DEVELOPMENT OF A DEMAND FEEDING SYSTEM FOR BROWN-MARBLED GROUPER *Epinephelus fuscoguttatus* AND ORANGE-SPOTTED GROUPER *Epinephelus coioides* JUVENILES

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ABSTRACT

DEVELOPMENT OF A DEMAND FEEDING SYSTEM FOR BROWN-MARBLED GROUPER *Epinephelus fuscoguttatus* AND ORANGE-SPOTTED GROUPER *Epinephelus coioides* JUVENILES

Demand feeding is a new feeding method by which fish can feed themselves. Fish switch on the feeding device when they require food. This method has several advantages because the fish can eat when they are most motivated to feed. The system can thus minimize feed loss and reduce water pollution. Before developing a suitable demand feeding device for groupers, fish circadian rhythms, visual acuity and visual axis were examined. Both brown-marbled grouper *Epinephelus fuscoguttatus* and orange-spotted grouper *Epinephelus coioides* juveniles showed typical diurnal rhythms. The visual axis of brown-marbled grouper juveniles was forward while the visual axis of orange-spotted grouper juveniles was upward and forward. Based on these results, a rearing experiment was done to evaluate the efficiency of different feeding methods for brown-marbled grouper and orange-spotted grouper juveniles. Three experimental groups, pendulum demand feeder group (PDF, FH221, Aquatic Eco-Systems, Inc.), infrared sensor demand feeder group (IRDF) and automatic feeder group (AF) were set with three replicates. The IRDF consisted of an infrared sensor (infrared light 950 nm) ending in a red pellet-like knob with food container. Both demand feeders (PDF and IRDF) were set to dispense 10-15 pellets when fish activated the trigger (pendulum rod and infrared sensor, respectively) located 2 cm below the water surface. The automatic feeder (AF) was set to dispense 150-170 pellets at 8:00 am and 4:00 pm. In the rearing experiment, ten juveniles were kept in a 500 L round polyethylene tank (nine tanks, 90 fish) with flow through water system and water exchange (90%) every morning. Throughout the experiment, fish were exposed to natural photoperiod. The experiment lasted for 25 days. Water temperature was 28.0 – 31.5 °C and salinity was 27-28 ppt. During rearing experiment, the fish were fed with pellets. Fish standard length (SL), total length (TL), body weight (BW), specific growth rates (SGR) and adjusted feed conversion ratio (FCR_{adj}) were compared. In brown-marbled grouper, total length of IRDF group was significantly higher ($P<0.05$) than that of PDF group. SL and BW growth rates of three groups were not significantly different ($P>0.05$). In orange-spotted grouper, there were no significant differences ($P>0.05$), but SL, TL, and BW growth rates of IRDF group showed higher tendency than those of AF and PDF groups. SGR of IRDF group for both grouper species was higher tendency than that of AF and PDF groups. FCR_{adj} was better in IRDF group. Therefore, IRDF demand feeding devices are considered suitable for juvenile rearing of groupers.

