obtaining long-term ecological datasets, and such datasets are part of a growing number of temporally extended studies. In recent decades, some programmes and initiatives related both to research and to environmental monitoring directives have marked the beginning of a new era in time-series ecological investigations (Ducklow *et al.*, 2009); among them is the establishment and diffusion of LTER networks at the national, European and global levels. The LTER sites consist of different reference ecosystems, research and monitoring facilities that established a network world wide. The International LTER (LTER-International; www.ilternet.edu) network, which began in 1993 as an offshoot of the United States LTER (US-LTER: www.lternet.edu) network, was driven by a need for collaboration at local, regional, national, and international levels, based on the sharing and integration of knowledge and data, the creation of synergistic research programmes, and the delivery of scientifically sound results to decision makers and the public (Bredemeier *et al.*, 2007). The novelty of the LTER networks consists of the individuation of research sites at which long-term observations and research can be maintained, as well as the creation of a legacy of well-designed and well-documented long-term observations and experiments which will yield results for future generations. The LTER sites are effectively "sensors" of ecological changes occurring at local, regional, and global levels; they are facilities at which the acquisition of ecological data should stimulate advanced research questions and hypotheses that can be addressed and verified by more focused short-term research and experimentation (Peters, 2010). The technological developments affecting LTER studies (especially the development of sensors and devices for environmental monitoring, and of information and communication technologies) are ongoing, and new approaches have been integrated with ecological observations conducted using traditional methodologies. One of the central goals of the LTER networks is the education of a new generation of scientists, through training, teaching, and acquisition of knowledge about LTER, based on the research being conducted at the LTER sites. The LTER activities should also extend to environmental managers, policymakers, and the general public, thus providing decision-making support, information, recommendations, and the knowledge and understanding necessary to address complex environmental challenges.

The European context

Development of the LTER network started in Europe in 2004, based on the framework of the Long-Term Biodiversity, Ecosystem and Awareness Research Network (AlterNet) (www.alter-net.info).

The following attributes are specific to the LTER-Europe network (Mirtl *et al.*, 2009): (1) collection of field data from a wide variety of ecosystems using a marked trans-ecodomain approach; (2) provision for documentation and use of long-term information and data on ecosystems at time scales of decades to centuries; (3) contribution to the understanding of the complexity of natural ecosystems and coupled socio-ecological systems; and (4) integration of LTER and Long-Term Ecological Monitoring (LTEM). The LTER-Europe network (Mirtl *et al.*, 2009) has no reliable long-term support from a central funding body comparable to the National Science Foundation support for the US-LTER network. In compliance with European strategies to overcome fragmentation in the field of environmental monitoring and research, the LTER-Europe network was basically built on previously existing facilities with a strong LTER connotation. Thus, the LTER-Europe network has developed into a complex mosaic of European environmental monitoring schemes, databases, and institutions. In 2012, the LTER-Europe network comprised 22 formal national LTER member networks (www.lter-europe.net) and more than 400 LTER sites. The process of design, integration, and harmonisation of LTER research activities and facilities is critical and is successfully ongoing (Mirtl *et al.*, 2009). The main challenges facing the LTER-Europe network are intrinsic to the processes that led to the establishment of the network of excellence and to the complex nature of the network itself, including: the large number of LTER sites, the presence of a wide array of different ecosystem domains (terrestrial, freshwater, and marine), multiple reasons for establishing the different LTER sites (related to both research and monitoring), the heterogeneity of parameters and methods used at the sites, the large amount of data related to a wide variety of themes, and a lack of comparability data sets. Currently, the Life+ project "EnvEurope" ("Environmental quality and pressure assessment across Europe: the LTER network as an integrated and shared system for ecosystem monitoring", www.enveurope.eu) is the flagship project for LTER-Europe that is contributing to the process of harmonization and consolidation of the network (Pugnetti *et al.*, 2012). EnvEurope (2010–2013) was motivated by and conceived in response to challenges of research of the LTER-Europe network, and it is synergistically dealing with several key aims of the LTER-Europe project. EnvEurope takes a cross-domain approach using over 60 LTER-Europe sites (approximately 20% of the total), which encompass terrestrial, continental waters, wetland, and marine ecosystems in 11 LTER countries. The main tasks of the project are to: (1) gather in a structured way and to manage and analyse information (metadata) about different sites and datasets across Europe; (2) define and provide tools for LTER dataset reporting and integrated data management in the domain of LTER; (3) find a conceptual framework allowing the comparability of data gained from LTER and monitoring sites across Europe; (4) test the LTER network as a harmonized set of sites, based on field measurements covering a broad spectrum of parameters; (5) investigate shared scientific hypotheses through individual case studies, using long-term metadata and data analyses involving as many sites as possible; and (6) produce a knowledge base related to the organization of the LTER-Europe network, to improve information flow through the network and to end users, and to increase the visibility of the LTER-Europe network as a reference base for policy makers and environmental managers at the European level. Aside from its main tasks, EnvEurope has also been structured to play a role in the conceptualisation and operation of the Shared Environmental Information System (SEIS) programme, which has been promoted by the European Commission and some components of which are being developed for the Global Monitoring for Environment and Security (GMES) programme, a joint initiative of the European Commission and the European Space Agency. The permanent long-term site network on which the EnvEurope project focuses could represent a valuable system for *in situ* validation of satellite data, thus also supporting the implementation of the GMES programme (Campanaro *et al.*, 2012).

History and configuration of the LTER-Italy network

Italy entered the LTER-International network in 2006 at the culmination of a national scientific process that started during the 1990s (Matteucci *et al.*, 2007; Bertoni *et al.*, 2012) and involved the National Research Council and various universities, scientific societies, and public agencies. As of 2012, LTER-Italy consists of 22 parent sites representing terrestrial, freshwater, and marine ecosystems (Table 1; Bertoni *et al.*, 2012), chosen according to LTER-International recommendations and following a process of scientific review by external experts. Many of the 22 LTER-Italy parent sites consist of additional research sites (Table 1 and Figure 1), managed and coordinated by public research and by monitoring institutions and universities. Of the total, 20 parent sites represent the main ecosystem typologies of Italy, while two parent sites (Himalayan Lakes and Marine Research Stations in Antarctica) are extra-territorial and are managed by national institutions. Regarding its governance, LTER-Italy consists of the organizations responsible for the LTER sites,

Table 1 - List of the LTER-Italy parent sites, research sites and main reference institutions. The contact institutions of the parent sites are evidenced in bold.

PARENT SITE	**RESEARCH SITE**	**MAIN REFERENCE INSTITUTIONS**
Coastal Transitional Ecosystems		
Venice Lagoon	- Venice Lagoon	**National Research Council (ISMAR**), University of Venice, Venice Natural History Museum
Po River Delta	- Sacca di Goro - Valli di Comacchio	**University of Ferrara**
Marine Ecosystems of Sardinia	- Cabras lagoon - S'Ena Arrubia lagoon - Santa Giusta lagoon	**University of Sassari**
Mar Piccolo of Taranto	- Mar Piccolo of Taranto	**National Research Council (IAMC)**
Marine Ecosystems		
Northern Adriatic Sea	- Gulf of Venice - Gulf of Trieste - Po Delta and Romagna coast - Senigallia-Susak transect	**National Research Council (ISMAR**), OGS Trieste
Portofino Marine Protected Area	-Portofino Marine Protected Area	**University of Genova**
Marine ecosystems of Sardinia	- Gulf of Olbia - Gulf of Asinara	**University of Sassari**
Gulf of Naples	- MareChiara - Lacco Ameno	**Stazione Zoologica A. Dohrn, Napoli**
Marine Research Stations in Antarctica	- Moorings A, B, D, H - Terranova Bay	**National Research Council (ISMAR**), University of Napoli, University of Genova

