AdriaClim

Climate change information, monitoring and management tools for adaptation strategies in Adriatic coastal areas

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Report on climate-related impacts on critical societal sectors to support disaster risk reduction and climate adaptation with a focus on Venice and its Lagoon

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INTRODUZIONE (IT)

Nell'ambito del progetto Adriaclim è stato possibile, a supporto della predisposizione del PAESC del Comune di Venezia, sviluppare due approfondimenti preliminari sulla relazione tra i fattori di pericolosità climatica e due componenti della matrice ambientale, acqua e biodiversità, con specifico riferimento agli impatti potenziali dei Cambiamenti Climatici sulla qualità delle acque della laguna di Venezia e sulla conservazione dei siti Natura 2000 in gestione da parte del Comune di Venezia (Bosco di Carpenedo e Biotopi Litoranei).

Entrambi gli approfondimenti hanno adottato lo stesso approccio metodologico, sebbene con declinazioni differenziate, basato su una gap analysis del quadro conoscitivo attuale (in un caso sviluppata sulla base di literature review, nell'altro sulla base di giudizio esperto con metodo Delphi), per poter supportare una robusta analisi del rischio e una appropriata decisione in tema di adattamento ai Cambiamenti Climatici.

Di seguito si riporta un riassunto degli esiti dei due approfondimenti, condotti rispettivamente dal Centro Mediterraneo per i Cambiamenti Climatici presso Università Ca' Foscari di Venezia (acqua) e SELC srl (biodiversità), con la supervisione scientifica del Comune di Venezia e del suo staff interno e di supporto consulenziale specialistico.

INTRODUCTION (EN)

As part of the Adriaclim project, in support to the preparation of the COV SECAP, it has been possible to develop two preliminary insights about the relationship between climate hazard factors and two components of the environmental matrix, water and biodiversity, with specific reference to the potential impacts of Climate Change on water quality of the Venice lagoon and on the conservation of Natura 2000 sites managed by the Municipality of Venice (Bosco di Carpenedo and Coastal Biotopes).

Both studies have adopted the same methodological approach, albeit with different declinations, based on a gap analysis of the current knowledge framework (in one case developed on the basis of literature review, in the other on the basis of expert judgment with the Delphi method), in order to support robust risk analysis and appropriate decision-making on climate change adaptation.

Below is a summary of the results of the two in-depth studies, conducted respectively by the Mediterranean Center for Climate Change at the Ca' Foscari University of Venice (water) and SELC srl (biodiversity), with the scientific supervision of the Municipality of Venice and its internal staff and specialist consultancy support.

PART 1. CLIMATE CHANGE AND WATER QUALITY

Transitional waters are highly productive ecosystems supporting a variety of habitats for biological diversity (Gonz Alez Castro et al., 2009; Kumari Gupta et al., 2019). They are of considerable socio-economic importance, providing invaluable ecosystem goods and services ranging from the provision of food, regulation of flooding and erosion, water purification and recreational services (Anthony et al., 2009; Newton et al., 2018; Velasco et al., 2018). However, they are highly fragile and vulnerable to modification induced by climate change hazards able to influence the hydro-morphodynamics of the systems at stake, with cascading effects on their physical, chemical and biological properties. According to the last IPCC Assessment Report (AR6, 2022), global warming, reaching 1.5°C in the near-term future, would cause unavoidable increases in multiple climate-related hazards (e.g., floods, droughts, etc.) and multiple risks (e.g. invasion of alien species, loss of fish production, the spread of infectious diseases) to ecosystems and humans. The impacts of such hazards are particularly significant in coastal and transitional environments located at the land-sea interface.

The Venice Lagoon is an example of a shallow transitional water body characterized by high complexity, heterogeneity, and it is a dynamic system which continuously evolves in response to modifications from multiple pressures (Solidoro et al., 2010). Intensive anthropogenic activities, within and around the lagoon, contribute to altering water quality and the ecological state of the lagoon itself, with climate change further exacerbating these impacts. Given the ecological and socio-economic importance of the Venice Lagoon, as well as its vulnerability to climate change related impacts, the objective of this study is to support the design and implementation of monitoring and adaptation plans for the lagoon. In particular, the research aims to:

1) establish a knowledge base on the effects of climate change on transitional waters,
2) provide a spatiotemporal analysis of water quality in the Venice Lagoon under both current and future conditions, considering potential climate change scenarios, and
3) identify additional research and environmental monitoring needs.

