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Sibling cannibalism in juvenile Asian sea bass (*Lates calcarifer*) reared under different photoperiods

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Abstract. The effect of the two photoperiods, constant darkness (24H D) and continuous light, (24H L) on the rate of sibling cannibalism in juvenile Asian sea bass (*Lates calcarifer* Bloch), also known as barramundi, reared indoors under intensive conditions was studied. The indoor experimental setup consisted of two separate systems each having three sixty-liter rectangular rearing tanks connected to a mechanical and a biological water cleaning unit. System 1 was kept under 24 hours of continuous light provided by two 36 watt fluorescent tubes. System 2 was kept under 24 hours of constant darkness except for a short period of 6 minutes during each feeding time. In the course of the study the experimental fish were transferred (after 70 rearing days) to larger rearing tanks of 100 L each. Juvenile Asian sea bass with an average weight of X= 0.73g (64 days post hatching) were used for the 112 day experiment. Each rearing tank was randomly stocked with 187 juveniles. A commercial fish feed (3mm sinking pellets: protein 46%, lipid 12%, fiber 4.6% and ash 8%; was provided to the fish by hand *ad libitum* four times during the day time. All live individuals in each rearing tank were counted once every two weeks and the rate of cannibalism was determined. Observed dead fish, not caused by cannibalism, were counted and recorded daily as mortality which was calculated. It was found that the accumulated observed mortality (not caused by cannibalism), was similar under 24H D (4.6%) and 24H L (4.1%) conditions. Although feed was provided *ad libitum,* cannibalism still occurred under both light and dark conditions. The rate of cannibalism, however, was significantly ($P < 0.05$) lower under constant dark conditions. The results show that a potential predator can swallow a prey up to a maximum of 67% of its own body length. Similar growth performances were observed in the fish groups reared under constant darkness and continuous light. Significantly ($p < 0.05$), however, highest survival was observed in the groups reared under constant darkness compared with the groups reared under continuous light. Fish reared under continuous darkness were more uniform in size and showed a normal population distribution curve while fish reared under continuous light conditions, showed higher heterogeneity in size and an abnormal distribution of population.
Key words: Asian sea bass, barramundi, sibling, cannibalism, photoperiods, mortality, growth.

Introduction. Cannibalism is a common behavior in teleost species (Kestemont et al 2003) that has been observed so far in 36 of 410 fish families and occurs at various ages or sizes depending on fish species and the respective environments (Hecht & Pienaar 1993). Among the commonly cultured fish species, cannibalism has been reported in walleye *Stizostedion vitreum* (Cuff 1980), African catfish *Clarias gariepinus* (Hecht & Appelbaum 1988), common carp *Cyprinus carpio* (van Damme et al 1989), Atlantic cod *Gadus morhua* (Folkvord 1991), perch *Perca fuviatilis* (Melard et al 1996), vundu catfish *Heterobranchus longifilis* (*Baras* et al 1999)*,* dorada *Brycon moorei* (Baras et al 2000)*,* swordtail (Jones 2002), orange spotted grouper *Epinephelus coioides* (Hseu et al 2003), giant grouper *Epinephelus lanceolatus* (Hseu et al 2004), barramundi *L. calcarifer* (Qin et al 2004) and in many others.

The Asian sea bass, known also as 'barramundi' is a highly priced and commercially popular species in aquaculture on the Asian and Australian continents (Tucker et al 2002). In barramundi culture cannibalism can cause severe losses during the early stages of development particularly before fish reach a length of about 10 cm (Qin et al 2004). In barramundi hatcheries frequent size grading of the fingerlings has to be employed to reduce the rate of cannibalism. This practice however, is not only labour intensive but also stresses the entire fish stock being graded. Although size heterogeneity strongly affects cannibalism, the intensity of cannibalism also varies according to

environmental conditions (Pienaar 1990). Previous studies on cannibalism in fish have focused mainly on regularly grading fish by size (Hoakanson & Lien 1986), reducing stocking density (Smith & Reay 1991) and feeding to full satiation (Qin & Fast 1996), while little research has been directed to manipulation of abiotic factors (Hecht & Pienaar 1993).

