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THE EFFECT OF PHYSICO-CHEMICAL PARAMETERS AND NUTRIENTS ON FISH GROWTH IN NARTA LAGOON, ALBANIA

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Abstract

The lagoons are one of the most productive ecosystems in the world. They are very important economically in fishing, ecological tourism, and agriculture and for scientific researches. The quality of lagoon water affects the species composition, their abundance and productivity of water and the human health as well because of the food chain. Water quality is defined in terms of the chemical, physical and biological contents of the water. Important physical and chemical parameters influencing the aquatic environment are temperature, pH, salinity, dissolved oxygen and redox potential. Others are total suspended and dissolved solids, nutrients, heavy metal contaminants, etc. These parameters are the limiting factors for the survival of aquatic organisms (flora and fauna). In this context, a study was conducted to evaluate how the physico-chemical parameters (pH, temperature T, dissolved oxygen DO, redox potential E, total suspended solids TSS, total dissolved solids TDS, salinity etc) of water and nutrients (N-NO2-, N-NO3- N-NH4+ and P-PO43-) affects the growth of fish in Narta Lagoon. This Lagoon, situated in the southern part of Albania, is one of the most important aquatic ecosystems due to its ecological values and fish farms.

Water samples were collected in five sampling points as follows: four samples within the lagoon and the fifth one in the channel that connect the lagoon with the sea. The physical-chemical parameters of water were determined immediately after the samples were taken to the laboratory. Conductivity, salinity and TDS were determined with a conduct meter (Model DDSJ 308A). pH and temperature, were measured with a pH meter (Model pHS-3BW). TSS (total suspended mater) was determined by pouring one liter volume of water through a pre-weighed filter of 0.42 μm pore size, then weighing the filter again after drying it at 105°C for 2 hours to remove all water. The concentration of dissolved oxygen (DO) was determined using Winkler method. Nutrients (nitrites, nitrates, ammonium and phosphates) contents were determined by spectrophotometric methods.

In general, physico-chemical parameters including dissolved oxygen (DO), resulted in normal levels. High concentration of TSS compared to European Directives for ciprinide waters, might have negative effects in photosynthetic processes and the production of dissolved oxygen in water.

Based on the results of inorganic nutrients content in water, it is shown that Narta Lagoon is characterized by generally oligotrophic conditions and is suitable for fish growth.

***Key words**: Narta lagoon, Physico-chemical parameters, Nutrients, Fish growth, Food chain.*

1. Introduction

Water quality is pointed as an important factor to the success or failure of a fish culture operation (Piper *et al*. [1]). Moreover in restricted exchange environments, there is a risk of high levels of nutrients that may cause the eutrophication of water and may potentially create undesirable effects to fish life (MacGravin [2]; Carrol *et al*., [3]) by decreasing the oxygen content in water. It is found that the mortality of rainbow trout may initiate at DO content below 3.0 mg L^{-1} (Summerfelt [4]). The increase in the input of nutrients to the marine system represents a serious threat to the integrity of marine ecosystems and the resources they support. The ammonium (NH_4^+), nitrite (NO_2^-) and nitrate (NO_3^-) are the most common ionic forms of dissolved inorganic nitrogen in aquatic ecosystems.

Fish is an inexpensive source of proteins and an important cash crop in many regions of the world, and water is the physical support in which they carry out their life functions such as feeding, swimming, breeding, digestion and excretion (Bronmark and Hansson [5]). So, good water quality is very essential for survival and growth of fish (Bhatnagar and Devi [6]). Water quality is defined in terms of the chemical, physical and biological contents of the water. Some important physical and chemical parameters influencing the aquatic environment are temperature, pH, salinity, and dissolved oxygen. Others are total suspended and dissolved solids, total alkalinity and acidity and heavy metal contaminants. These parameters are the limiting factors for the survival of aquatic organisms (flora and fauna). Poor water qualities may be caused by low water flow, municipal effluents and industrial discharges (Chitmanat and Traichaiyaporn [7]). All living organisms have tolerable limits of water quality parameters in which they perform optimally. A sharp drop or an increase within these limits has adverse effects on their body functions (Davenport [8]; Kiran [9]). Poor water quality can result in low profit, low product quality and potential human health risks. Production is reduced when the water contains contaminants that can impair development, growth, reproduction or even cause mortality to the cultured species. Some contaminants can accumulate to the point where it threatens human health even in low quantities and cause no obvious adverse effects. (PHILMINAQ [10]) Aquaculture, fish-trawling, chemical pollution, and sewage discharges are the most common sources of human impacts that affect biodiversity and the good and services it provides at regional scales (EEA [11]).