State-of-the-art understanding of climate change impacts on transitional waters: A global-scale literature review

A systematic review of scientific literature was performed to explore the current state of knowledge on climate change multi-hazard impacts on transitional water quality. The review revealed that various hazards can affect water quality either directly or indirectly. Flooding and drought were the most investigated climate change hazards with respect to their impacts on transitional water quality in the reviewed studies. Besides flooding and drought, other climate change induced hazards were identified including sea level rise, storm surge, tidal flooding, strong regime variations, wildfire, and

hot/cold events. Generally, climate change hazards can alter the physical, chemical, and biological state of transitional water with consequent impacts on the ecosystem quality. The most frequently reported alterations, from these climate-related hazards, were found with respect to salinity levels and in the concentrations of nutrients and chlorophyll-a. In response to these alterations, consequent impacts on primary productivity and phytoplankton composition, harmful algal blooms and habitat conditions (hypoxia/anoxia) were among the most reported impacts. Based on these results, a conceptual framework, highlighting the cause-effect relationships between hazards, water quality parameters, as well as consequent impacts on the ecosystem, was developed building on the DPSIR approach (Figure 01).

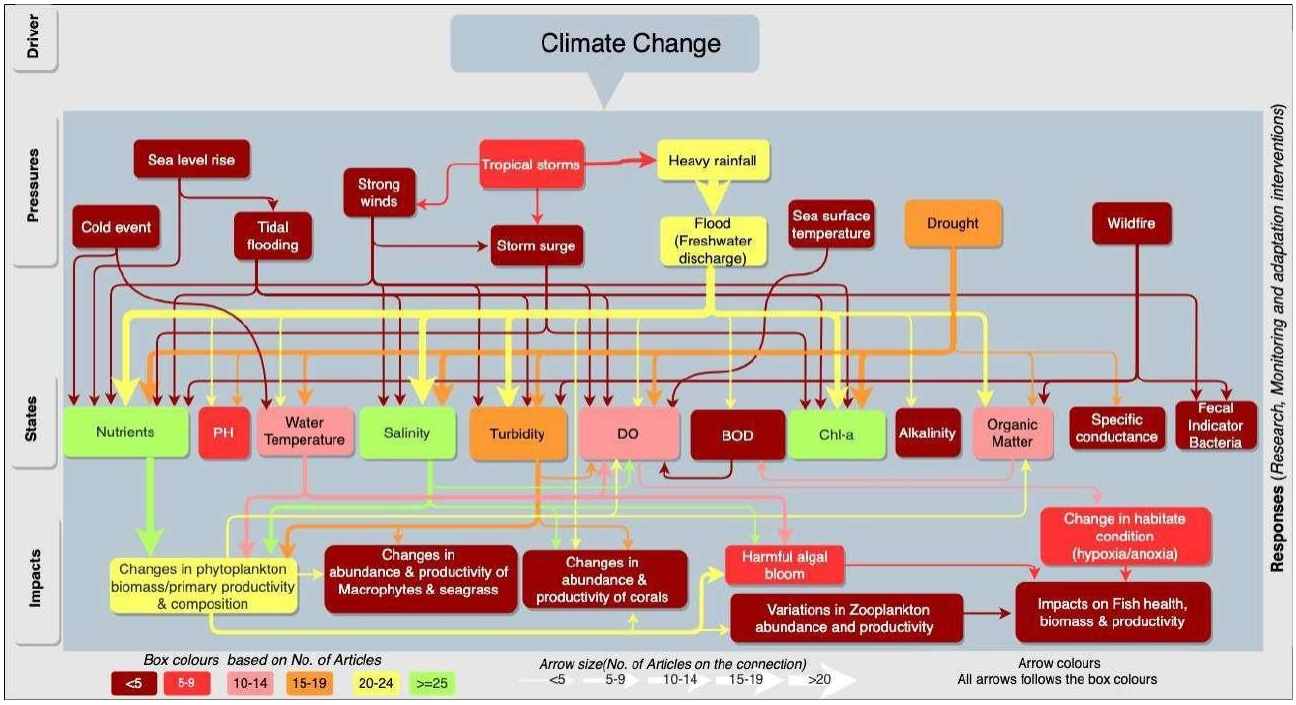

Figure 01. Conceptual framework representing cause-effect relationships between climate change-related hazards and transitional water quality. Colours applied to the textboxes indicate the level of evidence based on the number of reviewed studies related to each hazard and/or water quality parameter. The size of the arrows (thickness of the lines) reflects the number of studies related to that specific relationship, while their colours correspond to the colour of the source textboxes.