Dou et al (2000) reported that light intensity significantly affects cannibalistic behavior in Japanese flounder *Paralichtys olivaceus*. Qin et al (2004) reported that low light intensity and provision of refuges significantly reduced cannibalism in barramundi, yet the exact effect of constant darkness or continuous light on cannibalism has not been studied.

The present aim of the study is to observe the effect of the two photoperiods, constant darkness (24H D) and continuous light (24H L) on the rate of sibling cannibalism in barramundi juveniles reared indoors under intensive conditions.

Materials and Methods

Experimental System. The indoor experimental setup consisted of two separate systems labeled system 1 and 2. Each system consisted of three rectangular rearing tanks each of 60-L capacity connected to a mechanical and a biological water cleaning unit made of a 100-L water-cleaning tank filled with volcanic gravel and strongly aerated water. System 1 was kept under 24 hours of continuous light provided by two 36 watt fluorescent tubes. System 2 was kept under 24 hours of constant darkness except for a short period of 6 minutes during each feeding time. The two systems were filled with dechlorinated freshwater which was recirculated and pumped to each rearing tank at the rate of 3 liters per minute. Twenty percent of the water volume in each system was replaced daily to compensate for losses due to evaporation and sludge removal from the water cleaning unit. An air blower provided compressed air for maintaining oxygen levels in the rearing tanks above 4 ppm. Ammonia and nitrite levels in the rearing water were below the toxicity levels for Asian sea bass. Water temperature in the systems was kept at 28±1ºC using thermostatically controlled electric heaters. In the course of the study the experimental fish were transferred (after 70 rearing days) to larger rearing tanks of 100 L each.

Experimental Fish. Juvenile Asian sea bass produced via induced spawning ("Maagan Michael Hatchery", Israel), with an average weight of X= 0.73g (64 days post hatching) were used for the 112 day experiment. Each rearing tank was randomly stocked with 187 juveniles.

Feed and Feeding. A commercial fish feed (3mm sinking pellets: protein 46%, lipid 12%, fiber 4.6% and ash 8%; "Shivuk Rannan", Israel) was provided to the fish by hand *ad libitum* four times during the day time.

Observation. Representative fish samples (N=30) from each experimental group were weighed every two weeks to monitor growth performance. Survival (%), weight gain (g), weight gain (%), specific growth rate (SGR $\%d^{-1}$), feed conversion ratio (FCR) and protein efficiency ratio (PER) were calculated as follows:

$$\textbf{\textit{Survival}}\ (\%) = \frac{\text{No. of fish stocked} - \text{No. of mortalities}}{\text{No. of fish stocked}} \times 100$$

$$\textbf{\textit{Weight gain}}\ (g) = \text{Final mean weight (g)} - \text{Initial mean weight (g)}$$

$$\textbf{\textit{Weight gain}}\ (\%) = \frac{\text{Final mean weight (g)} - \text{Initial mean weight (g)}}{\text{Initial mean weight (g)}} \times 100$$

$$\textbf{Specific growth rate}\ (\%\ d^{-1}) = \frac{\text{Ln } \log_e \text{ final mean weight} - \text{Ln } \log_e \text{ initial mean weight}}{\text{Duration of the experiment (days)}} \times 100$$

$$\textbf{Feed conversion ratio} = \frac{\text{Amount of feed provided (g)}}{\text{Weight gain (g)}}$$

$$\textbf{Protein efficiency ratio} = \frac{\text{Weight gain (g)}}{\text{Protein absorbed (g)}}$$

Observed Mortality. Observed mortality was recorded daily. Observed dead fish, not caused by cannibalism, were counted and recorded as mortality which was calculated as follows:

$$\textbf{Mortality}\ (\%) = \frac{\text{Number of dead fish}}{\text{Initial number of fish}} \times 100$$

Cannibalism. All live individuals in each rearing tank were counted once every two weeks and the rate of cannibalism was calculated as follows:

$$\textbf{Cannibalism}\ (\%) = \frac{\text{Number of missing fish} - \text{Number of observed dead fish}}{\text{Initial number of fish}} \times 100$$

Predator-Prey Size Ratio. Predators, from both light and dark systems when found grasping their prey, were netted out and the length and weight of both the predator and its prey were measured and the ratio calculated as follows:

$$\textbf{Predator prey size ratio (\%)} = \frac{\text{Prey length (cm)}}{\text{Predator length (cm)}} \times 100$$

Statistics. The growth and survival data were analyzed using one-way ANOVA and Tukey's Multiple Range Test (Zar 1984). At the termination of the experiment the weights of all surviving fish in each treatment were recorded and plotted to produce the Gaussian Population Distribution Curve using Statistica software version 7.