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Freshwater ecosystems		
Subalpine Lakes	- Lake Maggiore - Lake Orta - Lake Garda - Lake Como - Lake Candia	**IASMA Trento**, National Research Council (ISE), Environmental protection Agency of Lombardia
Mountain Lakes	- Lakes Scuro and Santo Parmense - Lakes Paione Inferiore e Superiore - Lake Tovel - Lake Anterselva - Lake Braies - Lake Piccolo di Monticoli	**University of Parma**, National Research Council (ISE), IASMA Trento, Environmental Agency of Bolzano
Lacustrine Ecosystems of Sardinia	- Lake Cedrino - Lake Cuga - Lake Monte Lerno - Lake Sos Canales - Lake Temo	**University of Sassari**
Lake Trasimeno	- Lake Trasimeno	**University of Perugia**
Himalayan lakes	- Lakes Piramide Superiore and Inferiore	**National Research Council (ISE)**
Terrestrial Ecosystems		
Apennines: high elevation ecosystems	- Majella-Matese - Velino-Duchessa - Gran Sasso - Northern Apennines	**University of Molise**, University of RomaTre, National Forest Service, University of Pavia, University of Parma

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North-Western Alps	- Scientific Institution Mosso - Natural Reserve Mont Mars - Mont Avic - Cime Bianche - Tellinod - Tronchaney	**University of Torino**, Environmental protection Agency of Valle d'Aosta
Forests of the Alps	- Val Masino - Passo del Renon - Passo Lavazzè - Tarvisio - Valbona Reserve	**National Forest Service**, ERSAF, Autonomous Province of Bolzano, Autonomous Province of Trento, University of Torino
Forests of the Apennines	- Collelongo-Selva Piana - Piano Limina - Montagna di Torricchio	**National Research Council (ISAFOM)**, National Forest Service, University of Camerino
Mediterranean Forests	- Monte Rufeno - Colognole - Ficuzza	**National Forest Service**, Sicilia Region
Lowland Forests	- Bosco della Fontana	**National Forest Service**, University of Roma
Castelporziano National Reserve	- Castelporziano	**Castelporziano Reserve,** National Forest Service
Coastal Dunes of Central Italy	- Monumento Naturale Palude di Torre Flavia - Foce Trigno-Marina di Petacciato - Foce Saccione-Bonifica Ramitell	**University of RomaTre**, University of Molise
Pianosa Island	- Pianosa Island	**National Research Council (IBIMET)**

members of which constitute the National Site Representative Conference, and a Coordinating Committee; members are elected by the site responsibles and represent the main institutions involved in LTER research. A description of the sites, the long-term research activities, and the main institutions involved in the network can be found on the LTER-Italy website (www.lteritalia.it) and in Bertoni (2012). The LTER-Italy network is strongly interdisciplinary, and consists of terrestrial, marine (including coastal transitional), and freshwater ecosystems (Table 1 and Figure 1). Comparisons across eco-domains are rarely achieved in individual ecological studies, and conceptual and practical barriers among scientists working in the different domains have profound implications for addressing critical ecological issues (e.g., on biodiversity, climate change, and invasive species) that are of basic importance for conservation and management policies. Comparative studies that consider similar systems, taxonomic groups, or ecological functions in different aquatic and terrestrial habitats may reveal key ecological commonalities (Webb, 2012).

Coastal transitional ecosystems in the LTER-Italy network

Coastal Transitional Ecosystems (CTE; Tagliapietra *et al.*, 2009) are among the most ecologically and socio-economically vital sites on Earth. Given their global importance in terms of ecological diversity and economic value, and the potential impacts of human activities on these systems (e.g., from pollution, harvesting, species introduction, direct or indirect effects of climate change, reclamation, and hydraulic transformations), the environmental quality of CTEs is a matter of concern for both

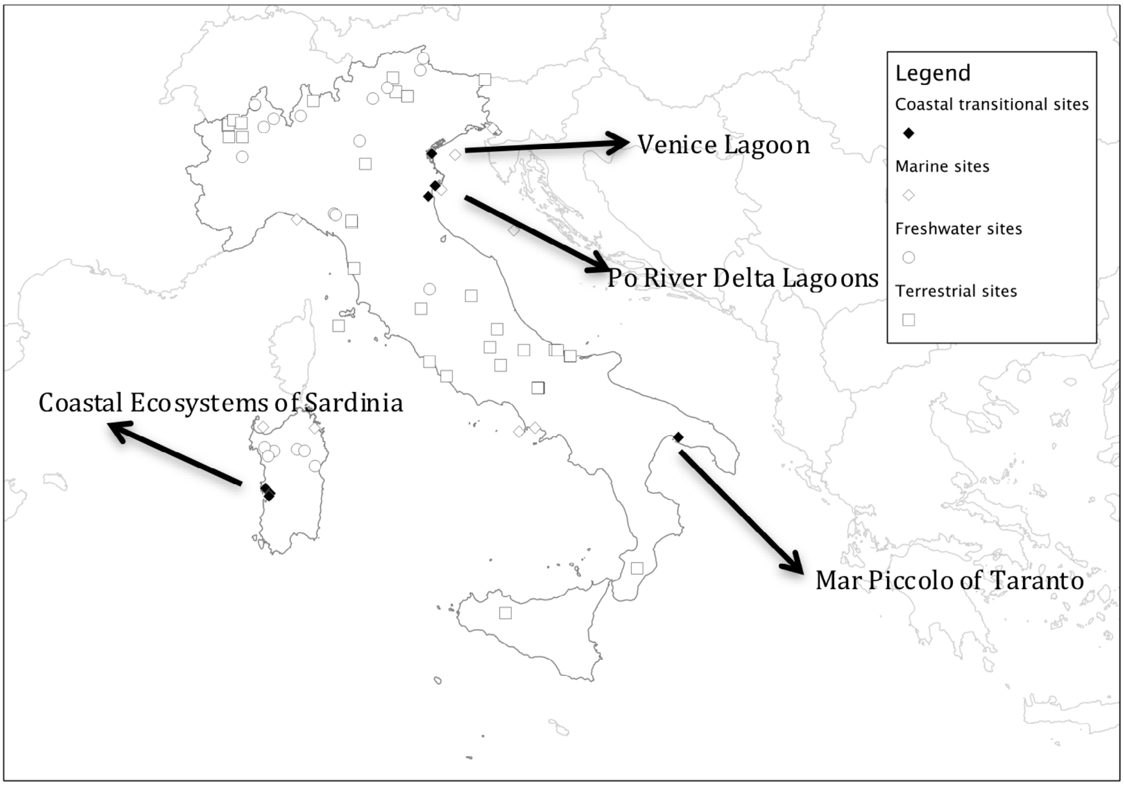

Figure 1. Map of the LTER-Italy (www.lteritalia.it) research sites.

scientists and environmental managers. Long-term perspectives are especially valuable in studies of CTEs because they are highly variable systems at various spatial and temporal scales, on account of their unique attributes, including their shallowness, strict benthic–pelagic coupling, and connectivity to both land and sea (Cloern and Jassby, 2008). The CTEs represent a challenge when dealing with the task of defining status and trends in water quality under ecological conditions (Elliott and Quintino, 2007). Both natural and anthropogenic stressors significantly affect these ecosystems. In Europe, the state of CTEs is seldom the mere result of natural evolution, as they have been subject to active management for millennia. To assess the significance of anthropogenic drivers of change, it is critical to understand the extent of natural variability and spatial heterogeneity in CTEs. In the LTER-Italy network, 4 of the 22 sites are CTEs (Figure 1); they are under the responsibility of different institutions (Table 1). On the northern Peninsula, the Venice Lagoon and the lagoons of the Po River Delta are characterized by a temperate climate and the presence of tides, and in the southern sector, the coastal ecosystems of Sardinia and the Mar Piccolo of Taranto are characterized by a Mediterranean climate and the absence of sensible tides. All of these shallow coastal bodies are complex, heterogeneous, and continuously evolving dynamic systems, sensitive to an array of external drivers and pressures. A large body of ecological research has been conducted, and is still going on, on CTEs since the beginning of the last century, focusing on different communities and ecological issues. An exhaustive description of the CTE sites, existing research and related bibliographic references, and the projects and participating institutions can be found on the LTER-Italy website (www.lteritalia.it) and in Bertoni (2012). Here, we provide a short description of the LTER CTEs and of related LTER topics.

