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Minerva I Morales
Professor, Catanduanes State University, Virac, Catanduanes 4800.

Roberto B Barba Jr
Faculty, College of Agriculture and Fisheries, Catanduanes State University.

Correspondence
Roberto B Barba Jr
Faculty, College of Agriculture and Fisheries, Catanduanes State University.

Effects of photoperiod, water levels and sex on the feeding efficiency and weight increment of Mudcrabs (*Scylla serrata* Forskall) in a crab-fattening culture system

Minerva I Morales, Roberto B Barba Jr

Abstract
A factorial experiment on the effects of photoperiod, sex, and different water levels was conducted to determine the feed efficiency, feeding behaviour, weight increment and survival percentage of mudcrabs cultured in individual and aggregate set up. Results revealed a single and interactive effects of both photoperiod and sex on weight increment and survival of mudcrabs while different water levels were insignificant to the parameters measured. Under zero photoperiod, mudcrabs exhibited less agitated movement concomitant with continuous feeding activity, indicative of the nocturnal feeding habits of the species, observed in fattening enclosure set-up. Feeding efficiency is highly significant for male crabs under zero photoperiod. Weight increment of mudcrabs attainable in 15-20 days in the usual crab-fattening practice under normal photoperiod could be possible in as early as 7-day period for crabs grown in induced dark condition (0L:24D), implicating a higher economic return in a capture-based culture system.

Keywords: photoperiod, feed efficiency, feeding behaviour, weight increment, capture-based culture system

1. Introduction
Photoperiod has been determined to be one of the factors that set some physiological changes in a number of flora and fauna [1]. It has been determined to be one of the timers which trigger and bring about growth and flowering in many plants, the molting, fat deposition, migration and breeding of birds, crustaceans, and in some mammals. Day length in mammalian species provides a noise-free environmental signal affecting the reproductive fitness, behavioral responses, energy balance, physiological cues and survival [2]. Aquatic species, on the other hand, exhibited specific responses when subjected to particular light and dark cycles (light: dark, L:D). Locomotor and foraging activity, feed conversion and protein efficiency in Tilapia (*Oreochromis niloticus*) fingerlings were significant when exposed to long photoperiods [3]. Growth and higher gonado-somatic index (GSI), indicator of gonadal development, were observed proportional to continuous long-day exposure in *Pseudorasbora parva*, compelling an early sexual maturity stage of the species [4]. Boeuf, G. and Bail, P.Y L., 1999 delineated the subtle effect of light on fish growth by way of looking into light quality (light spectrum), intensity and periodicity (light and dark cycles). Feeding efficiency reflects fish' diurnal feeding habit favored by long photoperiod. Variation in some species, however, can be attributed to photoperiod preference as species-specific function concomitant with developmental stages [5].
Crab fattening in cages and various containers have been determined to be technically and economically feasible. Land-based crab-fattening project may obtained an average growth increase of 20-25 g per crab in 14-15 days with the average stock weighing 200 grams [6]. With this system however, additional cost and efforts for water hauling can be incurred every time water has to be changed. In Makato, Aklan, crab fattening project reported in 1992, under this system, thin crabs were stocked in earthen ponds and fattened for 15-20 days before they were sold in the market. Fishers concluded that the technology was more profitable than the grow-out system of mudcrab culture. Fattened crabs are more fleshy, weigh heavier and oftentimes contain ripe gonads. Still, fattened female crabs command higher price and are preferred by customers than male crabs. The morphological difference in male and female crabs may

account for the difference in their feeding efficiency, thus, sex of Mudcrabs was considered in the present crab-fattening system.

