ORIGINAL PAPER

MONITORING WATER QUALITY OF PONDS AND PREDICTIONS RELATED TO CLIMATE CHANGE IMPLICATIONS ON FISH HABITATS

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Abstract. *SCDP-Nucet has an essential activity in aquaculture – especially in the genetic improvement of cultured carp and the preservation and usage of freshwater fish genotypes using advanced integrated technologies for fish farming. Climate changes have a crucial role in fish farming because they negatively affect the water bodies and the fish metabolism. This study aims to monitor the water quality of ponds associated with weather data during two years (i.e., 2022 and 2023), from May to September. The climate change implications on fish habitats were also discussed.*

Keywords: *climate change; fish; pond; water parameters; monitoring.*

1. INTRODUCTION

Climate change is directly related to the increase in global average temperature, as well as long-term shifts in weather patterns, with strong and irreversible consequences on Earth's climate. These shifts are on one side due to the intensifying of natural phenomena (i.e., volcanic eruptions, sun activity, etc.), and on the other to anthropic activities (i.e., industrial, household, commercial, traffic, etc.).

Currently, several studies describe that climate changes, such as increasing temperature, changing precipitation patterns, and increased frequency of extreme climatic phenomena directly influence the water resources and as well the aquatic ecosystem [1-3]. The human demand for freshwater involves disruptive exploitation in numerous terrestrial and aquatic ecosystems [4, 5]. In addition, drainage and discharge of contaminated waters increase the amount of exogenous chemicals that spread into freshwater ecosystems [6-8]. On the other hand, along with direct anthropogenic effects, climate change has been highlighted as a significant factor in the freshwater transformation process [4, 6, 9]. In this way, freshwater biodiversity is today widely recognized as being seriously threatened as a direct and/or indirect result of the human footprint.

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The effects of climate change are also visible in Romania through the increase in air temperature, through more frequent extreme weather phenomena (prolonged drought, heat waves, storms, floods, tornadoes, etc.). Temperature plays a critical role in the growth and development of aquatic animals [10]. Briefly, aquatic ecosystems are complex communities of plants, aquatic animals, and microorganisms that interact with each other and their environment.

Lentic and semi-lentic freshwater ecosystems are generally isolated and fragmented (i.e., lakes, ponds, lagoons, and marshes in which the water is more or less confined to a fixed area and with very little or limited current from a physical point of view) within large terrestrial landscapes [4, 11]. Aquatic plant diversity abounds in these ecosystems, both floating, emergent, and submerged. On the other hand, freshwater species living in these freshwater ecosystems cannot easily migrate, disperse to a new habitat, or avoid stressors as the environment changes. Because of this reduced likelihood of a successful escape, freshwater species must adapt or perish when faced with environmental fluctuations induced by rising water temperatures.

In Romania, most of the fish production is carried out in ponds, ponds, and reservoirs, through the extensive and semi-intensive growth of cyprinids in polyculture with other species. These systems are very vulnerable and strongly affected by climate change, both directly through problems related to water availability, ensuring the necessary levels in the conditions of increasing water and air temperatures, prolonged drought, evaporation, and extreme weather phenomena, but also indirectly through the physiological stress induced on fish populations, as a result of the increase in temperature, the lack of oxygen, the decrease in the metabolic rate and feeding, the increased incidence of diseases.

Climate change is one of the most important drivers of freshwater transformation, and the effects include changes in the structure and composition of biodiversity and its functioning. Understanding the ability of freshwater species to tolerate environmental fluctuations induced by climate change is essential for the development of adaptation and conservation strategies. Therefore, by studying the adaptation potential of freshwater species, the effects of climate change on biota and, consequently, on the structure and function of ecosystems are understood in depth [4, 9].

In recent years, epigenetic mechanisms have been increasingly invoked in this context, due to their essential role in gene-environment interactions. Environmental conditions to which fish are exposed (e.g., water temperature, pH, and the presence of contaminants), stocking density, and the composition of the diet used in aquaculture are among the factors with potential epigenetic effects.

Epigenetics is the branch of genetics that studies the variation of the phenotypic characters of organisms, due to the changing environmental conditions and implicitly their behavior. Epigenetics has the potential to change, generate, and maintain a phenotype. It is important to consider that epigenetics can also function to disrupt predictable and robust phenotypes by creating unexpected new variations. Epigenetics highlights potentially heritable changes in gene expression that do not involve changes in the DNA sequence. Epigenetic mechanisms act by changing the behavior of genes, inhibiting, or activating their expression, because of some environmental stimuli, without affecting, however, the genome and DNA structures. Changes through epigenetic mechanisms lead to the modulation of gene expression patterns [12]. DNA methylation is the best-known and best-understood epigenetic mechanism in response to variable environmental factors such as temperature, photoperiod, toxins, nutrients, etc. [13]. Epigenetic effects that affect gene expression are triggered by environmental changes and can persist throughout life or over several generations and can affect an individual's phenotype. Phenotypic plasticity widens physiological tolerance ranges under fluctuating environmental conditions when environmental challenge persists over the long term. In such scenarios, the expansion of resistance is rather achieved through genetic adaptation that configures consistent microevolutionary patterns [14]. Epigenetic changes, that is, chemical changes in the genome other than those in the DNA sequence, have been argued to play the role of determinants for both mechanisms of biological response to environmental challenges [15, 16]: (1) the increase in water temperature leads to a decrease in dissolved oxygen; (2) temperatures above the range of physiological thermal tolerance of organisms can cause negative effects on the reproductive processes of fish species;

In the context of climate change, phenotypic plasticity takes on relevance, as this process allows organisms to cope with the unpredictability of environmental stressors over time [17]. Multiple phenotypes resulting from a single genotype allow a wider tolerance of organisms to environmental changes and acclimatization to environmental fluctuations typical of these scenarios.