The lagoons are one of the most productive ecosystems in the world. They are very important economically in fishing, ecological tourism, and agriculture (Summerfelt [4]) and for scientific researches. Narta Lagoon is one of the most important coastal ecosystems in Albania. It is located in the northwestern part of Vlora district, Adriatic Sea, with geographical coordinates: 40° 32′ N latitude, 19° 28′ E longitude. Narta Lagoon is one of the largest lagoons in Albania with an area of 2670 ha. The maximum depth is 0.9 m with an average of 0.7 m. Water exchange with the sea takes place through a channel with reduced water input (1 - 5 m^3/sec) during the tide (Lami [12]). The Narta Lagoon is under consistent and sometimes severe pressure from diverse forms of human activities. The sources of pollution in the lagoon vary from industrial effluents such as the discharges in the past of a chlorine-alkali plant near Narta Lagoon, to domestic sewage from the surrounding inhabited areas and eutrophication due to urban and agricultural pollution. Moreover, Vjosa river, which originates in Greece and runs through the whole southern part of Albania, flows into the north of Vlora bay, transporting eroded suspended material containing relatively high levels of nickel and chromium as well as most urban and agricultural pollutants (Rivaro *et al*. [13]).Considerable amounts of these pollutants have reached Narta Lagoon due to water exchange between the lagoon water and sea water of Vlora Bay. Another pollution source of Narta Lagoon is the liquid discharges of "Norga" Brewery.

The aim of this study was to evaluate how the water quality affects the fish growth in Narta Lagoon. For this purpose, some quality parameters such as pH, temperature, dissolved oxygen, redox potential, total suspended solids, total dissolved solids, salinity etc., and nutrients (N-NO_2^-, N-NO_3^-, N-NH_4^+ and P-PO_4^{3-}) content in water samples collected in this lagoon have been determined.

2. Materials and Methods

Water samples were collected according to a network of five sampling points in Narta Lagoon as following: four samples within the lagoon and another sample in the channel that connect lagoon with the sea. The sampling stations are shown in Figure 1. Sample stations were chosen in order to do a better assessment of water quality of Narta Lagoon and to evaluate its possible polluting sources. Sample collection, transport and conservation was done according to standard methods recommended (APHA [14]).

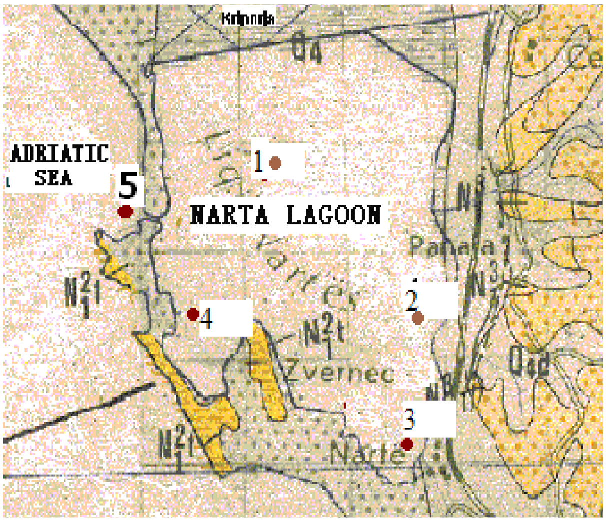


Figure 1. Map of sampling stations in Narta Lagoon

The physico-chemical parameters of water were determined immediately after the samples were taken to the laboratory. Surface water temperature, pH and redox potential were measured using a pH meter (Model pHS-3BW). Salinity, electrical conductivity (EC) and total dissolved solids (TDS) were measured with a conduct meter (Model DDSJ 308A). Total suspended mater (TSS) was determined by pouring one liter volume of water through a pre-weighed filter of 0.42 μm pore size, then weighing the filter again after drying it at 105 ^{0}C for 2 hours to remove all water. The concentration of dissolved oxygen (DO) was determined using Winkler method. Nutrients were measured according to APHA [14] standard procedures using UV 2401 PC, spectrophotometer for nitrogen compounds and PYEUNICAM SP-9 spectrophotometer for phosphate determination.