The Lagoon of Venice

The Lagoon of Venice is a large Mediterranean lagoon (550 km^2) in the northern Adriatic Sea with densely inhabited and industrial shoreline areas. Major sources of pressures include by high tourist numbers, fisheries, and aquaculture. The average depth of the lagoon is 1.2 m; it is characterized by large subtidal shallow areas, intertidal landforms such as salt marshes and mudflats, and a network of deeper (5–10 m) channels. The lagoon is separated from the Adriatic Sea by sandbars that are interrupted by three inlets. Water turnover in the lagoon is maintained by tidal flows through the inlets, with circulation resulting from the interactions of tide, wind, and seafloor topography; water renewal times range from a few days in areas close to the inlets to 1 month in the inner areas (Solidoro *et al.*, 2004; Cucco and Umgiesser, 2006). The mean tidal range in the lagoon is approximately 60 cm, with maxima of over 150 cm. The lagoon varies from polyhaline to euhaline. A total of 12 main tributaries discharge an average of 35.5 $m^3\ s^{-1}$ of freshwater annually into the lagoon, with seasonal peaks in the spring and autumn (Zuliani *et al.*, 2005). Nitrogen and phosphorus loadings are on the order of 4000 and 230 t $year^{-1}$, respectively (Collavini *et al.*, 2005). The Lagoon of Venice presents marked habitat heterogeneity and the classification of habitats is still a matter of debate (Tagliapietra *et al.*, 2009, 2011). The main LTER topics are the ecology and distribution of phyto- and zooplankton, phyto- and zoobenthos, and icthyo- and avifauna. Water column parameters, phyto- and zooplankton abundance, biomass, and taxonomy have been studied sporadically by the Consiglio Nazionale delle Ricerche-Istituto di Scienze Marine(CNR ISMAR), Venice, at different time scales (seasonal, monthly, and hourly) since the 1960s, and at monthly intervals at five stations located in the northern and central basins since 1997.

Since 1980, macroalgae and taxonomic and ecological aspects have been widely studied in many stations and in different years, paying, at first, particular attention to *Ulva* and *Gracilaria* blooms and production and, then, to the entire community and to the distribution and growth of aquatic angiosperms, in order to describe temporal and spatial variations and new species introduction (Sfriso *et al.*, 2009a; CEMAS-DAIS, Ca' Foscari University of Venice). Such data have improved the understanding of relationships between macrophytes and environmental parameters, and have enabled the formulation of the Macrophyte Quality Index (MaQI; Sfriso *et al.*, 2009b), which is used to classify Italian transitional systems according to the Water Framework Directive 2000/60/EC (Sfriso, 2010). Large datasets are also available for zoobenthic assemblages (mainly macroinvertebrates). Faunal studies and specimen collection have occurred since at least the 18th century (e.g., Venice Natural History Museum). Quantitative samplings of soft bottom communities have been performed since the 1930s (Vatova, 1931, 1940), but until the 1980s the samplings were sporadic and only loosely comparable with one another. Studies on hard substrate communities have also been conducted sporadically. Following the proliferation of macroalgae and the ensuing anoxia that occurred in the late 1980s–early 1990s, the Environmental Department of the City of Venice and the Venice Water Authority (Magistrato alle Acque di Venezia) produced a series of studies, followed by others performed in the broader context of the activities for the Safeguarding of Venice and the Venice Lagoon. Benthic monitoring was conducted by or on behalf of the Consorzio Venezia Nuova, a concessionaire of the Venetian Water Authority, created by-law after the 1966 storm surge. The monitoring and studies were conducted to build a knowledge base for "restoring of the environmental balance of the lagoon", and were imposed by the "Special law for Venice" as a prerequisite for building mobile gates to sea inlets. Other studies have been performed for the management of clam harvesting (ISPRA, Ca' Foscari University of Venice) and, more recently, in the context of the implementation of the Water Framework Directive (CORILA; CNR-ISMAR, Venice). Data on the composition and structure of fish assemblages have been available since the end of the 1990s (CEMAS-DAIS, Ca' Foscari University of Venice); historical data on catches and fishing efforts have been available since 1945. Census data for the wintering of aquatic avifauna have been collected since 1993 (Ca' Foscari University of Venice in collaboration with INFS and the Venice Provincial Administration).

The Po River Delta

The Po River Delta is an LTER parent site that includes two research sites, the Sacca di Goro and the Valli di Comacchio; these sites are also Natura 2000 sites, Sites of Community Importance (SCIs), and Special Protection Areas (SPAs). The University of Ferrara has a 30-year history of active research on the transitional environments of the Po River Delta, especially on the composition and distribution of benthic communities, which have been regularly monitored for over 10 years. The specific topics for LTER are the biodiversity of benthic aquatic fauna and birds, sediment chemistry and dynamics, and water chemistry.

The Sacca di Goro is a shallow-water embayment with an area of 26 km^2, an average depth of 1.5 m, and two 0.9-km-wide connections to the sea. It is characterized by a clearly delineated low-energy eastern zone, which is separated from two high-energy zones in the western and central areas; the western zone is influenced by freshwater inflow and the central zone is influenced by inflow from the sea. The eastern zone is very shallow (maximum depth, 1 m) and accounts for one half of the total surface area and one quarter of the water volume. The main freshwater inputs are from two branches of the Po River (the Volano and Goro branches), which enter from two canals (the Bianco and Giralda canals) with approximately equal discharge rates. The freshwater system is located mostly in a subsidence area, which is regulated by a system of pumping stations. The freshwater hydraulic residence time oscillates between 2.5 and 122 days with a mean value of 24.5 days, whereas the water exchange time ranges from 2 to 4 days. The tidal amplitude is approximately 80 cm. The bottom of the lagoon is flat and the sediments consist of alluvial mud with high clay and silt contents in the northern and central zone. Sand is more abundant near the southern shoreline of the lagoon, while sandy mud occurs in the eastern area of the lagoon. The Valli di Comacchio are a large (115 km^2) complex of shallow-water (depth range, 0.5–1.5 m) brackish lagoons located in the southernmost part of the Po River Delta. Nowadays, the Valli consist of three main basins (the Valle Magnavacca, Valle Fossa di Porto, and Valle Campo basins). This semi-enclosed complex is almost completely surrounded by earthen dikes and is separated from the sea by the strongly anthropogenically impacted 2.5-km-wide Spina spit. The Valli are connected to the Adriatic Sea by three marine channels, and water exchange with the sea is both tidal and regulated. From February to May, large amounts of freshwater are conveyed by the Reno River through two dams in the southernmost parts of the Valli. Because of the shallowness of the basins and the limited exchange of water, salinity is mostly influenced by meteorological events, such as evaporation and occasional heavy rainstorms. The bottoms of the Valli are typically muddy, but sparsely vegetated meadows of the seagrass *Ruppia cirrhosa* occur in the southern parts of the Valli; these meadows are the remnants of the more extensive macrophytic communities that characterized the bottom of the Valli in the early 1970s.

