THE IMPACT OF EXTENSIVE AQUACULTURE OVER THE QUALITY OF THE AQUATIC ENVIRONMENT

Elena Mocanu[1*], N. Patriche[1], Magdalena Tenciu[1], Veta Nistor[1], V. Eşanu[1]

[1]Institute of Research and Development for Aquatic Ecology, Fishing and Aquaculture of Galati, Romania

Abstract

The present paper presents the study results regarding the impact of extensive aquaculture on aquatic environment quality. The study was carried out at Cotu Chiului Research and Development Farm. The facility is located in the northern part of Galati county, adjacent to the pier-shore area of the Prut River Dam, in the km 36 protected natural area. The aquatic species 'structure and age stages of the biological material from Cotu – Chiului farm, is divided as follows: 51% goldfish, 19% catfish, 4% carp at different age stages, 26% plant feeder fish. Different indicators with high levels of pollution potential, such as nitrogen compounds (NO^{2-}, NO^{3-}, NH^{4+}), phosphorus and organic matter, have been monitored to be able to evaluate the physical-chemical changes of the aquatic life environment from Cotu Chiului farm. The study has been carried out on monthly water and soil samples, over the period of one year. The samples were collected from three growth ponds (EC1, EC2, EC3) which have similar morpho-hydrographic characteristics.

The study concluded that: - EC1 (December and November) - maximum values of nitrites (0.132±0.016 mg/l) and ammonia (0.142±0.008 mg/l), - EC 2 (July) - maximum concentration of phosphorus (0.07±0.004 mg/l), - EC1 and EC3 (August), EC2 (January) - high values of organic matter accumulations (96.63±0.1 mg/l) and respectively (91.95±0.12 mg/l). The physical-chemical parameters of the soil samples taken have registered the same evolution tendencies as the water characteristics from Cotu Chiului farm.

Key words: pollutant, extensive aquaculture, environment

INTRODUCTION

The quality of the aquaculture environment is an important component for the breeding technologies that improve the biologic material.

This paper presents the results of the monitoring study undertaken at Cotu Chiului farm to evaluate the physical – chemical indicators with a pollutant potential. The parameters that were monitored are the nitrogen compounds (NH_3, NO^{2-}, NO^{3-}, NH^{4+}) with phosphorus (PO_4^{3-}) and organic matter.

Nitrogen and phosphorus compounds increase the water toxicity levels affecting the aquaculture environment. Hence, their concentrations are limited by the Order of MEWM (Ministry of Environment and Water Management) no. 161/2006 [6] which deals with the classification of surface water quality in order to determine the ecological status of water areas.

The Cotu - Chiului Experimental Base, one of the Fisheries Development Facilities of the Research and Development Institute for Aquatic Ecology, Fisheries and Aquaculture Galati, has a total area of 112.18 ha, of which 100 ha of water areas distributed in three growth ponds: EC1, EC2, EC3.

The arrangement is located in the natural protected area - Lower Prut Floodplain Natural Park, according to HG 2151 of 2004, about 4.5 km from the Vlascuta Lake Nature Reserve.

The technological water supply is done gravitationally between February and May, using the Prut River, when the water level of the river allows it. The discharge of technological wastewater is done gravitationally through the outflow channels in the Prut River.

The main activities carried out in the Cotu - Chiului Experimental Base involve :

[*]Corresponding author: icpmocelena@yahoo.com
The manuscript was received: 18.09.2018
Accepted for publication: 25.10.2018

- the growth of young fish specimens in the first, second and third summer **in the natural regime**
- the selection of the breed stock
- the wintering of the whole fish stock.

The study regarding the monitoring of water physicochemical parameters started as a need to convert extensive aquaculture into ecological aquaculture. At the Cotu - Chiului Experimental Base no fertilizers are administered and the growth of the biological material up to the required commercial size is exclusively done using the natural productivity of the basins.

The collection of water samples was done with a monthly frequency, from March 2017-february 2018. Sediment samples were taken quarterly over the same period of time and the samples were deposited in refrigerating bags and conserved at 4^0C until analysis.