3. Results and Discussion

The physico-chemical characteristics in the water of Narta Lagoon are shown in Table 1.

The pH recorded in water samples collected in Narta Lagoon ranged from 7.72 to 8.16 with a mean value of 7.89. (Table 1 and Figure 2) Aquatic organisms are affected by pH because most of their metabolic activities are pH dependent (Wang *et al*. [15]). Fish have an average blood pH of 7.4; a little deviation from this value, generally pH between 7 to 8.5 is ideal for biological productivity. Fishes can become stressed in water with a pH ranging from 4.0 to 6.5 and 9.0 to 11.0 and death is almost certain at a pH of less than 4.0 or greater than 11.0 (Ekubo and Abowei [16]). The pH of an aquatic system is an important indicator of the water quality and the extent of pollution in the watershed areas. The pH values in water samples analyzed showed that the waters of Narta Lagoon are generally conducive to aquatic life.

Dissolved oxygen (DO) is an important environmental parameter for the survival of aquatic life. DO affects the growth, survival, distribution, behavior and physiology of shrimps and other aquatic organisms (Solis [17]). The principal sources of oxygen in water are atmospheric air and photosynthetic planktons. Obtaining sufficient oxygen is a greater problem for aquatic organisms than terrestrial ones, due to the low solubility of oxygen in water and solubility decreases with factors like: increase in temperature, increase in

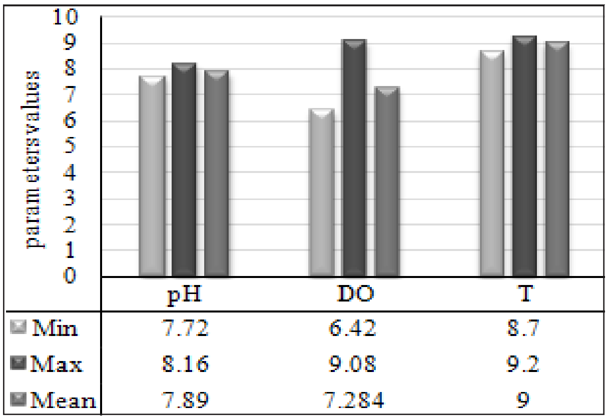


Figure 2. The minimum, maximum and mean values of pH, DO and T

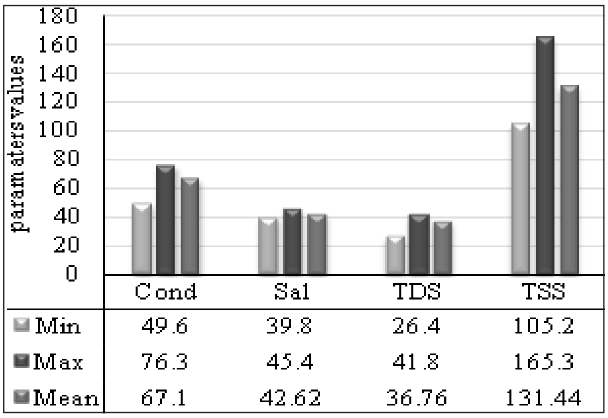


Figure 3. The minimum, maximum and mean values of conductivity, salinity, TDS and TSS

salinity, low atmospheric pressure, high humidity, high concentration of submerged plants, plankton blooms. Oxygen depletion in water leads to poor feeding of fish, starvation, reduced growth and more fish mortality, either directly or indirectly (Bhatnagar and Garg [18]). As a general rule, concentrations of DO above 5 mg/L are considered supportive of marine life, while concentrations below this are potentially harmful. At about 3 mg/L, bottom fishes may start to leave the area, and the growth of sensitive species such as crab larvae is reduced. At 2.5 mg/L, the larvae of less sensitive species of crustaceans may start to die, and the

