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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 11 (4): 532-538, 2008
ISSN 1028-8880

Oxyeleotris marmoratus, Predator or By-Product in Integrated Aquaculture Ponds

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Abstract: Participating farms in the Muang district of Nong Khai Province, were selected for the investigation of management practices and yields of marble goby, *Oxyeleotris marmoratus*, in integrated culture with Nile tilapia (*Oreochromis niloticus*). The research took place from February to May, 2007. The observed production of *O. marmoratus* in integrated aquaculture ponds indicated a wide range of management practices. The yields of *Oxyeleotris marmoratus* were between 22.1 to 316 kg ha^{-1} (average 81±78 kg ha^{-1}). The farmers tended to prefer *Oxyeleotris marmoratus* not only as a by-product, but also as the main product from their ponds. Most farmers realized that *Oxyeleotris marmoratus* predate Nile tilapia fingerlings from the natural spawning of mature Nile tilapia in the ponds. With respect to consumed prey, the frequency of occurrence of prawns was 73.3%, whilst that of small fish was 43.3%. In terms of prey biomass, prawns were also the most abundant food item, giving the relative abundance of 56.0%. A preliminary trial on predation pressure was conducted to confirm the role of Nile tilapia fingerling as live feed for *Oxyeleotris marmoratus* in integrated aquaculture ponds and it was found that the daily predation pressure was between 1.90 to 2.46 fish day^{-1}.

Key words: Integrated aquaculture, prey, marble goby, Nile tilapia, *Oreochromis niloticus*

INTRODUCTION

In natural conditions, *Oxyeleotris marmoratus* is found in rivers, swamps, reservoirs and canals along the Mekong and Chao Phraya river basins and also in the Malay Peninsula, Indonesia and the Philippines (Kottelat *et al*., 1993). This demersal fish feeds mainly on macrofauna such as prawns, benthos, small fish, crabs and aquatic insects, with a trophic level from 2.8 to 4.05 (Yap, 1988; Roberts, 1993). It may be the largest species of goby-like fishes, attaining a maximum standard length of 65 cm (Kottelat, 2001). *Oxyeleotris marmoratus* is a high-valued species (US$4 to 12 per kg) and has been cultured within cages in reservoirs, lakes and ponds in several Southeast Asian countries such as Malaysia, Thailand and Vietnam. Cage culture of *Oxyeleotris marmoratus* often suffers from serious disease problems caused by *Aeromonas hydrophilla*. As an example, the production of *Oxyeleotris marmoratus* reduced drastically in Thailand during the 1990s, resulting mainly from outbreaks of disease (Lin and Kaewpaitoon, 2000). Other problems in the culture of *Oxyeleotris marmoratus* include the lack of formulated feeds (Jee, 1980; Cheah *et al*., 1994; Lin and Kaewpaitoon, 2000).

Oxyeleotris marmoratus is one of the most important freshwater fish in commercial aquaculture as its tender, non-bony flesh and taste has led to an increasing market demand. The farming of *Oxyeleotris marmoratus* in Thailand is expanding but the production is limited. The small scale farmer sells live *Oxyeleotris marmoratus* for as high as US$8.8 per kg (Ingthamjitr *et al*., 2005) which is the highest price among freshwater fish in Thailand. Striped Snakehead (*Channa striata*) and *Oxyeleotris marmoratus* are the main carnivorous species cultured in northeastern Thailand. Recent figures show the annual aquaculture production of these fish was 540 and 0.7 metric tons respectively (DOF, 2004). In a typical case of small-scale cage culture of *Oxyeleotris marmoratus* on the Songkhram River in Nakhon Phanom Province, the fish farmer had two small 3×6×3 m cages: each cage was stocked with 300 wild juveniles that had been collected by the farmer, each fish weighing between 100 to 200 g. The caged fish were fed fresh fish collected from the river once a day and as a supplement, pellet feed and apple snail flesh were also used. The quantity of feed increased from 2 kg day^{-1} in the first month to approximately 7 kg day^{-1} in the month preceding harvesting (Ingthamjitr *et al*., 2005).

