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First results of floating cage culture of the African catfish *Heterobranchus longifilis* Valenciennes, 1840: Effect of stocking density on survival and growth rates

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Abstract

The main constraint of the culture of the African catfish *Heterobranchus longifilis* remains the high mortality rate due mainly to cannibalism. *Heterobranchus longifilis* is generally cultured in earth ponds, tanks and enclosures. Floating cage aquaculture can be an alternative system to these traditional techniques as it may allow predation control. Therefore, the purpose of this study was to test the effects of floating cages (1 m^3) on survival and growth parameters of *H. longifilis* at different stocking densities in man-made Lake Ayame. In a first experiment which started with fish of 0.8±0.1 g initial mean weight, five stocking densities (50, 100, 200, 500 and 1000 fish/m^3) were tested during a 90-day experiment. The results showed that unlike final mean weight (Wf) and mean daily weight gain (Mdwg), weight variation coefficient (final Cv), cannibalism (Cr), mortality (Mr) and survival (Sr) were density dependent: best results of survival, cannibalism and mortality (68.0±1.5%, 18.0±2.2% and 14.0±1.5% respectively) were recorded at the lowest density (50 fish/m^3). In a second experiment that began with fish of 13.4±0.5 g (Wi) and lasted for 270 days, the stocking densities tested were 6, 12, 25, 50 and 100 fish/m^3. Results of this experiment showed that all the parameters [Mr, Cr, Sr, final Cv and apparent feed conversion ratio (Afcr)] were influenced by the stocking densities. Higher Wf, Mdwg and Sr and lower final Cv, Cr, Mr, and Afcr were recorded at the lowest stocking densities (6 and 12 fish/m^3). Cage culture of *H. longifilis* results in a higher Sr, but a lower Mdwg compared to those usually recorded in traditional rearing systems. However, this low production potential of *H. longifilis* could be increased by the improvement of rearing conditions (feeding systems, culture management) as noted in other species.

Keywords: *Heterobranchus longifilis*; Floating cage; Density; Survival; Growth

1. Introduction

The catfish *Heterobranchus longifilis* is one of the most suitable species for aquaculture in West Africa (Legendre, 1989; Otémé et al., 1996). In optimal rearing conditions, this species can reach a mean daily growth rate of 8 to 10 g/d (Legendre, 1983; Otémé et al., 1996) against only 3.95 g/d for *Oreochromis niloticus* L. (Mélard, 1986), the most commonly farmed species in Côte d'Ivoire. Biological and ecological characteristics such as: omnivorous feeding habit, good acceptance of commercial pellet diets, resistance to disease and pollution, and ability to withstand poor water quality

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make *H. longifilis* an excellent candidate for aquaculture (Micha, 1973; Bard et al., 1976; Legendre, 1983). In spite of these advantages, one of the major constraints for successful rearing of this species remains the high mortality rate due to cannibalism and predation during the early life stages in traditional rearing systems (Otémé et al., 1996).

Cage aquaculture allows an easy observation of rearing populations and better predation control (Coche, 1978). Due to its apparent practicability, this rearing technology may be a viable alternative to traditional rearing techniques (Beveridge, 1996). Cage culture of tilapia species such as *O. niloticus* (Coche, 1978; Cavailles et al., 1981) and *Sarotherodon melanotheron* Rüppell 1852 (Ouattara et al., 2003) improves production and the rearing of mixed-sex populations without recruitment and stunting problems, which are important constraints in traditional culture systems. Floating cage culture of *Clarias gariepinus* Burchell 1822 (a close relative of *H. longifilis* from the Clariidae family) showed encouraging results in growth and survival rates. In an 8-week experiment carried out on 32 g (initial mean weight) fish, Hengsawat et al. (1997) reported that final mean weight ranged from 346 g (200 fish/m^3) to 385 g (50 fish/m^3), with survival rates varying from 85 to 95%. To date, no information is available on the survival and growth of *H. longifilis* cultured in floating cages. Therefore, the present study was designed to test the effect of stocking density on survival and growth rates of two different size groups of *H. longifilis* (initial mean weight: 0.8 and 10.0–15.0 g) in floating cages.

2. Materials and methods

This study was conducted from September 2002 to August 2003 (360 days) at the man-made Lake Ayame (Côte d'Ivoire). Floating cages used derived from Coche (1978) and Cavailles et al. (1981). Each cage (1 m^3 capacity) was made with a wood frame (1 × 1 × 1.5 m) covered with polyethylene netting of 1 mm (Experiment 1) or 10 mm (Experiment 2) mesh size.