Artificial ponds are well-known, they are very common worldwide and function much like natural, shallow lentic systems. In addition, the benthos in lentic systems tend to accumulate organic matter and detritus, to offer both a food source and a good habitat for fish. Thorp and Rogers [18] revealed that the set-up sediments of ponds, which have a relatively high organic matter content, gradients of oxygen, redox potential, pH, and other chemicals, are strongly dependent on pond depth.

Taking into consideration that the health and survival of fish species in ponds are based on the quality of aquatic environmental factors (i.e., dissolved oxygen, temperature, and saturation), in a strong correlation with air parameters, this study aimed to highlight the potential influence of the climate changes on the fish habitat in artificial ponds of Nucet Research and Development Institute for Fish Farming (Romania), during of two years, i.e., 2022 and 2023, from May to September.

2. MATERIALS AND METHODS

2.1. SITE DESCRIPTION

The ponds where the monitoring campaigns were performed are located in the middle of the South-West region of Dâmbovița County, belonging to the Nucet Research and Development Institute for Fish Farming (SCDP-Nucet), an institution subordinated to the Gheorghe Ionescu Șișești Academy of Agricultural and Forestry Sciences, with a total area of about 100 ha of water surface, divided into about 90 ponds of different sizes and uses. The fish farm is located near the Ilfov stream, from which it is fed, and the water used in the fish farming process is also discharged into this stream. Among the areas of expertise in which the unit has experience and results are: genetic improvement of cultured carp (through the creation of cross-breeds); conservation and use of freshwater fish genotype for the development of the fish farming - aquaculture sector, and restoration of the fish potential of natural aquatic ecosystems; holds Romania's freshwater fish genebank; promote and make the most modern integrated technologies for farmed fish farming more efficient; provides biological stocking material, which has proven bioproductive qualities to restructure fish production assortments.

In addition to research and development activities, SCDP-Nucet has an important activity in the production of biological material (larvae, juveniles, and broodstock of freshwater fish), as well as technological transfer to the entire fisheries sector.

Figure 1. SCDP–Nucet area.

Within the SCDP-Nucet, the ponds studied (Fig. 2) are artificial earthen ponds with identical surfaces and characteristics. The surface area of a basin is 2.15 ha, with a rectangular shape and an average depth of 1.5 m. It has a volume of about 32250 m^3.

Figure 2. The experimental research center for fish farming Nucet-Cazaci.

Technical constructional and functional characteristics of the ponds involved in the experiment are the ratio of sides: l/L= ½; duration of flooding/dewatering: 12-48 hours; nature of the soils on the bottom of the basin: highly productive alluvial soil complex; groundwater level: 4.00 m below mean ground level.

The bottom of the pond slopes uniformly towards the water outlet. The pond is equipped with water supply and drainage facilities, being gravity-fed/drained from/into the Ilfov stream. These water supply installations are simple reinforced concrete constructions with a specific shape and provided with screens that have the role of filtering the water in the case of the supply installation, and in the case of the discharge installation, have the role of preventing fish material from escaping.

Pond number 1 (Fig. 3.B1) is gravity-fed from the aqueduct on the right-hand side looking downstream through the water supply installation (A), after which the used water is discharged into basin number 2 (B2), and is also the feed water for B2. Through the spillway (E) the water is discharged from the system into another aqueduct located near the one from which water is supplied (B1).

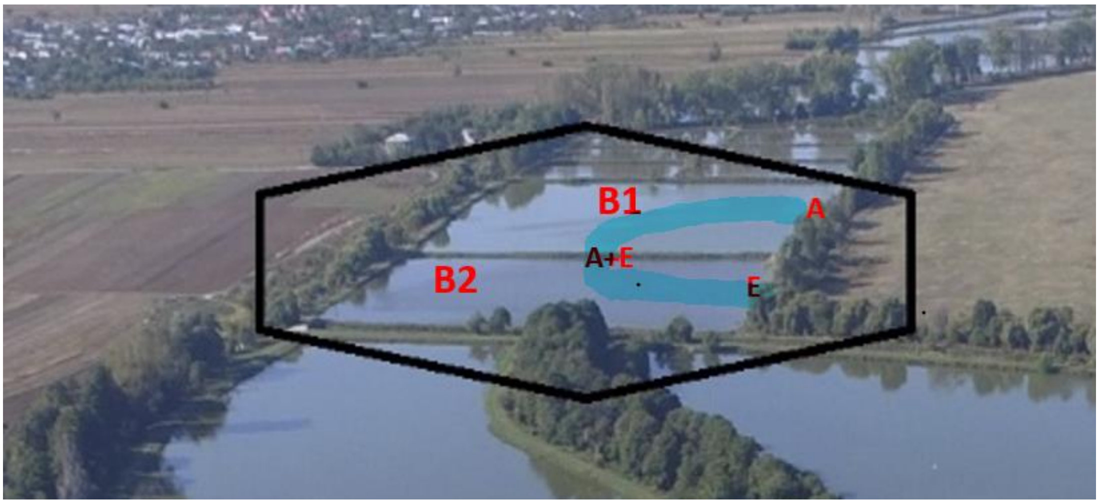


Figure 3. Water supply and discharge scheme in B1 and B2.

Before stocking with biological material (freshwater fish) the ponds are dried, and 10 days before the introduction of the fish, organic fertilizer, well-fermented manure, 3500 kg/ha, evenly distributed, is spread on the surface. Immediately after this work, the basin is flooded to the maximum level, using a 0.5 mm mesh screen on the side.