Potential climate change impacts on the water quality of the Venice Lagoon: A multi-parameter approach

An assessment of climate change impacts in the Venice Lagoon was conducted using a multi-parameter approach, which allowed the evaluation of water quality, ecological status, and the

aquatic life of selected species, in accordance with the Water Framework Directive (2000/60/EC), and the tolerance to changes in environmental conditions of representative aquatic species of the lagoon, i.e., Ruditapes philippinarum (Malina clam) and Aphanius fasciatus (Killifish). In particular, the CCMEWQI index developed by the Canadian Council of Ministers of the Environment (2001) was applied, which integrates the scope, frequency and amplitude of non-compliance tests of water quality parameters into a single value, representing the state of water quality in complex environmental systems. The application of the index has allowed an effective assessment of the spatio-temporal variations in water quality, as well as the analysis of extreme events, as emerged from historical data (under the 2013-2021 timeframe), which have highlighted strong variations in temperature (hot/cold) and precipitation (wet/dry). The alteration of water quality was also analyzed by integrating climate change scenarios (RCP 8.5) under both mid (2049) and long-term (2099) futures (Figure 02).

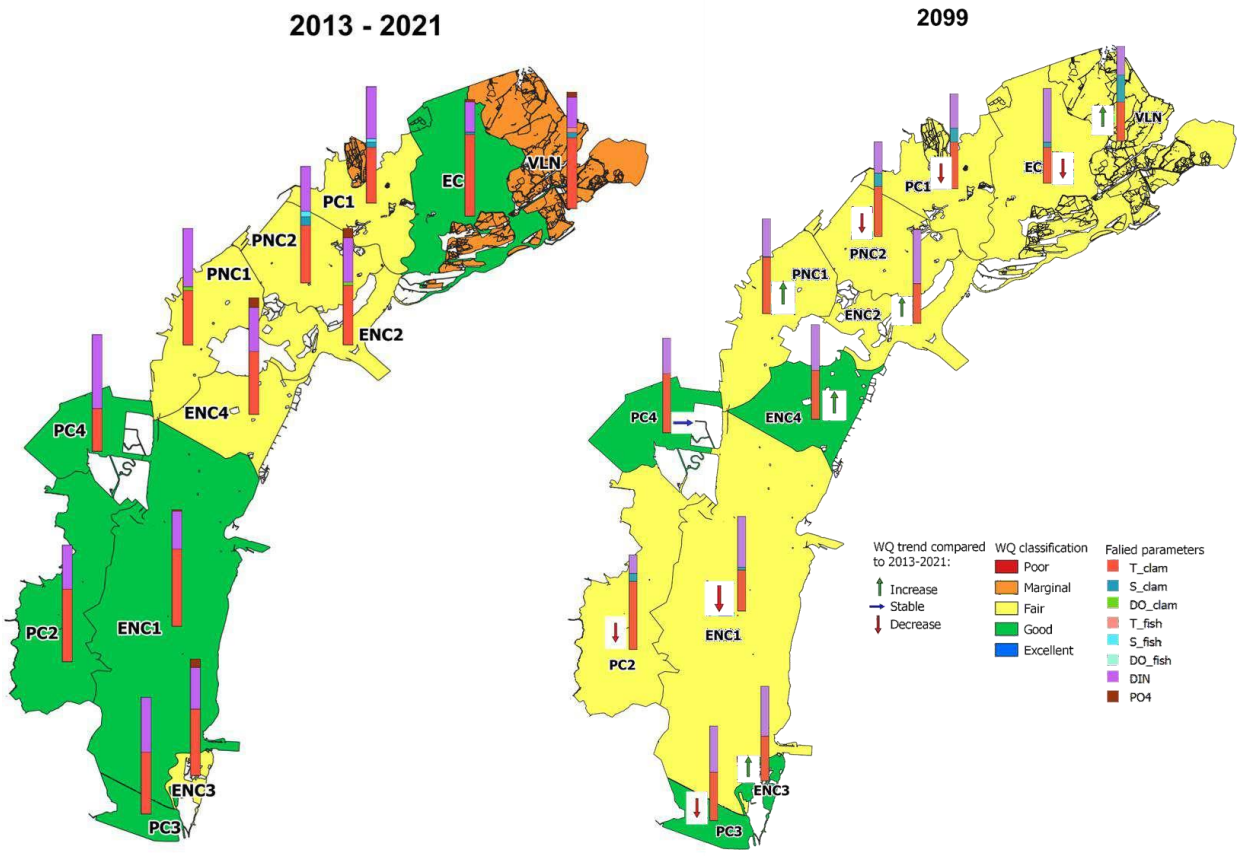

Figure 02. Classification of water quality status in the Venice Lagoon based on the application of the CCMEWQI under the historical period (2013-2021) and long-term future scenario (2099, RCP 8.5).