Results

Feeding Behavior. In both light and dark systems, larger specimens were much more active during feedings, chasing smaller siblings away from the provided feed, leaving them only the remains to feed on. During feedings, fish under constant light exhibited a uniform schooling towards the feed, while in the dark system they were scattered and approached the feed individually.

Observed Mortality. The accumulated observed mortality (not caused by cannibalism), was similar under 24H D (4.6%) and 24H L (4.1%) conditions (Figure 1).

Observed Cannibalism. In both light and dark systems larger specimens made repeated attempts to catch smaller siblings. When an attempt to seize a prey was successful, the predator would catch and swallow the prey head first. Occasionally, however, due to the prey size, the predator was unable either to continue swallowing its prey or to releasing it, the prey remaining lodged in the predator's mouth causing the death of both.

In the present study although feed was provided *ad libitum,* cannibalism still occurred under both light and dark conditions. However, the rate of cannibalism was significantly ($P < 0.05$) lower under constant dark conditions (Figure 1).

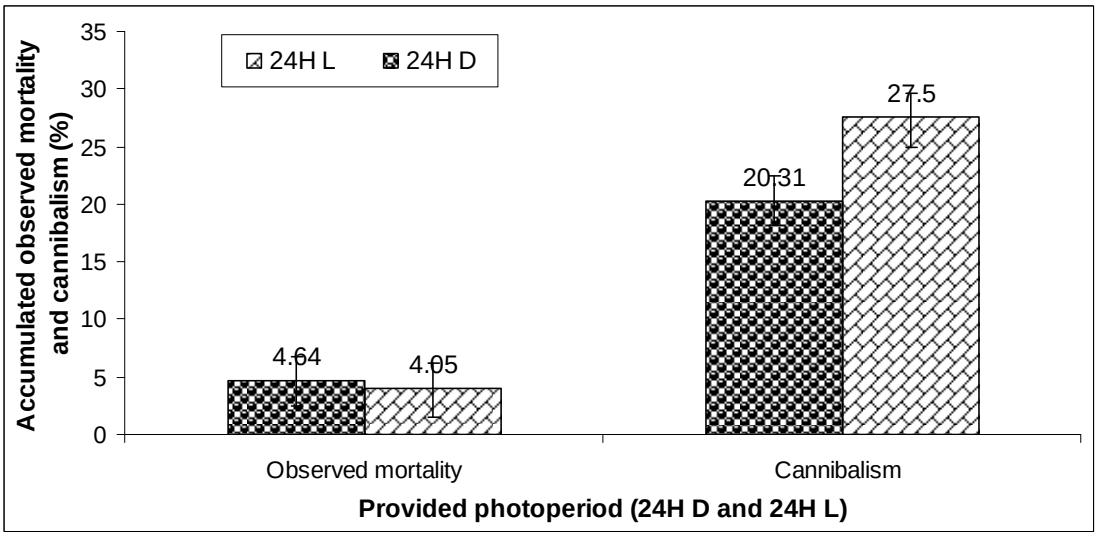

Fig. 1. Accumulated observed mortality (%) and cannibalism (%) of juvenile Asian sea bass reared under two photoperiods for 112 days

Table 1

Observed cannibalism in juvenile Asian sea bass reared under two photoperiods for 112 days

	Predator-Prey size ratio (%)	
Day of rearing	Continuous light condition (24H L)	Constant dark condition (24H D)
5	43.1	-
7	37.7	-
10	40.3	-
11	-	65.0
12	44.4	-
15	38.3	-
16	-	63.4
17	34.6	-
19	34.1	-
20	-	52.1
21	32.9	-
23	32.0	-
25	27.7	-
32	-	52.3
37	-	52.2
41	-	57.9
56	53.0	-
57	51.9	-
61	67.0	53.4
72	-	58.1
80	60.6	-
97	55.8	54.1
102	-	57.2
106	65.3	-
108	61.1	-
109	-	-
110	-	-
111	-	-
112	-	-

Predator-Prey Size Ratio. The calculated predator-prey size ratio is presented in Table 1. The results show that a potential predator can swallow a prey up to a maximum of 67% of its own body length (as occurred under continuous light condition on day 61 of the experiment).