After flooding, mineral fertilizers are applied to the ponds in such a way that 2 mg/L nitrogen and 0.5 mg/L phosphorus are maintained in the water permanently.

These concentrations can be obtained by distributing per hectare approx. 300 kg ammonium nitrogen and 150 kg superphosphate in repeated doses. Distribution of mineral fertilizers starts on the first day after flooding to stimulate phyto- and zooplankton development. The first dose is 50 kg/ha ammonium nitrogen and 25 kg/ha superphosphate, which is repeated after two days, then the interval between doses is 3-4 days, and the quantities per dose can be reduced to avoid uncontrolled phytoplankton growth in the water.

Optimal environmental conditions must be ensured during the growing season in these ponds, which consist of the following: ensuring optimal water flows, on average 1.5 - minimum 0.8 L/s; controlling the development of planktonic and benthic biomass and stimulating their development by administering mineral and organic fertilizers in doses determined based on physicochemical and hydrobiological analyses of water; monitoring water temperature three times a day, recording it, and making graphs of its variation. In addition to the temperature, any special meteorological phenomena (rain, storm, strong wind, hot spells, prolonged drought) are monitored and noted; control of solute oxygen, which must not fall below 5-6 mg/l; monitoring the state of maintenance and health of the fish stock using monthly or bi-monthly control fishing, where the following parameters are monitored: average individual weight for each species, assessment of the number of juveniles in the pond at the time of the control fishing and the state of health of the fish.

2.2. ANALYTICAL TECHNIQUES

To monitor water parameters (i.e., temperature, oxygen, and saturation) a Hanna instruments HI9829-11042 portable waterproof oxygen meter (Hanna Ltd., Romania) equipped with GPS was used. The dissolved oxygen measurement characteristics (biochemical oxygen consumption is calculated in mg/L by the difference between the initial and final values of the dissolved oxygen concentration) are: measuring range 0 - 50 mg/L (saturation 0-600%), resolution 0.01 mg/L (saturation 0.1%), accuracy - ± 1.5%, automatic calibration in one or two points 100% (8.26 mg/L) and saturation 0% provided with special probe HI764073 DO. The built-in temperature probe has automatic temperature compensation with one or two-point temperature calibration, and a measuring range of -2 - 120°C, resolution of 0.1°C, and accuracy ± 0.2°C (excluding probe error). The local air temperature was provided by the classic monitoring station mounted on the SCDP-Nucet area (Fig. 4).

Figure 4. Classic air temperature monitoring station.

2.3. WEATHER DATA

Whether data (i.e., wind speed, wind direction, atmospheric pressure, and dew point) were taken out from the platform http://freemeteo.ro for all monitored days and times.

3. RESULTS AND DISCUSSION

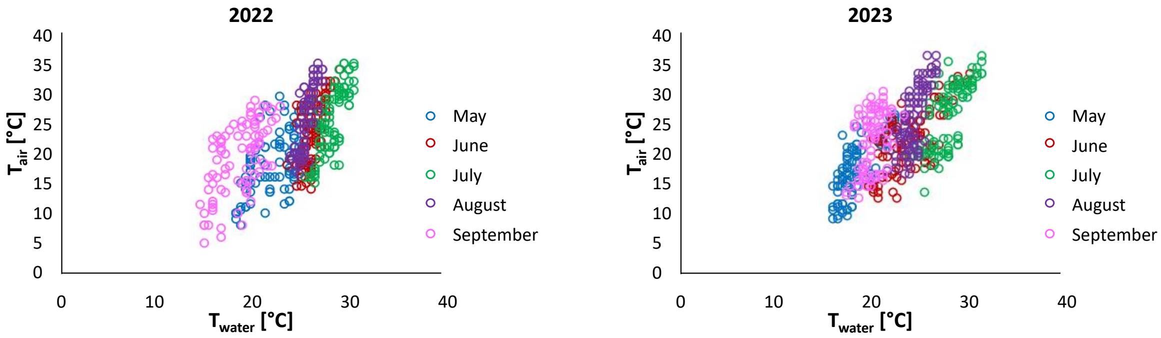
In the period of both monitored years (i.e., 2022, 2023) from May to September, the temperature of air and pond(s) water were recorded daily at 8 a.m., 12 p.m., and 4 p.m. All data were used to obtain the statistical results presented in Table 1.

Table 1. Descriptive statistics of temperature recorded in pond(s) water and air from SCDP-Nucet.

Monitoring period			Minimum	Maximum	Average	Median	Standard deviation
Water	**2022**	May	18.00	25.50	21.87	22.50	2.22
		June	24.00	29.00	26.32	26.00	1.03
		July	25.00	30.00	27.77	28.00	1.29
		August	25.00	28.50	26.76	26.50	0.82
		September	16.50	25.00	21.01	21.50	2.35
	2023	May	16.00	22.50	18.53	18.00	1.82
		June	20.00	30.80	24.43	24.00	2.60
		July	24.00	31.50	28.09	28.00	1.81
		August	23.00	28.50	26.14	26.00	1.22
		September	20.00	27.00	23.11	23.00	1.34
Air	**2022**	May	8.00	29.50	18.78	18.50	5.44
		June	14.00	34.00	23.70	24.00	5.21
		July	15.00	35.00	25.48	25.00	5.57
		August	16.50	35.00	25.76	26.50	5.27
		September	5.00	29.00	18.99	20.50	6.01

Monitoring period			Minimum	Maximum	Average	Median	Standard deviation
	2023	May	9.50	27.00	17.94	17.50	4.68
		June	13.00	34.00	22.63	22.25	5.21
		July	14.00	37.00	27.18	29.00	5.62
		August	17.00	37.00	26.94	27.00	5.40
		September	13.00	31.00	22.65	24.00	4.98

During to the monitoring campaign, the maximum temperature in air was higher in 2023 than in 2022 (except May, i.e., in 2022, it was recorded at 29.5°C, while in 2023, it was 27.0°C). However, the pond water was kept in good temperature condition, with just slight variations from 2022 to 2023. It is easy to remark a variation of +2°C in the air temperature of the summer of the year 2023 compared to the same period of 2022. Because water quality determines the diversity and robustness of ponds [19], all recorded data were used to draw the variation of water temperature *vs.* air temperature graphs (shown in Fig. 5).