To maximize fish production utilizing the available food organisms in ponds, the polyculture of many varieties of fish with different feeding niches has been commonly practiced (Oláh, 1980). Feed cost is considered to be the highest recurrent cost in aquaculture, often ranging from 30 to 60%, depending on the intensity of the operation (De Silva and Anderson, 1995). The use of animal manures for fish culture is an extension of traditional land-crop cultivation, which uses available on-farm resources within the reach of many small-scale farms in Asia (Zhu *et al*., 1990). The concept of tilapia production based on waste as feed for high market value carnivorous fish was proposed by Edwards (1988). To control overcrowding and its associated effects, culture with predators has also been studied: *Channa striata* or *Ophiocephalus striatus* (Chimits, 1957; Tongsanga, 1962; Chen, 1976; Cruz and Shehadeh, 1980; Hopkins *et al*., 1982; Wee, 1982); *Ophiocephalus obscures* (de Graaf *et al*., 1996); *Micropterus salmoides* (Swingle, 1960; Meschkat, 1967; McGinty, 1985); *Lates niloticus* (Meschkat, 1967; Bedawi, 1985; Ofori, 1988; El Gamal, 1992); *Hemichromis fasciatus* (Bardach *et al*., 1972); *Clarias* sp. (de Graaf *et al*., 1996); *Cichlasoma managuense* (Dunseth and Bayne, 1978); *Elops hawaiiensis* (Fortes, 1980) and *Megalops cyprinoides* (Fortes, 1980).

Cannibalism is the act of killing and consuming the whole or major part, of an individual belonging to the same species, irrespective of its stage of development. It is a common and widespread phenomenon throughout the animal kingdom. In fishes, cannibalism occurs at various sizes or ages and extends within and between cohorts or age classes, depending on species and environmental conditions (Smith and Reay, 1991). It is usually associated with size variation, limited food availability, high population densities, limited refuge areas and light conditions (Hecht and Pienaar, 1993). When looking at the size of prey, both the size of the predator's pharyngeal gape and oral gape are obvious restricting factors. Lawrence (1957) suggested that the pharyngeal gapes in Largemouth Bass and Bluegill are significantly smaller than their oral gapes and Sibbing (1991) stated that the presence of pharyngeal jaws and the palatal organ, narrowing the pharyngeal slits, seems more likely to restrict prey size among piscivorous *Barbus* rather than the oral gape. Many laboratory studies show that fish eat prey as wide as their mouth diameter, even if the pharyngeal gape is actually narrower than size of the prey (Kisalioglu and Gibson, 1976). This is due to the fact that most prey are deformable; once the fish prey is captured by the predator it can be swallowed, even if it is wider than the pharyngeal gape, as its shape can be altered by the actions of the pharyngeal jaw apparatus as the prey is being swallowed. Pharyngeal gape is likely to be more significantly constrained when the prey has a rigid, inflexible exoskeleton or shell (Wainwright and Richard, 1995).

From an aquaculture point of view, carnivorous fish (*Channa striata* and *Clarias* catfish) in aquaculture ponds are predators, but some researchers mention their role as a high market value by-product, especially the *C. striata*. Small scale aquaculture faces a problem of over crowding by Nile tilapia spawning which leads to low production levels of marketable size fish. Sex-reversal male Nile tilapia is not effective in long term pond culture and the control of predator fish is not effective in most pond fish culture on small scale farms (either the ponds are undrainable or cannot be completely drained). Thus, as a new approach in producing high market value fish, the integration of the culture of the predator, *Oxyeleotris marmoratus*, with Nile tilapia is a challenge in terms of pond aquaculture, especially under small scale operations.

This study describes the present practices of small-scale farmers in this area relating to the production of carnivorous fish, *Oxyeleotris marmoratus*, by utilizing integrated aquaculture concepts. It includes a preliminary laboratory trial on the predation pressure of *Oxyeleotris marmoratus* on Nile tilapia fingerlings to confirm that Nile tilapia fingerlings can be a source of live feed for the *O. marmoratus*.

