Climate change effect on hydrological and chemical parameters of shallow lakes of the Danube Delta (Romania)

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AbstractThe unique mosaic of ecosystems of the Danube Delta Biosphere Reserve, comprising an extensive network of channels, shallow pools and hundreds of lakes, combined with marshes, reed-beds, lagoons, islands and floodplains, form a valuable natural area, sheltering a high biodiversity. One of the main drivers of the functionality of these ecosystems is the climate change, affecting especially the shallow lakes, where increasing temperatures and the reduced precipitation level, particularly in summer, affect the hydrology and chemistry of these lakes, inducing cascading effects at ecosystem level. Due to the very low precipitation ratio in the area, these ecosystems rely almost entirely on the discharge and water quality of the Danube River, who recorded a declining trend in the last decades, accelerating the changes occurred at lakes level. This study aims to present some of the changes driven by climate change in selected shallow lakes and recommend measures to increase their resilience to cope with this impact.

Keywords: Climate change, hydrological regime, Danube Delta, shallow lakes

Introduction

Located at the confluence of the Danube River with the Black Sea, the Danube Delta Biosphere Reserve, an UNESCO World Heritage site, hosts a high number of protected species and habitats, representing a very valuable area for biodiversity conservation (Oosterberg, 2000). The eutrophication induced at the beginning of the ‘80s by the high nutrient loads brought by the Danube River (the main water source in the region) led to a massive development of algal blooms and loss of species who could not adapt rapidly to the new environmental conditions (Cristofor, 1987; Tudorancea & Tudorancea, 2006). After the reduction of nutrient input and the improvement of water quality in the ‘90s, a slight tendency of recovery of the aquatic ecosystems was noticed (Zinevici & Teodorescu, 2007). The impact of climate change however, especially in the South-Eastern part of the Danube River Basin, poses a new threat to these ecosystems, as increased frequency of extreme meteorological events, modified precipitation regime and river discharges, and increasing temperatures are already affecting the aquatic ecosystems (Sandu *et al*, 2009). Moreover, based on climate scenarios, it is expected that this impact will aggravate, as reduced precipitation ratios and increased temperatures and frequency of droughts will occur in the region, especially in summer (IPCC, 2007, ICPDR 2013). The impact of climate change is always stronger in fragile environments, such as coastal and deltaic areas. Trend analyses carried out recently show that particularly the proximity of the Black Sea is very likely to become more arid in the next decades (Cheval *et al*, 2017). Temperature and precipitation rate are the main climate parameters analysed within the climate change context, as they may trigger the most significant consequences, sometimes extended over large territories. Hence, the paper emphasizes the modifications of the climate parameters in the Danube Delta area over the last decades, as well as some of the changes triggerred at ecosystems level.

Methods

Two lake complexes located in the fluvio-marine part of the Danube Deltawere selected for a more in-depth analysis of the impacts occured in the last decades: Matita – Merhei and Rosu – Puiu (Fig.1).

Air temperatures and precipitation rates at the two meteorological stations located in the delta (Tulcea – at the entrance, and Sulina, at the confluence of the Danube with the Black Sea) were investigated between 1961 – 2014 to reveal the trends. Satellite images (Google Earth) were analyzed to identify the hydromorphological changes occurred in the two lake complexes over the last decades. The most representative lakes in both complexes were selected

for investigating the multiannual dynamics of average depths, temperatures and nutrient content. Data from IBB database and own research were investigated in relation with the trends recorded by the climate parameters, to emphasize the modifications occured at lakes level.

