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EFFECT OF CHANGES IN THE ROMANIAN LOWER SECTOR DANUBE RIVER HYDROLOGICAL AND HYDROTHERMAL REGIME ON FISH DIVERSITY

Ira-Adeline SIMIONOV, Stefan-Mihai PETREA, Alina MOGODAN, Aurelia NICA, Dragos CRISTEA, Mihaela NECULITA

"Dunarea de Jos" University of Galati, Galati, Romania

Corresponding author email: stefan.petrea@ugal.ro

Abstract

Climate variability and change has negative impact on fisheries ecosystems. Climate change can manifest a pervasive effect on freshwater ecosystems, by altering biodiversity patterns, abundance and distribution of species, biological interactions, phenology and organisms' physiology, performance and fitness. Central and Southern Europe, including Romania, is considered to be one of the most vulnerable regions affected by changes in the climate system. Therefore, the aim of the study was to evaluate the influence of Danube River water level and temperature regime, atmospheric thermic regime, from the last 3 years (2017-2019), on ichthyofauna diversity and abundance in the Lower Sector of the River. The year 2018 registered the highest values for water levels and the year 2019 recorded the maximum values for air temperatures, in all hydrometric stations. A general conclusion of this research is that the capture level of peaceful (non-ichthyophagous) fish species are higher compared to raptor (ichthyophagous) fish species. Based on these results, there is strong recommendation to incorporate climate variability and change in the modelling of fisheries management approaches to reduce the impacts of climate variability and change on fisheries-based livelihoods.

Key words: *climate change, Danube River, fish diversity, global warming, pontic shad.*

INTRODUCTION

Quick and persistent rises in temperature are expected to occur during the next decades (Diop et al., 2018). Global warming does not just affect the atmosphere and its effects have extended to the aquatic environments as well (Hannesson, 2007).

This phenomenon generated an increase in global temperature (ranging from 1.8 to 4.0°C), a change in weather patterns and hydrodynamics, and water level rise (Madeira et al., 2016).

Such climate changes negatively influence the fish migrations and habitat, augmenting fish stocks in some places and decreasing them in others (Hannesson, 2007).

Temperature is one of the most important environmental variables associated with aquatic life and its variability (Linderholm et al., 2014). Warming of aquatic systems is implicated in mass mortality, increased disease, hypoxia, species invasions, phenological shifts in planktonic food web dynamics, physiological limitation in oxygen delivery and increased costs of metabolism (Byrne, 2011).

According to Madeira et al. (2016) and Linderholm et al. (2014) early life stages are highly vulnerable to water temperature increase. Thermal windows widths are narrower for egg, larvae and spawners stages of fish, compared to juveniles and adults (Madeira et al., 2016). Thus, early exposure to stress in development can result in latent deleterious downstream effects, because performance of later ontogeny depends on the success of early stages (Byrne et al., 2013).

This process is called "development domino effect". In case of fisheries and aquaculture production, deviation from the optimal thermal range can affect fish growth rate, harvest or catch size and cause stock displacement of commercial species (Blanchet et al., 2019). As well, warming of freshwater systems (such as ponds and lakes) will affect access to water, which is the main constraint on these land-based production systems (Blanchet et al., 2019).

In the future, global warming, through its effect on water temperature, will manifest a strong influence on stock dynamics and harvest levels (Diop et al., 2018). The interaction of fishing with climate variability and change will influence fish species size, structure and composition of fish populations (Ng'onga et al., 2019).

The freshwater sector, including wild captures and aquaculture, relies exclusively on fish and represents less than 3% of the total European seafood production volume (Blanchet et al., 2019). The sensitivity of seafood production volume caused by exposure to warming of the ambient water was previously assessed based on the index of biological sensitivity (BS) (Blanchet et al., 2019). Freshwater fish species produced in European aquaculture have a high biological sensitivity index ranging (BS > 0.5), due to a long-life span and a high age at sexual maturity (Blanchet et al., 2019). According to Blanchet et al. (2019), Romania presents a relatively low vulnerability (BS = 0.45) to warming because the country aquaculture production is based on the common carp. In her study, Byrne (2011) highlighted the need for a regional approach in assessment of ecosystem change and risk to species.