Table 1. Physico-chemical parameters of Narta Lagoon

Station	Parameters							
	pH	DO (mg/L)	Temp (^{0}C)	Conductivity (mS/cm)	TDS (mg/L)	Salinity (‰)	TSS (mg/L)	Redox potential (mV)
N 1	7.75	7.22	8.9	76.3	37	43.8	117	-55.4
N 2	7.88	6.87	9.1	72.5	39.4	45.4	165.3	-46.9
N 3	7.72	6.42	9.2	69.3	41.8	42.5	142.9	-46.4
N 4	7.94	6.83	8.7	67.8	39.2	41.6	126.8	-43.8
N 5	8.16	9.08	9.1	49.6	26.4	39.8	105.2	-62.5

growth of crab species is more severely limited. Below 2 mg/L, some juvenile fish and crustaceans that cannot leave the area may die, and below 1 mg/L, fish totally avoid the area or begin to die in large numbers (Howell and Simpson [19]; U.S. EPA [20]; Boyd [21]). As it can be seen from Table 1 and Figure 2, the quantity of DO in the water of Narta Lagoon ranged from 6.42 - 9.08 mg/L with a mean value of 7.28 mg/L. Based on the above mentioned reports (DO concentration of 5.0 mg/L and above are desirable for fish survival), DO levels measured in this study are considered suitable for the aquatic biodiversity.

Temperature is the most important physical variable affecting the metabolic rate of fish and is therefore one of the most important water quality attributes in aquaculture (IEPA [22]). As fish is a cold blooded animal, its body temperature changes according to that of the environment, affecting its metabolism and physiology and ultimately affecting the production (Bhatnagar and Devi [6]). The temperature values of the waters of Narta Lagoon resulted in the interval 8.7 - 9.2 ^{0}C (as in Table 1 and Figure 2) with a mean value of 9° C. These values resulted lower than the optimal water temperatures (Target Guidelines) of 28 - 30 ^{0}C, within which maximal growth rate, efficient food conversion, best condition of fish, resistance to disease and tolerance of toxins (metabolites and pollutants) are enhanced (South African Water Quality Guidelines [23]). But this is not a concern for Narta Lagoon if we consider that the water samples were collected in winter.

Conductivity is an index of the total Ionic content of water, and therefore indicates freshness or otherwise of the water (Egborge [24]; Ogbeibu and Victor [25]). The electrical conductivity of saline waters of Narta Lagoon recorded during this study, ranged between 49.6 and 76.3 mS/cm with a mean value 67.1 mS/cm (Table 1, Figure 3). The fluctuation in electric conductivity was due to fluctuations in TDS and salinity (Boyd [26]).

Salinity is the measurement of the Ionic composition of water and it varies depending on mixing of relatively fresh inland waters with saltier marine waters (Twomeu *et al*. [27]). It is an important factor that affects the density and growth of aquatic organism`s population (Powell *et al*. [28]; Wuenschel *et al*. [29]; Ansa [30]; Jamabo [31]). In water samples of Narta Lagoon, salinity values fluctuated in a narrow range between 39.8 - 45%.

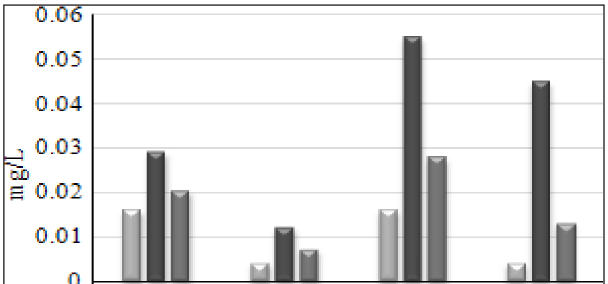
Total solids refer to any matter either suspended or dissolved in water. Everything that retained by a filter is considered a suspended solid, while those that passed through are classified as dissolved solids, i.e. usually 0.45μ in size (APHA [14]). High concentrations of TSS have several negative effects, such as decreasing the amount of light that can penetrate the water, thereby slowing photosynthetic processes which in turn can lower the production of dissolved oxygen; high absorption of heat from sunlight, thus increasing the temperature which can result to lower oxygen level low visibility which will affect the fish' ability to hunt for food; clog fish' gills; prevent the development of egg and larva. It can also be an indicator of higher concentration of bacteria, nutrients and pollutants in the water (PHILMINAQ [10]). Dissolved solid (DS) include bicarbonate, sulphate, phosphate, nitrate, calcium, magnesium, sodium, organic ions, and other ions important in sustaining aquatic life. However, high concentrations can result to damage in organism's cell (Mitchell and Stapp [32]), water turbidity, reduce photosynthetic activity and increase the water temperature. *TSS* content in Narta Lagoon water ranged between 105.2 mg/L and 165.3 mg/L with a mean value 131.44 mg/L. While *TDS* concentration resulted in the interval 26.4 mg/L to 41.8 mg/L with a mean value 36.76 mg/L (Figure 3). TSS resulted in higher content compared to standard values (< 10 mg/L or < 30 mg/L) of several countries (PHILMINAQ [10]) due to the water currents and swelling during sample collection (samples were collected in winter).