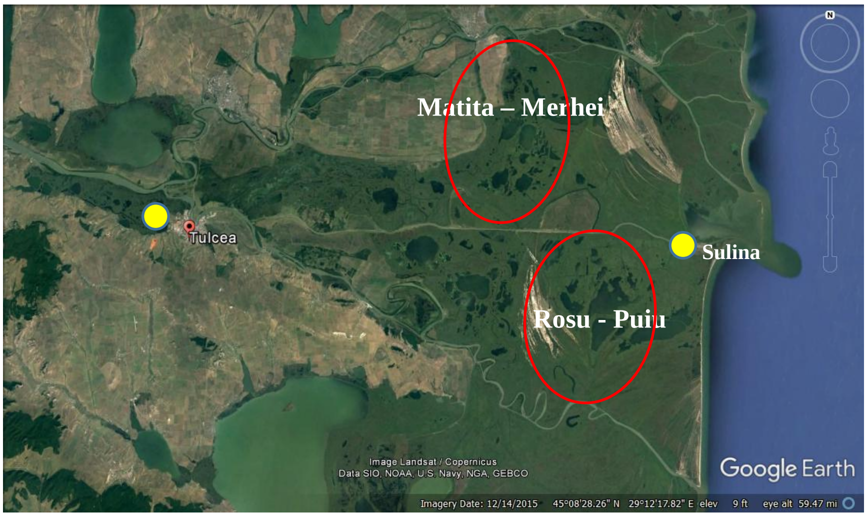

Fig. 1. Location of Matita – Merhei and Rosu – Puiu lake complexes, and Tulcea and Sulina meteo stations (yellow dots) (Danube Delta, Romania). Map source: Google Earth.

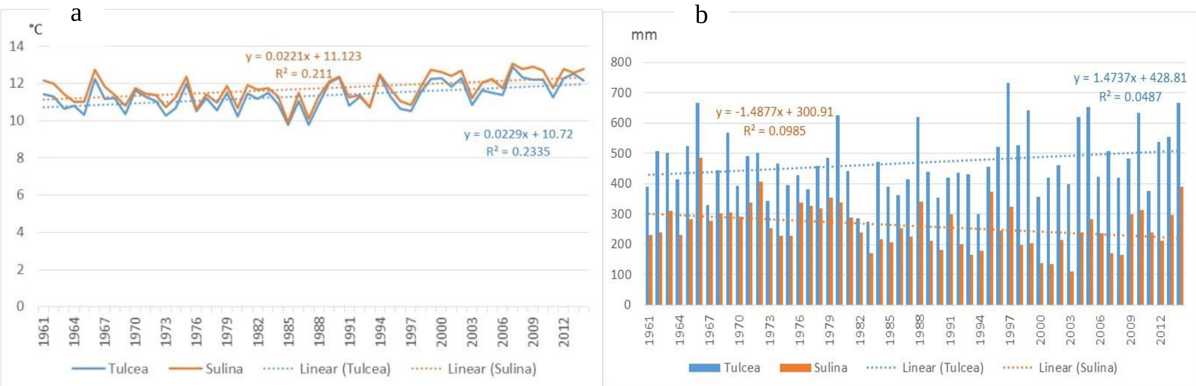

Fig.2. Mean annual air temperatures (a) and precipitation ratio (b) in Danube Delta area between 1961-2014

Results

Trends of the climate parameters in Danube Delta area

The analysis of the average annual air temperatures shows an increasing trend at both stations over the last 50 years (Tulcea - blue line, Sulina - red line). For annual precipitation amount, two different trends were recorded: while for Tulcea it increased (blue), for Sulina a decreasing trend was recorded for the same period (red).

Changes occured in Matita – Merhei complex

Matita – Merhei lake complex is located in the NE part of the Danube Delta, surrounded by Letea and Stipoc – Chilia sandbanks, with Sulina and Chilia arms as main water inflow, via a complex network of surface and underground channels. Due to the remote distance between the lakes and the water sources, these shallow lakes (average 1.5 – 2 m) are more sensitive to the fluctuations of the precipitation regime and temperature. Matita and Merhei lakes were selected as the most representatives for this complex. Their hydromorphological evolution between 1984 – 2014 show a slight regression of aquatic areas, while vegetation seems to conquer the lakes edges, especially in Merhei Lake, dominated by macrophytes (Fig.3).