Six female catfish were spawned at the hatchery of the Laboratory of Hydrobiology, University of Cocody on 30 July 2002. Catfish larvae were held in circular tanks for 30 days. During the first three weeks the fish were fed decapsulated *Artemia* cysts. They were then fed pellets (Table 1) reduced into flour. Fish were kept in floating cages for an adaptation period of three days before being allotted to the experiment. The study was divided into two experiments.

In Experiment 1 (90 days), fish of 0.8 g initial mean weight were stocked at densities of 50, 100, 200, 500 and 1000 fish/m^3 in floating cages of 1 mm mesh size. Fish harvested (mean weight 13.4 g) at the end of this experiment were mixed together and used in Experiment 2 (270 days). In this experiment, fish were placed in floating cages at five stocking densities (6, 12, 25, 50 and 100 fish/m^3). Three replicates of each stocking density were used during both experiments. Fish were fed three times a day (0630, 1230 and 1830 h) with a 35% protein commercial feed manufactured by FACI (*Fabrication d'Aliments Composés Ivoiriens*, Côte d'Ivoire) except on sampling days.

Fish were fed flour form feed the first 30 days of Experiment 1 and then 2 mm particle size granules up to the end of Experiment 2. The amount of feed was 10% (Experiment 1) and 5% (Experiment 2) of the body weight/day according to Hem et al. (1994). The composition of the commercial diet is summarized in Table 1.

Water temperature, dissolved oxygen concentration (oxy meter model WTW OXI 330), pH (pH meter model WTW pH 330) and transparency (Secchi disc, 30 cm diameter) were measured at three days intervals. Once a week in Experiment 1 and once a month in Experiment 2, all the fish of each cage were weighted (g) and counted. At the beginning and at the end of these experiments, 30% of the fish of each cage in Experiment 1 and all fish in Experiment 2 were randomly sampled and weighted individually. Everyday, dead fish of each cage were collected, examined and counted. A distinction was drawn between cannibalism and natural death.

Table 1
Commercial feed composition according to the manufacturer FACI (*Fabrication d'Aliments Composés Ivoiriens*, 18 BP 686 Abidjan 18, Côte d'Ivoire)

Ingredients	Ratio
Fish meal (%)	41
Wheat and rice bran (%)	35
Cotton and soya cattle-cake (%)	13
Copra cattle-cake (%)	10
Vitamin and mineral premix (%)	1
Analytic characteristics	
Crude protein (%)	35
Crude fat (%)	6
Minerals (%)	10
Crude fibre (%)	5
Calcium (%)	2.3
Phosphorus (%)	1
Sodium (%)	0.4
Vitamin C (mg/kg)	400
Vitamin A (IU/kg)	10,000
Vitamin D3 (IU/kg)	3000
Vitamin E (mg/kg)	135

The former was detected by the presence of discarded heads resulting from tail first cannibalistic attacks (type I cannibalism) and missing fish were presumed to have succumbed to complete cannibalism (type II) (Hecht and Appelbaum, 1988). Natural deaths were determined by the presence of complete fish floating in the cage (Haylor, 1991). The survival rate (Sr), mortality rate (Mr), cannibalism rate (Cr), final mean weight (Wf), mean daily weight gain (Mdwg), weight variation coefficient (Cv) and apparent food conversion ratio (Afcr) were calculated as follows:

Sr (%) = 100 Nf/Ni, with Nf and Ni: final and initial number of fish
Mr (%) = 100 Nd/Ni, with Nd: number of dead fish
Cr (%) = 100 Nm/Ni, with Nm: number of missing fish
Wf (g) = Tw/Nf, with Tw: total weight of fish
Mdwg (g/d) = (Wf−Wi)/t, with Wi: initial mean weight of fish and t: duration of the growth period (days)
Cv (%) = 100 (standard error of mean)/(mean weight)
Afcr = Ct/(Wf−Wi)Nf, where Ct is the total amount of food consumed during the experiment

Survival and growth data were presented as means±S.E. (standard error; n=3). An analysis of variance (ANOVA) was applied to test differences between stocking densities. This analysis was then followed by a Student–Newman–Keuls test when significant differences were observed. Multiple regression analysis between independent (densities) and dependent (survival and growth) variables was conducted to test the correlation between these variables. Differences were considered significant when $P<0.05$. Statistical analyses were performed using the STATISTICA 6.0 software (Statsoft, Inc.).

