EFFECTS OF HYDROGEN ION CONCENTRATION AND SALINITY ON THE SURVIVAL OF JUVENILE *Clarias gariepinus* (BURCHEL, 1822)

IYAJI, Florence Oyibo
Department of Science Laboratory Technology, Kogi State Polytechnic, Lokoja, Kogi State, Nigeria.

ABSTRACT

Experiments were conducted to determine the effects of the interactions of two environmental parameters, pH and salinity on the survival of juvenile Clarias gariepinus (4 – 12 g) under laboratory conditions. The pH values used were 3, 3.5, 4, 7 and 10 while salinity values varied thus: 0, 5, 10, 15 and 20 ppt in each of the pH values. Three and 3.5 pH had lethal effects in all salinities. The corresponding Lt_{50} values obtained at 5 and 10 ppt were higher than those obtained at 0, 15 and 20 ppt. At 4 and 7 pH, mortalities occurred only in the higher salinities, 15 and 20 ppt. At 10 pH, Lt_{50} values at salinities 10, 15 and 20 ppt were considerably low. The lower LT_{50} values recorded at 3, 3.5 and 10 pH with the higher salinity values indicated the lethal effects of the interactions of both parameters on fish.

Keywords: Hydrogen ion concentration, Salinity, Survival, *Clarias gariepinus*

INTRODUCTION

Aquatic organisms are directly affected by the physicochemical parameters of their environment. Boyd (1979), working on water quality in warm water aquaculture stated that aquatic organisms live in an environment foreign to man and consequently, one which is poorly understood. The development of high intensity fish culture which has lagged considerably behind that of the land animals like poultry and cattle may be attributed to lack of understanding. According to Kutty (1979) information on the various levels of environmental parameters and their interactions within the system is needed in formulating culture practices. Fry (1971) summarized the effects of environmental factors and grouped them into five categories namely; lethal, controlling, limiting, masking and corrective. The lethal factors restrict the range of the environment in which the organism can exist, beyond which metabolism is destroyed. Controlling and limiting factors both govern metabolic rates while masking and directive factors are exploited by the organism to maintain its being through organic regulation. Quite often, during the extreme fluctuations of a factor, the organism is exposed to the lethal factor for a short time and the capacity at which it resists the inclement condition would decide its survival. The correct information on the interaction of the parameters on culturable fish species would lead to effective utilization of the vast coastal swamplands, estuaries and lagoons with productivity comparable to that of the sea and inland lakes (Denyoh, 1967; Ezenwa and Ayinla, 1994).

Various studies carried out on the effect of pH and salinity on fish include those of Swingle (1961), Carter(1964), Jordan and Lloyd (1964), Parry *et al.* (1968), Calabrase (1969), Clay (1977), Chervinski (1983), Riiri (1986), Wilkie and Wood (1994; 1996), Norm (2001), Saha *et al* (2002), Fashina-Bombata and Busari (2003). Carter (1964) acclimated brown trout to full strength sea water (salinity 35ppt) and exposed them to alkaline solutions; a pH value of 9.5 gave a median lethal period of 20 hrs whereas fish at a pH of 9.5 at lower salinity value survived more than 5 days. Further investigation by Jordan and Lloyd (1964), confirmed that survival times of fish in lethal alkaline solutions were considerably less than those of rainbow trout in freshwater at similar pH values. Parry *et al.* (1968), experimenting with channel catfish, *Ictaluturus punctatus* juveniles in brackish water ponds (pH 3.5 - 4.5), demonstrated the species survival and growth in salinities ranging from 2 ppt to 11 ppt. Salinity tolerance limit of the catfish age six months to one year in similar pH values was found to be 12 ppt.

Aleem (1987) listed some stenohaline fresh water species like *Tilapia zillii, Oreochromis niloticus* and *Clarias gariepinus* as potential culture species in saline waters because of their ability to respond favourably in brackish waters with their characteristic low pH values. The possibility of the culture of *Clarias gariepinus* in brackish water environment has not been fully explored in Nigeria with numerous costal systems and enormous potential for aquaculture (Ezenwa and Ayinla, 1994). It has been reported that Nigeria spent $ 267,156,521 to import 356,217 metric tones of fish between 1993 and 1999 (FDF, 2000). The successful acclimation of the stenohaline fish to brackish water environment will significantly increase fish production and reduce importation and thereby help conserve resources.