The biological material used for the autumn fish population is one summer old and two summer old fish of the East Asian Cyprinids species, silver carp, bighead and grass carp, and predeveloped young catfish and carp.

During the study period, the species and age structure of the biologic material from the three ponds were divided as follows : 51% goldfish, 19% catfish, 4% carp at different age stages, 26% plant feeder fish.

MATERIAL AND METHOD

The water analysis was carried out according to the work protocols established in the standard methods of surface water analysis [7]. The mud samples have been mixed to obtain a watery mixture (soil/solvent=1/10), and then analysed using the specific chemical analysis methods [7].

The pH determination has been in accordance with SR ISO 10523:1997 using a laboratory pH-metre INO Lab pH 720. with a temperature scale incorporated.

The determination of chemical consumption of oxygen has been completed using SR ISO 6060:1996 standard.

The nitrogen and phosphorus compounds have been determined using the Standard Methods for the Examination of Water and Wastewater/2005 with a spectrophotometer DR 2800 using LANGE as the water quality kit.

From each pond there were 3 samples taken and they were analysed using two exhibits from each sample.

The statistical analysis was carried out by means of Excel tools. The average values are reported together with their standard deviations. The statistical interpretation of the considered data, shows a variation within the allowable threshold of $P<0.05$.

RESULTS AND DISCUSSION

In the reference period, the physical parameters of the water, the **pH** and the **temperature** (Table 1), were included in the normal values for each season, with small variations between ponds and very close to the average [8].

Table 1 Evolution of pH and temperature during March 2017 – February 2018, at Cotu - Chiului Experimental Base

Month 2017–2018	pH (upH)			Temperature (^{0}C)		
	Minimum	Maximum	Median±*SD**	Minimum	Maximum	Median±*SD**
March	7.9(EC1)	8.4(EC3)	8.16±0.205	11.6(EC1)	12.2(EC3)	11.93±0.249
April	8.4(EC3)	8.5(EC2)	8.46±0.047	14.5(EC3)	15.3(EC1)	14.93±0.329
May	8.6(EC1)	8.7(EC2)	8.66±0.047	22.7(EC3)	23.6(EC1)	23.1±0.374
June	8.8(EC1;EC2)	8.9(EC3)	8.83±0.047	21.8(EC3)	22.5(EC1)	22.1±0.294
July	8.7(EC1)	8.9(EC3)	8.8±0.081	19.8(EC3)	22.2(EC1)	20.0±0.163
August	8.8(EC1)	9.0(EC2;EC3)	8.93±0.094	27.6(EC3)	28.5(EC1)	28.03±0.368
September	8.7(EC1)	8.9(EC2;EC3)	8.83±0.094	14.8(EC3)	15.4(EC1)	15.06±0.249
October	8.63(EC1)	8.85(EC3)	8.77±0.099	8.8(EC3)	9.2(EC1)	9.0±0.163
November	8.17(EC2)	8.31(EC3)	8.24±0.057	4.3(EC3)	4.8(EC1)	4.53±0.205
December	8.16(EC1)	8.37(EC.3)	8.28±0.091	4.2(EC3)	4.7(EC1)	4.46±0.205
January	8.29(EC1)	8.38(EC2)	8.33±0.037	3.7(EC3)	4.3(EC1)	4.0±0.244
February	8.46(EC1)	8.76(EC3)	8.61±0.122	6.5(EC3)	7.5(EC1)	7.0±0.408

** Standard deviation*

For aquatic organisms, the recommended water pH values are between 6.5 and 8.5 upH [8]. In August 2007, the water showed a pronounced alkaline character, the pH reaching the value of 8.93±0.094, being known that these values indicate an intense biological activity.

The sediments pH had a soft alkaline reaction:

- minimum at EC1 pond in April: 7.7±0.04 upH;
- maximum at EC1 pond in August: 8.5±0.08 upH (Table 2).