3. Results

Water quality characteristics, monitored throughout the study (Experiments 1 and 2) period, are summarized in Table 2.

Table 2
In-cage water minimum and maximum temperature, dissolved oxygen, pH and transparency recorded from September 2002 to August 2003 in Lake Ayame (min=minimum, max=maximum, Temp=temperature, O_2=dissolved oxygen and Trp=transparency)

		Temp (°C)	O_2 (mg/l)	pH	Trp (mm)
Experiment 1	min	24.0	4.1	6.6	1010
	max	31.2	6.9	7.9	1290
Experiment 2	min	23.0	4.2	6.8	990
	max	31.4	6.8	7.7	1300

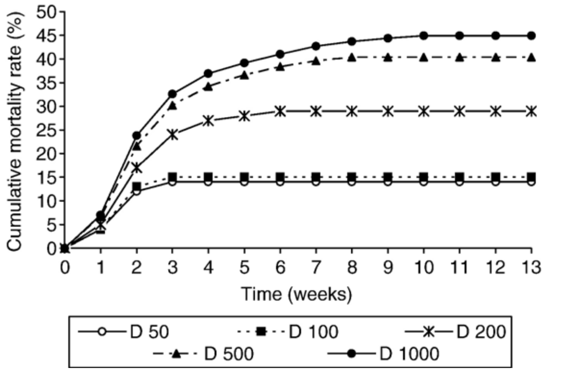

Fig. 1. Cumulative mortality rate in *Heterobranchus longifilis* (0.8 g initial mean weight) reared in floating cages for 90 days in Lake Ayame at five stocking densities (D50 to D1000=stocking densities of 50 to 1000 fish/m^3).

3.1. Experiment 1

Mortality (Mr) and cannibalism (Cr) rates of *Heterobranchus longifilis* of 0.8 g (Wi) reared in five different stocking densities (50, 100, 200, 500 and 1000 fish/m^3) are shown in Figs. 1 and 2. These results indicated that highest values of Mr and Cr were observed during the second week of the trial. Then, these phenomena decreased progressively and stopped earlier at the lower stocking densities. Multiple regression analysis showed that the final mean weight (Wf) and the mean daily weight gain (Mdwg) were not influenced (n=15; $P>0.05$) by stocking densities (50, 100, 200, 500 and 1000 fish/m^3). On the other hand, weight variation coefficient (final Cv), cannibalism (Cr), mortality (Mr) and survival (Sr) rates were directly linked (multiple regression; n=15; $P<0.05$) to stocking density. Final Cv, Cr and Mr increased with stocking density, whereas

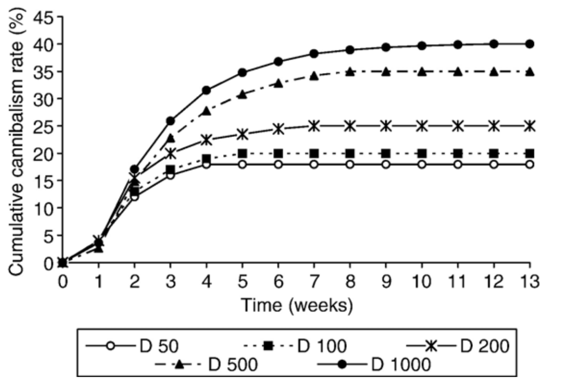

Fig. 2. Cumulative cannibalism rate in *Heterobranchus longifilis* (0.8 g initial mean weight) reared in floating cages for 90 days in Lake Ayame at five stocking densities (D50 to D1000=stocking densities of 50 to 1000 fish/m^3).

Table 3
Survival and growth parameters of *Heterobranchus longifilis* (0.8 g initial mean weight) reared in floating cages for 90 days in Lake Ayame at five stocking densities (*D*=stocking density, Wi=initial mean weight, Wf=final mean weight, Min and Max=minimum and maximum final weight, Initial Cv=initial weight variation coefficient, Final Cv=final weight variation coefficient, Cr=cannibalism rate, Mr=mortality rate, Sr=survival rate and Mdwg=mean daily weight gain)