Coastal lagoons of Sardinia

The three LTER lagoon sites (Cabras, Santa Giusta, and S'Ena Arrubia) are part of the parent site of the marine ecosystems of Sardinia, which also includes two marine areas (the Gulf of Asinara and the Gulf of Olbia). The lagoons are located along the west-central coast of Sardinia in the Gulf of Oristano. These sites consist of important wetland areas: IBA, SCI, and SPA. The sites are owned by the Regional Government of Sardinia. In most of these areas, fisheries and aquaculture are the most important human activities directly affecting the sites. The lagoons are affected by various environmental problems, such as eutrophication and salinization; they are typical shallow nanotidal Mediterranean lagoons that are well mixed with regard to circulation and stratification. The main concerns for LTER are the study of phytoplankton ecology, eutrophication, biodiversity, harmful algal species, and harmful algal blooms. Long-term data series are derived from high-frequency measurements and samplings of different environmental and biological parameters.

The Cabras Lagoon is elongate in shape and is perpendicular to the coastline, covering an area of approximately 23 km^2, and with a mean depth of 1.6 m and a maximum depth of 3 m. The area of the watershed is approximately 430 km^2. The input of freshwater to the lagoon is mostly from a small river, the Mare 'e Foghe River, located in the north. During the 20th century, human activities resulted in several modifications to the lagoon and its watershed that affected the hydrology and land use patterns of the area. The predominance of intensive agriculture and the release of poorly depurated urban wastewaters account for the high nutrient loads that have reached the lagoon in recent decades. In addition, in the late 1970s, water exchange with the sea was altered by the opening of a large canal, the Scolmatore spillway, which connects the lagoon to the adjacent Gulf of Oristano. A cement dam was built in the spillway to prevent further increases in the lagoon's salinity, and artificial barriers were constructed to control the fish catch, thereby impeding direct communication between the lagoon and the sea. Now the only link to the sea is via four very narrow creeks that flow into the large canal from the southern part of the lagoon over the barrier. A strong dystrophic crisis affected Cabras Lagoon in the early summer of 1999, killing the entire aquatic biota (Padedda *et al.*, 2012). Since this event, large reductions in fishing productivity have been observed. In 1998, fish productivity reached 40 tons km^{-2}, but this value fell to approximately 20 tons km^{-2} after 1999. Nevertheless, the lagoon has a high economic rating on account of extensive fishery activities that involve about 300 local residents.

The Santa Giusta Lagoon covers approximately 8 km^2, is approximately 1 m deep, and is nearly circular. The lagoon is choked, having been originally connected to the sea through the outlet of the River Tirso via a channel approximately 3 km long; this channel permits the only freshwater inflows during the wet period and scarce seawater inflows during the dry period. In 1958, the channel was deepened (to 3 m) and widened (to 6 m), and was separated from the river and connected directly with the sea. In addition, a fish catch system was built half-way down the Channel, causing a considerable reduction in depth and width, with repercussions on the tide exchange volume. In 1970, during the construction of an industrial harbour, a further canal communicating with the Oristano Gulf was constructed. Fish production prior to construction of the canal had always been high (greater than 500 kg ha^{-1} y^{-1}, and reaching a peak of approximately 800 kg ha^{-1} y^{-1} in 1977); however, during the 10-year period following construction of the canal, fish production progressively decreased, and in September 1989 a dystrophic crisis occurred. After 1990, the trophic status of the lagoon was kept under control for a period of about 12 years, and since then the trophic status has been controlled in a discontinuous manner. Recently (July 2010), a new serious fish-death event occurred, despite the diversion of urban waste to a sewage treatment plant (since 1995). In addition, a fish catch system was built half-way down the Channel, causing a considerable reduction in depth and width, with repercussions on the tide exchange volume. Sechi *et al.* (2001) compared the characteristics of the lagoon waters before and after the diversion, and found no substantial improvements in the trophic status of the lagoon during the years after the diversion, except for during some months in 1995. The insufficient reduction in nutrient concentrations resulted in a small decrease in the chlorophyll *a* concentration (from 11.3 to 10.2 mg m^{-3}) and a considerable decrease in the total density of phytoplankton; however, the latter was accompanied by changes in species composition. Phytobenthic biomass showed no particular differences before and after the diversion, and no changes in trophic status were evident; moreover, dystrophic crises still occurred after the diversion. A possible explanation may lie in the structure of the diversion system, which does not completely stop the inflow of sewage into the lagoon.

The S'Ena Arrubia Lagoon (Trebini *et al.*, 2005) covers an area of 1.2 km^2 and has a mean depth of 40 cm. Freshwater input is supplied by two rivers, the Rio Sant'Anna, which drains an area of 78.4 km^2, and the Canale delle Acque Basse, which drains an area of 50 km^2 (mostly comprised of a dried up ancient pond with an area greater than 3000 ha). The Canale delle Acque Basse is below sea level and water is pumped from it into the lagoon; a large part of the catchment area is used for intensive arable agriculture and cattle breeding, and as a result, the tributaries carry freshwater that is highly enriched in nutrients. Exchange of the S'Ena Arrubia Lagoon with the sea occurs via a canal constructed in the 1970s (length, 230m; width, 25m; depth, 1.3m). The lagoon is strongly eutrophic, and dystrophic crises and fish kills were observed as early as in the 1960s. The exchange canal with the sea was widened in 2000 so as to improve tidal flushing and thus reduce trophic levels and improve hydrodynamic flows. Trebini *et al.* (2005) studied the environmental consequences of this "reframing" by analysing a long-term series of nutrient and phytoplankton concentrations that included periods before and after the canal modifications. Results showed significant variations in salinity, chlorophyll *a*, class composition of phytoplankton assemblages, and water residence times, but not in nutrient concentrations. The authors indicated the necessity of coordinated and joint actions, both in the lagoon and in its watershed, to meet the objective of reduced eutrophication.

Mar Piccolo of Taranto

The Mar Piccolo of Taranto is an inner sheltered sea located north of the town of Taranto; the sea covers 20.72 km^2 and is divided by two promontories into two smaller inlets, the First Inlet and the Second Inlet (maximum depths of 12 and 8 m, respectively), which are characterized by different levels of confinement. Two canals allow communication of the sea with the nearby Mar Grande basin. Most of the hard substrates are artificial; soft substrates are sandy near the shore and muddy in the central zone of both inlets. The tidal range never exceeds 30–40 cm. The aquatic features of the Mar Piccolo are strongly influenced by 34 submarine freshwater springs ("Citri"), which contribute a combined maximum inflow of 80–350 l s^{-1} and which locally affect both the salinity and the temperature of seawater and convey the irrigating waters of the surrounding fields. Several small tributary rivers are also present; the most important tributary, the Galeso, with a mean flow of 50,000 m^{3}day^{-1}, discharges into the First Inlet (Cecere and Petrocelli, 2009).

The Mar Piccolo has been historically used for human activities, and up until 8 years ago, the basin contained the largest mussel farm in Italy (production of approximately 30,000 tons year^{-1}). Currently, mussels are reared only in the Second Inlet (about 20,000 tons year^{-1}), and only juvenile collection is allowed in the First Inlet (about 5000 tons year^{-1}; Cecere and Petrocelli, unpublished data). In the First Inlet, docks of the Italian Navy base, a small fishing fleet, and a water-scooping machine of the steel industry are present. Up until 2000, 14 urban sewage outfalls flowed into the basin; recently, the discharge of wastewater into the basin has been noticeably reduced, and only 5 sewage outfalls (1 in the First Inlet and 4 in the Second Inlet) are present.