Also the average depth of the lakes recorded a declining trend, reaching alarmingly low levels especially in very dry and hot years, such as 2007 (Fig. 4 A), while average water temperatures increased significantly, especially in summer.

Changes occured in Rosu - Puiu complex

This lake complex is located in the SE part of the Danube Delta, limited by Caraorman sandbank to the E, and bordered by the Black Sea in the W, with Sulina and Sfantu Gheorghe arms as main water inflow. The depth of the lakes in this complex is bigger than in Matita-Merhei (average depth 2.5 – 3 m). Moreover, as they are located in a closer distance to the Danube arms, the main water source, and along the Black Sea coast, they are less sensitive tothe variations of the precipitation regime. Rosu lake was selected as the most representative for this complex.Unlike Matita and Merhei lakes, its hydromorphological evolution shows a slight increase of aquatic areas, especially in the Eastern side, while the sea border shrinked(Fig.6).

Fig. 3. Evolution of Matita – Merhei lake complex between 1984 – 2014. Maps source: Google Earth.

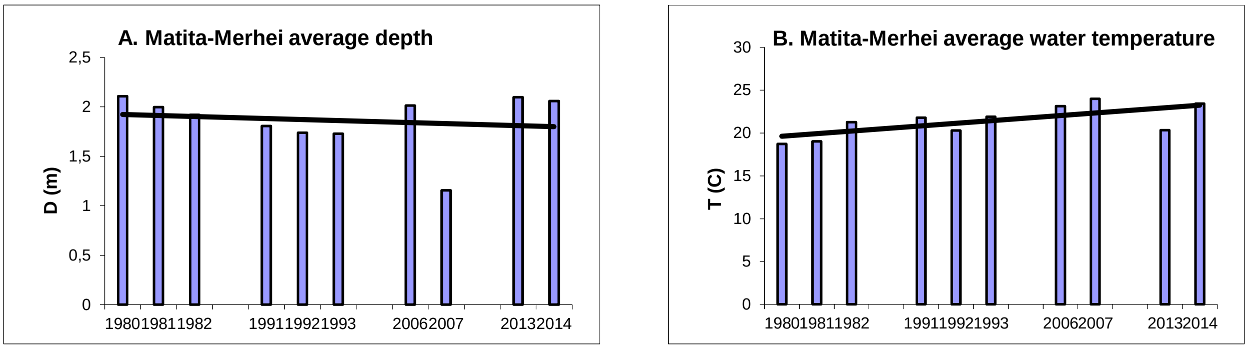

Fig. 4. Decrease of average depth recorded in Matita-Merhei lakes (A) and increase of average water temperature (B) between 1980 – 2014. Datasource: IBB database (1980-1993) and own measurements (2006-2014)

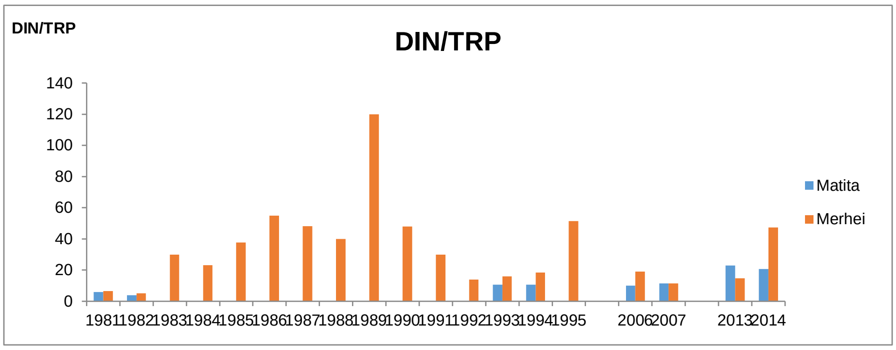

Fig. 5. Dynamic of ratio between dissolved inorganic nitrogen (DIN) and total reactive phosphorus (TRP) in Matita – Merhei lakes. Datasource: IBB database (1981-1982) , literature (1983 – 1995), own measurements (2006-2014)