D (fish/m^3)	50	100	200	500	1000	*P*-value
Wi (g)	0.80±0.10	0.82±0.09	0.81±0.11	0.80±0.12	0.79±0.14	>0.05
Initial Cv (%)	10.1±2.1	10.5±2.3	12.5±1.9	13.5±2.2	14.0±2.5	>0.05
Wf (g)	12.8±2.1	12.9±1.9	13.6±2.4	13.9±2.9	14.1±3.2	>0.05
Min (g)	9.8	9.2	8.1	6.0	5.0	
Max (g)	16.5	17.1	19.2	21.3	23.2	
Final Cv (%)	29.1±2.5[a]	31.1±2.4[a]	57.3±2.9[b]	70.4±3.1[c]	80.2±3.3[d]	<0.05
Cr (%)	18.0±2.2[a]	20.0±2.5[a]	25.0±1.5[b]	35.0±1.8[c]	40.0±2.1[d]	<0.05
Mr (%)	14.0±1.5[a]	15.0±1.8[a]	29.0±2.3[b]	40.4±1.9[c]	44.9±2.3[d]	<0.05
Sr (%)	68.0±1.5[a]	65.0±1.6[a]	46.0±2.1[b]	24.6±1.9[c]	15.1±1.2[d]	<0.05
Mdwg (g/d)	0.13±0.02	0.13±0.02	0.14±0.03	0.14±0.03	0.15±0.03	>0.05

Means that have a common superscript letter within a row are not significantly different ($P>0.05$).

survival rate (Sr) decreased. Interesting values of final Cv (29.1±2.5%), Cr (18.0±2.2%), Mr (14.0±1.5%) and Sr (68.0±1.5%) were recorded in 50 fish/m^3 stocking density. These parameters did not differ significantly from those recorded in 100 fish/m^3 (Table 3).

3.2. Experiment 2

Mortality and cannibalism rates of *Heterobranchus longifilis* of 13.4 g (Wi) reared at different stocking densities (6, 12, 25, 50 and 100 fish/m^3) are shown in Figs. 3 and 4. Mortality and cannibalism phenomena were only observed during the first two months at 50 and 100 fish/m^3 stocking densities for mortality and 25, 50 and 100 fish/m^3 for cannibalism. After 270 days, mortality (Mr), cannibalism (Cr), survival (Sr), weight variation coefficient (final Cv), final mean weight (Wf), mean daily weight gain (Mdwg) and apparent feed conversion ratio (Afcr) were influenced (multiple regression; $n=15$; $P<0.05$) by stocking densities. Higher Wf, Mdwg and Sr and lower final Cv, Cr and Afcr were recorded at the lowest (6 and 12 fish/m^3) stocking densities (Table 4). At the end of the experiment, mean weights recorded ranged from 460.1±45.0 g (6 fish/m^3) to 105.0±22.0 g (100 fish/m^3) with 100 and 72.0±2.0% survival rates, respectively.

4. Discussion

Water characteristics (temperature, dissolved oxygen concentration, pH and transparency) measured during the experimental period were within the range recommended for aquaculture (Boyd and Tucker, 1998).

The present investigation gives for the first time survival and growth data of the African catfish *Heterobranchus longifilis* reared in floating cages. The

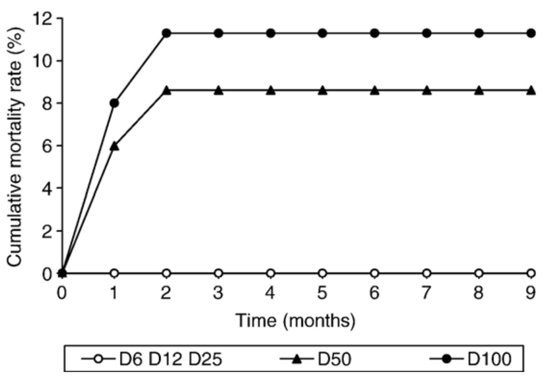

Fig. 3. Cumulative mortality rate in *Heterobranchus longifilis* (13.4 g initial mean weight) reared in floating cages for 270 days in Lake Ayame at five stocking densities (D6 to D100=stocking densities of 6 to 100 fish/m^3).

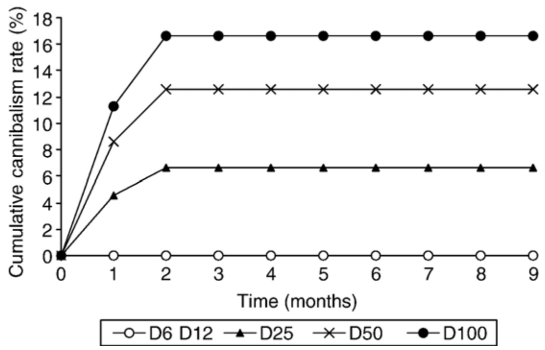

Fig. 4. Cumulative cannibalism rate in *Heterobranchus longifilis* (13.4 g initial mean weight) reared in floating cages for 270 days in Lake Ayame at five stocking densities (D6 to D100=stocking densities of 6 to 100 fish/m^3).