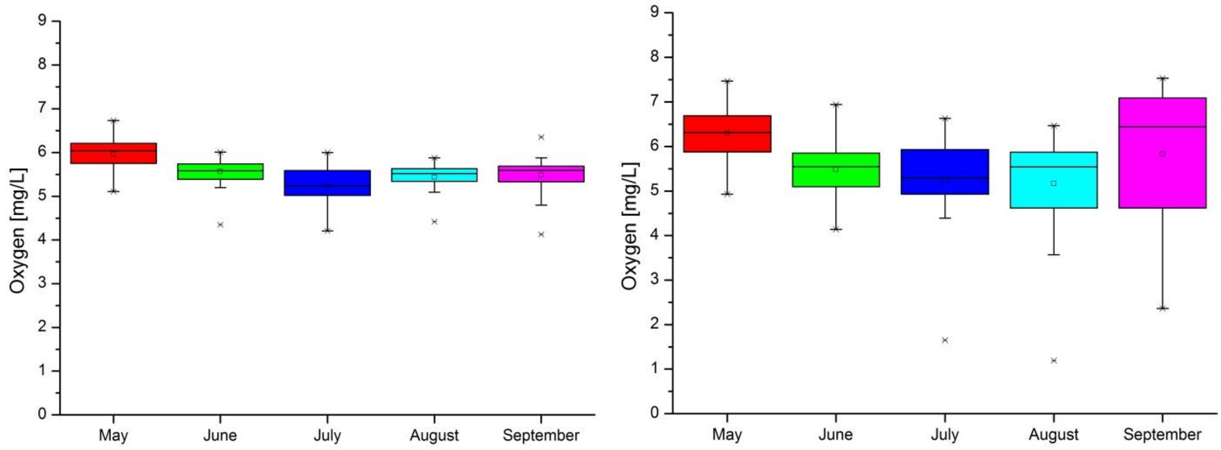


a) **b)**

Figure 5. The temperature of the pond(s) water *vs.* air temperature: a) May-September of 2022; b) May-September of 2023.

Among the most important water parameters that play a key role in the growth and welfare of fish are temperature and dissolved oxygen. Their relationship is very close, with temperature and oxygen influencing each other [20]. In the case of experimental ponds B1 and B2, a lower temperature limit can be observed, which does not drop below 15°C in the monitored months, being months of the warm season. The upper-temperature limit reached the threshold of 30°C, towards the critical limit where turbulence occurs in the foraging process. The optimal average temperature range in which freshwater fish on the farm consume maximum feed is 14 - 28°C [21]. After the 30°C threshold is reached, thermal discomfort occurs, and at the same time, the water chemistry can be influenced by the decomposition processes of uneaten feed, which settles to the bottom of the pond and enters the putrefaction process, resulting in the decomposition of hydrogen sulfide, which must be kept under control [22].

The dissolved oxygen (DO) data were presented in Fig. 6. As it can be seen, in 2022, the DO levels were constant between 4.13 and 6.73 mg/L, while in 2023, the intervals were extensive, from 1.19 to 7.53 mg/L. Due to fluctuations in temperature and dissolved oxygen in the water caused by climate change, fish are among the most capable animals that develop behavioral changes to survive, changing their tolerance ranges constantly in terms of food and oxygen requirements, creating a conservative character in terms of disease susceptibility, being able to minimize body activity to survive a much more extended period under stress-induced conditions [14].

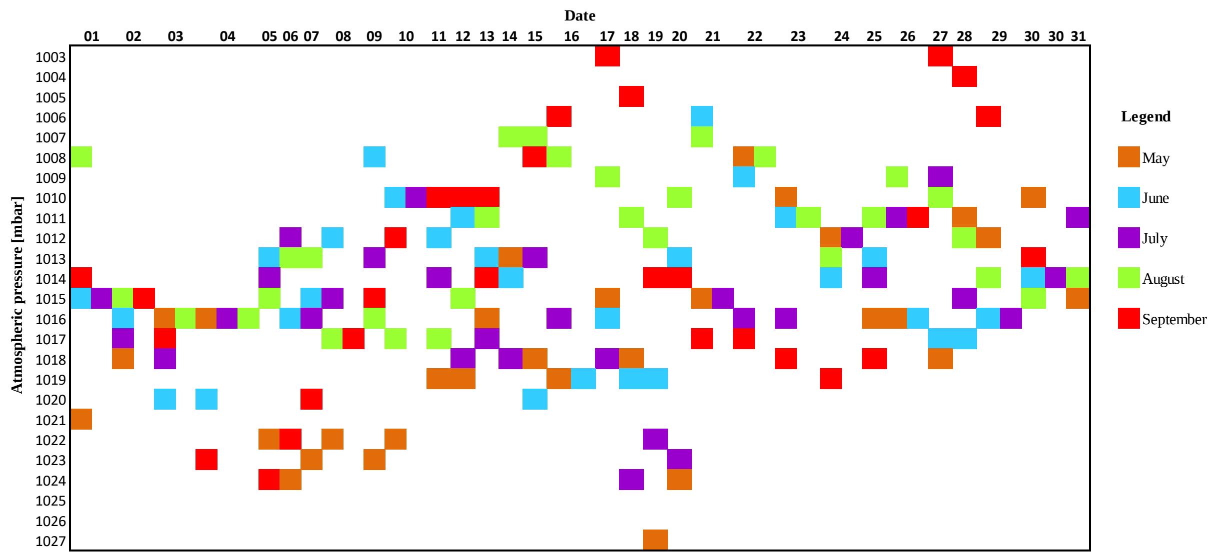


a) b)

Figure 6. Variation of dissolved oxygen in pond(s) water: a) 2022; b) 2023.