Redox potential is the activity or strength of red/ox processes in solution. As it can be seen the values of this parameter fluctuated between a minimum of - 62.5 mV and a maximum of - 43.8 mV (Table 1). Negative values of the redox potential in all stations indicate the reducing properties of lagoon water (Bellingham [33]).

Table 2. Nutrient content in Narta Lagoon

Station	Nutrient (mg/L)			
	Nitrate (NO_3^--N)	Nitrite (NO_2-N)	Ammonium (NH_4^+-N)	Phosphate (PO_4^{3-}-P)
N1	0.029	0.012	0.016	0.045
N2	0.018	0.007	0.018	0.006
N3	0.02	0.006	0.055	0.006
N4	0.016	0.007	0.016	< 0.004
N5	0.019	0.004	0.034	< 0.004

In Table 2 the nutrient content in the water of Narta Lagoon is shown. The nutrient input in the coastal areas has been dramatically increasing in the last decades due to intensification of human activities and urbanization along coastal regions (Newton *et al.* [34]; Newton and Mudge [35]). An initial consequence of nutrient over enrichment is the increase of plant growth which is often accompanied by changes in species composition such as a shift from a primarily diatom based plankton community to small flagellates. This may also be accompanied by an increase in the development of harmful algal blooms such as red and brown tides, which can be toxic to shellfish, fish, marine mammals resulting in changes in biodiversity, and in some cases, become a direct threat to humans (Hallegraeff [36]). One of the most serious consequences of nutrient over enrichment to marine ecosystems is the decreased level of dissolved oxygen within the water column. Increased plant growth results in increased sedimentation of organic matter. Bacterial decomposition of this material may result in the depletion of DO, causing either hypoxic or anoxic conditions. In shallow systems, excessive macroalgal growth can result in anoxic conditions within the water column, especially during periods of arm water temperatures and during night time. This can result in death and the subsequent decomposition of macrophytes causing further depletion of DO that may in turn result in the death and elimination of aerobic benthic organisms and in severe cases, fish kills (Rabalais *et al.* [37]).



	NO3- -N	NO2--N	NH4+-N	PO43--P
Min	0.016	0.004	0.016	0.004
Max	0.029	0.012	0.055	0.045
Mean	0.0204	0.0072	0.0278	0.013

Figure 4. The minimum, maximum and mean values of nutrient content

Nitrates are a form of nitrogen and a vital nutrient for growth, reproduction, and the survival of organisms. Santhosh and Singh [38] described the favorable range of 0.1 mg/L to 4.0 mg/L in fish culture water. However, OATA [39] recommends that nitrate levels in marine systems never exceed 100 mg/L. In figure 4 is shown that nitrate content in Narta Lagoon water fluctuated between 0.016 mg/L and 0.029 mg/L, with a mean value 0.020 mg/L. High content of nitrates in the lagoon may be not considered critical as they are the main nutrient for the aquatic biota and its intensive development causes rapid reduction of nitrates. Based on the recommended values about nitrate content in water, Narta Lagoon is considered favorable for the fish growth.

Nitrite can be termed as an invisible killer of fish because it oxidizes hemoglobin to methemoglobin in the blood, turning the blood and gills brown and hindering respiration also damages the nervous system, liver, spleen and kidneys of the fish (Bhatnagar and Devi [6]). The ideal and normal measurement of nitrite is zero in any aquatic system. Stone and Thomforde [40] suggested that the desirable range is 0 - 1 mg/L NO_2 and acceptable range less than 4 mg/L NO_2. According to Bhatnagar *et al.* [41] 0.02 - 1.0 mg/L is lethal to many fish species, > 1.0 mg/L is lethal for many warm water fishes and < 0.02 mg/L is acceptable. Santhosh and Singh [38] recommended nitrite concentration in water should not exceed 0.5 mg/L. OATA [39], recommended that it should not exceed 0.2 mg/L in freshwater and 0.125 mg/L in seawater. Nitrate content in Narta Lagoon resulted in the interval 0.004 - 0.012 mg/L (as in Figure 4) with a mean value 0.007 mg/L. These values resulted lower than the recommended value of nitrite content acceptable for fish growth.