In this work, attempts were made to study the effects of various levels of pH/Salinity interactions on the survival of juveniles of *Clarias gariepinus*. This is with a view to determining the safe levels of these parameters for the introduction of this fish species in the coastal brackish water environment for aquaculture production, not only in Nigeria but also in other parts of the world.

MATERIALS AND METHODS

Fish: Juvenile *Clarias gariepinus* (size range: 4 – 12 g, 9 – 15 cm total length) were bred and raised in the hatchery at African Regional Aquaculture centre, (ARAC) Aluu, Port Harcourt. The fish were fed with a mixture of powdered milk and ground shrimps in addition to NIOMR formulated feed (35 % protein) twice daily at 5 % body weight for two months before being used in the experiments. Feeding stopped 24 hours before the experiment.

Water: Saline water was collected from the open river at Buguma, River State, Nigeria (S=18 – 25 ppt). To obtain the required salinities, the saline water was mixed with fresh water and the values checked with a salinometer. To obtain the required pH, sulphuric acid or sodium hydroxide solutions were added gradually dropwise to water medium while the values were read using a pH meter model 191 CP-20 digital. Dissolved Oxygen (DO) was measured using the oxygen meter YS1 model 51B while Ammonia (N-NH_3) was measured using a spectrophotometer (Bausch and Lomb spectronic mini 20) at 410 nm wavelength. Temperature was measured using mercury in glass thermometer.

Experiment: Ten litre plastic troughs containing six litres of water were used. These were continuously aerated to keep the dissolved oxygen between 6 – 7 mg/l. The pH was constant at 3, 3.5, 4, 7 and 10 while salinity varied between 0 ppt and 20ppt in each pH value. Six juveniles of *Clarias gariepinus* were introduced into each trough. Observations were made between the time of fish introduction to a maximum period of one week, after which the experiments were terminated. Mortality was recorded at the exact period it occurred. Fish were considered dead when the opercula movement stopped and they failed to respond to touch stimuli. The methods followed were as described by Fry (1972), Kutty (1979) and Alabaster and Lloyd (1982).

RESULTS AND DISCUSSION

Table 1 summarizes the details of Lt_{50}'s obtained from arithmetic, probit and geometric mean calculations of time to death of fish exposed to various pH/salinity concentrations. The Lt_{50} obtained increased as the salinity decreased. At the lower pH values of 3, 3.5, Lt_{50} obtained at 0 ppt were considerably less than those obtained in 10 ppt and 5ppt. In 4 and 7 pH, complete mortalities were recorded only at higher salinities of 15 ppt and 20 ppt, and at pH 10, mortality occurred at 10 ppt salinity. At 0 ppt, no mortality was recorded in each case. At pH 10, the Lt_{50} obtained at higher salinities were less than those in 4 and 7 pH.

In all pH tested, complete mortalities were observed in salinities of 15 ppt and 20 ppt. Table 1 summarized the relationship between Lt_{50} and pH values in various salinity concentrations and between salinity and Lt_{50} in different pH values respectively.

Dissolved oxygen (DO) concentration ranged between 6 - 7.5 mg/l. Mean ammonia (N-NH_3) concentration was 2.0 ± 0.0036mg/l while Temperature ranged between 24.8 - 27.3 °C. The series of experiments on the effects of pH and salinity combinations on the survival of *Clarias gariepinus* juveniles revealed that pH 3, 3.5 and 10 were lethal to fish in all salinity concentrations. This observation is in line with those of Brett (1979); Holmes and Donaldson (1969) who attributed the death of fish to the destruction of the gills and skin tissues by the lethal effects of pH. These tissues are responsible for the processes of osmoregulation and active ion exchange in fish.

The Lt_{50} obtained at pH 3, 3.5 at 5 ppt and 10ppt were considerably higher than those obtained in the same pH values at 0ppt as shown in Table 1. According to Roberts (1981) the body salt concentration of teleost fish is about 7.5 %. The saline concentrations in which the fish were exposed are close to the body salt concentration. Roberts (1981) further explained that bronchial ionic uptake in fish increases with the external salt concentration up to a point when the mechanism becomes saturated. Fish in 5 ppt and 10ppt salinities could be said to be in the saturated range. Thus, although the tissues were destroyed, fish did not expend energy in maintaining body salt concentration, the saline solution being about the same with the body salt concentration (Norm, 2001), hence their longer survival rate.