Table 4
Survival and growth parameters of *Heterobranchus longifilis* (13.4 g initial mean weight) reared in floating cages for 270 days in Lake Ayame at five stocking densities (*D*=stocking density, Wi=initial mean weight, Wf=final mean weight, Min and Max=minimum and maximum final weight, Initial Cv=initial weight variation coefficient, Final Cv=final weight variation coefficient, Cr=cannibalism rate, Mr=mortality rate, Sr=survival rate, Mdwg=mean daily weight gain and Afcr=apparent food conversion ratio)

D (fish/m^3)	6	12	25	50	100	*P*-value
Wi (g)	14.0±1.3	13.2±1.6	12.8±2.0	13.8±1.2	13.1±1.5	>0.05
Initial Cv (%)	10.0±2.1	14.0±2.3	12.1±1.9	13.1±2.2	13.9±2.5	>0.05
Wf (g)	460.1±45.0[a]	400.1±39.0[a]	310.1±29.1[b]	180.0±25.0[c]	105.0±22.0[d]	<0.05
Min (g)	299.5	288.9	210.6	99.8	65.9	–
Max (g)	513.2	501.6	429.2	245.0	185.5	–
Final Cv (%)	18.2±2.5[a]	20.1±2.4[a]	38.2±2.8[b]	61.4±3.3[c]	72.2±3.8[d]	<0.05
Cr (%)	0.0	0.0	6.6±2.0[a]	12.6±3.0[b]	16.4±4.0[b]	<0.05
Mr (%)	0.0	0.0	0.0	8.6±2.0	11.3±2.3	>0.05
Sr (%)	100[a]	100[a]	93.4±2.0[b]	78.8±1.9[c]	72.0±2.0[d]	<0.05
Mdwg (g/d)	1.65±0.15[a]	1.42±0.15[a]	1.09±0.10[b]	0.62±0.09[c]	0.34±0.10[d]	<0.05
Afcr	5.5±0.4[a]	6.3±0.2[a]	6.9±0.3[b]	7.9±0.2[c]	8.9±0.4[d]	<0.05

Means that have a common superscript letter within a row are not significantly different ($P>0.05$).

comparison of data recorded in this study to those of previous investigations (Legendre, 1991; Otémé et al., 1996) revealed a variation of the survival with the type of rearing systems (floating cage, earth pond, raceway, enclosure and cage-enclosure) (Table 5). According to Otémé et al. (1996), the best survival rate in *H. longifilis* is obtained when cannibalism and mortality phenomena are under control. Such expectation, for early growth stages (68%) and for grow-out stages (100%) seem to have been reached under the cage culture conditions in this study. Under culture conditions, the main causes that have been pointed out to explain survival reduction in *H. longifilis* and *C. gariepinus* were cannibalism and territorial aggression (Hecht and Appelbaum, 1987). In other cannibal fishes such as *Perca fluviatilis* L. and *Brycon moorei* Steindachner 1878 (Baras, 1998; Baras et al., 2000), territoriality and dominance hierarchy settings were also found to influence fish survival. These observations suggest a positive effect of floating cages on *H. longifilis* survival. Nevertheless, stocking densities were also found to influence survival of fish in floating cages in the present study. This was not the case for larvae (50 to 250 larvae/l), fry (50 to 150 fry/l) and larger (32 g initial mean weight, reared at 50, 100, 150 and 200 fish/m^3) catfish *C. gariepinus* reared in floating cages (Haylor, 1991, 1992; Hengsawat et al., 1997). As in the present work, cannibalism was density dependent in *C. gariepinus* (Hecht and Appelbaum, 1988). This link between high rate of cannibalism and high stocking densities could be explained by the increase in encounters probability between congeners or by the reduction of interindividual space (Li and Mathias, 1982; Krise and Meade, 1986; Van Damme et al., 1989). The observed cannibalism in fish cultured in cages may also be the resultant differential sizes within each cage. In fact, at the end of the study with the small fish, the extreme sizes in each group (fish/m^3) differed

Table 5
Survival and growth parameters of *Heterobranchus longifilis* in different rearing systems (*T*=time, *D*=stocking density, Wi=initial mean weight, Sr=survival rate, Mdwg=mean daily weight gain and Afcr=apparent food conversion ratio)

