Growth performance of silver grey catfish, *Chrysichthys nigrodigitatus* fingerlings fed salt-rich diets in fresh water system

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Abstract. The influence of dietary salt (sodium chloride) on growth performances of *Chrysichthys nigrodigitatus* fingerlings was investigated, by feeding duplicate groups of fish (av. wt. 39.37±1.03 g) maintained in freshwater system in 1m x 1m x 2m rectangular tarpaulin with diets containing different levels of un-iodized sodium chloride (0.00, 0.02, 0.04, 0.06, 0.08, and 1.0 g kg^{-1}). The diets were fed at 3% body weight, twice daily in equal split doses, seven days a week, for 24 weeks. *C. nigrodigitatus* accepted all experimental diets. Fish receiving diets containing 0.04, 0.06 and 0.08 g kg^{-1} salt exhibited higher ($p > 0.05$) growth rates. The 0.08 g salted feed further exhibited the best ($p > 0.05$) specific growth rate (% body weight day^{-1}), percent weight gain and significantly higher ($p < 0.05$) protein-energy ratio (PER) and the worst (highest) feed conversion ratio (FCR) while those fed 0.04 and 0.06 g salt kg^{-1} feed showed significant reduction ($p < 0.05$) in FCR, which is preferred, and growth rates not significantly different from the highest value. The highest survival (73.84%) was achieved in fish groups fed with 0.04 and 0.06 g salt kg^{-1} feed diet and the lowest (70.33%) recorded in the control diet group. Fish receiving diets containing 0.04 g and 0.06 g diets exhibited significantly lower ($p < 0.05$) mortality. The control, 0.00 g salt diet group recorded the best protein synthesis (i.e., least nitrogen metabolism, *Nm*) and the 0.08 g salt fish group the least. The overall status of the plot of weight against length of 222 individuals was positively correlated ($r = 0.777$, $p < 0.05$) with the growth coefficient, b = 3.0388, indicating positive allometry. This study showed the beneficial effect of 0.04 to 0.06 g sodium chloride supplemented diets on the growth of *C. nigrodigitatus* fingerlings during its culture in fresh water ecosystem all through life.

Key Words: food intake and appetite, sodium chloride supplementation, osmoregulatory and growth responses, Na^+/K^+-ATpase pump.

Introduction. The aquaculture industry is ever expanding in number and types of species cultured and culture systems. Significant growth of this industry depends on sound nutritional practices, one of which is the use of common salt as an additive in fish feed. This practice has become regular in Asia (Veerina et al 1993; Yakupitiage 1993) and Europe, particularly in mariculture. According to Keshavanath et al (2003), freshwater fish take up salt from the surrounding water to maintain their osmotic balance, a process that consumes energy. The freshwater fish culture environments generally impose high, but opposite, transepithelial osmotic and ionic gradients on fish, apparently with considerable strain on the cardiovascular system (Janssen & Smiths 1989; Rothe 1985). Fish in low-saline water show a passive outward flux of ions such as Na^+ and Cl^- to the water via the gills, faeces and renal system, which must be compensated by the active uptake of ions from the water and from the diet (Evans et al 2005). Since minerals absorbed from water do not always meet the total metabolic requirements in fish, their supplementation through the diet promotes growth (Hepher 1988). Providing fish diet with a sufficient amount of salt can reduce stress and spare energy to satisfy the needs for osmoregulation, in favour of growth (Harpaz et al 2005; Arockiaraj & Appelbaum 2010). Harper et al (1997) record that farm animals require 600 to 2500 mg Na kg^{-1} diet, depending on species, age or reproductive status.

The silver catfish, *Chrysichthys nigrodigitatus* is a highly valued food-fish that grows relatively fast in medium to high density culture in major rivers in West Africa including Nigeria. They are among the frequent commercial fish catches in these rivers; caught mostly with drag net, hook and line, bottom-set gillnet as well as bottom-set traps, since they are bottom dwellers. *C. nigrodigitatus* has been investigated for possibilities of its culture (Silvalingam 1972; Ezenwa 1981, 1982; Ekanem 1992, 2000) which throughout West Africa is carried out largely in brackish water environment throughout life. Knowledge of the growth rate, reproductive biology and physiological characteristics of this species in response to salt diets are important for management, sustainable utilization and to ensure successful culture of this species in different conditions in both fresh and brackish water environments. It is reasonable to expect that diet is an important source of salts that could satisfy the osmoregulatory requirements of the fish in freshwater or low saline water.