Ammonia is the by-product of protein metabolism excreted by fish and bacterial decomposition of organic matter such as wasted food, feces, dead planktons, sewage etc. The unionized form of ammonia (NH_3) is extremely toxic while the ionized form (NH_4^+) is not and both the forms are grouped together as "total ammonia" (Bhatnagar and Devi [6]). In terms of Ammonium NH_4^+ standard, Australia, New Zealand and South Australia have the value set at less than 1.0 mg/L for both freshwater and marine. (PHILMINAQ [10]) In sample analyzed, ammonium content fluctuated between 0.016 to 0.055 mg/L (Figure 4). Referred to recommended values for ammonia content, this parameter resulted acceptable for fish growth.

Almost all of the phosphorus (P) present in water is in the form of phosphate (PO_4) and it is an essential plant nutrient as it is often in limited supply and stimulates plant (algae) growth and its role in increasing the aquatic productivity is well recognized. High levels of both phosphate and nitrate can lead to eutrophication, which increases algae growth and ultimately reduces dissolved oxygen levels in the water (Murdoch *et al.* [42]). According to Stone and Thomforde [40] the phosphate level of 0.06 mg/L is desirable for fish culture. Bhatnagar *et al.* [41] suggested 0.05 - 0.07 mg/L is optimum and productive; 1.0 mg/L is good for plankton/shrimp production. Phosphates in Narta Lagoon generally resulted in very low levels in all stations; in value that fluctuated in the interval 0.004 to 0.045 mg/L and a mean value of 0.013 mg/L (Figure 4). However, the phosphate content in Narta Lagoon is lower than recommended optimal values for fish growth. Higher content of nutrient generally resulted in station N1 where the urban and agricultural wastes of inhabited areas are discharged through the channel that passes through Narta village.

4. Conclusions

- This study was conducted to evaluate how the physico-chemical parameters and nutrient content in the water affects the growth of fish in Narta Lagoon. In general, physico-chemical parameters including temperature, pH, dissolved oxygen, conductivity, salinity and total dissolved solids resulted in appropriate levels to sustain the aquatic life. The values obtained for the total suspended solids (TSS) resulted higher the values recommended in the standards used by different countries (< 10 mg/L or < 30 mg/L).

- High concentration of TSS might have negative effects in photosynthetic processes and the production of dissolved oxygen in water, consequently in fish growth. Compared to standard values nitrogen compounds and phosphates in Narta Lagoon were in low content. This indicates favorable conditions for fish cultivation.

- Based on the results of inorganic nutrient content in water, it is shown that Narta Lagoon is characterized by generally oligotrophic conditions and is suitable for fish growth. But, there should be a constant monitoring of the physical and chemical parameters in water of Narta Lagoon in the future, because of the increase of anthropogenic activities around the area.

5. References

[1] Piper R. G., McElvain I. B., Orme L. E., McCraren J. P., Flower L. G. and Leonard J. R. (1982). *Fish hatchery management*. U. S. Fish and widelife Service, Washington, D.C. USA.

[2] MacGarvin M. (2000). *Scotland's Secret, Aquaculture, Nutrient Pollution, Eutrophication and Toxic Blooms*. World Wildlife Fund, Perth, Scotland, 21P.

[3] Carrol M. L., Cochrane S., Fieler R., Velvin R., White P. (2003). *Organic enrichment of sediments from salmon farming in Norway: environmental factors, management practices, and monitoring techniques*. Journal of Aquaculture 226, pp 165-180.

[4] Summerfelt R. C. (2000). *Water Quality Considerations for Aquaculture*. Department of Animal Ecology, Iowa State University, Ames, USA, pp 2-7.

[5] Bronmark C. and Hansson L. A. (2005). *The biology of lakes and ponds*. Oxford University Press, Oxford, UK, pp. 285.

[6] Bhatnagar A., and Devi P. (2013). *Water quality guidelines for the management of pond fish culture*. International Journal of Environmental Sciences Volume 3, No 6, pp. 1980-2009.