Considering that mudcrabs are nocturnal feeders [7, 8], thus, actively feeding at night, manipulating photoperiod may create an environment conducive for continuous feeding activity. Adopting a culture system for mudcrabs may, therefore, consider its nocturnal feeding habit [9]. In effect, crabs may grow faster in a shorter culture-period. This in turn will result to a faster turnover of harvest, more cropping cycle in a given time, therefore increased income and profit for the aquaculturist. Also, determining the required water level in the culture media for optimum growth of crabs will also help in the water management scheme in a fattening-culture system and reduce cost of water hauling in a land-based set-up. Hence, this study determined the effects of normal and zero photoperiods at three levels of water on the feeding efficiency and weight increment of male and female Mudcrabs in a fattening-culture system.

2. Materials and Methods

2.1 Experimental Set-up A

Twelve 35-liter capacity glass tanks were prepared and was provided with NSBI aerator. They were set outdoor near the brackish water ponds to facilitate water exchange. Six of the glass tanks maintained normal photoperiod while the other six were completely covered with thick black plastic for 24 hours to effect total darkness. Three glass tanks were stocked with male crabs and the other three tanks were stocked with female crabs, both for normal and zero photoperiod treatments. Water levels evaluated were 30, 20 and 10 cm with a salinity maintained at 20 ppt. Fifty percent of the water were siphoned and replaced every afternoon. Water temperature was also monitored and recorded.

Individual crab with an average weight of 200 ± 1.0 gram was used in the experiment. Feeding rate of 10% of body weight was given during the experiment. One kind of diet was maintained for the duration of the evaluation and was divided into three ratios of 20%, 20% and 60% given at 0900 H, 14000H and 1800H, respectively.

2.2 Experimental Set-Up B

Twelve 1 sq.m. Experimental area holding different water levels 30, 20 and 10 cm were prepared. The bottoms were lined with black plastic to prevent water loss from seepage. Each was provided with NSBI aerator. Six of the area maintained normal photoperiod while the other six were top covered with thick black plastic for 24 hours to effect total darkness. Three areas were stocked with all male crabs and the other three with all female crabs, for both treatments.

Four to five crabs with an average weight of 1 ± 150 grams and mean carapace width of 8.5 cm were used in the experiment. They were stocked in the experimental crab-fattening culture system. Feeding rate of 10% of body weight was observed during the experiment. One kind of diet was maintained for the duration of the evaluation and was divided into three ratios of 20%, 20% and 60% at 0900H, 1400H and 1800H, respectively. Salinity level was maintained at 20 ppt. Fifty percent of the water were siphoned and replaced every afternoon while constantly monitoring the water temperature.

2.3 Experimental Set-Up C

A 2 x 2 x 3 factorial experiment in a completely randomized design was conducted to determine the effects of normal and zero photoperiods to male and female crabs in 10, 20 and 30 cm water levels. Six replications were made to determine treatment effects. Treatment effects were analyzed by Factorial Analysis of Variance.

3. Results and Discussion

3.1 Behavior, Feeding Efficiency of Mudcrabs Kept under the Photoperiods Evaluated.

Mudcrabs kept in zero photoperiod culture media appeared to be calm than crabs subjected to normal photoperiod. Movements of experimental animals under the zero photoperiod set-up were minimal. They appear to be less agitated, both in male and female crabs, under set-up A and B. compared to the specimen kept under normal photoperiod. Since mudcrabs prefer to burrow in the mud specially to escape from adverse pond or mangrove condition, the effect of darkness by the zero photoperiod set-up may have provided favorable effect to the mudcrabs, thus, agitated movements and attempts to escape from the set-up were not observed.

Feeds given at three ratios a day to animals kept at zero photoperiods were completely consumed but not to mudcrabs kept under the normal photoperiod. Feed given to animals kept at normal photoperiods were not totally consumed, except feed ratio at 1800 H. about 80% of feed given at 0900 H and 1400 H were left unconsumed. The zero photoperiod treatment of the 24-hour darkness effect of the black plastic cover may have created an environment that resulted to a continuous feeding activity and higher feeding efficiency both in individual and aggregate set-up (refer to Table 1 and 2).