In addition to decomposition processes, temperature fluctuations influence the amount of dissolved oxygen in the water. The lower limit of dissolved oxygen in the water is 4-5 mg/L [23]. Oxygen crises in the water occur mainly in the early morning hours and are caused by photosynthesis by plants (phytoplankton and macroscopic vegetation) [24]. Below this threshold value, aquatic populations show visible changes in behavior. In the case of fish, they migrate from the deep layers of the water body to the surface in search of the necessary oxygen, becoming visible and thus drawing attention to the initiation of artificial oxygenation processes. To maintain the dissolved oxygen in the optimal range above 6 mg/L, the first step is to recirculate a quantity of water removed from the system through the spillway while introducing a new flow of clean water from the Ilfov River. If this operation does not change the oxygen concentration in the water, strategically positioned aerators are installed, operating continuously until the problem is remedied.

The pressure that the air applies to the Earth's surface is known as barometric or air/atmospheric pressure [25]. The fish experiences less gravitational pull as the barometric pressure decreases. The atmospheric pressure values for the five months of monitoring in 2022 and 2023 are shown in Fig. 7. The values for atmospheric pressure were lower in September 2022 as well as in August and May 2023.



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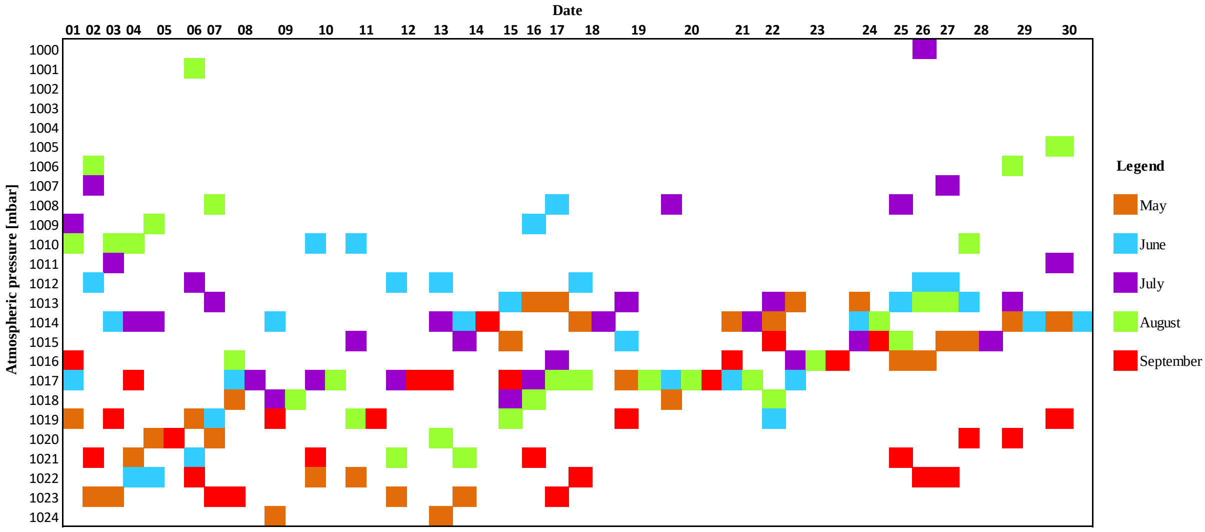
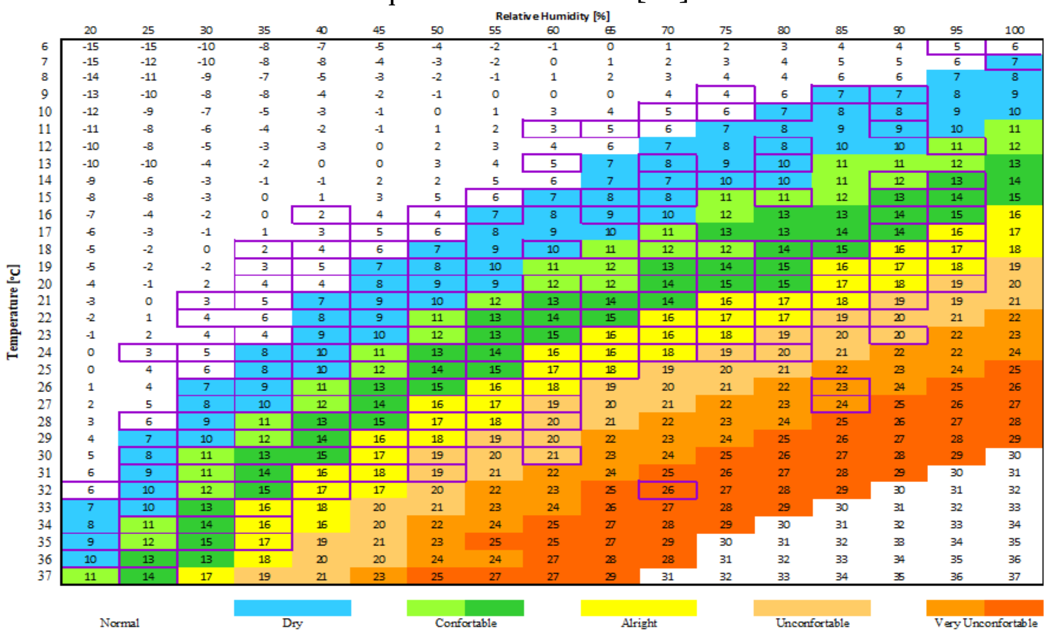


b)

Figure 7. Atmospheric pressure data: a) 2022; b) 2023.