[7] Chitmanat C., and Traichaiyaporn S. (2010). *Spatial and temporal variations of physical-chemical water quality and some heavy metals in water, sediments and fish of the Mae Kuang River, Northern Thailand*. International Journal of Agriculture and Biology, 12, (6), pp. 816-820.

[8] Davenport Y. (1993). *Responses of the Blennius pholis to fluctuating salinities*. Marine Ecology Progress Series, 1, pp. 101-107.

[9] Kiran B. R. (2010). *Physico-chemical characteristics of fish ponds of Bhadra project at Karnataka*. Rasāyan Journal of Chemistry, 3, (4), pp. 671-676.

[10] PHILMINAQ, Annex 2. *Water Quality Criteria and Standards for Freshwater and Marine Aquaculture* <URL:http://www.aquaculture.asia/files/PMNQ%20 WQ%20standard%202.pdf. Accessed 04 October 2014.

[11] EEA (European Environment Agency). (2006). *Priority Issues in the Mediterranean Environment*. European Environment Agency - EEA Report, Copenhagen, Denmark, 4, pp. 88.

[12] Lami S. (2004). *Defining of the strategies for a sustainable management concerning the trophic state in the Lagoon of Narta and Lagoon of Orikumi*. Report, pp. 12.

[13] Rivaro P., Cullaj A., Frache R., Lagomarsino C., Massolo S., De Mattia M. C., and Ungaro N. (2011). *Heavy metals distribution in suspended particulate matter and sediment collected from Vlora Bay (Albania): A methodological approach for metal pollution evaluation*. In: Tursi, A., and Corselli, C. (Eds.), Coastal Research in Albania: Vlora Gulf, Journal of Coastal Research, Special Issue No. 58, pp. 54-66.

[14] APHA. (1998). *Standard methods* for the *examination* of *water* and *wastewater* (20th Ed.), American Public Health Association, Washington, D.C, USA.

[15] Wang W., Wang A., Chen L., Liu Y. and Sun R. (2002). *Effects of pH on Survival, Phosphorus Concentration, Adenylate Energy Charge and Na+-K+ ATPase Activities of Penaeus chinensis Osbeck Juveniles*. Aquatic Toxicology, 60, pp. 75-83.

[16] Ekubo A. A., and Abowei J. F. N. (2011). *Review of some water quality management principles in culture fisheries*, Research Journal of Applied Sciences, Engineering and Technology, 3, (2), pp. 1342-1357.

[17] Solis N. B. (1988). *The biology and culture of Penaeus monodon*. Department Papers. SEAFDEC Aquaculture Department, Tigbouan, Boilo, Philippines, pp. 3-36.

[18] Bhatnagar A., and Garg S. K. (2000). *Causative factors of fish mortality in still water fish ponds under sub-tropical conditions*. Aquaculture, 1, (2), pp. 91-96.

[19] Howell P., and Simpson D. (1994). *Abundance of marine resources in relation to dissolved oxygen in Long Island Sound*. Estuaries, 17, pp. 394-402.

[20] U.S.EPA. (United State Environmental Protection Agency). (2000). *Ambient aquatic life water quality criteria for dissolved oxygen (saltwater)*. Cape Cod to Cape Hatteras, EPA/822/R-00/12.

[21] Boyd C. E., Lichtkoppler F. (1979). *Water Quality Management in Fish Ponds*. Research and Development Series No. 22 International Centre for Aquaculture (J.C.A.A) Experimental Station Auburn University, Alabama, pp. 45-47.

[22] IEPA (Ireland Environmental Protection Agency) (2001). *Parameters of Water Quality: Interpretation and Standards*, Environmental Protection Agency Johnstown, pp. 133.

[23] South African Water Quality Guidelines. (1996). *Agricultural Water Use: Aquaculture*. Department of Water Affairs and Forestry of South Africa, Pretoria, (2nd Ed.), Vol. 6, pp. 185.

[24] Egborge A. M. B. (1994). *Salinity and the distribution of rotifers in the Lagos harbour-Badagry creek system, Nigeria*. Hydrobiologia, 272, pp. 95-104.