Growth and Survival. The growth performances are presented in Table 2 and Figure 2. Similar growth performances were observed in the fish groups reared under constant darkness and continuous light. Significantly ($p < 0.05$), however, highest survival was observed in the groups reared under constant darkness compared with the groups reared under continuous light.

Table 2

Growth performances of juvenile Asian sea bass reared under two photoperiods for 112 days

Parameters	*24 Hours Light (24H L)*	*24 Hours Dark (24H D)*
Initial weight (g)	0.73 ± 0.32	0.73 ± 0.32
Final weight (g)	19.84 [a] ± 2.6	20.09 [a] ± 1.2
Weight gain (g)	19.11 [a] ± 3.1	19.36 [a] ± 2.3
Weight gain (%)	2617.9 [a] ± 192.3	2652.1 [a] ± 103.2
FCR	1.67 [a] ± 0.61	1.65 [a] ± 0.29
PER	2.07 [a] ± 0.41	2.1 [a] ± 0.38
SGR (% d^{-1})	2.38 [a] ± 0.73	2.39 [a] ± 0.42
Survival (%)	68.44 [a] ± 7.6	75.04 [b] ± 3.2

- a and b denote significant differences at $P < 0.05$ level by one-way ANOVA and Tukey's Multiple Test

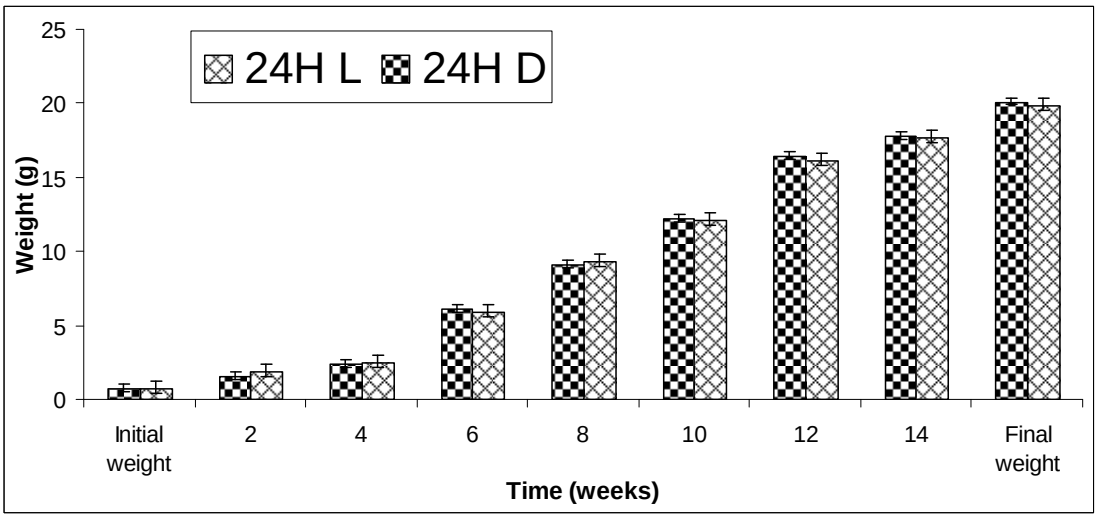

Fig. 2. Weight (g) of juvenile Asian sea bass reared under two photoperiods for 112 days

Gaussian Population Distribution Curve. Statistical analyses of Gaussian Population Distribution confirmed that fish reared under continuous darkness were more uniform in size and showed a normal population distribution curve (Figure 3). Fish reared under continuous light conditions, however, showed higher heterogeneity in size and an abnormal distribution of population (Figure 4).

Discussion

Previous studies have shown that food availability affects cannibalism in fish (Hoakanson & Lien 1986; Qin & Fast 1996). Parazo et al (1991) reported that although the extent of cannibalism in Asian sea bass is size-dependent, the ability of a cannibal to detect conspecifics depends on the habitat complexity and ambient light levels. For visual-feeder fish, searching, chasing, and capturing prey require some degree of light. Hecht &

Appelbaum (1988) and Pienaar (1990) reported that dim light significantly reduced the incidence of territorial aggressive behavior and cannibalism in African catfish.

