Investigation of small-scale farming status of Tire track eel (*Mastacembelus favus*) in the Mekong Delta, Vietnam

Nhi H. Y. Nguyen[1*], Hang T. T. Nguyen, Hanh T. B. Nguyen[2], Nguyen, Van T. T. Phan, Thang D. Tran, Man M. V. Ho, & Lan T. Trinh

[1]Department of Aquaculture, An Giang University, Vietnam National University Ho Chi Minh City, Vietnam

[2]Experimental and Practical Area, An Giang University, Vietnam National University Ho Chi Minh City, Vietnam

ARTICLE INFO

Research Paper

Received: May 04, 2023

Revised: October 06, 2023

Accepted: October 12, 2023

Keywords

Feed and feeding

Mastacembelus favus

Mekong delta

Small-scale farming

Tire track eel

***Corresponding author**

Nguyen Huu Yen Nhi

Email:
nhynhi@agu.edu.vn

ABSTRACT

Tire track eel (*Mastacembelus favus*) is an economically important freshwater fish in the Mekong Delta. However, there is a lack of academic information about the current farming status, feed, and feeding related to this species in the region. Therefore, a field survey of small scale farming of tire track eel was conducted in An Giang, Dong Thap, Hau Giang and Kien Giang provinces of Vietnam. The objective of the survey was to determine the current farming practices information on households, especially the feed and feeding status of tire track eel in order to improve and develop a suitable feed for this fish in the future. The results showed that most of the small-scale farmers cultured fish in earthen ponds with or without plastic liners. Tire track eels were fed with feeds of other species and typically fed 3 - 5 times/d during the fingerling stage, and twice per day during the grow-out period. In terms of feed ingredients, crude protein contents in the feeds were 39.5 - 45.5% while crude lipid contents were 7.7 - 12.7%. Feed conversion ratios of tire track eels were 2 - 5. The farming periods of fish were 11.8 - 14 months when the fish reached the harvesting sizes of 318.2 - 421.4 g/fish, with the survival rates of 40 - 80%. It took 2.5 months to cultivate the fingerling stage (around 3 g/fish) from the fry with the survival rate of 55.7%. It was reported that this species was raised with a simple technique and got less illness compared to other fish species. However, the main reason of fish deaths during farming period related to management factors such as poor water quality due to decomposition of uneaten feed in water or lacks of dissolved oxygen due to high stocking density or power supply failures.

Cited as: Nguyen, N. H. Y., Nguyen, H. T. T., Nguyen, H. T. B., Phan, V. T. T., Tran, T. D., Ho, M. M. V., & Trinh, L. T. (2024). Investigation of small-scale farming status of Tire track eel (*Mastacembelus favus*) in the Mekong Delta, Vietnam. *The Journal of Agriculture and Development* 23(3), 11-22.

1. Introduction

Tire track eel (*Mastacembelusfavus*) is a native fish species that live mainly in freshwater but is also found in brackish water with low salinity (Pethiyagoda, 1991; Sokheng et al., 1999; Mongabay, 2020). In the wild, they are very widely distributed, at different habitats, from upstream to downstream, swampy areas, estuaries, or in riverbeds with fine or coarse sandy bottoms and places with thick vegetation (Ahmad et al., 2018; Jamaluddin et al., 2019; Jamaluddin et al., 2021). This is a hidden species, so they usually concentrate mainly on the bottom of flowing water bodies (canals, lakes) in the summer months or in flooded areas in the rainy season. They often bury themselves in the gravel bottom during the day and are active at night (Rainboth, 1996). Pethiyagoda (1991) reported that the maximum length of the tire track eel was 90 cm and the weight of 500 g. This fish has a slow growth rate. In the wild, one-year old tire track eels range from 150 - 250 g/fish in weight, 18 - 25 cm in length; while these parameters of two-year old fish fluctuated between 450 - 500 g/fish and 35 - 40 cm in weight and length, respectively. The natural spawning season of this fish in the Mekong river is the rainy season, from April to August every year, but mainly in June and July (Rainboth, 1996; Riede, 2004; Trieu, 2010). Tire track eel is an important food fish that is considered to be of high quality, contributing to local people's livelihoods and well-being in the Mekong Delta.

Tire track eel is a new culture fish species with high economic value, so many households in the Mekong Delta have been stocking it in form of small-scale farming. In the developing world, a small-scale or smallholder farm is a family-owned enterprise operating on up to 10 ha, or 24 acres, with most smallholder farmers cultivating less than 2 ha, or 5 acres, of land (Knight, 2022). The author also stated that small-scale farmers usually face challenges (e.g., related to their farm sizes, remote and rural locations), which hinder their ability to grow a prosperous business, while many lack the ability to access to credit, formal markets and high quality inputs like fingerling, farming equipment or medicine to maintain their animal healthy. In addition, there is a lack of academic information about the current farming status as well as the feed and feeding information of farming this species, thus this study has been conducted to provide some of this species and its farming information. The objectives of the study were to determine information on feed use, management skills, and techniques in raising tire track eels, as well as to examine advantages and disadvantages encountered in this farming. These will be basic useful information for farmers, local governments and researchers to do further research and improve the current system, and to develop suitable feeds for culturing this species with a more sustainability in the future.

