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Editorial

Ecological Status Assessment of Transitional Waters

Chiara Facca

Department of Environmental Sciences, Informatics and Statistics, Ca' Foscari University of Venice, via Torino 155, 30172 Venice, Italy; facca@unive.it; Tel.: +39-(0)-41-234-7733

Received: 26 October 2020; Accepted: 6 November 2020; Published: 12 November 2020

Abstract: Transitional Waters are worldwide high valuable ecosystems that have undergone significant anthropogenic impacts. The ecological assessment is therefore of fundamental importance to protect, manage and restore these ecosystems. Numerous approaches can be used to understand the effects of human pressures, and, in case, the effectiveness of recovery plans. Eutrophication, climate change and morphological loss impacts can be assessed by means of aquatic vegetation, benthic fauna, and nekton. Moreover, before planning new infrastructures or interventions, predictive approaches and statistical analyses can provide indispensable tools for management policies.

Keywords: CO_2 flux; salinity; desalinization; trophic status; eutrophication; aquatic angiosperms; benthic fauna; nekton; uncertainty analysis

1. Introduction

The ecosystems that can be found between the land and the sea are characterized worldwide by a wide range of different natural conditions [1]. Therefore, several definitions are used to describe the habitats along coasts [2]. The United Nations glossary of environment statistics defines coastal lagoons as "Sea-water bodies situated at the coast, but separated from the sea by land spits or similar land features. Coastal lagoons are open to the sea in restricted spaces" [3]. The European Water Framework Directive legally defines Transitional waters (TWs) the "bodies of surface water in the vicinity of river mouths which are partly saline in character as a result of their proximity to coastal waters but which are substantially influenced by freshwater flows" [4]. The term "transitional waters" is now consolidated as a scientific term [2]. In the transition between the land and the sea, and hence, from freshwater to marine environment, a number of ecosystems can be found: rias, fjords, fjards, estuaries, lagoons [5,6]. TWs are often characterized by shallow waters [1] that are rapidly influenced by external changes, and, so, they are considered to be naturally stressed [7]. Moreover, the species' taxonomic richness tends to be limited compared to the adjacent sea or freshwater environments [5,8]. However, the morphological structure and the isolation from the sea provide a sheltered habitat for numerous species of flora and fauna, and a high productivity, making TWs valuable ecosystems [9]. Beyond the natural variability, TWs have been long exploited by human activities to settle cities and harbors, for land-reclamation, aquaculture and more recently, tourism, making them more and more vulnerable [1,9] and deteriorated. Among the 27 European Member states, only six have Coastal lagoon habitats with Favorable conservation status [10]; in China major urban and economic developments are causing loss of coastal wetlands and serious environmental problems [11]; in North America, where there is one of the most extensive surfaces of coastal lagoons (17.6% of coastline), eutrophication represents one of the greatest long-term threats to the ecological integrity [1].

The degradation of such ecosystems of exceptional ecological, recreational, and commercial value [1] has brought up the need to adopt restoration and/or protection measures, that, to be adequately planned, require an accurate ecological status assessment. Since the second half of the 20th century, when Chlorophyll *a* was first proposed as an index of productivity and trophic conditions in transitional and coastal waters [12,13], uncountable methods, based on both biotic and abiotic parameters, have been validated to provide a reliable assessment of environmental conditions. In the framework of National and International regulations aiming at preventing further degradation, the number of indices is continuously increasing. The necessity to have reliable tools, assessing TW status, responds not only to the implementation of management policies but also to improve the knowledge on biological, ecological, and anthropogenic interactions in these very complex ecosystems. Therefore, a constant update of the research on the effects that human pressures have on TWs is of fundamental importance.

The present Special Issue collects eight original research papers and one review, that describe completely different methods of assessing the ecological status of TWs. The number of approaches is different, certainly in proportion to the ecosystem complexity.

2. Overview of this Special Issue

Zhang et al. [14] describe the role of biological processes in carbon dioxide fluxes. A balance mass model has been used to calculate the net ecosystem production (NEP) and the CO_2 flux caused by biological processes and its contribution to the air–sea CO_2 exchange flux. Results show that seawater in the near-shore region of the Changjiang estuary (China) is a source of atmospheric CO_2, and the front and offshore regions generally serve as atmospheric CO_2 sinks. This procedure can provide interesting information on the assessment of trophic status and of the potential carbon stock of coastal waters, above all in the framework of ongoing climate change.

Considering again primary producers, Sfriso et al. [15] describe the role of aquatic angiosperms in TWs, where they are demonstrated to favor the maintenance of good ecological conditions. Seagrass transplantations are an important tool for restoring TWs, and they can be successful in areas where the effects of eutrophication are under control. After a year from the first transplantations, some indices used to assess the ecological status highlight an improvement of water quality due to the increase in seagrass beds.

Benthic fauna has been long used to assess environmental conditions [16], and in the present issue, three papers present data on the relationship between the zoobenthos of TW bottoms and different anthropogenic pressures.

Among zoobenthic organisms, meiofauna has been poorly studied due to the small size and the necessity of time and appropriate analysis techniques. However, it has a well-recognized role in the food webs connecting microbial components to higher trophic levels that contributes to the overall carbon fluxes and organic matter mineralization. Moreover, Semprucci et al. [17] support the hypothesis that meiofaunal organisms are good indicators of the spatial heterogeneity in TWs. Meiofauna displays, in fact, significant spatial variations in relation to environmental conditions, mainly salinity, dissolved oxygen and trophic components, and no changes on the temporal scale.