Length-weight relationship in aquatic organisms is an indication of growth pattern relating weight as a function of length. Information on length-weight relation of fishes are based on empirical relationship where "*a*" value for this relationship varies mostly with environmental factors while "*b*" value tends to remain unchanged during a given life phase (Bagenal 1978; Enin 1994). According to Offem et al (2008) this relationship for *C. nigrodigitatus* in the Cross River is $W_t = 1.997L_t^{2.206}$, $W_t = -2.831L_t^{3.040}$ and $W_t = -2.245L_t^{2.995}$ for upper, middle and lower sections, respectively. The authors further reported that fish and fish parts dominated the diet while condition factors varied from 0.718 minimum to 0.996 maximum for this species in the Cross river. Udoh et al (2015) established the von Bertalanffy growth model for this species as $L_t = 120.23\ [1 - exp\ (-1.5(t\text{-}(0))]$ in the lower Cross River at Itu.

Despite its place of pride in coastal fisheries and aquaculture there is still a dearth of information on the biology of this fish species (Offem et al 2008) in order to popularize its culture. The aim of this study was to determine the influence of salt-rich diets on the growth performance and growth pattern of *C. nigrodigitatus* juveniles cultured in fresh water medium in order to contribute information required for the baseline management of this fish species in Niger Delta area of Nigeria.

Material and Method. A total of 500 juvenile *C. nigrodigitatus* caught by artisanal fishers between January and March, 2013 at Itu in the lower Cross River, were accumulated for this study. The fish were caught using fishing traps and fine-mesh surrounding net and purchased in batches of 100 to 150 specimens on landing at Itu, near Cross River Bridge. The collected fish were transported in semi-chilled 50 Litre vats to the laboratory at the University of Uyo for acclimation. During acclimation the juveniles were held in two tarpaulin rearing tanks (1m x 1m x 2m) continuously aerated with 2HP air pump, with partial water renewal every 12 hours for seven days. Mass mortalities were recorded during acclimation period; thereafter surviving fish were transferred to outdoor tanks in fish hatchery complex and fed the control diet used in this experiment till commencement of study.

After acclimation, eight to ten surviving fingerlings of C. *nigrodigitatus* of average weight 39.37±1.03 g and 18.23±0.14 cm total length were distributed randomly into tarpaulin tanks (1m x 1m x 2m) in duplicates (two tanks per treatment) set-up in linear series containing fresh water each to a depth of 0.8 m. Thirty to fifty percent partial renewal with fresh clean water was executed weekly in each tank system to compensate for losses from evaporation and sludge removal. The experimental diets were prepared by adding 0.00 g, 0.02 g, 0.04 g, 0.06 g, 0.08 g and 1.00 g (corresponding to 0.0, 0.2, 0.4, 0.6, 0.8 and 10.0%, respectively) of non-iodized common salt obtained from the open market, each to 1.0 kg of pelleted commercial fish feed (protein 42%, lipid 8%, fiber 3% and ash 8% of Chi Feed® Nigeria). Each test feed was kneaded for uniformity after adding salt, re-pelleted, sun-dried for 6 hours and stored in separate air tight containers till use. Fish were kept off food a day before commencement of feeding trial. The fingerlings were fed their respective diets at a daily rate of 3% body weight in two split doses for a period of 24 weeks, which means six months. Feeding was generally completed in 5-10 minutes.