ABSTRAK

Permintaan makan adalah satu kaedah makan baru yang mana ikan boleh makan sendiri. Ikan menghidupkan peranti suapan apabila mereka memerlukan makanan. Kaedah ini mempunyai beberapa kelebihan kerana ikan boleh makan apabila mereka paling bermotivasi untuk makan. Sistem ini boleh mengurangkan pembaziran makanan dan mengurangkan pencemaran air. Sebelum membangunkan penyuap permintaan yang sesuai untuk kerapu, ritma sirkadian, ketajaman dan paksi penglihatan ikan telah dikaji. Juvana kerapu harimau Epinephelus fuscoguttatus dan kerapu hijau Epinephelus coioides menunjukkan ritma harian biasa. Keputusan menunjukkan bahawa paksi penglihatan juvana kerapu harimau adalah ke hadapan manakala paksi penglihatan juvana kerapu hijau adalah ke atas dan ke hadapan. Berdasarkan keputusan ini, satu eksperimen penternakan telah dijalankan untuk menilai keberkesanan kaedah makan yang berbeza terhadap juvana kerapu harimau dan kerapu hijau. Tiga kumpulan eksperimen iaitu kumpulan penyuap permintaan berbandul (PDF, FH221, Aquatic Eco-Systems, Inc.), kumpulan penyuap permintaan inframerah (IRDF) dan kumpulan penyuap automatik (AF) telah ditetapkan dengan tiga replikasi. IRDF terdiri daripada sensor inframerah (cahaya inframerah 950 nm) yang berakhir dengan tombol pelet berwarna merah dengan bekas makanan. Kedua-dua penyuap permintaan (PDF dan IRDF) telah ditetapkan untuk memberikan 10-15 pelet apabila ikan mengaktifkan picu (bandul rod dan sensor inframerah masing-masing) yang terletak 2 cm di bawah permukaan air. Penyuap automatik (AF) telah ditetapkan untuk memberikan 150-170 pelet pada jam 8:00 am dan 4:00 pm. Dalam eksperimen penternakan, sepuluh juvana diternak dalam tangki polietilena 500 L (sembilan tangki, 90 ikan) dengan sistem air mengalir dan pertukaran air (90%) setiap pagi. Ikan didedahkan kepada fotokala semula jadi sepanjang eksperimen. Eksperimen ini berlangsung selama 25 hari. Suhu air adalah 28.0-31.5 °C dan saliniti 27-28 ppt. Ikan diberi makan pelet semasa eksperimen dijalankan. Panjang piawai (SL), panjang penuh (TL), berat badan (BW), kadar pertumbuhan specifik (SGR) dan kadar penukaran makanan terlaras (FCR_{adj}) ikan telah dibandingkan. Bagi ikan kerapu harimau, panjang penuh ikan kumpulam IRDF adalah lebih tinggi dengan ketara ($P<0.05$) berbanding dengan kumpulan PDF. Tiada perbezaan yang signifikan ($P>0.05$) antara ketiga-tiga kumpulan eksperimen dalam kadar pertumbuhan SL dan BW. Bagi ikan kerapu hijau, walaupun tiada perbezaan yang signifikan ($P>0.05$), tetapi kadar pertumbuhan SL,TL, dan BW kumpulan IRDF menunjukkan kecenderungan lebih tinggi daripada kumpulan AF dan PDF. SGR kumpulan IRDF kedua-dua spesies kerapu menunjukkan kecenderungan lebih tinggi daripada kumpulan-kumpulan AF and PDF. FCR_{adj} adalah lebih baik dalam kumpulan IRDF. Oleh itu, sistem penyuap permintaan inframerah (IRDF) adalah dianggap sesuai untuk penternakan juvana kerapu.

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%	Percentage
°	Degree
°C	Degree Celsius
µm	Micrometre
am	*ante meridiem*
D	Depth
cm	Centimetre
g	Gramme
H	Height
kg	Kilogramme
L	Litre
L'	Length
ln	Natural logarithm
m	Metre
ml	Millilitre
mm	Millimetre
mm^2	Square millimetre
nm	Nanometre
pm	*post meridiem*
ppt	Parts per thousand
PVC	Polyvinyl chloride
RM	Ringgit
SD	Significant difference
TL	Total length
W	Width

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CHAPTER 1

INTRODUCTION

1.1 Fisheries and Aquaculture in Malaysia

In Malaysia, the fisheries sector has two subsectors which are marine capture fisheries and aquaculture. In 2011, marine capture fisheries produced 1,373,105 tonnes (82.43%), valued at RM6,939.47 million (73.98%) respectively decreasing by 3.90% in terms of quantity and 4.32% in terms of value compared to 2010. Aquaculture showed a decline of 23.07% in production and 12.45% in production value in 2011 as compared to 2010. The total production in 2011 was 287,057 tonnes valued at RM2, 385.64 million (Department of Fisheries, 2011).

The growth in aquaculture for high value species has an important impact on national and international fish trade (Helga, 2006). Groupers have shown a steady increase in production from 2007 to 2011 in aquaculture subsector. The grouper productions in aquaculture from 2007 to 2011 were 4,207 tonnes, 4,400 tonnes, 3,807 tonnes, 4,570 tonnes, and 6,306 tonnes respectively. The increase of grouper production depends on the high price in the market and demand from the local and international consumers (Department of Fisheries, 2008; 2009; 2010; 2011).

1.2 Feeding Methods for Fish Rearing

In aquaculture sector, fish feeding methods are divided into hand (manual), automatic, and demand feeding. Hand feeding is the most common method which allows fish culturists to note the feeding behaviour and fish activity during each feeding time. However, it is a labour-intensive method, increased handling of the feed, and inappropriate in large farms (Pillay, 1990; Southgate, 2003).