Table 2 Variation of physical – chemical parameters to the sediments during March 2017 – February 2018, at Cotu - Chiului Experimental Base

Analyzed parameters	U.M.	April-2017			August-2017			November-2017			February-2018		
		EC1	EC2	EC3	EC1	EC2	EC3	EC1	EC2	EC3	EC1	EC2	EC3
pH	upH	7.7 ±0.04	7.9 ±0.04	7.8 ±0.05	8.5 ±0.08	8.2 ±0.09	8.1 ±0.09	8.0 ±0.05	7.96 ±0.05	8.03 ±0.05	8.29 ±0.12	8.30 ±0.1	8.34 ±0.12
Organic matter	mg $KMnO_4$/ 100g sol	23.76 ±0.12	26.26 ±0.07	25.01 ±0.16	110.92 ±0.125	49.4 ±0.17	45.22 ±0.18	123.75 ±0.178	36.93 ±0.16	76.53 ±0.11	130.31 ±0.22	98.75 ±0.12	77.58 ±0.17
Nitrites	mg/ 100g sol	0.132 ±0.002	0.132 ±0.002	0.132 ±0.002	0.053 ±0.005	0.028 ±0.002	0.029 ±0.006	0.029 ±0.005	0.008 ±0.002	0.013 ±0.003	0.076 ±0.004	0.042 ±0.002	0.029 ±0.006
Ammonium	mg/ 100g sol	0.388 ±0.021	0.570 ±0.02	0.381 ±0.029	1.570 ±0.024	1.256 ±0.04	0.201 ±0.04	15.29 ±0.257	13.690 ±0.030	2.150 ±0.091	4.58 ±0.163	5.470 ±0.127	1.710 ±0.122
Nitrates	mg/ 100g sol	1.030 ±0.082	0.250 ±0.036	0.250 ±0.024	1.085 ±0.044	0.252 ±0.95	0.314 ±0.034	1.012 ±0.08	0.350 ±0.143	0.500 ±0.224	1.024 ±0.033	0.500 ±0.098	undetected
Phosphates	mg/ 100g sol	0.173 ±0.014	0.250 ±0.040	0.085 ±0.004	0.195 ±0.028	0.515 ±0.049	0.070 ±0.016	0.185 ±0.020	0.300 ±0.040	0.080 ±0.016	0.192 ±0.010	0.153 ±0.008	0.090 ±0.008

The results show that the variation of temperature and pH follows the same evolution tendency. During this period, in the same time with the temperature increase, aquatic organisms and submerse vegetation start to grow which triggers several processes and chemical transformations changing the acid-base equilibrium of the ponds.

The content of **oxidable organic matters**, measured in mg $KMnO_4$/l, has varied between values below the maximum accepted for aquatic organism waters (60 mg $KMnO_4$/l) and values above this limit. The minimum and maximum values determined in the water samples were:

- EC1 pond, minimum in March - 29.07±0.13 mg $KMnO_4$/l and the maximum was in August 96.63±0.12 mg $KMnO_4$/l, above the maximum value accepted of 60 mg $KMnO_4$/l;
- EC2 pond, minimum in March 45.60±0.12 mg $KMnO_4$/l and maximum in January 91.95±0.12 mg $KMnO_4$/l, above the maximum value accepted;
- EC3 pond, minimum in April 45.03±0.14 mg $KMnO_4$/l and maximum in August 96.63±0.01 mg $KMnO_4$/l [5], above the maximum value accepted (Figure 1).

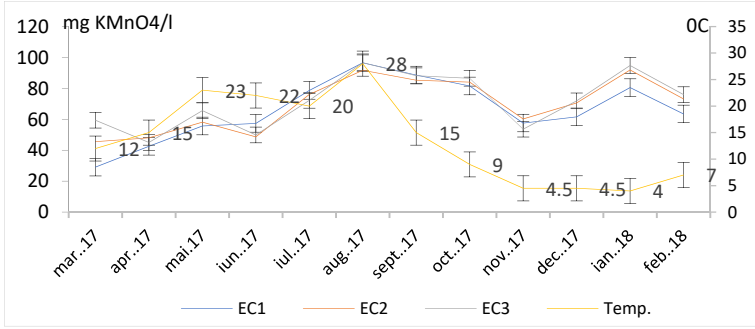

Fig. 1 The evolution of organic matter and of temperature during March 2017 – February 2018 at Cotu - Chiului Experimental Base

During the analysed period, the chemical consumption of oxygen to the permanganate potassium alternate between 10.63 mg O_2/l and 24.16 mg O_2/l, hence, the water from the pond has been placed in the quality class II – IV, according to Order of MEWM No.161/2006[1] regarding the classification of surface waters quality.