The Mar Piccolo has been studied since the beginning of the last century. Research was first conducted to establish the conditions optimal for mussel culture, and includes a discontinuous series of data on temperature, salinity, dissolved oxygen in seawater, nutrients, and chlorophyll; these discontinuous data streams are available starting from that time. The first investigation of biota was on macroalgae, and also dates to the beginning of the last century; all samples collected during that period are stored *in exsiccata* in the rich Pierpaoli Herbarium, and the collection constitutes a historical data series. Accurate studies of phytobenthos commenced at the end of the 1980s, from both floristic and vegetational points of view; these studies are ongoing. The first studies on zoobenthos date to the second half of the last century; biocenotic maps have been prepared on the basis of these studies (which are still ongoing). Investigations on phytoplankton (in both active and resting stages) and nekton, especially juveniles of commercially important species, were conducted more recently (in the 1990s); however, an important data series from these studies is currently available (Cecere and Petrocelli, 2009). Current research focuses on trends in important chemical and physical variables, changes in the composition of biocoenoses, and the presence and behaviour of alien species. The biodiversity of phytobenthic and zoobenthic communities constitutes the main LTER research topic.

Strengths, weaknesses, and opportunities provided by LTER-Italy coastal transitional ecosystems

The actual integration of the LTER observations at the LTER-Italy CTEs is still at an early stage: comparisons of time series, individuations of shared hypotheses, and definitions of common experimental protocols and activities are difficult challenges, although vital for the meaningful and fruitful evolution of LTER activities related to CTEs. There are noticeable dissimilarities in the histories of ecological research at the four LTER-Italy CTEs and in the institutions that manage them; however, some common key issues should be identified and pursued as core LTER-Italy CTE research activities. We here suggest some of the most important activities for LTER-Italy CTE research and give also some examples of related results.

i) *Identification of variability patterns in the structure of biotic communities* (e.g., abundance, biomass, and species compositions). It is important to know the causal factors of heterogeneity at different spatial and temporal scales for different ecosystem components, so as to define meaningful spatial and temporal scales for investigations. In several respects, environmental and biological variability may mask anthropogenic impacts. The ways in which the organization of biocoenoses is influenced by environmental gradients (e.g., of salinity, nutrients, and exposure to air in intertidal zones), the interplay of biotic and abiotic factors, and responses of biocoenoses to natural saprobity (Tagliapietra *et al.*, 2012a) are key tasks for LTER investigations in the near future. At the same time, communities in CTEs are characterized by high interannual variability and by stochastic processes such as patterns of colonization (Barnes, 1980; Pérez-Ruzafa and Marcos-Diego, 1992).

Gathering of regular samples is of crucial importance to provide a reliable reconstruction of annual plankton variations, from both a qualitative and a quantitative viewpoint, an issue that appears particularly important for CTEs, due to their intrinsic variability (Cloern and Jassby, 2010; Winder and Cloern, 2010). Despite the high degree of variability in planktonic habitats, regular cycles in the composition and abundance of phytoplankton assemblages (with a prevalent unimodal annual periodicity) can be identified in the Venice Lagoon based on data from 10 years of investigation (Bernardi Aubry *et al.*, 2013); annual climate fluctuations (temperature and irradiance) are the most recognizable driver of seasonal trends in phytoplankton biomass. In addition, the same primary species show recurrent seasonal successions, such that a "phytoplankton calendar" can be defined. For zooplankton communities, while single species often show stochastic patterns, seasonal successions of larger taxonomic units are fairly predictable (Bandelj *et al.*, 2008). Also, the spatial and temporal dynamics of fish assemblages, as related to different uses of shallow habitats by various functional groups, can be identified in the Venice Lagoon on the basis of regular pluriannual observations (Franco *et al.*, 2006; Franzoi *et al.*, 2010). Unvegetated and sparsely vegetated shallow mud habitats commonly play a nursery role to various functional groups of marine migrants, and shallow seagrass bed habitats act as spawning grounds for resident and highly specialized segments of the fish community.

ii) *Identification of common trends*. It is difficult to make inferences about trends, often obtained from the application of synthetic indices, without knowledge of possible periodic shifts in species compositions or long-term cyclical patterns. In this respect, comparisons among different CTEs might give important clues about the ecological meaning of observed changes. Changes in community structures can be due to typological shifts (e.g., shifts from an estuarine lagoon to a eu/hypersaline marine embayment) rather than to actual improvement of conditions. Common modifications of macrophyte were detected in the same years in both the Venice Lagoon (Sfriso and Facca, 2007; Sfriso *et al.*, 2009a) and Mar Piccolo (Cecere and Petrocelli, 2009; Cecere *et al.*, 2010); phanerogams (such as *Cymodocea nodosa* (Ucria) Ascherson, *Ruppia cirrhosa* (Petagna) Grande, and *Zostera marina* (Linnaeus) increased simultaneously, indicating an improvement of ecosystem quality in both ecosystems. In the Mar Piccolo, on both soft and hard substrates, where nitrophilous seaweeds dominated in the 1990s (e.g., Ulvales and Gracilariales), species such as *Padina pavonica* (Linnaeus) J.V. Lamouorux and *Peyssonnelia dubyi* P. *et* H. Crouan are now present (Cecere and Petrocelli, unpublished data). In the past 10 years, a general tendency in the reduction of chlorophyll *a* and cell size has been observed in the phytoplankton of the LTER Sardinian lagoons. These trends have been accompanied by modifications in the class compositions of the assemblages, with an increase in the importance of Cyanobacteria (Pulina *et al.*, 2012, 2011). A significant decrease in phytoplankton abundance and biomass in the same years has also been recorded in the Venice Lagoon, although without changes in size or species composition (Bernardi Aubry *et al.*, 2013).

iii) I*ndividuation of the occurrence of alien species and evaluation of their invasiveness*. CTEs are naturally exposed to alien immigration due to connections with both freshwater and marine environments and as a consequence of the typologies of human activities that are conducted in CTEs (e.g., aquaculture and fish and mussel farming). Lagoons can therefore be considered as models for addressing ecosystem fragility or resilience to alien species. The maintenance of regular multidecadal observations allows the early detection of alien species, and the monitoring of their diffusion, invasiveness, and effects on native communities.

A large number of alien species characterizes the benthic fauna and flora of the LTER CTEs. The Venice Lagoon is considered as the main hotspot of species introductions on the whole of the Italian coast, with the presence of more than 60 alien species, including 29 invertebrate and 34 macrophyte species (Occhipinti-Ambrogi *et al.*, 2011; Keppel *et al.*, 2012; Sfriso *et al.*, 2012; Tagliapietra *et al.*, 2012b; Sfriso *et al.*, 2013). The 34 non-indigenous species of macrophytes occupy areas where conditions are optimal for settlement and spreading, and they display significant range extensions in terms of coverage and biomass patterns. Among these macrophytes, the biomass of *Undaria pinnatifida* (Harvey) Suringar and *Sargassum muticum* (Yendo) Fensholt can reach up to 10–15 kg fwt m^{-2} (Sfriso *et al.*, 2009a). In the Mar Piccolo, 13 species of alien seaweeds have been detected since the 1980s, introduced mostly through imported molluscs (Petrocelli *et al.*, 2012), and 10 species of invertebrates (Gravili *et al.*, 2010; Prato *et al.*, 2013). Until recently, none of the alien seaweeds have exerted a negative impact on native populations (Cecere and Petrocelli, unpublished data). In the lagoons of the Po River Delta, over a dozen non-indigenous invertebrates are present; the date mussel *Arcuatula senhousia* is a good example of a species that has successfully established itself by exploiting naturally disturbed and sparsely occupied environments, rather than interjecting itself among and displacing existing species (Mistri, 2002).

Regarding plankton species, the non-indigenous calanoid copepod *Acartia tonsa* Dana first appeared in the Venice Lagoon in high abundances during the summer of 1992, leading to rapid and marked modifications of zooplankton communities (Solidoro *et al.*, 2010). Notable outbreaks of the invasive floating macrophytes *Eichhornia crassipes* (Mart) Solms (water hyacinth) and *Hydrocotyle ranunculoides* L. have been observed in the northern part of the Cabras Lagoon (Mare 'e Foghe) since 2010 (Brundu *et al.*, 2012). Currently, the high salinity values in the lagoon (which are higher than those in the freshwater tributary) seem to be the main obstacle to their spread into the lagoon (Sechi N., personal communication). The presence and distributions of alien species in the other LTER Sardinian lagoons are unknown.