MATERIALS AND METHODS

Study area and production layout: Nong Khai Province is the northernmost of the northeastern provinces of Thailand, located in Mekong River Basin, which also forms the border with Laos. The province is subdivided into 13 districts (Amphoe) and 4 minor districts (King Amphoe). Participating farms in Muang district, Nong Khai, were selected for an investigation into pond environment conditions and the production of *Oxyeleotris marmoratus* in integrated culture with Nile tilapia. The research took place from February to May, 2007. Integrated water samples were taken from the entire water column near the center of each pond at about 09:00 to 10:00 h for water analysis. The chemical parameters of the pond water (total alkalinity (mg $CaCO_3$ L^{-1}), total hardness (mg $CaCO_3$ L^{-1}) and chlorophyll a concentrations (μg L^{-1})) were analyzed according to standard methods (APHA, 1985). At the time of collecting the water samples, the visibility (cm) was measured using a Secchi disc, temperature (°C) and conductivity (μS cm^{-1}) by a Hach model Sension 5, dissolved oxygen (mg L^{-1}) by a YSI model 52 oxygen meter and the pH level with a Consort C533 meter.

Gut content: *Oxyeleotris marmoratus* (200 to 300 g) were randomly sampled from 20 fish ponds in the study area for gut content analysis, with the samples being fixed immediately upon capture with a 10% formalin solution. The formalin solution was also injected directly into the fish coelom and gut to avoid post-capture digestion. Quantitative analysis of gut content was described by two parameters: frequency of occurrence (O_{fi}) and the relative abundance of prey in terms of weight (A_{wi}), which was calculated using the following formula (Bowen, 1996; Jobling *et al*., 2001):

$$O_{fi} = 100 \times N_i/N_f$$

Where:
N_i = No. of fish with prey i in the stomach
N_f = No. of stomachs with food

$$A_{wi} = 100 \times (\Sigma S_i/\Sigma S_t)$$

Where:
S_i (g) = Weight of prey i in the stomach
S_t (g) = Total weight of stomach content

Predation pressure of *Oxyeleotris marmoratus* on Nile tilapia fingerling: Over 30 days the predation of *Oxyeleotris marmoratus* on Nile tilapia fingerlings was observed in triplicates of different containers; glass aquariums (75 L of water), circular fiber tanks (150 and 300 L of water). All the containers were aerated with an air diffuser during the trial. A single *Oxyeleotris marmoratus* (200 to 300 g) was added to each container and fed with two different prey densities; 15 and 30 prey per container. The prey, Nile tilapia fingerlings, was categorized into three size groups: small (S), 0.5 to 2.0 g; medium (M), 2.0 to 5.0 g and large (L), 5.0 to 10.0 g. Five and ten tilapias of each size group were mixed at a 1:1:1 ratio according to prey density. The numbers and sizes of the prey consumed daily were determined by noting the difference between the initial prey stock and that remaining after 24 h. Any dead or consumed fish were then replaced with fish of a similar size. With respect to the chemical parameters of the ground water used in the containers, the total alkalinity (mg $CaCO_3$ L^{-1}) and total hardness (mg $CaCO_3$ L^{-1}) were analyzed according to standard methods (APHA, 1985). The temperature (°C) and conductivity (µS cm^{-1}) were measured by a Hach model Sension 5, dissolved oxygen (mg L^{-1}) by a YSI model 52 oxygen meter and the pH level with a Consort C533 meter. The daily predation pressure was determined using the following formula (Ofori, 1988):

$$\text{Daily predation pressure} = \frac{(\text{Total No. of prey eaten by one predator} \times 100)}{(\text{Total No. of prey supplied} \times \text{No. of days})} \times 100$$

RESULTS AND DISCUSSION

The observed production of *Oxyeleotris marmoratus* in integrated aquaculture ponds indicated a very wide range of practices and yield. From the 20 ponds observed it was found that for those covering an area between 0.32 to 5.70 ha (average 1.27±1.28 ha), the stocking density of Nile tilapia was between 0.12 to 16 fish m^{-2} (average 3.1±4.7 fish m^{-2}) and the yield of *Oxyeleotris marmoratus* between 22.1 to 316 kg ha^{-1} (average 81±78 kg ha^{-1}). There were only 10 farms in this study that had been intentionally stocked with *Oxyeleotris marmoratus* from hatcheries or other ponds. The remaining farms had acquired wild *Oxyeleotris marmoratus* stock through flooding during the rainy season or from irrigated water from rivers or reservoirs. It was also found that these ponds had not been drained properly prior to their use. The farmers tended to prefer *Oxyeleotris marmoratus* not only as a by-product but also as a main product from their ponds, due to the fact that its market value was 10 times higher than that of Nile tilapia and carps. The farm gate price for *Oxyeleotris marmoratus* with a body weight of more than 400 g was about US$10 per kg. The marketing of the fish was uncomplicated for the farmers, as merchants came direct to the farms to purchase them.