Obviously, all ponds, quantity of organic matters was the highest in August, a period when the development of algae and aquatic vegetation was higher.

In EC1 pond, the high value of the organic matter during January 2008 is determined by the mud and the dead vegetation concentration which is specific to the lower temperatures. In EC2 and EC3 ponds the high value of organic matter is justified by the decomposition of the unconsumed food.

In sediments (Table 2), organic substances present the following minimum and maximum values: at EC1 pond - values of 23.76±0.121 mg $KMnO_4$/100g soil were determined in April and in February 2008, 130.31±0.225 mg $KMnO_4$/100g soil [3]. All other ponds registered intermediate values.

At high temperatures, oxygen concentrations are reduced, and the transformation of the organic substance obtained from the physiologic activity of organisms and aquatic vegetation it's not triggered properly. On the other hand, during a warm winter, with high temperatures, the accumulation of organic matters, resulted from the aquatic plants mineralization usually registers a significant increase.

The content of **ammonia** in the water registered during this study, in mg/l (Figure 2), is lower than the maximum value which becomes toxic for fish species (0.2 mg/l).The following minimum and maximum values were recorded:

- EC1 pond - 0.0046±0.006 mg/l in December and 0.142±0.008 mg/l in November;
- EC2 pond - 0.0066±0.007 mg/l in December and 0.118±0.006 mg/l in November
- EC3 pond - 0.007±0.005 mg/l in December and 0.158±0.004 mg/l in November [12].

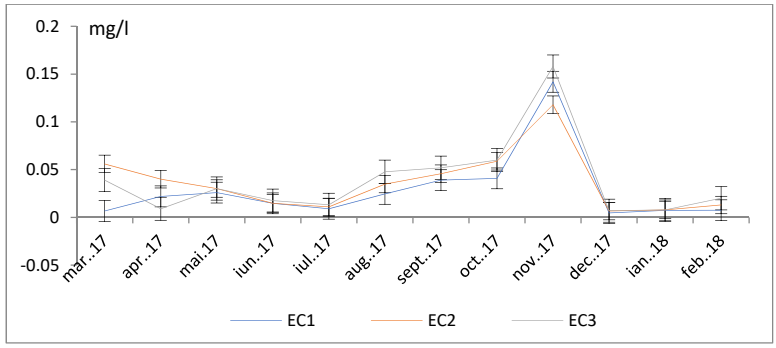

Fig. 2 The evolution of ammonia content during March 2017 – February 2018 at Cotu - Chiului Experimental Base

The ammonia concentration in the sediments (Table 2) registered high values in February 2008 (4.58±0.163 mg/100g soil at EC1 pond and 5.470± mg/100g soil at EC2 pond) [3].

Nitrites (Figure 3) have registered values lower than the maximum accepted value for all stations, in many situations no nitrates concentrations were detected[8]. The highest value was determined at EC1 pond in December: 0.132±0.016 mg/l. From this point of view, the water quality has been classed in quality classes I – III, according Order of MEWM no. 161/2006 demands [6].

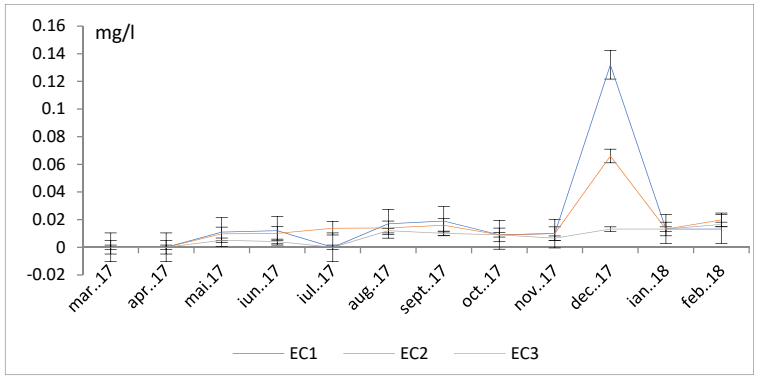

Fig. 3 The evolution of nitrites values during
March 2017 – February 2018 at Cotu - Chiului Experimental Base