Fish biomass (n = 8) and survival were measured every four weeks from each experimental unit and averaged. Length nearest 0.1 cm and weight to the nearest 0.1 g were taken using a measuring board and electronic weighing balance (Ohaus®), respectively; and the amount of feed given was recalculated based on the new body weight at each sampling. Fish feed and growth indices were obtained as follows (Abd El-Hakim et al 2010; Zarnoch et al 2012):

Survival % = No. of fish stocked – Mortality/No. of fish stocked x 100

Mortality % = [(initial number – final number/final number + initial number)/2]/number of days ×100

Weight gain (g) = Final mean weight (W_2) – Initial mean weight (W_1)

Average weight gain (%) = [(Final mean weight – Initial mean weight)/Initial mean weight] ×100

Specific growth rate (SGR) (% g day^{-1}) = [Ln (final mean weight) – Ln (initial mean weight) x 100/days of feeding

Protein-energy ratio (PER) =wet weight gain (g)/amount of protein fed (g)

Feed conversion ratio (FCR) = Amount of feed provided (g) / Weight gain (g)

Nitrogen metabolism (N_m) = (0.549) (a + b) h (Zeitoun et al 1973) where, a = initial weight of fish, b = final weight of fish, h = culture period in days

Gross feed conversion efficiency (GFCE) (%) = FCR^{-1}.100 (Lovell 1989)

The growth and survival data were analysed using one-way ANOVA and Turkey's multiple range test (Appelbaum & Arockiaraj 2009).

Results and Discussion. *C. nigrodigitatus* accepted all experimental diets. Fish growth performance and survival are presented in Table 1 and Figures 1-3. The highest growth rates were achieved in the fish groups fed with 0.02 and 1.0 g salt-added diet ($p > 0.05$), followed by those fed with 0.08 g, 0.06 g, 0.04 g and control diet, respectively. However, growth increment did not record any significant difference ($p > 0.05$) with respect to varying salt content of feed. The final mean length of *C. nigrodigitatus* observed did not vary significantly ($p > 0.05$) between the various levels of salt added in diet.

Table 1

Growth performance of *C. nigrodigitatus* fingerlings fed varying levels of salt-enriched diets for 28 weeks

Diet indices	*Control*	*Experimental diets (Mean ± SE, g kg^{-1} salt added)*				
	0.0	*0.02*	*0.04*	*0.06*	*0.08*	*1.0*
Initial length (cm)	18.14±0.82^a	19.03±0.46^a	18.15±0.75^a	18.25±0.61^a	17.88±0.70^a	18.08±0.97^a
Final length (cm)	23.20±0.00^a	21.10±1.33^a	22.750±0.65^a	22.750±0.25^a	23.80±1.10^a	23.267±0.52^a
Initial weight (g)	39.59±4.33^a	44.10±3.11^a	37.11±3.34^a	37.65±2.61^a	37.14±3.87^a	41.62±5.99^a
Final weight (g)	99.60±0.00^a	80.3±11.1^a	95.30±9.20^a	97.45±7.65^a	108.0±13.8^a	92.00±2.10^a
Weight gain (g)	10.00±6.98^a	0.37±0.45^b	6.20±4.38^d	0.77±0.42^c	9.70±4.27^a	0.75±0.31^{b,c}
SGR	0.55±0.35^a	0.37±0.26a	0.56±0.24^b	0.57±0.28^b	0.64±0.34^b	0.47±0.30^a
Survival (%)	70.33±2.52^a	71.08±4.22^b	73.84±2.78^a	73.84±2.78^a	71.06±3.08^b	72.48±3.47^a
FCR	1.61±1.24^a	0.04±0.60^a	0.66±0.71^b	0.20±0.51^a	4.03±3.52^a	0.66±0.70^b
ADWG (g)	1.43±1.00^a	0.89±0.63^b	1.36±0.61^c	1.42±0.68$^{a.c}$	1.69±0.87^b	1.20±0.71^b
Weight gain (%)	19.42±12.51^a	12.47±8.91^b	18.40±8.16^{a,c,d}	19.01±9.81^{a,d}	22.35±12.72^b	16.28±10.89^b
PER	9.91±5.83^a	6.96±4.68^a	10.76±4.60^b	10.67±4.90^b	11.54±5.74^a	8.72±5.18^a
N_m	11.76±1.57^a	13.06±1.13^a	12.85±1.64^b	12.84± 1.54^b	13.58±1.89^a	13.14±1.33^a
GFCE%	62.27^a	2358.05^b	150.77^b	510.89^b	24.83^a	150.91^a
Condition factor	0.73±0.02^a	0.75±0.03^a	0.71±0.03^b	0.74±0.03^a	0.76±0.03^a	0.71±0.01^b

^{a,b} values with same superscript in each row are not significantly different ($p > 0.05$); SGR = Specific growth rate; ADWG = Average daily weight gain; FCR = Feed conversion ratio; PER = Protein-energy ratio; N_m = Nitrogen metabolism; GFCE % = Gross feed conversion efficiency.