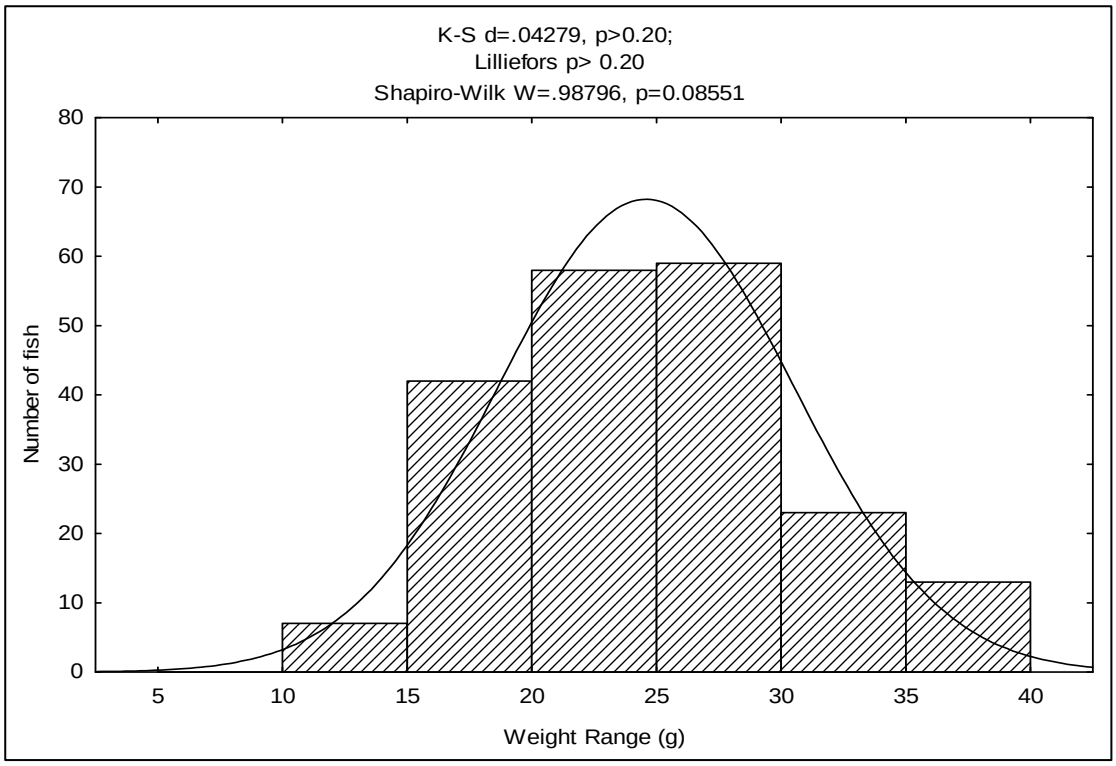

Fig. 3. Normal population distribution curve of juvenile Asian sea bass reared under constant darkness