The lower Lt_{50} obtained at 0ppt could also be explained in the light of failure of the affected tissues to regulate body salt-water balance. The fresh water fish have higher body salt concentration than the surrounding water environment which they maintain through osmoregulation. The direct transfer of stenohaline freshwater fish into acid/alkaline or saline water elicits a stress response and the extent of the response depends on many variables such as season, temperature, saline concentration, acid/alkaline concentrations, species and size of fish (Swann, 1999). The major problem faced in 0ppt is that of excess water intake. As fish strife to regulate and maintain the body salt/water balance, much energy is expended leading to weakness and early death.

At pH values of 4 and 7 mortality observed at 15 ppt and 20ppt could be due to effects of salinity alone as fish did not die at these pH values even at 0ppt.

At pH 10, in higher salinities of 15ppt and 20ppt, the Lt_{50} obtained were less than those in pH 4 and 7 in the same salinity values. The low Lt_{50} at pH 10 in higher salinities was in line with Carter, (1964) who reported that trout acclimated to full strength seawater and exposed to high pH values had less survival rate than those found in freshwater. According to Saha *et al.* (2002), *Clarias batrachus* survived in alkaline water of pH 10 for several days in freshwater environment. Saha *et al.* (2002) further explained that the restriction of oxygen uptake due to pathological changes at the gill lamellae was the cause of death in freshwater teleost exposed to varying alkaline pH water in higher salinities. Wilkie and Wood (1994; 1996) also suggested that the acute increase in plasma pH, possibly due to disturbances of acid-base balance at higher salinities could be the primary cause of death of fish in higher pH waters.

Table 1: Median lethal time (LT_{50}) of juvenile *Clarias gariepinus* (4 – 12 g) exposed to various pH/salinity concentrations, taken from arithmetic plots, probit plots and geometric mean calculations

pH Values	Salinity Values														
	20 ppt			15 ppt			10 ppt			5 ppt			0 ppt		
	LT_{50}	GM	P	LT_{50}	GM	P	LT_{50}	GM	P	LT_{50}	GM	P	LT_{50}	GM	P
pH3	31	32.50	31.6	50	51	46.7	219	219.4	218	260	265	263	46	46	49
pH3.5	33	34.80	33.1	58	59	57.5	750	760	758.57	1000.9	1116.8	1000	168	173	169
pH4	39	40	39	424	425	416	ND	ND	ND	ND	ND	ND	ND	ND	ND
pH7	46.77	48	47.35	385	388	380	ND	ND	ND	ND	ND	ND	ND	ND	ND
pH10	19.95	21	21.8	30	30	31	63	63.3	60.25	ND	ND	ND	ND	ND	ND

Key: *Lt_{50} Median lethal time, P: Probit mean, GM: Geometric mean*

The mode of toxicity of hydroxyl ion concentration is similar to those of hydrogen ion concentration. Apart from destroying the gill and skin tissues of the fish as earlier mentioned, both also affect the oxygen carrying capacity of the blood haemoglobin (Lagler *et al.*, 1977).

From the results obtained and the foregoing discussion, it is important to note that at lower pH levels of 3.5 -4, salinity must be between 5-8ppt for the survival and growth of the juveniles of *Clarias gariepinus* since this range is within the body salt concentration. Fresh water of 0ppt and higher salinities of 10ppt and above would be lethal to fish at such pH levels. More investigations need to be carried out on the interaction of pH levels and salinity concentrations at closer ranges and on graded fish in order to establish the actual safe levels/concentrations for the different sizes of the fish species.

REFERENCES

ALABASTER, J. S. and LLOYD, C. (1982). *Water quality criteria for fresh water fish.* Butterwort Scientific, New York.

ALEEM, S. O. (1987). Tilapia breeding and seed Production. *Proceedings of the Aquaculture Training Programme (ATP) conducted by African Regional Aquaculture Centre (ARAC) Aluu and Nigerian Institute for Oceanography and Marine Research, Port Harcourt.*

BOYD, C. I. (1979). *Water quality in warm water ponds*. Auburn University Agricultural Experiment Station, Alabama. USA.

CALABRASE, A. (1969). *Effects of acids and alkalis on survival of bluegills and largemouth bass in warm water ponds. In: Water quality in warm water* ponds. Auburn University Agricultural Experiment Station, Alabama. USA.

CARTER, L. (1964). *Effects of acidic and alkaline effluents on fish in sea water.* Butterwort Scientific, New York.