During the last decade, Romania has experienced the highest summer temperatures in the last 100 years (Ionita et al., 2013; Rimbu et al., 2015). Also, global warming related to extreme climate events such as extreme precipitation or drought, can modify the water cycle causing abnormal fluctuations of water level (Cheng et al., 2019). Therefore, the aim of the study was to determine the influence of Danube River water temperature and level regime on fish stock structure and diversity, in the last 3 years (between 2016 and 2019).

MATERIALS AND METHODS

The study area is represented by the Lower Sector of Danube River, respectively Braila (170 river kilometer), Galati (150 river kilometer) and Tulcea (70 river kilometer) (Figure 1).

The water temperature (T°C) and level (cm) were daily recorded in the hydrometric stations and the data was provided by Galați Lower Danube River Administration. In this study, the maximum and minimum values of water temperature and level were selected for each month, in order to point out the effect of extreme climate events.

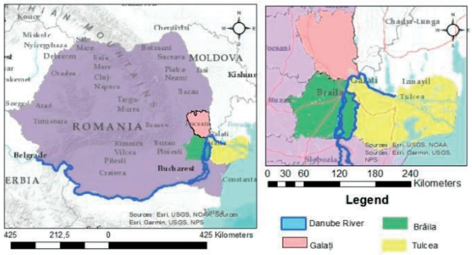

Figure 1. GIS mapping of the studied area

In the South-East part of Romania, commercial fishing is undertaken in the Danube Delta Biosphere Reserve and total fish catches are reported in the following geographical units: Danube River, Gorgova-Uzlina, Dranov Island, Black Sea and Black Sea basin, Matita Merhei, Razim-Sinoe, Rosu Puiu, Somova Parches, Sontea-Fortuna. The highest values of fish capture are reported in Danube River area, thus, in this study, the data recorded within this area has been analysed. The data recorded for the reported total fish capture between the years 2016-2019 was provided by the Danube Delta Biosphere Reserve Authority.

The following fish species are reported as capture in Danube River fishing area: *Abramis brama* (Linnaeus, 1758), *Alosa caspia* (Eichwald, 1838), *Alosa immaculata* (Bennett, 1835), *Leuciscus aspius* (Linnaeus, 1758), *Barbus barbus* (Linnaeus, 1758), *Blicca bjoerkna* (Linnaeus, 1758), *Carassius gibelio* (Bloch, 1782), *Cyprinus carpio* (Linnaeus, 1758), *Esox lucius* (Linnaeus, 1758), *Pelecus cultratus* (Linnaeus, 1758), *Perca fluviatilis* (Linnaeus, 1758), *Rutilus rutilus* (Linnaeus, 1758), *Scardinius erythrophthalmus* (Linnaeus, 1758), *Silurus glanis* (Linnaeus, 1758), *Sander lucioperca* (Linnaeus, 1758), *Tinca tinca* (Linnaeus, 1758), *Vimba vimba* (Linnaeus, 1758).

The identified fish species were separated into two groups, based on the fish feeding regime, as following: non-ichthyophagous group (freshwater bream, caspian shad, white bream, prussian carp, common carp, roach, rudd, vimba bream, tench) and ichthyophagous group (shad, asp, barbel, northern pike, wels catfish, european perch, pike-perch, sichel).

Species diversity was expressed by calculating the biomass diversity index of Simpson (DI), according to Tian et al. (2006). Thus, the following formula was applied:

$$DI = 1 - \sum_{i}^{n} \frac{Y_i(Y_i - 1)}{Y(Y-1)} \quad (1)$$

where Y_i represents the quantity of fish species items and Y represents the sum of total n items, for each of the studied years. In general, Y is the number of individuals, but units of weights (tons) are accepted as well (Tian et al., 2006). **DI** value ranges from 0 to 1, where 0 represents the community composed of only one species.

Statistical analysis was performed by using Origin Pro Software. In order to evaluate the normality of data distribution, Kolmogorov-Smirnov normality test was performed, followed by the variance test One-Way Anova and Tukey test.