Fig. 7 highlights that the values recorded in 2023 have mostly stable the same in 2023 compared with 2022. This parameter is crucial for the fish culture because the atmospheric pressure influences the changes in oxygen and nutrients. Fish can sense changes in atmospheric pressure with the help of their lateral lines and fins, and their responses to these changes are directly correlated with the conditions that these changes bring [26]. Fish typically sink deeper when atmospheric pressure drops and rise to the surface when pressure increases. Fish consume less food on days of low pressure than on days of constant, high pressure when they tend to feed more to build up a supply of food for days of low pressure [27]. These changes also have effects on fishing. The most downward pressure (1000 mbar) was recorded in 2023 on July 26th, while in 2022, the lowest pressure (1003 mbar) was recorded on September 17th and 27th. If are compare both monitored years, it can be observed that in 2022, low atmospheric pressures were frequently recorded. With the pressure changes, the fish need a longer time interval to adjust to the fluctuations of this parameter. During this period, adaptation to change is delayed. Besides migrating, depending on the species, from the epilimnion to the metalimnion, they require a reconfiguration of the "internal compass" to avoid the inherent obstacles in the aquatic environment [28].



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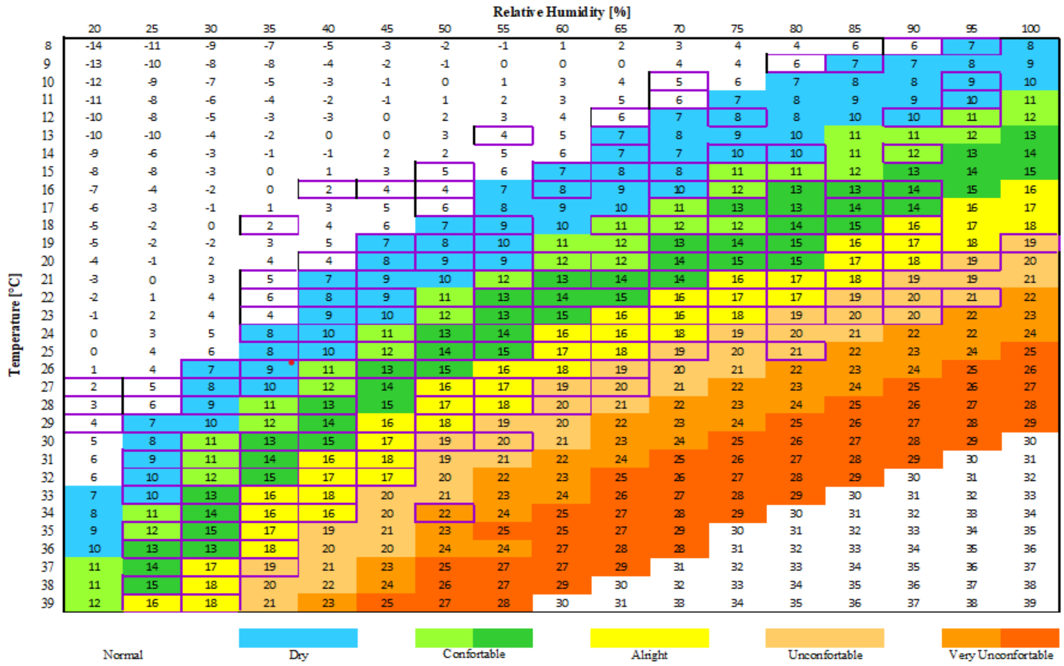


Temperature [°C] \ Relative Humidity [%]	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
8	-14	-11	-9	-7	-5	-3	-2	-1	1	2	3	4	4	6	6	7	8
9	-13	-10	-8	-8	-4	-2	-1	0	0	0	4	4	6	7	7	8	9
10	-12	-9	-7	-5	-3	-1	0	1	3	4	5	6	7	8	8	9	10
11	-11	-8	-6	-4	-2	-1	1	2	3	5	6	7	8	9	9	10	11
12	-10	-8	-5	-3	-3	0	2	3	4	6	7	8	8	10	10	11	12
13	-10	-10	-4	-2	0	0	3	4	5	7	8	9	10	11	11	12	13
14	-9	-6	-3	-1	-1	2	2	5	6	7	7	10	10	11	12	13	14
15	-8	-8	-3	0	1	3	5	6	7	8	8	11	11	12	13	14	15
16	-7	-4	-2	0	2	4	4	7	8	9	10	12	13	13	14	15	16
17	-6	-3	-1	1	3	5	6	8	9	10	11	13	13	14	14	16	17
18	-5	-2	0	2	4	6	7	9	10	11	12	12	14	15	16	17	18
19	-5	-2	-2	3	5	7	8	10	11	12	13	14	15	16	17	18	19
20	-4	-1	2	4	4	8	9	9	12	12	14	15	15	17	18	19	20
21	-3	0	3	5	7	9	10	12	13	14	14	16	17	18	19	19	21
22	-2	1	4	6	8	9	11	13	14	15	16	17	17	19	20	21	22
23	-1	2	4	4	9	10	12	13	15	16	16	18	19	20	20	22	23
24	0	3	5	8	10	11	13	14	16	16	18	19	20	21	22	22	24
25	0	4	6	8	10	12	14	15	17	18	19	20	21	22	23	24	25
26	1	4	7	9	11	13	15	16	18	19	20	21	22	23	24	25	26
27	2	5	8	10	12	14	16	17	19	20	21	22	23	24	25	26	27
28	3	6	9	11	13	15	17	18	20	21	22	23	24	25	26	27	28
29	4	7	10	12	14	16	18	19	20	22	23	24	25	26	27	28	29
30	5	8	11	13	15	17	19	20	21	23	24	25	26	27	28	29	30
31	6	9	11	14	16	18	19	21	22	24	25	26	27	28	29	30	31
32	6	10	12	15	17	17	20	22	23	25	26	27	28	29	30	31	32
33	7	10	13	16	18	20	21	23	24	26	27	28	29	30	31	32	33
34	8	11	14	16	16	20	22	24	25	27	28	29	30	31	32	33	34
35	9	12	15	17	19	21	23	25	25	27	29	30	31	32	33	34	35
36	10	13	13	18	20	20	24	24	27	28	28	31	32	33	34	35	36
37	11	14	17	19	21	23	25	27	27	29	31	32	33	34	35	36	37
38	11	15	18	20	22	24	26	27	29	30	32	33	34	35	36	37	38
39	12	16	18	21	23	25	27	28	30	31	33	34	35	36	37	38	39