The output of the analysis suggests that the impacts of climate change in the Venice Lagoon do not distribute homogeneously, with some areas of the lagoon (i.e., central-north and south sub-basins) being more influenced than others. The increase in the frequency and magnitude of the extreme conditions of water quality parameters also have tangible effects on the ecological status and aquatic life of the Venice Lagoon. The results of the analysis indicate an increase in water temperature, salinity and nutrient concentrations, as well as a decrease in dissolved oxygen both in the medium and long term. Above all, temperature and dissolved inorganic nitrogen are the parameters of most concern for water quality in the future, while extremes in salinity and dissolved oxygen have the potential to compromise the tolerance of species and ecosystems. Furthermore, the interactions among stressors might potentially create a dynamic and changing environment, where one variable may amplify or counteract the negative impacts of another.

Analysis of knowledge gaps and identification of priority actions for the design of adaptation measures in the Venice Lagoon

A further analysis of the current state of knowledge on the impacts of climate change was carried out with a specific focus on the Venice Lagoon, identifying the knowledge gaps and needs for future research and development needs.

In particular, with regard to research and knowledge, the performed review revealed few examples of studies exploring the specific relationships between climate change hazards and water quality parameters. Limited efforts have been made to deepen the understanding of the interactions between multiple hazards, as well as the response processes of ecosystems to such interaction scenarios. Besides, the modelling approaches were characterized by the adoption of single global/regional climate models (GCM/RCM), consideration of few climate variables, as well as a limited number of climate change scenarios. Furthermore, the lack of consideration of future scenarios involving changes in land use and the adoption of adaptation measures has been observed.

Therefore, to develop appropriate adaptation measures for the Venice Lagoon it is necessary to consider the:

- Investigation of cause-effect relationships between climate change hazards and multiple biogeochemical parameters, considering multi-hazard interactions at the land-sea interface.
- Integration of ecosystem processes that influence water quality dynamics in the assessment of climate change impacts, through the development of a methodology capable of assimilating different numerical models (hydrodynamic, morphodynamic, vegetation dynamics, nutrient and carbon) in synergy with artificial intelligence.
- Development of global and regional climate models including multiple climate change scenarios, to reduce the uncertainties inherent in the models themselves.

- Analysis of future scenarios of land use at the catchment scale, water management, adaptation in transitional waters (e.g., riparian buffers, saltmarshes, and aquatic vegetations, etc.), and structural and engineering measures, to support strategic planning and adaptation processes.

With respect to monitoring, data on water quality, climatic and hydrometeorological parameters were noted to be available from periodic measurements and continuous monitoring networks within the lagoon, as well as from its land and marine boundaries. Among the monitoring programs that provide relatively continuous data include the MELa, SAMANET and ARPAV monitoring networks. Considering the heterogeneity of the lagoon (in terms of hydrodynamics, morphological and physical features) and the requirements for continuous data with a high temporal resolution to detect changes in water quality parameters at each stage in the evolution of hazard events, the spatial and temporal resolution of the current monitoring programs may not be sufficient. In addition to in situ measurements, the availability of long-term time series of earth observation data may offer opportunities for the analysis of multi-hazard impacts of climate change on water quality. However, the current applications of remote sensing are limited to a few water quality parameters mainly related to primary productivity such as chlorophyll-a, macrophytes and organic matter. Therefore, for the monitoring and availability of data on water quality in the Venice Lagoon, it is necessary to consider:

- The widening of automatic monitoring networks with a high temporal resolution, such as SAMANET, in order to provide long-term and continuous data allowing to capture and represent the heterogeneity of the lagoon.
- A harmonized monitoring of water quality and forcing factors (such as hydrometeorological, hydrological, and atmospheric conditions capable of modifying the state of water quality) that enables the construction of relationships between water quality parameters and hazard factors, using measurements with similar temporal and spatial resolution.
- Coordination among agencies and monitoring programs to establish a common monitoring framework with respect to the spatial and temporal resolution and the parameters monitored. This would allow a comparative analysis of water quality, as well as provide opportunities for higher spatial resolution by combining the data from the different monitoring programs.
- The expansion of remote sensing applications to cover other variables such as nutrient concentrations, exploiting the available long-time series satellite imageries in combination with in-situ measurements.