Dec. 1984 Dec. 2014

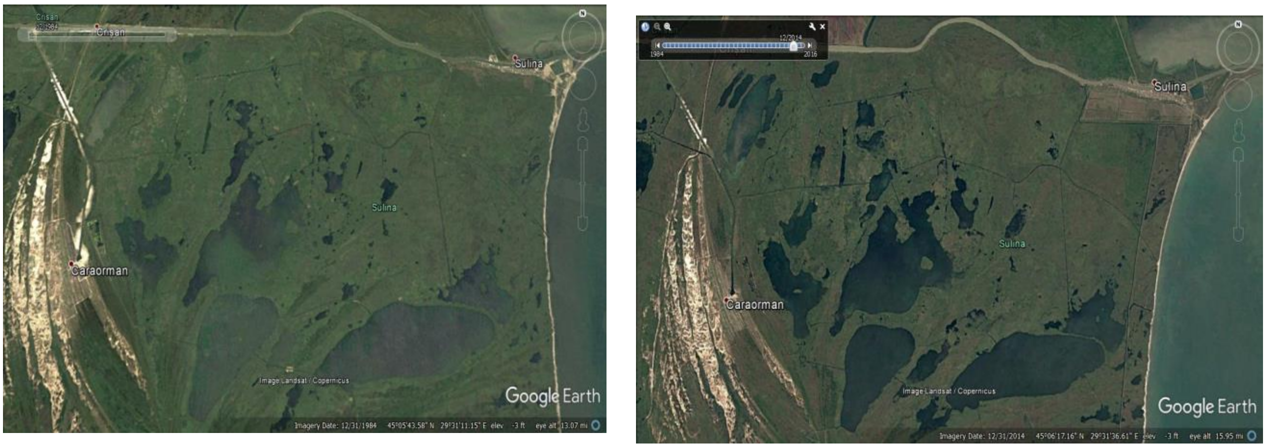

Fig. 6. Evolution of Rosu – Puiu lake complex between 1984 – 2014. Maps source: Google Earth.

The hydromorphological changes visible on the satellite maps are confirmed by the increasing trend of the average depth of this lake (Fig. 7). For water temperatures however, no trend could be noticed.

Discussion

Over the past 50 years, air temperatures increased with about 1°C in delta area, while the precipitation ratio show marked local differences probably due to the different wind regime: while in Tulcea area, at the entrance in the Danube Delta, the precipitation amount increased, in Sulina, located at the confluence with the Black Sea, it decreased in average with about 100 mm. These trends are felt differently by the two lake complexes, depending on their hydromorphology, geographic location and distance to the Danube main arms (the main water source in the region). Matita – Merhei complex, located in the NE part of the Delta, in a remote distance from the Danube, encompasses shallower lakes, more sensitive to the variability of air temperature and precipitation level.The increase of annual avearage air temperature and the decrease of the precipitation ratio in Sulina area (located in the vicinity of this complex) induced an increased water temperature and a decrease of average depth of the investigated lakes (Fig. 4).

Rosu – Puiu lake complex, located in the vicinity of the Black Sea, in a closer distance to Danube arm and encompassing large, deeper lakes, was not so much affected by the change of climatic parameters: the average depth of Rosu Lake increased, while the water temperature did not record a significant trend over the last 30 years, despite the increase of air temperature in the delta. Correlated with the increasedcoastal erosion and the shrinkage of the beach area along the Black Sea coast (Grigoras, 2012) we assume that water infiltration from the marine environment occurred, but the investigations carried out in this lake until 2014did not emphasize a salinity increase.

After the eutrophication peak in the 80's (visible in the satellite images in 1984), the lakes had the tendency to return to their previous state especially after 1990, when the water quality of the Danube River improved significantly.