Table 1. Response of Male and Female Crabs to Normal and Zero Photoperiods at Three Water Levels in a Crab-Fattening Culture System

Factors	Normal Photoperiod						Zero Photoperiod					
	Male			Female			Male			Female		
Water Levels (cm)	10	20	30	10	20	30	10	20	30	10	20	30
Initial Wt. (g)	200	200	220	200	195	210	200	195	205	200	215	210
Final Wt. (g)	225	228	238	215	219	220	288	269	300	245	250	265
Wt. Increment (g)*	25	28	18	15	24	10	88	74	95	45	35	55
% Increase	12.5	14	8.18	7.5	12.3	4.76	44	37.9	46.3	22.5	16.3	26.2
Feeding Efficiency (Feeding Rate/ Growth Rate) **	5.6	5.0	8.5	9.3	5.6	4.7	2.0	2.13	2.17	3.1	4.3	2.6
% Survival ***	75	65	75	92	65	85	100	95	100	100	100	90

*Weight increment is highly influenced by photoperiod and sex of crabs (P<0.01);

**Feeding efficiency is significantly higher (P<0.01) in crabs at zero photoperiod and in male crabs;

***Rate of survival is significantly higher at zero photoperiod (P<0.01).

In prawn hatcheries, gravid prawns that are usually caught from the wild for breeding purposes are kept in a "dark room". The environment created in the "dark room" triggers continuous feeding activity in prawns and consequently, the release of viable eggs. The same environment appears to have influenced the continuous feeding activity in crabs resulting to a higher weight increment in seven days compared to the 15-20 days crab-fattening practice in normal photoperiod. It was however noted, that feeding of crabs and consequently its growth was affected when both pinchers are absent. The presence of one pincher nonetheless is sufficient to attain the growth rate presented in this study. Losing the pinchers is automatic among crabs where it cuts off its appendage just to be free from adverse condition.

Findings of the study indicated that feeding activity in mudcrabs can be influenced by manipulating photoperiod. Chiu, *et al*., (1986) studied factors affecting the feeding rhythm of milkfish *Chanos chanos*. Results of the study showed that regardless of biological, physical and chemical factors simulated to effect continuous feeding of the fish, its whole digestive track was consistently empty from 10 PM to 2 AM indicating absence of feeding even before 10 PM. Both results have implications on the feeding management of aquatic organisms in a given culture system [10].

In a mix culture of mudcrabs and milkfish in ponds, a feed conversion rate (FCR) of 1.7 using trashfish [11] while an FCR of 1.2 could be possible using golden apple snail, *Pomacea canaliculata*, in a monoculture of mud crabs in brackishwater ponds [12]. However, both ponds still contain natural organisms where crabs can feed on. Results of the present study showed that feeding efficiency of mudcrabs was highly influenced both by photoperiod and sex of crabs. Zero photoperiod significantly influenced higher weight increment in male than in female crabs (P<.01). Highest feeding efficiency of 1.0 was recorded under the aggregate set-up (B) of male crabs, zero photoperiod and 30 cm water level (refer to Table 2).

Table 2. Response of Aggregate of Male and Female Crabs to Normal and Zero Photoperiods at Three Levels of Water in a Crab-Fattening Culture System

	Normal Photoperiod						**Zero Photoperiod**					
	Male			**Female**			**Male**			**Female**		
Water Levels (cm)	10	20	30	10	20	30	10	20	30	10	20	30
Initial Wt. (g)	950	850	950	1.05	1.10	1.05	940	980	1.0	960	985	1.05
Final Wt. (g)	1.06	975	1.09	1.15	1.21	1.18	1.45	1.51	1.7	1.31	1.29	1.38
Wt. Increment (g)*	115	125	140	100	110	135	510	530	700	350	305	330
% Increase	12	14.7	14.7	9.5	10	12.8	54.2	54.1	70	36.4	30.9	31.4
Feeding Efficiency (Feeding Rate/ Growth Rate **	5.7	4.76	4.75	7.0	7.0	5.4	1.3	1.3	1.0	1.9	2.26	2.12
% Survival ***	70	90	85	75	90	85	100	100	100	100	100	100