RESULTS AND DISCUSSIONS

The mean annual highest water temperature in Braila Station was registered in 2019 (17.16 ± 8.39°C) and the lowest in 2017 (16.25 ± 9.07°C) (Figure 2). In case of the water level, the annual mean highest value was recorded in 2018 (345.25 ± 190.46 cm) and the lowest (298.91 ± 109.50 cm) in 2017 (Figure 2). Despite the upward tendency, water temperature and level values did not register significant differences ($p > 0.05$) in all studied years, in Braila Station.

In Galati Station, the mean annual highest water temperature was registered in 2019 (16.86 ± 8.62°C) and the lowest in 2017 (16.35 ± 9.41°C) (Figure 3.). In case of the water level, the highest mean annual value was recorded in 2018 (343.91 ± 173.17 cm) and the lowest (297.25 ± 102.14 cm) in the year 2017 (Figure 3.). Even though there is an upward tendency from one year to another, the differences registered in case of water temperature and level values were not significant ($p > 0.05$) in all studied years, in Galati Station.

The highest mean annual water temperature in Tulcea Station was registered in 2019 (17.15 ± 8.52°C) and the lowest in 2017 (16.20 ± 9.28°C) (Figure 4). In case of the water level, the highest annual mean value was recorded in 2018 (221.5 ± 118.30 cm) and the lowest (190 ± 74.14 cm) in 2017 (Figure 4). However, in Tulcea Station, the differences registered in case of water temperature and level values were not significant ($p > 0.05$) in all 3 studied years.

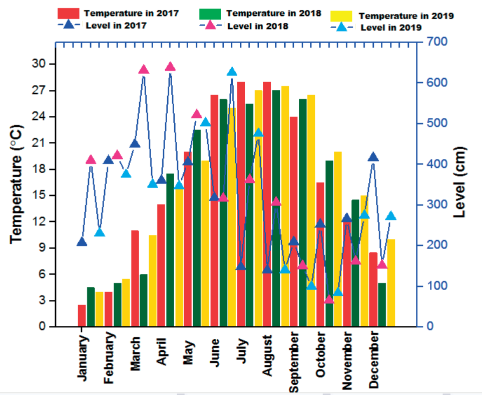

Figure 2. Water temperature and level in Danube River, Braila Station

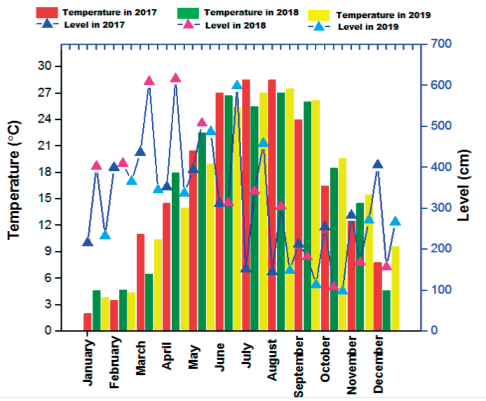

Figure 3. Water temperature and level in Danube River, Galati Station

The means highest water temperatures were registered in August for all stations and studied years. In case of the water level, the mean highest levels were recorded in March, for the year 2017 in all studied stations, in April, for the year 2018 in all studied stations and in June, for the year 2019 in all studied stations. The year 2018 registered the highest water levels in all stations, due to the unusual and heavy rainfall in the form of snow, sleet and rain, followed by snow melting phenomena (Galati Lower Danube River Administration, 2019). In 2017, the lowest water levels were recorded in August, in all sampling stations and in 2018, 2019, the lowest levels were registered in October.

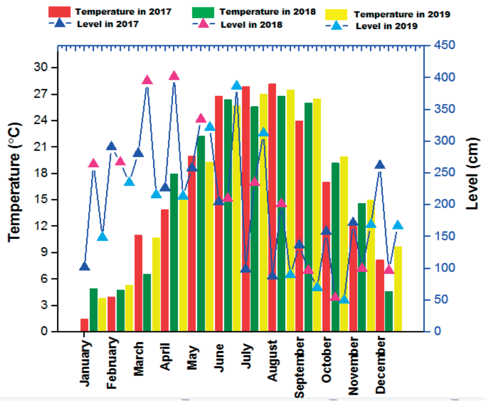

Figure 4. Water temperature and level in Danube River, Tulcea Station

The correlation analysis (Pearson coefficient) revealed that in 2017, water temperature and level were negatively correlated, in all studied stations (Pearson coef. = -0.50). In 2018 and 2019, the values registered for water temperature and level, in all the studied stations, did not manifest a correlation relationship (Pearson coef. < 0.5).