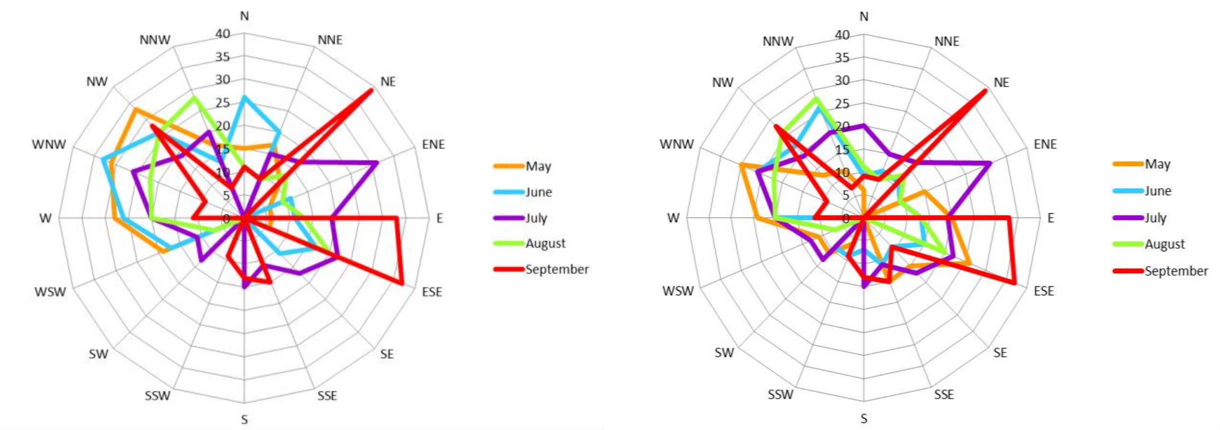
b)

Figure 8. Determination of the dew point according to the temperature and the relative humidity of the air with the indication of the dew point temperature recorded in: a) 2022 and b) 2023.

The relationship between dew point and air temperature is directly proportional [29]. The dew point results from the effect of relative humidity and temperature [30] (Fig. 8). The dew point decreases with increasing pressure; however, in most situations, consideration of relative humidity and pressure-dependent air temperature is adequate [31].

The dew point represents a parameter that directly influences the digestion processes of the fish. With the increase in the temperature of the water implicitly of the dew point, there is an intensification of the metabolism, and the ingestion of food intensifies, thus stimulating the growth of the populated material [21]. In the case of carp, at a temperature of 8-14°C the duration of protein digestion is 20 h, at 26-30°C it is 4-6 hours. Sudden temperature changes can cause fish to die through thermal shock. Given the fact that fish are poikilothermic animals, sudden variations cause stress to individuals, a phenomenon that directly affects the good functioning of the body and the appearance of behavioral abnormalities [32].

The wind speed and direction (Fig. 9) directly influence the fish and, implicitly, their life in the aquatic system [33].



a) b)

Figure 9. Wind rose for the 5 monitored months of: a) 2022 and b) 2023

The faster the wind gusts, the more disoriented the fish are. If the wind gusts are towards the shore, small fish (both shape and weight) are carried towards the shore/dike/shore and become accessible to catch through the nets, and large fish tend to group, making it easier for their fishing with nets [34]. Another consequence of the wind speed is the movement of additional feed from the specially arranged places, the fish being disoriented, and the feed remains unconsumed and rots. As a result, the chemical quality of the water in the fish ponds is also affected [35].

The turbidity of the water and the angle of the sun determine how much light enters the water on a given day [36]. Fish have rod and cone eyes, and the rods are what allow them to sense ambient light levels. Fish eyes differ from human eyes in that they have fixed pupils that cannot dilate because they have no eyelids [37]. Therefore, fish are forced to seek cover, shade, murky areas, or dive to reduce ambient light to levels that are comfortable for them. Oxidative processes of supplementary feed are directly influenced by high temperatures, which are associated with the fish growing season (and thus the feeding period) in the aquatic environment [38].