* Weight increment is highly influenced by photoperiod and sex of crabs (P<0.01);

**Feeding efficiency is significantly higher (P<0.01) in crabs at zero photoperiod and in male crabs;

***Zero photoperiod significantly influenced the high rate of survival (P<0.01) in crabs.

3.2 Single and Interactive Effects of Photoperiod, Sex and Water Levels on the Feeding Efficiency, Survival and Growth Increment of Male and Female Crabs.

Results of the study showed that there is no significant interaction between the three water levels evaluated and the feeding efficiency of mud crabs in both sexes evaluated under normal and zero photoperiods. This implies that crab-fattening can have the same growth and survival compared to a water level of 20 or 30 cm. This finding further means a reduction in operating expenses especially in a land-based crab-fattening system wherein hauling of water is an added operating cost.

Likewise, no interaction effect was manifested by water levels evaluated on the weight increment and survival of mudcrabs in a fattening-culture system. Consistently, photoperiod and sex of crabs had single and interactive influence (P<0.01) on the weight increase and survival of the cultured species. Crabs kept in zero photoperiod in set-up A and B had significantly higher weight increment (P<0.01) than those kept in normal photoperiod (refer to Table 1 and 2). Male crabs also had significantly higher weight increment (P<0.01) than female crabs.

Some mortality occurred in the cultured species under set-up A and B, normal photoperiod, hence, lower survival rate was recorded. For cultured species under set-up A and B, zero photoperiod, there was almost a consistent 100% survival for all the trials evaluated. The high survival rate may be accounted for the favorable culture media affected by the black plastic cover, favoring crabs who prefers to burrow in the mud and are nocturnals.

3.3 Economic Analysis.

Results of the partial budget analysis of technologies developed in Mudcrab culture and fattening is presented in Table 3. Analysis was made on a per kilogram stock costing P120.00 of marketable size crabs either caught from the wild or from fishponds. Under the crab-fattening system at zero photoperiod, a mean growth increment of 500 to 700 and 300-30 g per kilogram in 7-10 days, male and female, respectively, is attainable. In fishponds, it takes 120 days for juvenile crabs to attain marketable size of 4 to 5 pieces per kg or an average of 200 to 250 g per piece. Some farmers culture mudcrabs with milkfish and lately with *Gracilaria* with the latter serving as shelter for crabs aside from being an additional crop [13]. Trashfish is provided as supplemental feed to mudcrabs under the system. And because other organisms are still present in the pond serving as food for crabs a feed conversion value of 1.7 was reported [11], which means that 1.7 kg of trashfish is needed to produce a kilogram of marketable crabs. At P30/kg of trashfish, cost of feed for one cropping is only P52.00 and net benefit of P69.00 at a market price of P120/kg., the net benefit in pond culture of crabs is the least compared with the crab-fattening systems, with the highest net benefit provided by the crab-fattening system at zero photoperiod, both for male and female crabs.

Generally, fattened crabs command higher price at lower increment values are obtained in fattening under normal photoperiod. In the system, cost of feed is the only additional cost and takes 15 to 20 days to really fatten the crabs and achieve a significant weight increase. With an added variable cost of P25.00 per 1 sq m of black plastic, an income of P53 to

P103 higher than fattening in normal rearing condition (without black plastic cover) can be achieved in as early as 7 to 10 days (see Table 3). In effect, the P53 to P103 price difference between fattening in a normal and zero photoperiods can still be doubled due to the number of cropping cycles attainable in only half the period required under normal photoperiod.

While increase in weight is higher in male than female crabs, the relatively higher price accorded to female crabs in the market, may still result to a higher net return on female crabs under zero photoperiod system. Female crabs are highly sought for because of its gonads or *aligue*, thus, commanding higher price.