The total fish catches reported from Danube River, within the sector situated in Danube Delta Biosphere Reserve, was as it follows: for 2017 a total of 704.832 tons, for 2018 a total of 652.517 tons and for 2019 a total of 1 032 tons (Figure 5). In 2017 and 2019 the highest catches were reported for *A. immaculata* (263, respectively 348 tons), whereas in 2018 the highest catches were reported for *C. gibelio* (244 tons) (Figure 5). The decrease of reported *A. immaculata* catches in 2018 may be caused by the extreme flooding phenomenon manifested in that year. According to Smederevac-Lalić et al. (2018), extreme spring floods have a negative influence on survival of pontic shad eggs and larvae, due to high turbidity. However, flooded terrestrial vegetation provide suitable spawning substrate for phyto-philic and phyto-lithophilic cyprinids, such as the prussian carp (Janac et al., 2010). In addition, flooded vegetation provides efficient refuge against predators, high food availability and higher temperature to support the rapid growth of many juvenile fish (Janac et al., 2010). The high water temperature may be beneficial for fish species from the ichthyophagous group, such as the northern pike, by stimulating the growth rate of juveniles, through elevations of individual metabolic rates, and also through the extension of the local growing season for northern pike (Szczepkowski, 2006; Winfield et al., 2008). However, if northern pike eggs are incubated at a temperature above 15°C, larval abnormalities are expected to increase and premature hatching could occur, preventing the functional attachment of yolk-sac larvae to substrate and sank to the bottom where toxic conditions are encountered (low oxygen, presence of hydrogen sulfide) (Hassler, 1982). This phenomenon could increase larvae mortality rate by 40%.

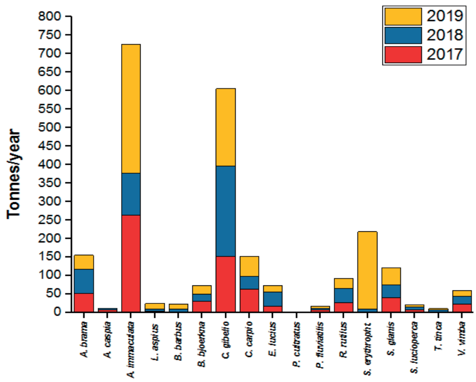

Figure 5. Quantitative distribution of different fish species captured from Danube River

Other ichthyophagous fish species, such as the perch and pikeperch, can be disadvantaged by the early water warming during spring season, which negatively affects the survival of larvae, due to early hatching and increased risk of exposure to cold weather, as well as starvation during subsequent development (Kokkonen et al., 2019). According to Lappalainen et al. (2003), at a water temperature higher than 20°C, the number of normally hatched larvae decreases. Furthermore, it is well known that during warm springs and summers, the spawning of pikeperch occurs earlier, but if the temperature drops suddenly, spawning may be interrupted (Lappalainen et al., 2003).

The raising water temperature can affect fish reproduction as well. For instance, the

pikeperch requires a wintering period to induce puberty and slightly higher temperatures, that are still well below 20 °C, to ideally progress vitellogenesis (Swirplies et al., 2019). Gonad maturation can be completely inhibited at temperatures higher than 20 °C, by preventing energy allocation to the gonad and increasing fish growth rate (Swirplies et al., 2019).
The highest values were reported for fish capture from the non-ichthyophagous group and within the group *C. gibelio* recorded the highest capture as biomass (Table 1). In the ichthyophagous group, the highest value was recorded in case of *A. immaculata* capture.