All the LTER-Italy CTEs have been involved in the ongoing Alien Species Showcase "Patterns of ecosystem fragility to alien and invasive species in Europe" (http://www.lifewatch.eu/alien_species), recently set up in the context of the LifeWatch European research infrastructure (www.lifewatch.eu). The study case is developed through an inter-operability exercise on a set of databases covering collections of species along an ideal transect ranging from the deep regions of the Southern Adriatic-Ionian Sea to the high altitude woodlands in Central and Northern Italy (Basset *et al.*, 2012; Corriero *et al.*, 2012).

iv) *Close collaboration between LTER CTE sites and environmental monitoring programs*. According to the Water Framework Directive (WFD), periodic monitoring should be performed by law on different 'biological quality elements' using standardized protocols, despite the problems of harmonization that will emerge in any new program. The LTER programs provide a valuable opportunity for collecting periodic data that, over time, will represent long-term data series. In this sense, the LTER network acts as both a reference structure and a catalyst, by optimizing the resources for data collection and their comparability. All four CTE sites are contributing to the definition of water quality indicators and reference conditions for the WFD (especially with regard to phytoplankton, phyto- and zoobenthos, and nekton communities) by making long-term data available, by sharing expertise for the development of monitoring programs and quality indices, and by contributing an ecologically sound understanding to the interpretations of monitoring results (Mistri and Munari, 2008; Munari *et al.*, 2009; Sfriso *et al.*, 2009b; Munari and Mistri, 2010; Sfriso, 2010; Facca *et al.*, 2011; Ghezzo *et al.*, 2011; Bazzoni *et al.*, 2012).

Final remarks

The interdisciplinary nature of LTER networks requires the effective sharing of methodologies, experiments, ecological data, and knowledge, which should produce intellectual and experimental partnerships among disciplines and researchers that are fundamentally necessary for knowledge-driven environmental policy. One of the goals of the LTER-Italy CTE component is to facilitate cooperation between the LTER sites (and their research activities) and to develop knowledge to support WFD requirements. The LTER includes studies and activities that go beyond the requests of the WFD, and which place more emphasis on ecological processes by seeking to broaden research efforts to other biological compartments and ecological issues. The WFD itself foresees the selection of a few 'nodal' stations, in which the study of ecological variables and processes can be performed in detail, with the aim of providing tools for the interpretation of data collected during regular campaigns. These stations should be the same as LTER sites, thus taking advantage of existing ecological facilities, knowledge, and expertise. The mandatory environmental monitoring and surveillance to be conducted under the WFD could, from the LTER side, represent one of the best guarantees for maintenance of the LTER site observations, as the WFD activity would ensure the continuity of data collection and therefore the formation of consistent and regular time series datasets. This is a point of great importance as, besides providing financial support for the collection of data on plankton, macrophytes, benthic macroinvertebrates, and fishes, the WFD may offer a tool for coordinating the activities of various groups, with the final goal being the optimization of knowledge and resources. Nevertheless, the assessment of environmental quality cannot be fully performed (and could even lead to misleading results) without knowledge of natural variations, especially regarding long-term trends and cycles.

Finally we wish to stress the vital role that the LTER CTEs sites could have at the European and global level, from one side, through fostering the cooperation on long-term key ecological issues as well as on methodologies and data sharing. From the other side, by their nature of ecotones, the transitional sites could effectively contribute to flow of concepts, hypotheses, and data between marine and terrestrial/freshwater ecologists, thus enhancing the trans-ecodomain approach that characterise the LTER networks: carefully construed cross-system comparisons may offer an effective path to understanding how the environment determines ecological process.

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References

Bandelj V, Socal G, Park YS, Lek L, Coppola J, Camatti E, Capuzzo E, Milani L, Solidoro C 2008. Analysis of multitrophic plankton assemblages in the lagoon of Venice. *Marine Ecology Progress Series* 368: 23–40.

Barnes RSK 1980. *Coastal Lagoons. The Natural History of a Neglected Habitat.* Cambridge Studies in Modern Biology 1. Cambridge, UK, Cambridge University Press, 106 pp.

Basset A, Bastianini M, Bernardi Aubry F, Cabrini M, Cardone F, Cataletto B, Cavraro F, Cecere C, Cibic C, Corriero G, De Olazaba A, D'onghia G, Finotto S, Fiore N, FornasaroD, Franzoi P, Gaudiano L, Giangrande A, IngrossoW, Keppe E, Longo C, Malavasi S, Maiorano P, Mastrototaro F, Mistri M, Munari C, Nonnis Marzano C, Petrocelli A, Pierri C, Pugnetti A, Rosati I, Sigovini M, Sion L, Tagliapietra D, Tirelli T, Ungaro N, Zucchetta M. 2012. Taxonomic guilds and community fragility to alien species in lagoon ecosystems. XXI Congresso S.It.E, Alessandria, 10-13 Settembre 2012, Abstract.

Bazzoni AM, Pulina S, Padedda BM, Bernardi Aubry F, Lugliè A, Sechi N, Socal G, Facca C 2012. Utilizzo del fitoplancton per la valutazione della qualità ambientale della Laguna di Cabras (Sardegna occidentale, Italia). *Biologia Ambientale* 26:84-88.

Bernardi Aubry F, Acri F, Bianchi F, Pugnetti A 2013. Looking for patterns in the phytoplankton community of the Mediterranean microtidal Venice Lagoon: evidence from ten years of observations. *Scientia Marina* 77 (1): 47-60.

Bertoni R (a cura di) 2012. *La Rete Italiana per la ricerca ecologica a lungo termine (LTER-Italia). Situazione e prospettive dopo un quinquennio di attività*. Aracne Editrice, Roma.

Bertoni R, Cindolo C, Cocciufa C, Freppaz M, Mason F, Matteucci G, Pugnetti A, Ravaioli M, Rossetti G, Zingone A 2012. *Le ragioni della ricerca ecologica a lungo termine.* In Bertoni R (a cura di) *La Rete Italiana per la ricerca ecologica a lungo termine (LTER-Italia). Situazione e prospettive dopo un quinquennio di attività*. Aracne Editrice, Roma, 15-22.

Bredemeier M, Tennis P, Sauberer N, Petriccione B, Torok K, Cocciufa C, Morabito G, Pugnetti A 2007. Biodiversity assessment and change: the challenge of appropriate methods. In Hester RE, Harrison RM (ed) *Biodiversity under threat.* RCS Publ., Cambridge, UK, 217-251.

Brundu G, Stinca A, Angius L, Bonanomi G, Celesti-Grapow L, D'Auria G, Griffo R, Migliozzi A, Motti R, Spigno P 2012. *Pistia stratiotes* L. and *Eichhornia crassipes* (Mart.) Solms.: emerging invasive alien hydrophytes in Campania and Sardinia (Italy), Bulletin OEPP/EPPO 42(3):568–579.

Campanaro A, Oggioni A, Pugnetti A, Colangelo P, Bastianini M, Giardino C, Focaccia P, Freppaz M, Ravaioli M 2012. Sensing long-term environmental change through regional monitoring: the Long Term Ecosystem Research Network (LTER). *Window on GMES, a GMES4 Regions Publication special issue*: 152-161.

Cecere E, Petrocelli A 2009. The Mar Piccolo of Taranto. In: Cecere E, Petrocelli A, Izzo G, Sfriso A (eds) *Flora and Vegetation of the Italian Transitional Water Systems*. CoRiLa, Stampa Multigraf, Spinea, Venezia, Italy, 195-227.