Table 3. Partial Budget Analysis of the Mudcrab Culture Technologies per Kilogram Basis (Less Cost of Fixed Asset, Labor and Security)

Variable Costs	Mudcrabs Culture Technologies			
	Pond Culture with Feeding	**Fattening in Normal Photoperiod**	**Fattening at Zero Photoperiod (Female)**	**Fattening at Zero Photoperiod (Male)**
Cost of 1 Kg Stock (P)	120.00*	120.00	120	120.00
Feed Required (g/kg)	1.7	150 g	75	75 g
Cost of Feed at P30/kg	51.00	7.00	3.50	3.50
Culture Period (days)	120	15-20	7-10	7-10
Black Plastic Cover (P)	-	-	25.00	25.00
Electricity (P)	-	7.50	3.50	3.50

Assuming that cost of fattened crabs is P200 and P250/kg for male and female crabs, respectively; 10pcs/kg; 50% survival at the end of 120-day culture period.

4. Summary, Conclusion and Recommendations

Mud crabs, *Scylla serrata*, are known to be nocturnal feeders. Manipulating photoperiod to effect a 24-hour darkness (0L: 24D) resulted to a significant weight increment and survival of the cultured species ($p<0.01$) compared with the same set-up under normal photoperiod. Factor interaction between photoperiod and sex of crabs was determined to favor zero photoperiod and male crabs resulting to higher feeding efficiency, weight increment and survival of the cultured species ($P<0.01$) relative to the set-up with normal photoperiod and female crabs counterpart. Consistent findings were determined both in set-up A and B.

The zero photoperiod environment effected a continuous feeding activity in crabs kept under the system, even at daytime. The activity resulted to faster growth increment of 500 to 700 and 325 to 350 g per kilogram of male and female crabs, respectively, in 7-10 days. This growth increment is normally achieved in 15 to 20 days in a crab fattening system with normal photoperiods.

Crabs in a normal photoperiod consume less or none at all during daytime. Crabs in normal photoperiod may therefore be given feed ration at about 1800 H only. Doing so will prevent further deterioration of the water quality caused by the feed given and save cost for water exchange. The three levels of water on the culture media which were evaluated, 10, 20 and 30 cm did not have a significant influence on the weight increment, feeding efficiency and survival of the crabs studied. This implies that crab-fattening can be practiced even in minimal water level of 10 cm and still achieve the same growth and survival compared to a water level of 20 or 30 cm. These findings further suggest a reduction in operating expense especially in a land-based crab-fattening system wherein hauling of water entails added operating cost for a capture-based culture system.

The economic benefit for fattened crabs in zero photoperiod is over hundred percent in seven days only, for male and female crabs compared to 70% in a crab-fattening system in normal photoperiod but achieved in 15 to 20 days. Under the zero photoperiod scheme two cropping cycles can already be performed, thus, more economic returns can be attained by the farmers using the zero photoperiod fattening system with only P25.00 for the black plastic cover as an added cost. This technology therefore can be easily replicated and adopted at the farmer level.

While feeding efficiency and growth increment in male crabs is faster than female crabs, the higher price accorded to female crabs because of its gonads or *aligue* resulted to the same economic benefits. Culturing both sexes have potential for high economic returns.

The crab-fattening scheme developed may also facilitate gonadal maturation for Mudcrab breeding and hatchery purposes. Considering that mudcrabs is a highly sought commodity with expanding local and international market, mass production of seeds and juvenile crabs is a felt need to expand production. Mudcrab population caught from the wild for purposes of stocking in fishponds and for market is continuously experiencing rapid reduction. More so, gravid crabs for breeding purposes. The technology developed therefore may not only be used for fattening purposes, but also applicable to achieve early gonadal development and maturation for breeding and hatchery purposes and supply the insatiable demand for juvenile crabs, thus, increasing production.

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