Table 1. The share of non-ichthyophagous and ichthyophagous fish capture from total

Year	Non-Ichthyophagous	Ichthyophagous
2017	51%	49%
2018	68%	32%
2019	56%	44%

The values reported for fish capture did not register significant differences ($p > 0.05$) between the studied years.
As well, when compared, the values reported for fish capture in the two groups (non-ichthyophagous and ichthyophagous) did not manifest significant differences ($p > 0.05$), in all studied years.
The DI values show a decreasing trend in fish diversity from the year 2017 to year 2019 (Figure 6). When calculated for each group, the DI registered higher values in case of the non-ichthyophagous group (DI = 0.756), compared to the ichthyophagous group (DI = 0.396), in the year 2017. The same phenomenon was observed in the year 2019, when the non-ichthyophagous group registered higher values (DI = 0.720), compared to the ichthyophagous group (DI = 0.396).
In case of 2018, the DI was similar for both groups (DI = 0.653, respectively DI = 0.651). This fact is associated to a change in the reported catches from the ichthyophagous group, respectively a decrease of *A. immaculata* capture and an increase of capture within the rest of the species which belong to this group.

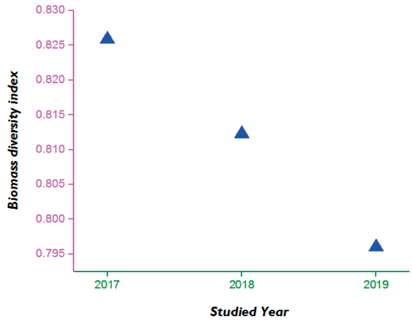

Figure 6. Annual changes in the estimated diversity index

A very strong negative correlation (Pearson = -0.999) was identified between water temperature and DI, in case of all studied years. Thus, high water temperature is associated to low fish diversity. In this study, it is observed that especially the fish species from the ichthyophagous group suffer a decline in biodiversity. This fact was confirmed by Korzeniewska and Harnisz (2020) as they mentioned that water heating has a negative impact and limit the occurrence of fish species that prefer colder environments (*E. lucius, P. fluviatilis, S. lucioperca*).

CONCLUSIONS

Water temperature in the lower sector of Danube River manifested an upward tendency in the last 3 years, registering the highest mean values in 2019.
The water level shows an increasing trend during the studied timeline, with the highest values recorded in 2018, due to extreme floods manifested in that year in the Lower Sector of Danube River. Fish diversity in the Lower Sector of Danube River recorded a decreasing trend, during the years 2017-2019 and the total capture of peaceful (non-ichthyophagous) fish species are higher compared to raptor (ichthyophagous) fish species.
The correlation analysis revealed a negative correlation between water and temperature, as well as between water temperature and fish diversity. Based on these results, there is strong recommendation to incorporate climate variability and change in the modelling of fisheries management approaches to reduce the impacts of climate variability and change on fisheries-based livelihoods.

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This study can be used for the development of biodiversity protection strategies and for future research, in order to create mathematical models, which can predict long-term fish biodiversity in Danube River.

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REFERENCES

Blanchet, M.A., Primicerio, R., Smalas, A., Arias-Hansen, J., Aschan, M. (2019). How vulnerable is the European sea food production to climate warming? *Fisheries Research*, 209, 251-258.

Byrne, M., Gonzalez-Bernat, M., Doo, S., Foo, S., Soars, N., Lamare, M. (2013). Effects of ocean warming and acidification on embryos and non-calcifying larvae of the invasive sea star *Patiriella regularis*. *Marine Ecology Progress Series*, 473, 235-246.

Byrne, M. (2011). Impact of ocean warming and ocean acidification on marine invertebrate life history stages: vulnerabilities and potential for persistence in a changing ocean. *Oceanography and Marine Biology: An Annual Review*, 49, 1-42.

Cheng, J., Xu L., Feng, W., Fan, H., Jiang, J. (2019). Changes in water level regimes in Chinas's two largest freshwater lakes: characterization and implication. *Water*, 11, 917.

Diop, B., Sanz, N., Duplan, I. J. J., Guene, E. H. M., Blanchard F., Pereau J.C., Doyen L. (2018). Maximum Economic Yield Fishery Management in the Face of Global Warming. *Ecological Economics*, 154, 52-61.