[25] Ogbeibu A. E., and Victor R. (1995). *Hydrological studies of water bodies in the Okomu forest reserves (Santuary) in Southern Nigeria. 2 physico-chemical hydrology*. Trop. Freshwater Biol., 4, pp. 83-100.

[26] Boyd C. E. (1981). *Water Quality in warm water fish ponds*. Crftmaster Printer, Inc. Opelika, Alabama, USA.

[27] Twomeu L. J., Piehler M. F., and Paerl H. W. *Priority Parameters for monitoring of freshwater and marine systems, and their measurement*. Institute of Marine Sciences, University of North Carolina at Chapel Hill, USA. <URL:http://www.eolss.net/sample-chapters/c09/e6-38a-04-01.pdf. Accessed 05 October 2014.

[28] Powell C. B., Thayer G. W., Lacroix M., Chesire R. (2001). *Interannual Changes in Juvenile and Small Resident Fish Assemblages and Sedgegrass Densities in Florida Bay*. Extended Abstract Book, Florida Bay Conference, pp 199.

[29] Wuenschel M.M., Werner R. G., Hoss D. E., Powell A. B. (2001). *Bioenergetics of Larval Spotted Seafront (Cynoscion nebulosus) in Florida Bay*., Florida Bay Conference. Extended Abstract Book, Florida Bay Conference, pp 215.

[30] Ansa E. J. (2005). *Studies of the benthic macrofauna of the Andoni flats in the Niger Delta Area of Nigeria*. Ph.D Thesis University of Port Harcourt, Port Harcourt, Nigeria, pp. 242.

[31] Jamabo N. A. (2008). *Ecology of Tympanotonus fuscatus (Linnaeus, 1758) in the mangrove swamps of the Upper Bonny River, Niger Delta, Nigeria*. PhD. Thesis, Rivers State University of Science and Technology, Port Harcourt, Nigeria, PH, pp. 340.

[32] Mitchell M. K., and W. B. Stapp. (1992). *Field Manual for Water Quality Monitoring, an environmental education program for schools*. GREEN: Ann Arbor, MI, USA.

[33] Bellingham K. *Physicochemical Parameters of Natural Waters*. Stevens Water Monitoring Systems, Inc. <URL:http://www.stevenswater.com/articles/waterparameters.aspx. Accessed 11 October 2014.

[34] Newton A., Icely J. D., Falcão M., Nobre A., Nunes J., Ferreira J., Vale C. (2003). *Evaluation of eutrophication in the Ria Formosa coastal lagoon, Portugal*. Continental Shelf Research, 23, pp. 1945-1961.

[35] Newton A., Mudge S. M. (2005). *Lagoon-sea exchange, nutrients dynamics and water quality management of Ria Formosa (Portugal)*. Estuarine, Coastal and Shelf science, 62, pp. 405-414.

[36] Hallegraeff G. M. (1993). *A review of harmful algal blooms and their apparent global increase*. Phycologia, 32, pp. 79-99.

[37] Rabalais N. N., Turner R. E., Justic D., Dortch Q., Wiseman W. J., and Gupta B. K. (1996*). Nutrient changes in the Mississippi River and system responses on the adjacent continental shelf*. Estuaries, 19, pp. 386-407.

[38] Santhosh B. and Singh N. P. (2007). *Guidelines for water quality management for fish culture in Tripura*. ICAR Research Complex for NEH Region, Tripura Center, Publication no. 29.

[39] OATA (Ornamental Aquatic Trade Association). (2008). *Water Quality Criteria-ornamental fish*. Company Limited by Guarantee and Registered in England No 2738119 Registered Office Wessex House, 40 Station Road, Westbury, Wiltshire, BA13 3JN, UK.

[40] Stone N. M., and Thomforde H. K. (2004). *Understanding Your Fish Pond Water Analysis Report*. Cooperative Extension Program, University of Arkansas at Pine Bluff Aquaculture / Fisheries, USA.

[41] Bhatnagar A., Jana S. N., Garg S. K. Patra B. C., Singh G., and Barman U. K. (2004). *Water quality management in aquaculture*. In: Course Manual of summer school on development of sustainable aquaculture technology in fresh and saline waters, CCS Haryana Agricultural, Hisar (India), pp. 203- 210.

[42] Murdoch T., Cheo M. and O'Laughlin K. (2001). *Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods*. Adopt-A-Stream Foundation, Everett, WA, USA, pp. 297.