Another reason why *Oxyeleotris marmoratus* was a preferred product was the lack of necessity in feeding them, as most farmers realized that *O. marmoratus* predate the fingerlings from the natural spawning of the mature Nile tilapia in the ponds. There were, however, some farmers who bought more Nile tilapia fingerlings from hatcheries as feed for the *Oxyeleotris marmoratus*. This possibly indicates that those farmers had some misunderstanding regarding relevant ecology. Tilapia are an excellent culture species, partly because they grow well on a variety of natural food organisms, including plankton, green leaves, benthic organisms, aquatic invertebrates, larval fish, detritus and decomposing organic matter (Schroeder, 1978). The stocking of predatory fish, such as the *Channa strita*, in small numbers may control excessive reproduction and hence maintain a balanced pond population; the potential for fry control exists in many species (Little and Muir, 1987). Little *et al*. (1996) mentioned that the most valuable role the fry or fingerlings of tilapias produced in rice fields may be as a food source for wild fish. Middendorp (1992) indicated that yields of unstocked wild fish were less variable and on average, much higher when tilapias were stocked (325 vs. 163 kg ha^{-1}). However, when compared to the *Channa strita*, the market price of *Oxyeleotris marmoratus* is much higher (4 times). The yield of *Oxyeleotris marmoratus* from integrated aquaculture ponds in the present may not reflect the carrying capacity of those ponds because the appropriate stocking density of the *O. marmoratus* integrated with Nile tilapia culture has not been studied. The major constraint is the lack of *Oxyeleotris marmoratus* seed in the area; most are wild seed that directly entered the fish ponds from external water supplies, although some farmers do buy the small size *Oxyeleotris marmoratus* (<200 g) from the small-scale capture fisheries.

The harvesting of the *Oxyeleotris marmoratus* is easily done by trapping, which is not as labor intensive when compared to seining and the smaller sized ones (<200 g) are often restocked back into the pond or other ponds. On the other hand, the use of trapping in the partial harvesting of *Channa strita* from integrated culture or polyculture systems is more difficult and not as efficient.

In general, most integrated aquaculture ponds that receive high organic matter loading tend to have adverse effects on the fish; however, the *Oxyeleotris marmoratus* is a facultative air-breather fish capable of surviving under terrestrial conditions for up to a week *Oxyeleotris marmoratus* appears to be the first known teleost that responds to air exposure by activating hepatic glutamine synthetase to detoxify internally produced ammonia (Jow *et al*., 1999). In the present study the level of basic water quality parameters, visibility and chlorophyll a concentrations indicated a eutrophic condition in the fish ponds (Table 1) and the effect of water quality on the yield of *Oxyeleotris marmoratus* needs to be verified further.

Gut content analysis of *Oxyeleotris marmoratus* from fish farms showed that the frequency of occurrence of prawns was 73.3%, whilst that of small fish was 43.3%. In terms of prey biomass, prawns were also the most abundant food item, giving the relative abundance of 56.0% (Table 2). The size of tilapia fingerlings ranged from 0.09 to 6.09 g and 1.7 to 5.5 cm and the prawns from 0.02 to 0.48 g and 1.0 to 4.2 cm. A study on the cove culture of *Oxyeleotris marmoratus* and carps in the Tri An Reservoir in Vietnam showed that the major food items of *O. marmoratus* were small fresh water prawns, followed by small wild fish and benthos (Luong *et al*., 2005). In the case of aquaculture ponds, freshwater prawns and benthos may be consumed by other fish. However, the results confirmed that yield of *Oxyeleotris marmoratus* is dependant, or partly dependant, on Nile tilapia and that Nile tilapia is a major food source of *O. marmoratus* in this culture systems.