In these cases, various new technologies such as automatic-timer feeder and demand feeder have been developed to improve the feed efficiency. Automatic

feeding has become widely used in aquaculture since it reduces the labour cost because the time and quantity of feed to be given have been preset following the feeding times. However, direct observation on fish feeding activity will be limited or difficult. This might lead to overfeeding and consequently promoting water quality problems in the culture system (Southgate, 2003).

Demand feeding is a new feeding method where the fish can obtain feed on demand by actuating a trigger when they are most motivated to feed. This feeding method permits fish to obtain feed as required (Pillay, 1990). Feed wastage and water pollution are the general drawbacks of demand feeding when there is no proper adjustment of the demand feeder and/or accidental actuation of trigger by fish. Nevertheless, these drawbacks can be set to a minimum level by properly adjusting the feeders prior to affixing over the tanks or ponds.

Demand feeding system generally can be divided into two categories, which are manually controlled (without electric supply) and electronically controlled. Nonetheless, both categories share the same basic principle. Modern advanced demand feeders usually have the electronically controlled system with a motor and sometimes a microcomputer that records feeding activity of fish (Rubio *et al.*, 2004). Some demand feeders may include a feedback system to control feed delivery. The detection of uneaten feed at the bottom of the tank controls the feed delivery from the feeding device (Coves *et al.*, 1998).

However, these demand feeding systems have largely been designed for material and labour efficiencies, and have ignored the fish (Ang and Petrell, 1998). Fish dominance may overlap the profitability of the demand feeders. Besides, fish feeding behaviour is a limiting factor because some fish species do not adapt to the devices or some other over-actuate the devices and the feed wastage is increased. Therefore, as each fish species exhibits different feeding behaviour, the knowledge of their feeding behaviour with regard to circadian rhythms is essential to develop suitable feeding devices for each fish species (Covès *et al.*, 2006; Velázquez *et al.*, 2006; Sunuma *et al.*, 2007).

1.3 Brown-Marbled Grouper and Orange-Spotted Grouper

Brown-marbled grouper (*Epinephelus fuscoguttatus*) (Figure 1.1), which belongs to the family Serranidae and subfamily Epinephelinae, is commercially important aquaculture species especially in the Southeast Asia and Middle East with market demand higher than the supply from captured fisheries (James *et al.*, 1998). It is widely distributed in shallow tropical and subtropical waters of the Indo-Pacific region (Randall and Heemstra, 1991; James *et al.*, 1998).

Figure 1.1: A juvenile brown-marbled grouper, *Epinephelus fuscoguttatus*, 143 mm in total length and 59.8 g in body weight.

According to the market and restaurant surveys done, together with the Hong Kong Government statistics on the values of imports of live reef food fish into the country compiled by Frazer and Thierry (2001), they informed that brown-marbled grouper of less than 1.8 kg in size is preferable by consumers because the plate-sized fish is preferable in restaurant and they have low risk of contamination from the toxins produced by dinoflagellates. Besides that, restaurant owners in Hong Kong prefer eating brown-marbled grouper than leopard coral trout (*Plectropomus leopardus*) as brown-marbled grouper is the most famous grouper species in local consumers' mind due to its better taste.

Orange-spotted grouper (*Epinephelus coioides*) (Figure 1.2) or known as *kerapu hijau* in Malaysia occurs in the southern Red Sea and east to the western Pacific, Palau and Fiji (Heemstra and Randall, 1993). It was very popular among Malaysian fish farmers in the early 1990's. This grouper has become the first grouper species successfully cultured artificially in Malaysia in late 1988 by the Marine Finfish Production and Research Centre (MAFPREC), Fisheries Department of Malaysia (Hussin *et al.*, 2008).