In addition to the aforementioned research and monitoring actions, the following recommendations related to adaptation actions are proposed:

- Management and adaptation plans should take into account basin-level water allocation, diversion and retention/storage considering the impacts of both increased fresh water and nutrient discharge (e.g., eutrophication), as well as effects of reduced nutrient discharge (e.g., reduced primary productivity and aquatic food web).
- Effective stormwater management approaches should be implemented in order to solve issues related to stormwater runoff from urban areas and river basins, including the reduction, controlling and/or runoff delaying.
- Management and monitoring of socio-economic developments in the upper catchment area (e.g., taking into account future increases and/or decreases in anthropogenic loads of nutrients and sediments) should be considered.
- Finally, there is a need for the promotion and maintenance of important hydrologic, morphological and nutrient-cycling features that represent adaptive nutrient management strategies in the face of climatic changes. Features such as riparian buffers, saltmarshes, and aquatic vegetation should be highly integrated as functionally important and essential features of long-term nutrient management strategy that best accommodates potential climatic change impacts.

PART 2. CLIMATE CHANGE AND BIODIVERSITY

The Comune di Venezia (Municipality of Venice) in the framework of its institutional activities is the manager of two Natura 2000 sites, i.e., the IT IT3250010 Bosco di Carpenedo and the IT3250023 Lido di Venezia: biotopi litoranei.

The Bosco di Carpenedo extends over a surface of 13 ha and includes the remnant of an ancient forest and some meadows, in two separated areas. While of limited surface, the Bosco di Carpenedo is of great importance, being what remains of large ancient oak hornbeam forest which in the past extended across thousands of hectares ha in the mainland of Venice. Surrounded by urban areas, high traffic roads and agricultural fields, the Bosco di Carpenedo still host several species included in the Birds and Habitats Directives and four habitats under the Habitat Directives.

The Lido di Venezia: biotopi litoranei is located along the Lido and Pellestrina barrier islands, which border the lagoon of Venice and separate it from the Adriatic Sea. Divided in four separated areas, totaling 166 ha, the N2000 Site includes several littoral habitats, from beach and embryonic shifting dunes to well-developed dunes, the highest in the northern Adriatic, and littoral woodlands. Despite subject to heavy anthropic pressure, mostly due to sun bathers, the N2000 Site still holds many species of European community concern, including a small population of the threatened Kentish plover Charadrius alexandrines.

The main results of af the activity have been the following:

• a detailed analysis of the relevant scientific literature, identifying the main gaps in the knowledge of both Natura 2000 sites;

• new data were gathered for selected groups of taxa in the Bosco di Carpenedo, the Site for which more knowledge gaps were identified in the first phase. The occurrence and distribution of some species of Coleoptera, amphibians, birds and mammals were studied, with both field campaigns made by expert biologists and camera trapping. The results showed that amphibians were highly reduced in both richness and abundance during the 2022 drought, while birds and mammals – including several species of Chiroptera – seemed less affected;

• the existing maps of land use (Corine Land Cover) were updated, for the whole Bosco di Carpenedo and for three areas (San Nicolò, Alberoni and Ca' Roman) of the Lido di Venezia: Biotopi litoranei;

• questionnaires were sent to four experts, who had previous and detailed knowledge of the two N2000 sites, and then analyzed using a Delphi-method approach. The questionnaires had the purpose of helping the Comune di Venezia in identifying the main threats posed by climatic changes to both Sites, and in finding the most appropriate ways to cope with the expected variations in functions and structures of both Sites. Extension of the current protected area was deemed as useful

by the experts involved for both N2000 Sites; excavation of a well and creation of new ponds were suggested for the Bosco di Carpenedo. For the Lido di Venezia: biotopi litoranei, the most important measure to be adopted is a better regulation of anthropic occurrence on dunes, reducing (where feasible) the number of visitors and planting psammophilous species;

• a revision of the existing, quite old management Plans of both N2000 Sites has been strongly recommended, given the rapid changes both Sites are showing;

• a detailed list of monitoring activities to be performed at both N2000 Sites was proposed. The focal issue is to establish a long-term monitoring, which at present is totally lacking. The monitoring activities, considering what is currently known and what is less understood, will focus on selected abiotic (beach morphology) and biotic components, such as vegetation, xilofagous Coleoptera, amphibians and reptiles, birds, Chiroptera. These activities will be useful in identify the state of ecosystems using key indicators, the responses of the biotopes and to address the future management actions