In sediments, nitrites concentrations were present in all samples, with the lowest value determined at EC2 pond: 0.008±0.002 mg/100g soil and the highest value of 0.132±0.002 mg/100g soil, in April at all ponds (Table 2).

The maximum values of the nitrites concentration have been registered in December, respectively for ammonia in November. Both concentrations have not exceeded the maximum accepted limits recommended for aquatic environments.

The fish population developed at Cotul Chiului farm using biological material was affected by the fishing activities carried out during November with fishing nets. [10]. The sediments and benthonic organisms were disturbed through the fishing activities, hence the movement of the organic biodegradable material has intensified and this action produced an increase in ammonium and ammonia values in November in the EC1, EC2 and EC3 ponds, to maximum values ever recorded. This increase is important because it is significantly higher than the values recorded throughout the study period ($P<0.05$) [13].

The phosphates, measured in mg/l, have registered the following minimum and maximum values:

- EC1 pond – minimum was of 0.022±0.005 in August and maximum of 0.055±0.003 in July;
- EC2 pond – minimum was of 0.027±0.002 in August and maximum of 0.070±0.004 in July;
- EC3 pond – minimum was of 0.017±0.003 in August and maximum of 0.059±0.002 in July (Figure 4).

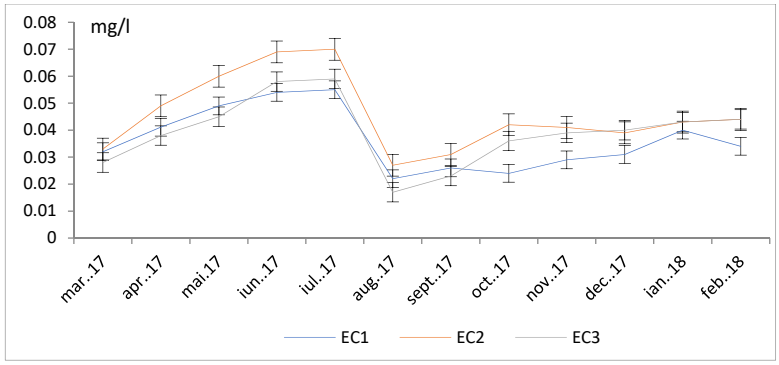

Fig. 4 The evolution of phosphate ions during
March 2017 – February 2018 at Cotu - Chiului Experimental Base

The phosphates ions values are lower than the maximum accepted values for aquatic environments, hence the water quality is in class I, according to Order MMGA no. 161/2006 regarding the quality classification for surface waters; but, however looking at the fish productivity, the water lacks the neccessary nutrients.

There is an important difference between phosphates values recorded from July to August ($P<0.05$). The large values of phosphates from June and July increase the development of plankton which caused the phosphate depletion starting with August [2]. The lack of fertilizers lead to low levels of phosphates ions in the next months [5].

The sediments also contain reduced quantities of phosphates (Table 2), the lowest value registered in August at EC3 pond – 0.070±0.016 mg/100g soil and the highest value still in August, but at EC2 pond – 0.515±0.049 mg/100g soil samples. Considering the reduced quantities of nutrients present, we can draw the conclusion that the productivity of the pond is reduced [11].

The ammonium values, in mg/l, registered in the analyzed period, are presented below:

- EC1 – 0.051±0.002 in July and 1.158±0.003 in November
- EC2 –0.049±0.002 in July and 1.189±0.004 in September
- EC3 – 0.046±0.002 in July and 1.142±0.004 in November (Figure 5)

The maximum values registered are lower than the maximum value accepted, of 2 mg/l. Over this value the ammonium contain become dangerous, especially in conditions with high values of pH, when a part of ammonium ions found in the water is toxic ammonia. [9, 4].