The preliminary trial on predation pressure was conducted to confirm the role of Nile tilapia fingerlings as live feed for *Oxyeleotris marmoratus* in integrated aquaculture systems. The results of the experimental

Table 1: Summarization of water quality of water sampled at 0900-1000 am from 20 fish ponds in Nong Khai province during February to May 2007

Total alkalinity (mg $CaCO_3$ L^{-1})	Total hardness (mg $CaCO_3$ L^{-1})	Chlorophyll a (µg L^{-1})	Secchi disk visibility (cm)	Temperature (°C)	Conductivity (µS cm^{-1})	Dissolved oxygen (mg L^{-1})	pH
27-199	25-297	64.2-2021	6-39	31.1-39.2	69.8-732	3.1-9.6	7.5-10

Table 2: Gut content of *Oxyeleotris marmoratus* sampled from selected farms from February to May 2007

	Frequency of occurrence (O_{fi})			Relative abundance in items of weight (A_{wi})		
Food items	N_f (No.)	N_i (No.)	(O_{fi} (%)	S_i (g)	S_t (g)	A_{wi} (%)
Prawns	30	22	73.3	19.0	33.9	56.0
Fish	30	13	43.3	14.9	33.9	44.0

N_i = No. of stomach with food, N_f = No. of fish with the prey i in the stomach, S_i = Weight of prey i in stomach content, S_t = Total weight of stomach content

Table 3: Summarized data of predation pressure trial of marble goby (*Oxyeleotris marmoratus*) on various sizes of Nile tilapia fingerling (prey) at 15 and 30 preys/container

Container	Initial No. of tilapia (prey)	Total No. of tilapia supplied during the trial	Total No. of tilapia consumed	Size composition of tilapia consumed (% of total) S	M	L	Average daily predation pressure
Glass aquaria (75 L)	15	56	41	58.5	29.3	12.2	2.44
	15	36	21	38.1	38.1	23.8	1.94
	15	47	32	50.0	31.3	18.8	2.27
Fiber glass tank (150 L)	15	52	37	48.6	37.8	13.5	2.37
	15	57	42	42.9	45.2	11.9	2.46
	15	49	34	50.0	26.5	23.5	2.31
Fiber glass tanks (300 L)	15	41	26	69.2	23.1	7.7	2.11
	15	43	28	39.3	32.1	28.6	2.17
	15	44	29	65.5	24.1	10.3	2.25
Glass aquaria (75 L)	30	79	49	63.3	24.5	12.2	1.97
	30	99	69	42.0	42.0	15.9	2.32
	30	106	76	48.7	31.6	19.7	2.39
Fiber glass tanks (150 L)	30	110	80	51.2	30.0	18.8	2.42
	30	104	74	54.0	25.7	20.3	2.32
	30	107	77	46.8	36.4	16.9	2.40
Fiber glass tanks (300 L)	30	75	45	55.6	15.6	28.9	2.00
	30	101	71	56.3	22.5	21.1	2.34
	30	94	64	46.9	28.1	25.0	1.92
Range		36-110	21-80	38.1-69.2	15.6-45.2	7.7-28.9	1.92-2.46

units water analysis showed that the total alkalinity (mg $CaCO_3$ L^{-1}), total hardness (mg $CaCO_3$ L^{-1}), temperature (°C), conductivity (μS cm^{-1}), dissolved oxygen (mg L^{-1}) and pH were 305±2.3, 194±7, 26.2±0.15, 360±22.5, 6.2±0.4 and 9±0.1, respectively. The daily predation pressure was between 1.9 to 2.46 fish per day (Table 3). Size variation is considered one of the primary causes of cannibalism (Hecht and Appelbaum, 1988; Katavic *et al*., 1989) and the notion that the gape of the predator is an important constraint on prey use is wide spread in fish biology and is frequently cited as the explanation for correlations between prey and predator body size (Shirota, 1978; Felley, 1984). It has been stated that the *Channa strita* could consume prey bigger than the size predicted from the predators' mouth width (Qin and Fast, 1996), so further study should be undertaken to verify the prey size selection of *Oxyeleotris marmoratus*.

CONCLUSION

Oxyeleotris marmoratus is not a by-product, but rather acts as a cash crop in integrated culture with Nile tilapia in the study area. An improvement in the present culture practice of *Oxyeleotris marmoratus* may lead to increased yields and higher incomes for the rural farmers who face problems with regards to the use of commercial feed. This culture system may reveal ecological aquaculture concepts for the production of carnivorous fishes.

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