Authors	Rearing system	*T* (d)	*D* (fish/m^2)	Wi (g)	Sr (%)	Mdwg (g/d)	Afcr
Legendre (1983)	Enclosure	207	–	106	–	7.6	–
	Enclosure	170	–	280	–	10.4	–
Legendre (1991)	Earth pond	70	10	0.8	55	0.30	–
	Earth pond	308	0.7	0.2	66	3.52	1.41
	Cage-enclosure	380	4	28	92	2.81	3.54
	Enclosure	487	2	35	72	4.27	4.35
	Tank	146	7.5	50	97	3.24	1.52
Otémé (2001)	Earth pond	180	10	10–15	80–90	–	–
Present study	Floating cage	90	50*	0.8	68	0.13	–
	Floating cage	270	12*	13.2	100	1.42	6.30

Stocking densities with (*) are expressed in fish/m^3.

by 59% (50), 54% (100), 42% (200), 28% (500), and 22% (1000). The larger fish exhibited significant cannibalism in groups stocked at 50 or 100 fish/m^3 where minimal sizes were 100 and 66 g, respectively, and maximum sizes were close to 200 g. The lack of mortality at the lower stocking densities could be related to the minimal sizes exceeding 200 g. Closely grading of fish to minimize size variability during the study might reduce cannibalism, as has been demonstrated in some species in intensive culture (Otémé et al., 1996; Gilles et al., 2001). Another explanation of the observed mortalities and cannibalism could be related to conditions during the first part of the studies. Almost all mortalities occurred in the first 2–3 weeks of the first study, and in the first 2 months of the study with the larger fish. During an initial period, some fish often are reluctant to accept the feed, fail to eat, and become weak and vulnerable as observed in the sharptooth catfish *Clarias gariepinus* (Baras and d'Almeida, 2001). Alternatively, the fish may prefer to prey on other fish, but these problems may decrease once the fish adjust to feeding on the diets provided. Early mortalities also could be related to the initial presence of small and weak fish (Smith and Reay, 1991; Folkvord and Ottera, 1993).

Several studies were performed on growth performance of *Heterobranchus longifilis* in other rearing systems (Table 5). Although the initial mean weight and stocking density were not similar (for early growth and grow-out stages) among these former experiments, growth performances and apparent feed conversion ratio recorded in pond, cage-enclosure, enclosure and tank were better than those noted in the present study. Beyond 15 g, the growth of *H. longifilis* was not affected by rearing systems such as earth ponds, enclosures, cage-enclosures and tanks (Otémé et al., 1996). These systems have in common an important natural productivity formed by organic detritus, vegetable and animal remains, seeds, gastropods, batrachian larvae, insects, aquatic vertebrates and planktonic preys (Gilles et al., 2001). According to Micha (1973) and Otémé et al. (1996), *H. longifilis* is an omnivorous fish with carnivorous tendencies. Therefore, in these rearing systems, in addition to artificial food, fish take advantage of the natural resources. In contrast, species reared in floating cages depend exclusively on artificial food (Coche, 1978). These observations could explain growth (2.74–4.27 g/d versus 0.34–1.65 g/d) and apparent feed conversion ratio (1.41–4.35 versus 5.5–8.9) differences between these rearing systems (earth pond, enclosure, cage-enclosure and tanks) and those recorded in this study (floating cages).

Results of this study showed that beyond 12 g, *Heterobranchus longifilis* growth becomes density dependent. The highest growth rates were recorded in the lowest stocking densities. Similar results were observed in both tilapia (Mélard, 1986; Ruane et al., 2001; Ouattara et al., 2003) and catfish (Hogendoorn and Koops, 1983; Hengsawat et al., 1997; Barcellos et al., 2004). Individual growth and population density are known to be closely linked. Interindividual contacts, competition for food and stress that are more important in high densities could have adverse effects on growth performances (Haylor, 1992; Barcellos et al., 2004). Growth of the larger-sized fish was dramatically affected by stocking density. Unfortunately, this study provided no significant data to ascertain the limiting factors involved: the deterioration of water quality with increased densities and standing crops that adversely affect growth (Gavine et al., 1995; Breitburg et al., 1999). It is well known that diet requirements are stringent for fish cultured in cages. The availability of natural food could decrease at the high densities, which possibly resulted in nutritional deficiencies. Future studies based on nutrient requirements identification may be necessary to support this method of culture at significant densities.

In conclusion, the use of floating cages help reach a good Sr, a reduction of cannibalism and mortality rate. However, this is obtained when the fish are cultured at very low density, which does not seem to be cost effective for farmers.

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