On termination of the growth experiment, the average weight of individual fish in different treatments ranged between 80.3 g and 108.0 g in 0.02 g and 0.08 g salt groups, respectively; with non-significant ($p > 0.05$) difference among the treatment means. However, these values did not vary significantly ($p > 0.05$) among the different treatments. The best performance of fish in terms of growth rates, average weight gain, ADWG, SGR (% body weight day^{-1}) and significantly higher ($p < 0.05$) PER, was recorded with diets having 0.08 g salt supplementation (Table 1). Fish in the control group (with no added salt) performed better than those of the 0.02 and 1.0 g kg^{-1} added salt treatments ($p < 0.05$). The fish fed 0.08 g salt recorded the highest FCR while those fed 0.04 and 0.06 g salt diets showed significant reduction ($p < 0.05$) in FCR, which is preferred (Table 1). The protein digestibility or nitrogen metabolism, N_m values were significantly ($p < 0.05$) affected by the dietary salt treatments; the 0.08 g salt fish group displayed the highest N_m values while the control, 0.0 g salt diet group, the least (Table 1). The highest survival (73.84%) was achieved in fish groups fed with 0.04 and 0.06 g salt added feed and the lowest (70.33%) recorded in control diet groups (Table 1).

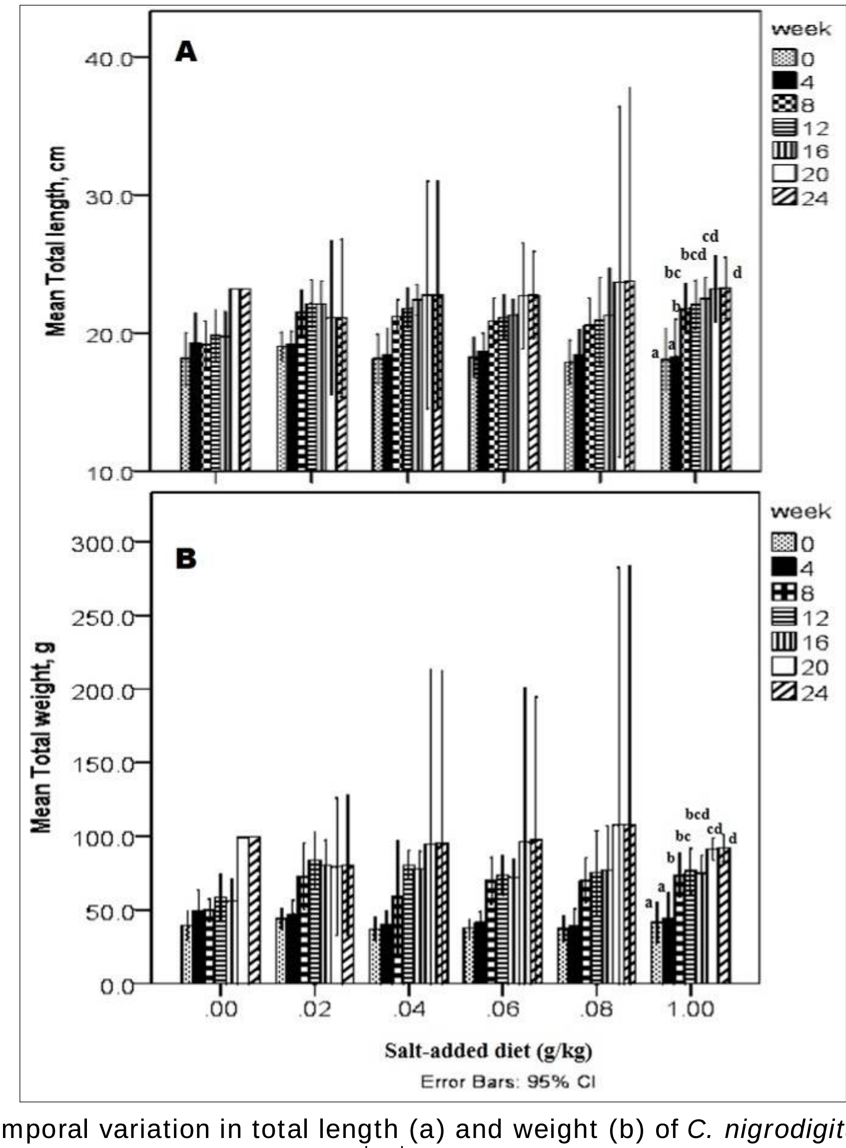

Figure 1. Temporal variation in total length (a) and weight (b) of *C. nigrodigitatus* fed with varying levels of salt diet for 24 weeks ([a,b,c,d] denote columns with same superscript are not significantly different, $p > 0.05$).