Cecere E, Portacci G, Petrocelli A 2010. Sulla presenza di *Ruppia cirrhosa* (Spermatophyta, Ruppiaceae) nel Mar Piccolo di Taranto. *Proceedings of the "Riunione Scientifica Annuale del Gruppo di Lavoro per l'Algologia*, Abano Terme, 22-23 ottobre 2010: 29 (http://www.societabotanicaitaliana.it/detail.asp?IDSezione=7&IDN=957).

Cloern JE, Jassby AD 2008. Complex seasonal patterns of primary producers at the land-sea interface. *Ecology Letters* 11: 1–10.

Cloern JE, Jassby AD 2010. Patterns and scales of phytoplankton variability in estuarine-coastal ecosystems. *Estuaries and Coasts* 33: 230-241.

Collavini F, Bettiol C, Zaggia L, Zonta R 2005. Pollutant loads from the drainage basin to the Venice Lagoon (Italy). *Environment International* 31: 939-947.

Corriero G, Acosta A, Allegrini MC, Austoni M, Barbone E, Bartolozzi L, Basset A, Bastianini M, Bavestrello G, Bernardi Aubry F, Boero F, Boggero A, Buia MC, Cabrini M, Campanaro A, Campetella G, Canullo R, Cardone F, Carranza ML, Cataletto B, Cattaneo C, Cattaneo Vietti R, Cavraro F, Cecere E, Cervellini M, Cesaroni D, Chelli S, Chiapparelli S, Cianferoni F, Cibic T, Cocciufa C, Elia AC, De Felici S, De Olazaba A, D'Onghia G, Finotto S, Fiore N, Fontaneto D, Fornasaro D, Franzoi P, Fraschetti S, Frate L, Fuentes D, Gaino E, Gaudiano L, Giangrande A, Goretti E, Ingrosso W, Keppel E, Labadessa R, La Porta G, Longo C, Lorenti M, Lorenzoni M, Lucarini D, Ludovisi A, Malavasi S, Manca M, Maiorano P, Marchetto A, Marra M, Dörr AM, Mastrototaro F, Mazzocchi MG, Mercurio M, Minari M, Mistri M, Monti M, Morabito G, Munari C, Nonnis Marzano C, Oggioni A, Patti FP, Pelino G, Petrocelli A, Pierri C, Pugnetti A, Riccarducci G, Rosati I, Riccardi N, Santoro R, Sarno D, Sbordoni V, Sorino R, Scipione B, Sfriso A, Sigovini M, Sion L, Stanisci A, Tagliapietra D, Tirelli V, Tursi A, Ungaro N, Volta P, Zingone A, Zucchetta M, Zupo V 2012. Ecosystem vulnerability to alien and invasive species. XXI Congresso S.It.E, Alessandria, 10-13 Settembre 2012, Abstract.

Cucco A, Umgiesser G 2006. Modelling the Venice Lagoon residence time. *Ecological Modelling* 193: 34-51.

Duarte CM, Cebriàn J, Marbà N 1992. Uncertainty of detecting sea change. *Nature* 356: 190.

Ducklow HW, Doney SC, Steinberg DK 2009. Contributions of Long-term research and time-series observations to marine ecology and biogeochemistry. *Annual Review of Marine Science* 1: 279–302.

Elliott M, Quintino V 2007. The Estuarine Quality Paradox, Environmental homeostasis and the difficulty of detecting anthropogenic stress in naturally stressed areas. *Marine Pollution Bulletin* 54: 640-645.

Facca C, Socal G, Bernardi Aubry F, Sfriso A, Acri F, Bianchi F, Ponis E 2011. Il fitoplancton come elemento di qualità biologica ai fini dell'implementazione della Water Framework Directive (WFD, CE 2000/60) per le acque di transizione. *Biologia Marina Mediterranea* 18(1): 372-373.

Franco A, Franzoi P, Malavasi S, Riccato F, Torricelli P 2006. Use of shallow water habitats by fish assemblages in a Mediterranean coastal lagoon. *Estuarine Coastal and Shelf Science* 66: 67-83.

Franzoi P, Franco A, Torricelli P 2010. Fish assemblages in different shallow water habitats of the Venice Lagoon. *Hydrobiologia* 555:159-174.

Ghezzo M, Sarretta A, Sigovini M, Guerzoni S, Tagliapietra D, Umgiesser G 2011. Modeling the inter-annual variability of salinity in the lagoon of Venice in relation to the water framework directive typologies. *Ocean & Coastal Management* 54: 706-719.

Gravili C, Belmonte G, Cecere E, Denitto F, Giangrande A, Guidetti P, Longo C, Mastrototaro F, Moscatello S, Petrocelli A, Piraino S, Terlizzi A, Boero F 2010. Non-indigenous species (NIS) along the Apulian coast, Italy. *Chemistry and Ecology*, 26 (1): 121-142.

Keppel E, Sigovini M, Tagliapietra D 2012. A new geographical record of *Polycera hedgpethi* Er. Marcus, 1964 (Nudibranchia: Polyceridae) and evidence of its established presence in the Mediterranean Sea, with a review of its geographical distribution. *Marine Biology Research* 8 (10): 969-981.

Kirby RR, Beaugrand G, Lindley JA, Richardson AJ, Edwards M, Reid PC 2007. Climate effects and benthic-pelagic coupling in the North Sea. *Marine Ecology Progress Series* 330: 31–38.

Magnuson JJ 1990. Long-term ecological research and the invisible present. *BioScience* 40(7): 495-501.

Matteucci G, Bianchi F, Bertoni R, Pugnetti A, Ravaioli M 2007. Ricerche ecologiche e cambiamenti climatici: il ruolo del CNR. In Carli B, Cavarretta G, Colacino M, Fuzzi S (eds) *Clima e cambiamenti climatici: le attività di ricerca del CNR*. Consiglio Nazionale delle Ricerche, Rome, Italy, 417-420.

Mirtl M, Boamrane M, Braat L, Furman E, Krauze K, Frenzel M, Gaube V, Groner E, Hester A, Klotz S, Los W, Mautz I, Peterseil J, Richter A, Schentz H, Schleidt K, Schmid M, Sier A, Stadler J, Uhel R, Wildenberg M, Zacharias S 2009. LTER-Europe design and implementation report - Enabling "Next Generation Ecological Science": Report on the design and implementation phase of LTER-Europe under ALTER-Net & management plan 2009/2010. Umweltbundesamt (Federal Environment Agency Austria), Vienna, Austria.

Mistri M 2002. Ecological characteristics of the invasive Asian date mussel *Musculista senhousia* in the Sacca di Goro (Adriatic Sea, Italy). *Estuaries* 25: 431-440.

Mistri M, Munari C 2008. BITS: a SMART index for soft-bottom, non-tidal lagoons. *Marine Pollution Bulletin* 56: 587-599.

Munari C, Mistri M 2010. Towards the application of the Water Framework Directive in Italy: assessing the potential of benthic tools in Adriatic coastal transitional ecosystems. *Marine Pollution Bulletin* 60: 1040-1050

Munari C, Manini E, Pusceddu A, Danovaro R, Mistri M 2009. Response of BITS (a biotic index based on taxonomic sufficiency) to water and sedimentary variables and comparison with other indices in three Adriatic lagoons. *Marine Ecology: an Evolutionary Perspective* 30: 255-268.

Occhipinti-Ambrogi A, Marchini A, Cantone G, Castelli A, Chimenz C, Cormaci M, Froglia C, Furnari G, Gambi MC, Giaccone G, Giangrande A, Gravili C, Mastrototaro F, Mazziotti C, Orsi-Relini L, Piraino S 2011. Alien species along the Italian coasts: an overview. *Biological Invasions* 13(1): 215-237.