CHERVINSKI, J. (1983). Salinity tolerance of young catfish *Clarias gariepinus* (Burchell). *Journal of Fish Biology*, 25: 147 – 149.

CLAY, D. (1977). Preliminary observations on salinity tolerance of *Clarias gariepinus* from Israel. *Bamidgeh,* 29: 102 – 109.

DENYOH, F. M. K. (1967). Pond fish culture development in Ghana. *FAO Fish Report,* 44(2): 156 – 160.

EZENWA, B. I. and AYINLA, O. A. (1994). Conservation strategies for endangered fish in Breeding and nursery grounds within the coastal wetlands of Nigeria. *Aquatic Conservation in Marine and Freshwater Ecosystems,* 4: 125 – 133.

FASHINA-BOMBATA, H. A. and BUSARI, A. N. (2003). Influence of salinity on the developmental stages of African catfish *Heterobranchus longifilis* (Valenciennes, 1840). *Aquaculture*, 224: 213 – 222.

FDF (2000). *Fish Supplies and Values of the Federal Republic of Nigeria, 1993 – 1998.* Federal Department of Fisheries, Lagos, Nigeria.

FRY, F. E. J. (1971). The effects of environmental factors on the physiology of fish. Pages 1 – 98. *In:* HOAR, W. S. and RANDHAL, D. J. (Eds). *Fish Physiology,* Volume 6, Academic Press, New York.

HOLMES, W. W. and DONALDSON, E. M. (1969). Excretion, ionic regulation and metabolism. Pages 1 – 89. In: Hoar, W. S. and Randall, D. J. (Eds.). *Fish Physiology,* Volume 1, Academic Press, New York.

JORDAN, D. M. H. and LLOYD, R. (1964). The resistance of rainbow trout *Salmo gairdneri* R and Roach *Rutilis rutilis* L. to alkaline solutions. *In;* ALABASTER, J. S. and LLOYD, C. (Eds.). *Water quality criteria for fresh water fish.* Butterwort Scientific, New York.

KUTTY, M. N., (1979). Aquaculture in South East Asia. Some points of emphasis. *Aquaculture,* 20: 159 – 168.

LAGLER, K. F., BARDACH, J. E., MILLER, R.R. and PASSINO, D. R. (1977). *Ichthyology.* John Willy and Sons, New York.

NORM, M. (2001). *Pond Water Chemistry.* Koi Club of San Diego, USA.

PARRY, W., GUNTHIE, I. and AVAULT, J. W. (1968). Preliminary experiments on the culture of blue, channel and white catfish in brackish water ponds. Pages 123 – 130. In: ALLEN, K. O. and AVAULT, J. W. (Eds.). *Effects of salinity on growth and survival of channel catfish.* School of Forestry and Wild life Management, Louisiana State University.

Baton Rouge, Louisiana.

RIIRI, P. M. (1986). *Effects of pH on survival, feeding, food assimilation, conversion efficiency, metabolism and growth of Oreochomis niloticus (Lin. 1757).* Department of Fisheries, Rivers State University of Science and Technology. Port Harcourt.

ROBERTS, M. B. V. (1981). *Biology; A functional Approach.* Willy and Sons, New York.

SAHA, N., KHARBULI, Z. Y., BHATTACHARJEE, A., GOSWAMI, C. and HAUSSINGER, D. (2002). Effect of alkalinity (pH10) on ureogenesis in the air-breathing walking catfish *Clarias batrachus. Comparative Biochemistry and Physiology Part A: Molecular and Integrative Physiology,* 132A: 353 – 364.

SWANN LA DON, (1999). *A fish farmers guide to understanding water quality.* Illinois-Indiana Sea Grant Program, Purdue University. USA.

SWINGLE, H. S. (1961). Relationships of pH of ponds waters to their suitability for fish culture. Pages 21 – 45. *In:* ALABASTER, J. S. and LLOYD, C. (1982). *Water quality criteria for fresh water fish.* Butterwort Scientific, New York.

WILKIE, M. P. and WOOD C. M. (1994). The effects of extremely alkaline water pH 9.5 on rainbow trout gill function and morphology. *Journal of Fish Biology,* 45: 87 – 98.

WILKIE, M. P. and WOOD C. M. (1996). The adaptations of fish to extremely alkaline environment. *Comparative Biochemistry and Physiology,* 113 B: 665 – 673.