Mortalities resulting from varying the level of salt in fish diet compared to the control diet are presented in Figure 2. The final mortality at the end of the study varied from 20.05% in 0.02 and 1.0 g salt added group to 24.70% in the control; while the 0.04 to 0.08 g salt added diet groups showed 20.24% mortality (Figure 2a). The figure also indicates close range of mean mortalities from 22.42% (0.04 and 0.06 g salt added diet) to 25.43% in the control (Figure 2a). Cumulative mortalities on a logarithmic scale indicate high coefficients (effects) of salt-enriched diets on the fish (Figure 2b) with 0.04 g feed recording the least cumulative effect (mortality), 0.08 g salt diet, the highest; and in between them is the control (0.0), 0.02 and 1.0 g salted diets (showing homogenous effects).

The effect of test feed on the growth pattern of *C. nigrodigitatus* during the 24 weeks culture period is reflected in Table 2 and Figure 3. The *b*-values range from 2.66 in the control (Figure 3a) to 3.59 in 0.06 g (0.6%) salt enriched diets (Figure 3d) and from 2.4803 at the on-set of experiment terminating with a lower value of 1.8292 six months later (Table 2). The overall status in the length-weight plot of 222 *C. nigrodigitatus* was positively correlated ($r = 0.884$, $p < 0.05$) with exponential equation of $Wt = -2.2095Lt^{3.0388}$ (Figure 3g). The condition factor was higher for fish fed salted diets than the control. It varied from 0.71±0.03 minimum (0.02 g and 1.0 g salt supplementation) to 0.76±0.03 maximum (0.08 g salt supplementation) for the Cross River species cultured in this study.