Padedda BM, Pulina S, Magni P, Sechi N, Lugliè A 2012. Phytoplankton dynamics in relation to environmental changes in a phytoplankton-dominated lagoon (Cabras Lagoon, Italy). *Advances in Oceanography and Limnology* 3: 147-179.

Parr TW, Ferretti M, Simpson IC, Forsius M, Kovacs-Lang E 2002. Towards a long-term integrated monitoring programme in Europe: network design in theory and practice. *Environmental Monitoring and assessment* 78: 253-290.

Pérez-Ruzafa A, Marcos-Diego C 1992. Colonization rates and dispersal as essential parameters in the confinement theory to explain the structure and horizontal zonation of lagoon benthic assemblages. *Rapp. Comm Int. Mer Medit.* 33: 100.

Peters DPC 2010. Accessible ecology: synthesis of the long, deep, and broad. T*rends in Ecology and Evolution* 25: 592-601.

Petrocelli A, Portacci G, Cinelli F, Cecere E 2012. Nuovi "alieni" nei mari italiani. Proceedings of the "*Riunione Scientifica Annuale del Gruppo di Lavoro per l'Algologia*", Ischia, 9-10 novembre 2012: 25. (http://www.societabotanicaitaliana.it/detail.asp?IDSezione=7&IDN=957).

Prato E, Parlapiano I, Biandolino F 2013. Seasonal fluctuations of some biological traits of the invader *Caprella scaura* (Crustacea: Amphipoda: Caprellidae) in the Mar Piccolo of Taranto (Ionian Sea, southern Italy), *Scientia Marina* 77: 169-178.

Pugnetti A, Mirtl M, Diaz-Delgado R 2012. Harmonious methods. *International Innovation Environment*, August 2012: 12-14.

Pulina S, Padedda BM, Satta C, Sechi N, Lugliè A 2012. Long-term phytoplankton dynamics in a Mediterranean eutrophic lagoon (Cabras Lagoon, Italy). *Plant Biosystems* 146: 259-272.

Pulina S, Padedda BM, Sechi N, Lugliè A 2011. The dominance of cyanobacteria in Mediterranean hypereutrophic lagoons: a case study of Cabras Lagoon (Sardinia, Italy). *Scientia Marin*a 75: 111-120.

Richardson AJ, Walne AW, John AWG, Jonas TD, Lindley JA, Sims DW, Stevens D, Witt M 2006. Using continuous plankton recorder data. *Progress in Oceanography* 68: 27–74.

Sechi N, Fiocca F, Sannio N, Lugliè A 2001. Santa Giusta Lagoon: phytoplankton and nutrients after waste water diversion. *Journal of Limnology* 62(2): 194-200.

Sfriso A 2010. Macrophyte Quality Index (MaQI) per la valutazione dello stato ecologico dei sistemi di transizione dell'ecoregione-Mediterranea. In Bonometto A, Gennaro P, Boscolo Brus R (eds) *Linee Guida per l'applicazione del Macrophyte Quality Index (MaQI). Implementazione della Direttiva (2000/60/CE)*. ISPRA, 1-34.

Sfriso A, Facca C 2007. Distribution and production of macrophytes and phytoplankton in the lagoon of Venice: comparison of actual and past situation. *Hydrobiologia* 577: 71-85.

Sfriso A, Curiel D, Rismondo A 2009a. The Venice Lagoon. In Cecere E, Petrocelli A, Izzo G, Sfriso A (eds) *Flora and Vegetation of the Italian Transitional Water Systems*. Corila, Multigraf, Spinea, 17-80.

Sfriso A, Facca C, Ghetti PF 2009b. Validation of the Macrophyte Quality Index (MaQI) set up to assess the ecological status of Italian marine transitional environments. *Hydrobiologia* 617: 117-141.

Sfriso A, Wolf MA, Maistro S, Sciuto K, Moro I 2012. Spreading and autoecology of the invasive species *Gracilaria vermiculophylla* (Gracilariales, Rhodophyta) in the lagoons of the north-western Adriatic Sea (Mediterranean Sea, Italy). *Estuarine, Coastal and Shelf Science* 114: 192-198.

Sfriso A, Wolf MA, Sciuto K, Morabito M, Andreoli C, Moro I 2013. *Gracilaria viridis* sp. nov. (Gracilariales, Rhodophyta): a new red algal species from the Mediterranean Sea. *Phycologia* 52: 65-73.

Solidoro C, Melaku Canu D, Cucco A, Umgiesser G 2004. A partition of the Venice lagoon based on physical properties and analysis of general circulation. *Journal of Marine System* 51: 147-160.

Solidoro C, Bandelj V, Aubry Bernardi F, Camatti E, Ciavatta S, Cossarini G, Facca C, Franzoi P, Libralato S, Melaku Canu D, Pastres R, Pranovi F, Raicevich S, Socal G, Sfriso A, Sigovini M, Tagliapietra D, Torricelli P 2010. Response of Venice Lagoon Ecosystem to Natural and Anthropogenic Pressures over the Last 50 Years. In Kennish M and Paerl HW (ed) *Coastal Lagoons - Critical Habitats of Environmental Change*. CRC press, Taylor and Francis Group, 483-511.

Tagliapietra D, Sigovini M, Volpi Ghirardini A 2009. A review of terms and definitions to categorise estuaries, lagoons and associated environments. *Marine and Freshwater Research* 60(6): 497-509.

Tagliapietra D, Zanon V, Frangipane G, Umgiesser G, Sigovini M 2011. Physiographic zoning of the Venetian Lagoon. In Campostrini P (ed) *Scientific Research and Safeguarding of Venice,* vol. VII,- 2007-2010 results, CORILA, Venezia, 161-164.

Tagliapietra D, Keppel E, Sigovini M, Lambert G 2012a. First record of the colonial ascidian *Didemnum vexillum* in the Mediterranean: Lagoon of Venice (Italy). *Bioinvasions Records* 1(4): 247-254.

Tagliapietra D, Sigovini M, Magni P 2012b. Saprobity: a unified view of benthic succession models for coastal lagoons. *Hydrobiologia* 686(1): 15-28.

Trebini F, Padedda BM, Ceccherelli G, Lugliè A, Sechi N 2005. S'Ena Arrubia lagoon (centre-western Sardinia): response of primary producers to nutrients in relation to watershed influence and management. *Chemistry and Ecology* 21(6): 491-502.

Vatova A 1931. Ricerche preliminari sulle biocenosi della laguna veneta. *Bollettino della Società Adriatica di Scienze Naturali, Trieste* 30: 53-62.

Vatova A 1940. Le zoocenosi della Laguna veneta. *Thalassia* 3(10): 1-28.

Vogt KA, Gordon JC, Wargo JP, Vogt DJ, Asbjornsen H, Palmiotto PA, Clark HJ, O'Hara JL, Keaton WS, Patel-Weynand T, Witten E 1997. *Ecosystems. Balancing Science with Management.* Springer-Verlang New York, USA.

Webb TJ 2012. Marine and terrestrial ecology: unifying concepts, revealing differences. *Trends in Ecology and Evolution* 27 (10): 535-541.

Winder M, Cloern JE 2010. The annual cycles of phytoplankton biomass. *Philosophical Transactions of the Royal Society of London, Biological Sciences* 365: 3215-3226.

Wolfe DA, Champ MA, Flemer DA, Mearns AJ 1987. Long-Term Biological Data Sets" Their Role in Research, Monitoring, and Management of Estuarine and Coastal Marine Systems. *Estuaries* 10(3): 181-193.

Zuliani A, Zaggia L, Collavini F, Zonta R 2005. Freshwater discharge from the drainage basin to the Venice Lagoon (Italy). *Environment International* 31(7): 929-938.