The ratio of mineral forms of nutrients(DIN/TRP) emphasize the shift of nutrients availaibility in the aquatic environment: while before 1980 this ratio was below 10, indicating nitrogen as possible limiting factor of algal growth, there is a marked increase between 1983 – 1995, showing a possible phosphorus limitation. Even if after 2000 the DIN/TRP values decrease, showing a possible recovery tendency, they are still above the values recorded in early '80s. The effect of climatic changes raise a new threat for these shallow lakes, as increasing water temperatures and declining water depths tend to mobilize the nutrients stored at sediment level, enhancing the risks of algal blooms and cyanobacterial mass development, imparing the water quality and posing health hazard for human and wildlife health.

Conclusions

The different trends recorded by the precipitation amounts in Tulcea and Sulina area (70 km distance), highlight that, while the temperature regime is due to large scale mechanisms, the precipitations may be influenced by important local variations.

The remote, shallow lakes located in the NE part of the Danube Delta tend to be more affected by the climatic changes, while larger, deeper lakes, better connected to the main arms of the Danube River show more resilience to temperature increases and reduced precipitation regime.Increasing water temperatures tend to remobilize nutrients stored at sediment level, increasing the risk of algal blooms. As these impacts are expected to aggravate in the future, according to climate scenarios, mitigation measures should be taken to support the shallow lakes of the delta to cope with these changes: reducing nutrients loads into lakes, aerating or removing the upper layers of sediment, improving water circulation and connectivity of the Danube River arms with the remote lakes could contribute to reduce the negative effects.

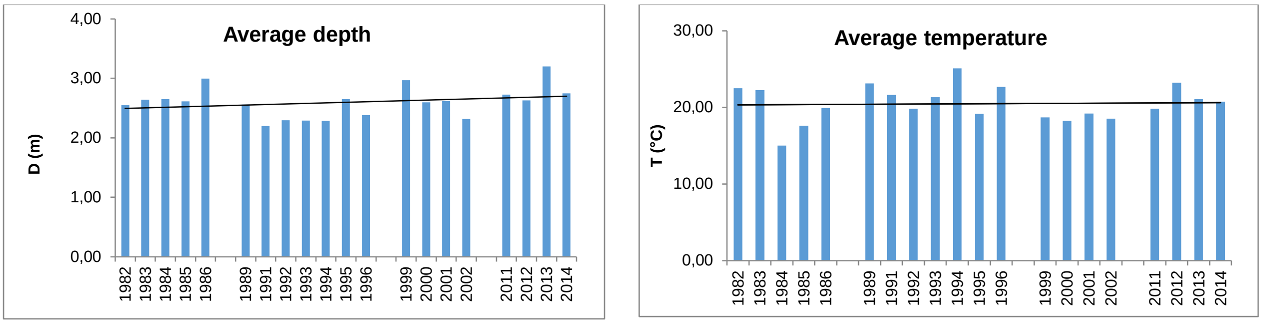

Fig. 7. Average water depth and temperature recorded in Rosu Lake (1981 – 2014). Datasource: IBB database (1980-1993) and own measurements (1996-2014).

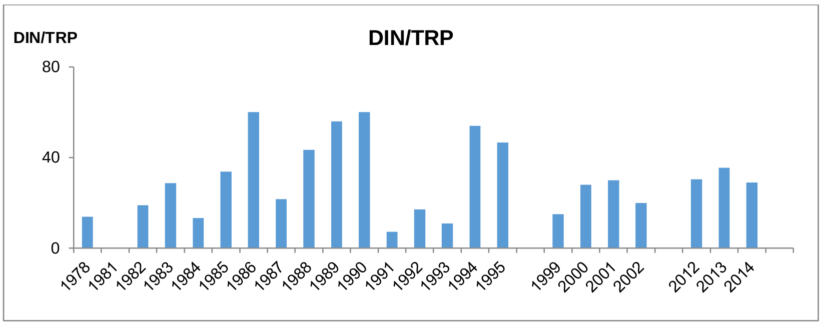

Fig. 8. Dynamic of ratio between dissolved inorganic nitrogen (DIN) and total reactive phosphorus (TRP) in Rosu Lake. Datasource: IBB database (1978) , literature (1982 – 1995), own measurements (1999-2014)

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