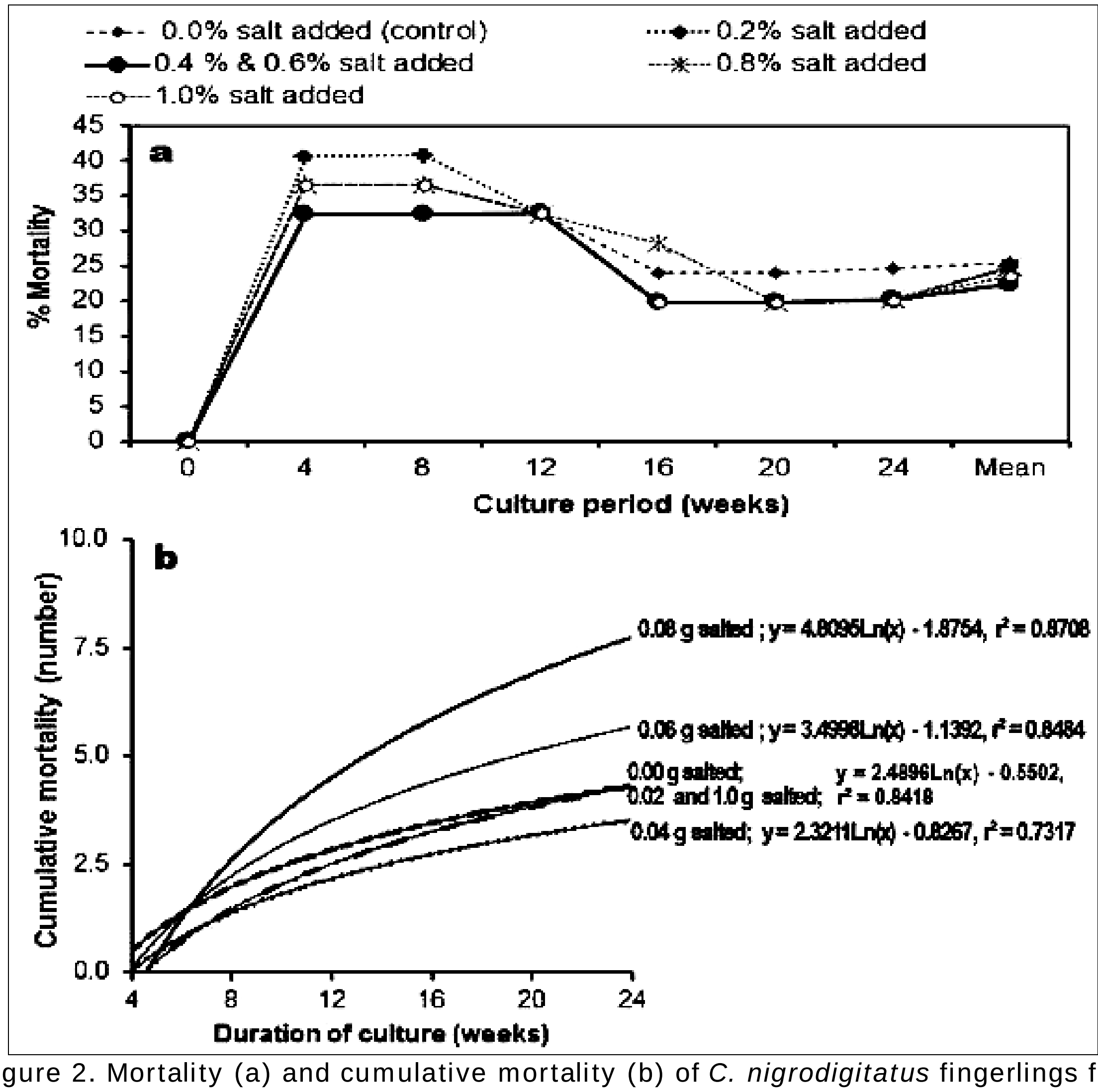

Figure 2. Mortality (a) and cumulative mortality (b) of *C. nigrodigitatus* fingerlings fed varying levels of salt-enriched diets in fresh water ecosystem for 24 weeks.

Table 2

Effect of catfish feed on the growth pattern of *C. nigrodigitatus* during the 24 weeks culture period

Culture period (weeks)	*a*	*b*	*r*	r^2	*n*
4	-1.5436	2.4803	0.957	0.9155	53
8	-1.7	2.6126	0.944	0.8914	48
12	-0.8882	2.0367	0.401	0.1607	33
16	-1.2144	2.32	0.849	0.7202	31
20	-1.2285	2.3145	0.852	0.7265	31
24	-0.5129	1.8292	0.805	0.6486	26