Fish are most comfortable on the surface during the early morning and late evening when the sun is at a steep angle to the surface of the water. This is because there is less ambient light in the water than there is during other times of the day. The ambient light in the water is lower in the morning and evening than it is during the day due to the angle at which the sun shines on it [39]. Fish will therefore feed more easily in the morning and evening on bright, sunny days than they will during the middle of the day. The amount of ambient light that reaches the water can also be influenced by cloud cover, so fish will feed on cloudy days rather than sunny ones [40]. The climate conditions on the monitored periods are presented in Fig. 10.

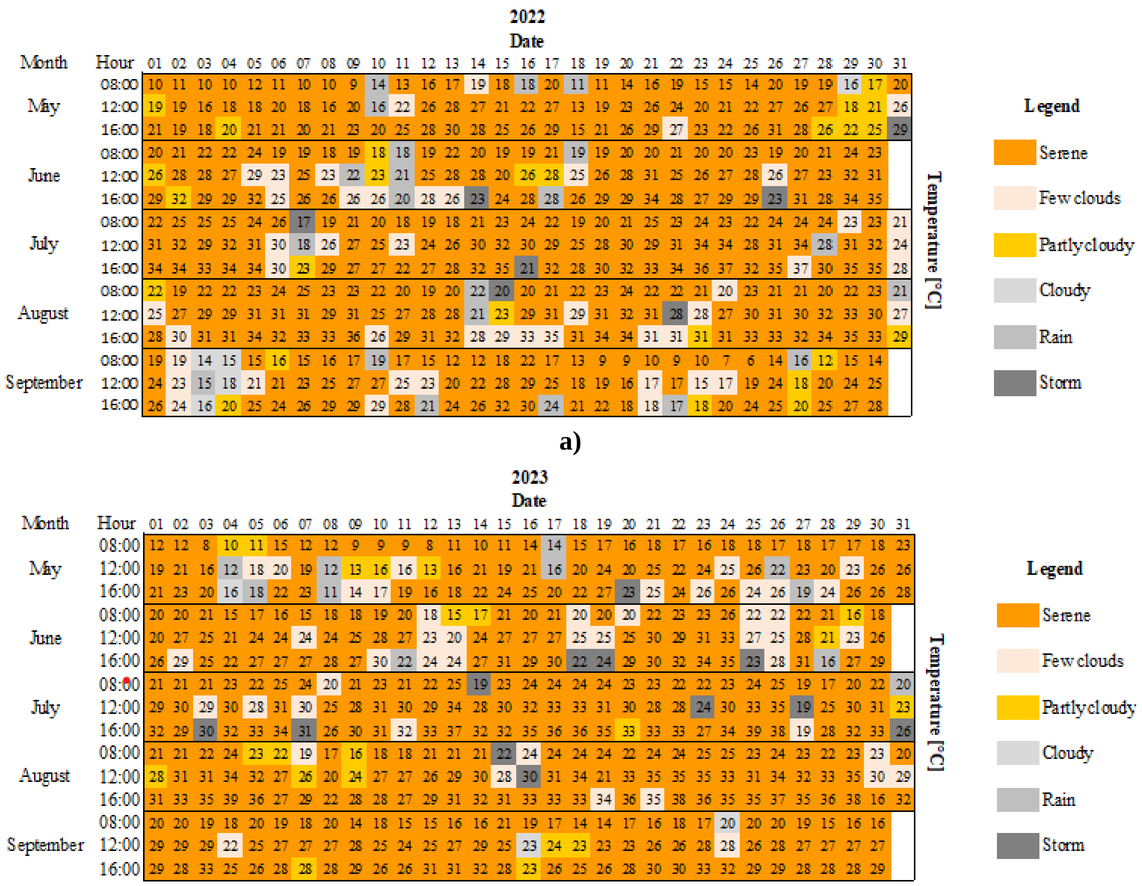


Figure 10. Climate changes recorded in the monitored 5 months of: a) 2022 and b) 2023.

The various hues of light will not be as deeply visible under overcast skies as they would be on a clear day. At high temperatures, accelerated food decomposition processes take place, giving rise to hydrogen sulfide-ammonia, which, accumulating in large quantities, causes the death of fish by asphyxiation. With the high temperature, the amount of dissolved oxygen in the water drops considerably, sometimes below the limit of 4 mg/L. The feeling of hunger is stopped and the fish begin to stop consuming the additional food, directly influencing the decrease in the growth rate of the specimens. The development of natural food (aquatic plants) in the aquatic ecosystem collapses (the period of maximum abundance of phyto/zooplankton is directly correlated to a milder temperature range, in practice (temperatures below 30°C).

4. CONCLUSIONS

Monitoring the aquatic environmental conditions at times is crucial for successful fish farming. In this regard, data obtained by these two monitoring campaigns (i.e., 2022 and 2023, from May to September), in artificial ponds of Nucet Research and Development Institut for Fish Farming, Romania, demonstrated that continuously and accurately measuring water quality parameters in direct relation to climate changes, can lead to timely predictions to forecast potential risks to fish populations and take favorable measures. It can be concluded that the parameters of the pond water (i.e., dissolved oxygen and temperature) were associated with weather data (temperature, pressure, wind speed and direction, dew point) during two years of monitoring campaigns (for each year from May to September), correlated with recorded climate changes data, showed a decrease of dissolved oxygen amount in the water drops considerably, sometimes below the limit of 4 mg/L. In this case, the feeling of hunger is stopped and the fish begin to stop consuming the additional food, directly influencing the decrease in the growth rate of the specimens.

In the future, the obtained historical data on water quality and corresponding fish species survival rates in artificial habitats, related to climate change, obtained in multiple monitoring campaigns, for long periods (e.g., ten years), can offer valuable insights to researchers to take measures to maintain optimal conditions and enhance as much as possible the overall well-being of the aquatic ecosystem.

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