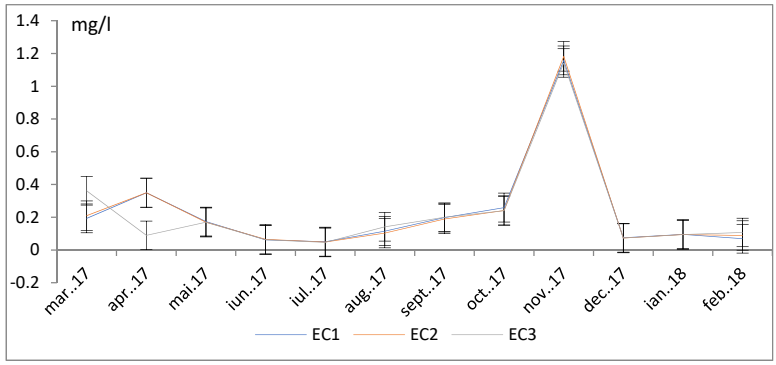

Fig. 5 The evolution of the concentration of ammonium ions during March 2017 – February 2018 at Cotu - Chiului Experimental Base

The water from Cotu Chiului farm is inscribed in quality classes between I la IV, with recorded variations from one month to other, during the whole studied period. The assessment has been made in accordance with the ammoniac nitrogen levels, according to Order of MEWM no. 161/2006 regarding the quality classification for surface waters.

For sediments, the ammonium ions registered different values (Table 2), the maximum values are significantly higher than the accepted values. These values were determined in February and especially in November at EC1 and EC2 ponds, values which were reflected also by the ammonium quantity, present in the water in that period.

The **nitrates values**, in mg/l registered in water samples from the three ponds are presented below:

- EC1 - minimum value was of 0.65±0.09 in March 2007 and maximum - 0.90±0.04 in February 2008;
- EC2 - minimum value was of 0.50±0.03 in February and maximum - 1.09±0.06 in August;
- EC3 minimum value was of 0.60±0.04 in February and maximum 0.968±0.05 in August (Figure 6) [9, 5].

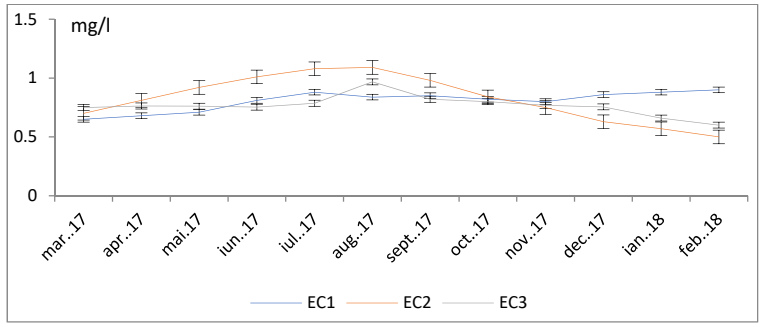

Fig. 6 The evolution of the concentration of nitrate ions during March 2017 – February 2018 at Cotu - Chiului Experimental Base

The nitrate ions water concentrations are reduced; hence the sampled water is classed in class I for quality, according to Order of MEWM no. 161/2006. However, regarding the productivity of the ponds, the water sampled lacks in nutrients [9].

For the sediments samples taken (Table 2), the values of nitrate ions were different, hence no records of nitrates were detected in February at EC3. Maximum values under the values for productive muds were recorded in August, of 1.085±0.044 mg/100g soil, at EC1 [10].

The values of some chemical-physical parameters, close to the highest values, also appear in bad conditions of aeration [4]. The high concentration of organic substance is specific to aquatic environments that do not have a permanent water supply and this supply of water can't be provided every time the climate conditions requires it (extended periods of drought and high temperatures in the summer months).

CONCLUSIONS

•The summer period has been highlighted as the most sensitive period, where values that exceed the reference values for the main water and soil physical-chemical indicators have been registered.