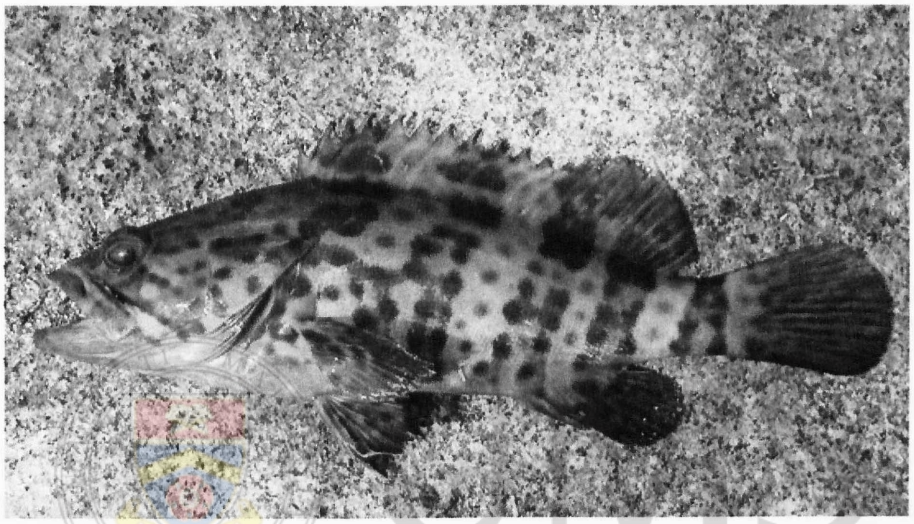

Figure 1.2: A juvenile orange-spotted grouper, *Epinephelus coioides*, 103 mm in total length and 16.9 g in body weight.

1.4 Significance of Study

The current status of grouper aquaculture in Malaysia has great potential for further expansion by several factors including improvements of technology and strong support from the local government (Hussin *et al.*, 2008). However the most urgent issue facing the aquaculture industry in Malaysia is the grouper seed production. It is constrained by limited availability of seeds from the wild and poor survival of fish in the hatcheries (Hussin *et al.*, 2008). One of reasons of the poor survival might be due to feeding methods. Feeding methods are important because fish change feeding habit and pattern with growth. Hence, feeding methods should also be changed following fish growth. Therefore, through this study, a suitable demand feeding device for groupers was aimed to be developed.

In order to develop a suitable demand feeding device, understanding of the fish circadian rhythms is essential to determine the feeding time of fish. Fish will not be fed according to staffs' working schedule. But, fish are allowed to address their natural feeding rhythms and they will feed themselves according to their requirement (Sanchez and Tabata, 1998). Therefore, demand feeding system helps to reduce feed loss in aquaculture.

1.5 Objectives

The general objective of this study is to develop a new demand feeding device for groupers. To achieve this objective, the specific objectives are as follows:

a. To determine the circadian rhythms of brown-marbled grouper and orange-spotted grouper juveniles.
b. To determine the visual acuity and visual axis of brown-marbled grouper and orange-spotted grouper juveniles.
c. To compare the efficiency of three feeding methods namely automatic-timer feeder, pendulum demand feeder and infrared demand feeder in terms of the growth rate of brown-marbled grouper and orange-spotted grouper juveniles.

CHAPTER 2

LITERATURE REVIEWS

2.1 Methods of Feeding in Aquaculture

Methods of feeding for fish rearing are divided into three categories, which are manual (by hand), automatic, and demand feeding. The first one, manual feeding, is a simple and the most commonly used feeding method among the three feeding methods. One of the advantages of this feeding method is that it allows the immediate decision of feeding amount by the fish. However, it is a high labour cost method (Pillay, 1990; Azzaydi *et al.*, 1998) and fish cannot eat the food, for instance, if they want to feed during midnight.

Automatic feeding is nowadays widely used especially in intensive fish farming. In automatic feeding, decided amount of pellets is dispensed from the automatic feeder at specific time. The amount of pellets, frequency, and time of feeding are usually controlled following the feeding tables. The feeding tables are used as a guide to the farmer to ration pellets appropriately. However, it causes an overfeeding in cultured fish as their appetite may vary with time and fish feeding rhythms are not being properly considered (Pillay, 1990; Azzaydi *et al.*, 1998; Southgate, 2003).

Demand feeding is a new feeding method introduced in aquaculture. This feeding method allows fish to control the feed intake by actuating the feeder switch or sensor of the demand feeder. It appears to be an easier and less expensive approach as compared to the other methods. It reduces the labour cost associated with daily hand feeding. Besides these advantages, low feed loss can be achieved in culture system when the reward level (the amount of pellets dispensed at each actuation by a fish) is set correctly (Amano *et al.*, 2007). Nonetheless, the disadvantages of demand feeding method include the tendency of overfeed because of improper feeder adjustment, and pellets are dispensed only in a small section of the ponds or tanks in regard to farming conditions.