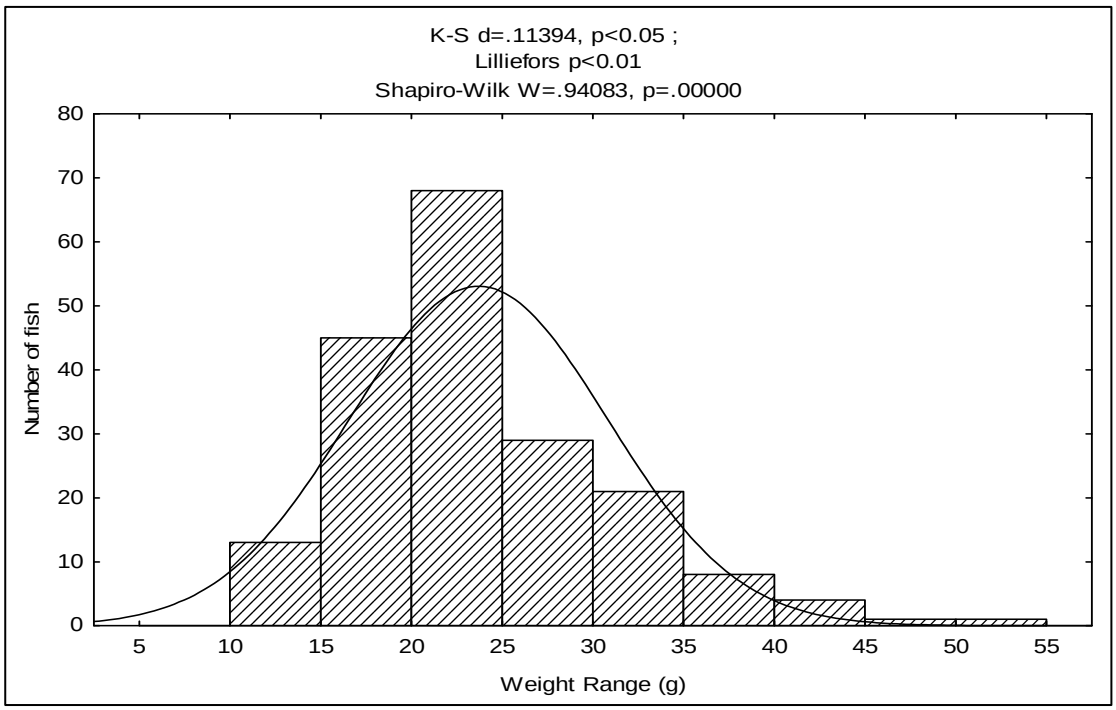

Fig. 4. Abnormal population distribution curve of Asian sea bass reared under continuous light conditions

Food availability was found to have greatest effect on the behavior of African catfish and hence on the rate of cannibalism (Hecht & Appelbaum 1988). In the present study although feed was provided *ad libitum* cannibalism still occurred in both treatments, thus cannibalism in juvenile barramundi is ongoing, in spite of *ad libitum* feeding. The rate of cannibalism, however, was significantly ($P < 0.05$) lower under constant dark conditions, possibly due to reduction in fish activity. The rate of the recorded accumulated mortality, not caused by cannibalism, was similar under 24H L and 24H D conditions. Survival rate, however, was significantly lower in the 24H L system, indicating that the occurrence of cannibalism contributes crucially to the overall survival rate of the population. The present study shows that cannibalism in barramundi can be reduced when constant darkness is provided. In contrast, under continuous light condition aggressive behavior was more pronounced and this in turn was reflected in a significantly ($P < 0.5$) higher rate of cannibalism.

Although the present findings show that constant darkness significantly reduces the rate of cannibalism in barramundi juveniles, studies of other species reported different results on the effect of light levels on cannibalism. Cannibalism in dorada *Blycon moorei* occurred during the daytime and at night and even persisted in permanent darkness (Baras et al 2000). Dou et al (2000) reported that cannibalism among juvenile Japanese flounder was more frequent in light than in darkness. Piennar (1990) and Hecht & Pienaar (1993) reported that African catfish in darkness have reduced levels of cannibalism and territorial aggression resulting in better growth performance. Again the present results show clearly that constant darkness reduced cannibalism and increased survival in juvenile barramundi significantly.

The results of predator-prey size ratio agree with earlier studies by Parazo et al (1991) and Qin et al (2004) who found that a barramundi cannibal can swallow a sibling with a body length of 70% or less than its own. The present results suggest that sibling cannibalism in juvenile Asian sea bass can begin when the body length of a cannibal reaches about one and half times that of the prey fish. From the results of the present findings a 4.5cm long barramundi can swallow a sibling prey of 3cm long. Finally although fish in the present study were weaned from live *Artemia* to take dry feed, cannibalism still prevailed under *ad libitum* feeding on dry feed.

Conclusion

The rate of sibling cannibalism in juvenile Asian sea bass can be reduced significantly by providing continuous darkness, without affecting other growth parameters. The application of constant darkness is therefore a useful strategy in significantly reducing cannibalism when rearing Asian sea bass. Furthermore, such a strategy also leads to the formation of a more uniform population of fish which is a desire of the grower. Finally this strategy may be useful in rearing other cannibalistic species.

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