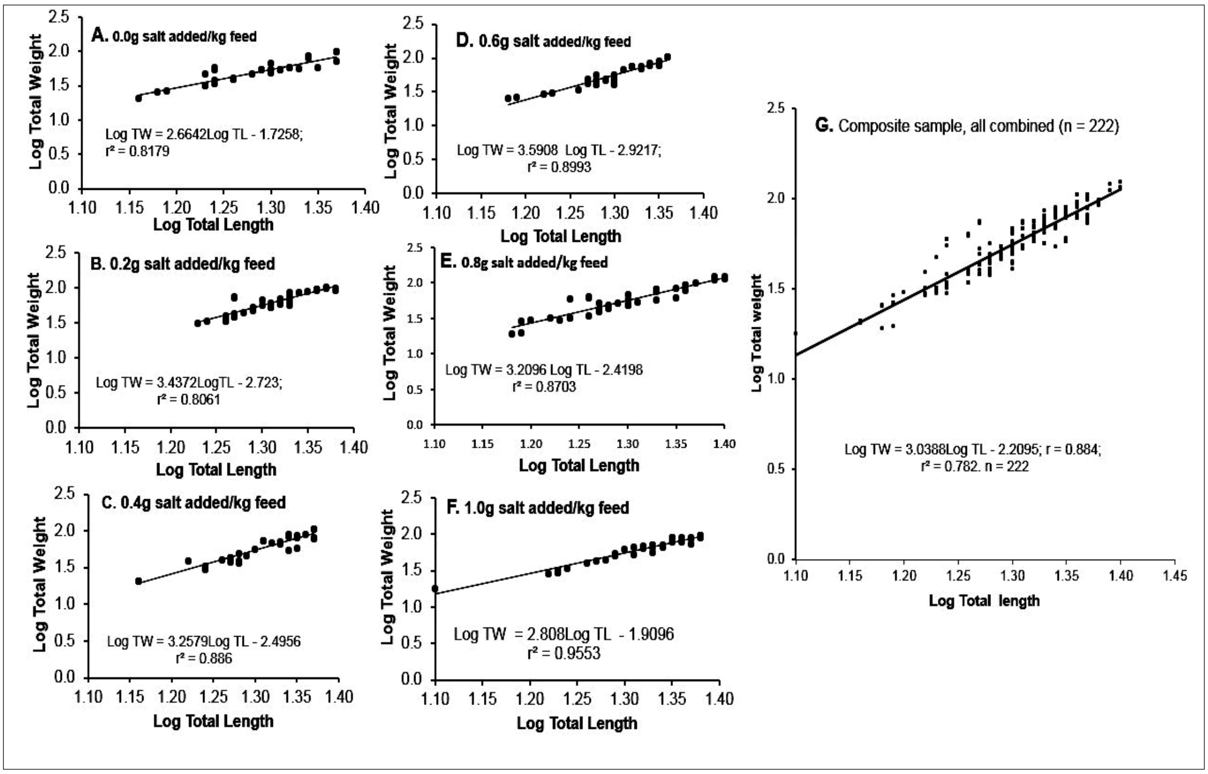

Figure 3 a-g. Length-weight relationship of *C. nigrodigitatus* fingerlings fed varying levels of salt intake.

Several findings by different authors have revealed that dietary salt addition is beneficial evoking significant increment ($p < 0.05$) in growth and survival rates of test fish. In this study, dietary salt improved the growth and feed conversion efficiency in juvenile *C. nigrodigitatus* in conformity with earlier works. Harpaz et al (2005) reported that adding 0.04 g of salt to the diet of *Lates calcarifer* resulted in significant improvement in their FCR while Gatlin et al (1992) observed that red drum (*Sciaenops ocellatus*) juveniles exhibited greater feed efficiency and significant weight gain when 0.02 g NaCl kg^{-1} feed was added to their diet at varying salinities. Similar results were elicited in *C. nigrodigitatus* in this study when 0.02 g, 0.04 g and 0.06 g NaCl kg^{-1} feed were administered (Table 1). According to Salman & Eddy (1988), food intake and appetite of the rainbow trout (*Oncorhynchus mykiss*) were not affected by adding salt to the diet, but however growth was positively influenced. Other beneficial effects of dietary salt supplementations include increasing appetite and digestibility (Fontainhas-Fernandes et al 2000), enhanced brush border enzyme activity (Harpaz et al 2005), increased digestive enzyme activity coupled with higher nutrient digestibility resulting in better utilization of nutrients (Ogino & Kamizono 1975); promoting plasma growth hormone (GH), pituitary growth hormone (GH) and pituitary (mRNA) (Eddy & Norman 2009); and as therapy for parasite infestation on silver catfish (*Rhamdia quelen*) fingerlings by application of 1.2% salt in fish food and water (Garcia et al 2007).