•The water temperature increase determines and increase tendency for the pH values.

•The water temperature increase during the summer period determined a slight increase of the organic matter, however these values align with values also registered during January 2018.

•Toxic substances represented by nitrites and ammonia values which were detected in quantities below the accepted limits do not represent a risk factor for the fish species.

•During November, the fishing activities carried out using fishing nets and the supply of additional fish stock in the three ponds have generated a negative impact on the ecosystem, disrupting the sediments and the benthic organisms.

•All applied technologies in extensive aquaculture did not have pollutant effects on the quality of the water in the three ponds.

•Concerning the concentration of organic substance, the nitrogen and phosphate compounds in EC2, EC2 and EC3 growth ponds, in terms of their recorded concentrations have been always under the maximum allowed value.

•The study's results were interpreted in accordance with Ord. MMGA nr.161/2006 which represents the Romanian normative document that ensures the European Directive is respected.

•From the physic-chemical point of view, the water at the Cotu Chiu Aquaculture Unit corresponds to the physiological needs of aquatic organisms in ponds. The river tributary waters do not inflict a negative impact upon the natural receiver (the Prut River), which indicates that it is possible to sustain out the ecological production of fish.

•The macrophyte vegetation resulting from the maintenance of the hydro technical works represents a fraction of the food mass for the phytophagous species, the rest being used as a natural fertilizer to enrich the aquatic

environment demands. This practice is used to support the required premises for the implementation of ecological fish farming in the Cotu - Chiului Experimental Base.

ACKNOWLEDGEMENT

This paper was financed by the Sectoral Plan ADER 2020 (MADR), project number 10.2.1/01.10.2015, „Elaboration and implementation of a monitoring program, to reduce pathological risks in aquaculture, to reduce losses and to ensure animal health and welfare".

REFERENCES

[1] Boyd C.E., Tucker C.S., 1998: Pond Aquaculture Water Quality Management.
[2] Boyd C.E., Tucker C.S., Station A.A.E., 1992: Water Quality and Pond Soil Analyses for Aquaculture.
[3] Hargreaves J.A., 1998: Nitrogen biogeochemistry of aquaculture ponds. In Aquaculture,166 (3-4), 181-212
[4] Kumar S., Sterner R.W., Finlay J.C., Brovold S., 1987: Spatial and Temporal Variation of Ammonium in Lake Superior.
[5] Milstein A., Hephert B., Teltch B., 2008: The effect of fish species combination in fish ponds on plankton composition. In Aquaculture Research, 19 (2) 127-137
[6] Order MEWM (Ministry of Environment and Water Management) no. 161/2006 regarding the classification of surface water quality in order to determine the ecological status of water bodies.
[7] Popa P., Patriche N., Mocanu R., Sarbu C., 2001: The aquatic environment quality-Explication and control methods. Bucharest 11-70
[8] Pote J.W., Cathcart T.P., Deliman P.N., 1990: Control of high pH in aquacultural ponds. In Aquacultural Engineering, 9 (3) 175-186
[9] Sardessai S., Sundar D., 2007: Variability of nitrate and phosphate, National Institute of Oceanography, Goa, pp 59–66
[10] Schneider O., Sereti V., Eding E.H., Verreth J.A.J., 2005: Analisys of nutrient flows in integrated intensive aquaculture systems. In Aquacultural Engineering, 32 (3-4), 379-401
[11] Shrestha K.M., Lin C.K., 1996: Phosphorus fertilization strategy in fish ponds based on sediment phosphorus saturation level. In Aquaculture, 142 (3-4) 207-219
[12] Sriyasak P., Chitmanat C., Whangchai N., Promya J., Lebel L., 2015: Effect of water de-stratification on dissolved oxygen and ammonia in tilapia ponds in Northern Thailand, International Aquatic Research, Volume 7, Issue 4, pp 287–299
[13] Sriyasak P., Whangchai N., Chitmanat C., Promya J., Lebel L., 2014: Impacts of climate and season on water quality in aquaculture ponds. KKU Res J 19(5):743–751