Galați Lower Danube River Administration, *Activity Report* for the year 2018, Registered No. 4673 from 08.02.2019, Galați.

Hannesson, R. (2007). Geographical distribution of fish catches and temperature variations in the northeast Atlantic since 1945. *Marine Policy*, 31, 32-39.

Hassler, T. (1982). Effect of temperature on survival of northern pike embryos and yolk-sac larvae. *The Progressive Fish Culturist*, 44, 174-178.

Ionita M., Rimbu, N., Chelcea, S., Patrut, S. (2013). Multidecadal variability of summer temperature over Romania and its relation with Atlantic Multidecadal Oscillation, *Theoretical and Applied Climatology*, 113, 305-315.

Janacˇ, M, Ondracˇkova´, M, Jurajda, P, Valova´ Z, Reichard, M. (2010). Flood duration determines the reproduction success of fish in artificial oxbows in a floodplain of a potamal river. *Ecology of Freshwater Fish*, 19, 644–655.

Kokkonen, E., Heikinheimo, O., Pekcan-Hekim, Z., Vainikka, A. (2019). Effects of water temperature and pikeperch (*Sander lucioperca*) abundance on the stock–recruitment relationship of Eurasian perch (*Perca fluviatilis*) in the northern Baltic Sea. *Hydrobiologia*, 841, 79-94.

Korzeniewska, E. and Harnisz, M. (2020). Polish river basins and lakes - Part I, *Hydrology and Hydrochemistry*, The Handbook of Environmental Chemistry, Springer Nature Switzerland, Page 326.

Lappalainen, J., Dorner, H., Wysujack, K. (2003). Reproduction biology of pikeperch (*Sander lucioperca* L.) - a review. *Ecology of Freshwater Fish*, 12, 95-106.

Linderholm, H.W., Cardinale, M., Bartolino, V., Chen D., Tinghai O., Svedang H. (2014). Influences of large- and regional-scale climate on fish recruitment in the Skagerrak-Kattegat over the last century. *Journal of Marine Systems*, 134, 1-11.

Madeira, D., Araujo, J.E., Vitorino, R., Capelo, J.L., Vinagre, C., Diniz, M.S. (2016). Ocean warming alters cellular metabolism and induces mortality in fish early life stages: A proteomic approach. *Environmental Research*, 148, 164-176.

Ng'onga, M., Kalaba, F.K., Mwitwa, J., Nyimbiri, B. (2019). The interactive effects of rainfall, temperature and water level on fish yield in Lake Bangweulu fishery, Zambia, *Journal of Thermal Biology*, 84, 45-52.

Rimbu, N., Stefan, S., Necula, C. (2015). The variability of winter high temperature extremes in Romania and its relationship with large-scale atmospheric circulation, *Theoretical and Applied Climatology*, 121, 121-130.

Smederevac-Lalić, M., Kalauzi, A., Regner, S., Navodaru, I., Višnjić-Jeftić, Ž., Gačić Z., Lenhardt, M. (2018) Analysis and forecast of Pontic shad (Alosa immaculata) catch in the Danube River, *Iranian Journal of Fisheries Sciences*, 17, 443-457.

Swirplies, F., Wuertz, S., Baßmann, B., Orban, A., Schäfer, N., Brunner, R.M., Hadlich, F., Goldammer, T., Rebl A. (2019), Identification of molecular stress indicators in pikeperch *Sander lucioperca* correlating with rising water temperatures. *Aquaculture*, 501, 260-271.

Szczepkowski, M. (2006). The impact of water temperature on the growth and survival of juvenile northern pike (*Esox lucius* L.) reared on formulated feed. *Archives of Polish Fisheries*, 14, 85-93.

Tian, Y., Kidokoro, H., Watanabe, T. (2006). Long-term changes in the fish community structure from the Tsushima warm current region of the Japan/East Sea with an emphasis on the impacts of fishing and climate regime shift over the last four decades. *Oceanography*, 68, 217-237.

Winfield, I.J., James, B.J., Fletcher, J.M. (2008). Northern pike (*Esox lucius*) in a warming lake: changes in population size and individual condition in relation to prey abundance. *Hydrobiologia*, 601, 29-40.