The levels of sodium chloride supplementation that induced the best growth differed with species: 1% in rohu (*Labeo rohita*) (Gangadhara et al 2004) and 1.5% in mrigal (*Cirrhinus mrigaia*) and common carps (*Cyprinus carpio*) (Nandeesha et al 2000), 1.5 and 2% in Tambaqui (*Colossoma macropomum*) fingerlings (Keshavanath et al 2012), 2% in Japanese eel (*Anguilla japonica*) (Arai et al 1974; Appelbaum & Arockiaraj 2009), prawn (*Macrobrachium rosenbergii*) and juvenile red drum (Gatlin et al 1992), 4% salt in Asian sea bass (*L. calcarifer*) (Harpaz et al 2005), 5% in European sea bass (*Dicentrarchus labrax*) (Eroldogan 2003; Eroldogan et al 2005); 12% in rainbow trout (Macleod 1978; Smith et al 1995) and between 1% to 12% (1%, 1.5%, 6%,8%, 10% and 12%) in gilthead sea bream (*Sparus aurata*) (Appelbaum et al 2008; Appelbaum & Arockiaraj 2008, 2009; Arockiaraj & Appelbaum 2010). Similarly this study showed significant increment ($p < 0.05$) in survival rate with fish fed 0.04 and 0.06 g salt supplementation diet compared to the control fish (no salt supplementation) which recorded the lowest survival rate (Table 1, Figure 2). According to Macleod (1978) and Appelbaum & Arockiaraj (2009) addition of excessive salt to the diet could interfere with the balance of other essential dietary components thereby exerting adverse effect on food intake, low digestibility and absorption, and faster evacuation of food due to change in gastric/intestinal environment and may influencing fish body composition or result in a pathological effect, consequently leading to reduced growth. An obvious effect of the salt-rich diet was observed in the PER and food conversion efficiency (GFCE%) in the fish. Increasing salt content increased feed and protein intake, and hence PER, with highest FCR (4.03), recorded with 0.08 g salted feed. Results from this study suggest that the gains of salt supplementation above 0.08 to 1.0 g could evoke adverse effects on fingerlings of *C. nigrodigitatus,* resulting in low digestibility, very high FCR, very low food conversion efficiency and very high (highest) N_m (Table 1), culminating in reduced growth and generation of more pollution/waste. However, Garcia et al (2007) applied 1.2% salt in food and water of silver catfish fingerlings without adverse effect on the fingerlings.

Salt supplementation acts as a ready reserve to meet the osmoregulatory requirement of freshwater fishes and reduces physiological stress because of their role in electrolyte and acid-base balance through the passive Na^+ and Cl^- flux (Evans et al 2005). The Na^+/K^+-ATPase pump located on the basolateral membrane of the intestinal epithelium salts influences intestinal Na^+/K^+ - ATPase activity, and helps to balance the osmotic gradient between the blood and the luminal fluids (Zaugg et al 1983; Bisbal & Specker 1991; Loretz & Fourtner 1991; Olson & Hoagland 2008). In nature, osmoregulatory and growth responses to dietary NaCl would depend upon the NaCl content of the prey items. Thus dietary salt contents should be similar or tend to be similar to levels that might be found in nature (Field et al 1978; Frizzell et al 1979; Halm et al 1985). Other beneficial effects of salt supplementation include preventing fishes from deformity and malformation (Ogino & Kamizono 1975). The influences of dietary salts may be affected by the ambient salinity (Smith et al 1989; Deane & Woo 2009). For instance, Appelbaum & Arockiaraj (2008) recorded the highest survival and growth rates when gilthead sea bream juveniles fed a diet consisting of 12% added salt (compared to those fed 8% and 10% salt supplementation) were reared in brackish water of 2.9 ‰ salinity. Li & Yamada (1992) suggest that some metabolic processes are affected by a high salinity of the ambient water.

The length exponents, *b* of *C. nigrodigitatus* obtained in the study were generally ≥ 3.0 except for control ($b = 2.66$). This indicates that weight growth of this species is positively allometric, i.e., the fish gets relatively plump as it grows longer (Wooton 1979); the dynamics of *C. nigrodigitatus* in salt-rich diets could be analysed using conventional population dynamics models for aquatic animals (Pauly 1984). The condition factors of the cultured species in this study are comparable to those obtained for wild species in the same river system (Offem et al 2008).

Recommendations. The present study is a contribution to the limited information regarding the culture and biology of *C. nigrodigitatus* and its development for aquaculture in fresh water farms all through life. This study demonstrates that incorporating 0.02 to 0.06 g NaCl kg^{-1} into the diet of *C. nigrodigitatus* fingerlings significantly improved fish growth performance by improving their ability to digest and utilize food more efficiently, with no visible detrimental effect. Benefits derived from salt supplementation above 0.08 to 1.0 g may attract adverse effects. Further studies need to be conducted to ascertain the optimum level of dietary salt requirement for the fingerlings of silver grey catfish, *C. nigrodigitatus*, to improve its farming in entirely fresh water ecosystem.

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