Benthic epifauna community composition, together with in-laboratory bioassay on brittle stars, were studied by Petersen et al. [18] to verify the impact of desalination brine discharges. In fact, seawater desalination by reverse osmosis is increasing due to the shortage of freshwater supply. Human population growth, agricultural expansion and environmental changes are causing the decline of natural freshwater, and, hence, Desalination Plants are becoming the main response. However, continuous discharge of high-salinity brine into coastal environments may have a severe impact on the ecosystem. Significant salinity anomalies can be detected even some hundred meters from the shore, but a careful assessment of site characteristics, when the desalination plants are constructed, can avoid changes in biological communities. Therefore, to ensure adequate mixing of the discharge brine, desalination plants should be located at high-energy sites with sandy substrates, and discharges should occur through diffusor systems.

Macrozoobenthic fauna was also studied to assess the ecological conditions of TWs on long term scale by Magni et al. [19]. The proposed studied case was a Chinese TW, severely damaged by domestic and industrial pollution and land reclamation already in the 1970s. In late 1980s, restoration interventions started to recover a healthy status and the related ecosystem services. Decade by decade, the continuous improvement of the environmental conditions was reflected in the major recovery and revitalization of the soft-bottom benthic assemblage. Beyond highlighting the importance and success of a good restoration plan, the data further confirm the effectiveness of macrozoobenthic fauna as biological tool to follow the recovery progress and the future evolution of TWs. However, the monitoring activities revealed another important threat for TWs, that is the role of invasive species.

The effectiveness of restoration was assessed also by Scapin et al. [20] who investigated the distribution of nekton communities along a salinity gradient. The long-lasting exploitation of TWs often has determined morphological alterations and hydrodynamism changes. The general pattern of TWs in recent and future decades is toward the homogenization of the physical characteristics with a tendency to marinization [21]. Therefore, the creation of new freshwater inputs is expected to restore the lost transitional attributes mitigating the negative effects of climate change and rising the nekton biomass thanks to the increase in oligo-mesohaline species. The use of a predictive approach with a functional perspective was demonstrated to provide tools to forecast the effects of salinity alteration regimes for both ecologists and ecosystem management [20].

Likewise, Castillo [22] studied the role of seasonal freshwater outflow on abundance of delta smelt and on the entire aquatic community. Qualitative community models were used to describe the effects of salinity variations on community interactions and stability patterns. It turned out that the overlap among pelagic and benthic species and trophic levels was significantly related to their salinity-dependent and geography-dependent distributions. In particular, the relative position of the near-bottom 2 salinity-isohaline along the estuary had different effects on the delta smelt subadults. Therefore, the management of hydrological conditions could be of help to mitigate the declining trends of delta smelt and of other native fish populations.

Focusing on the morphological structures that characterized TWs (i.e., salt marshes, small channels, isolated pools, etc.), Facca et al. [23], by literature review, describe how the presence and abundance of lagoon fish species may provide important indications on TW conservation status. In fact, the occurrence, distribution and biology of resident fish fauna tightly depend on salt marsh complexity, habitat connectivity within the lagoon or among adjacent lagoon systems. This complex system of small creeks and pools has a relevant role, not only for lagoon residents, but also for migrant species, that usually use TWs as a nursery. The review also highlighted the risk connected to the potential impact of alien species.

Being aware that an ecosystem assessment requires the continuous collection of data, as also demonstrated in all the above described studies, Cacciatore et al. [24] propose a tool to optimize the sampling effort in TWs monitoring activities, by applying a multi-approach. The combination of inferential statistics, spatial analyses and expert judgment allows us to optimize the monitoring effort ensuring, at the same time, a high reliability of the achieved information. This approach can be particularly useful for the routine monitoring activities aiming at classifying the water bodies status.

3. Conclusions

The effects of eutrophication have become particularly evident in the TWs worldwide from the 1970s [15,19]. The progressive deterioration of TWs and the concurrent loss of ecosystem services induced National and International authorities to act, protecting and restoring these habitats (US Clean Water Act, European Water Framework Directive, and the National Water Act in South Africa). At present, the positive results of the interventions counteracting the eutrophication phenomenon can be observed and confirmed by the good responses of aquatic vegetation, benthic fauna and nekton [15,17,19,20]. However, other significant threats to TWs are recently requiring attention, such as (i) the impact of climate changes determining alterations of hydrodynamism and of freshwater supply [14,18,22], (ii) the constant loss of morphological structures [23], (iii) the impact of alien and invasive species [19,23]. Climate changes are altering salinity regimes causing unbalances in the biological communities [20,21] and, hence, requiring interventions to manage the freshwater inputs [20,22]. In the framework of climate changes, the understanding of air–sea CO_2 exchange flux is of particular importance [14], because TWs can either be a source or a sink of atmospheric CO_2. The loss of habitat morphological features is related to both sea level rise and anthropogenic exploitation and requires urgent actions to save the vocational habitat of numerous aquatic species [23].

TWs require concrete management policies to prevent further deterioration and to plan the needed recovery interventions. Aiming at supporting this decisional process, the usefulness of biological communities to assess ecological conditions under anthropogenic impacts are widely described [17–19,23,24].

Funding: This research received no external funding.

Acknowledgments: I am thankful to all authors that contribute with their research articles to enrich this special issue. A special thanks goes to the MDPI *Water*'s Editorial Office, to Vanessa Sun and to all the reviewers and Academic Editors that dedicated their time and expertise in the manuscript revisions.

Conflicts of Interest: The author declares no conflict of interest.

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