2. Materials and Methods

2.1. Study sites

The study was carried out in An Giang, Dong Thap, Hau Giang, and Kien Giang provinces (Figure 1). These provinces were selected because they are the main Tire track eel farming areas in the Mekong Delta, Vietnam. Besides, these provinces have the specific agro-ecological characteristics of each location which form interlacing waterways and irrigation networks, providing a favourable environment for the agriculture and fishery sectors. Dong Thap is the upstream location of the Tien river and represents a wetland, with alkaline soil and agriculture with high production of fish. Hau Giang and An Giang are both located along the Hau river and produce large quantities of rice and fish. Kien Giang is one of the coastal provinces.

It has U Minh Thuong forest, one of the region contains peat swamp areas in the Mekong river basin which are important source of freshwater and fish for local consumption (Tran, 2016). The selected provinces are located in the lower basin of the Mekong Delta which distributes both branches of the Mekong river (Hau river and Tien river) and has both inland and coastal provinces of the Mekong Delta.

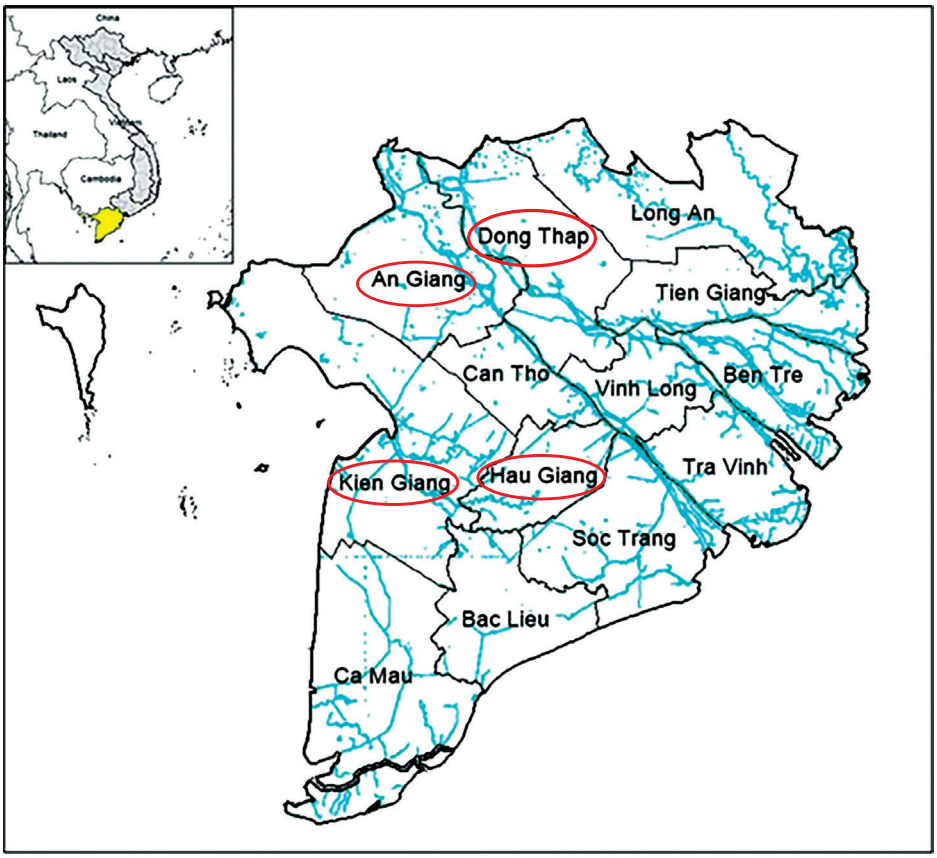

Figure 1. The provinces where the survey was conducted (Red circles).

2.2. Survey methods

Secondary data collection: annual reports and statistics on aquaculture as well as farming techniques of Tire track eel were collected from Department of Fisheries, Agricultural Extension Center, Statistical Department and Departments of Agriculture and Rural Development at the four surveying provinces. In addition, information related to the field of study is also collected from relevant websites. The secondary data collection was conducted before primary data collection.

The survey was carried out from April to November 2021. In total, ninety tire track eels farmers including 17 farmers in An Giang, 29 farmers in Dong Thap, 31 farmers Hau Giang and 13 farmers in Kien Giang were interviewed. The primary information was collected by observations, informal discussion and direct

interviews with farmers who were raising Tire track eel in these provinces, using a prepared questionnaire. The collected data included information on farming households, feed use; managements skills and techniques of raising Tire track eel; farming models; advantages and disadvantages encountered in the current farming models. Additionally, the feed used in the farming households were also sampled (5 samples/province) and analysed for nutritional compositions to evaluate the current status of feed use on farms.

2.3. Feed sampling and nutritional analysis

During the investigation, the feed samples (5 samples/province) were randomly collected from fish farms for nutritional analysis. The collected feed samples (between 200 g and 300 g) were analysed for moisture, protein, fat, carbohydrates (NFE), ash, fiber, energy, amino acids. Dry matters were determined by drying in an oven at 105°C until constant weights. Ash contents were determined by incineration of the sample at 550°C for 4 h. Crude proteins were calculated as 6.25 × % N analysed by the Kjeldahl method, ether extract (EE) were measured using the Soxhlet method and crude fibre (CF) contents were analysed using standard methods (AOAC, 2000). Amino acid contents were determined by high-performance liquid chromatography (HPLC) according to (Vázquez-Ortiz et al., 1995). Nitrogen-free extracts (NFE) were calculated according to methods described in AOAC (2000) as: (NFE = 100 - (%protein + %lipid + %fibre + %ash)). Gross energy contents (kcal/kg) were calculated according to (NRC, 1993), using values of 5.64, 9.44 and 4.11 kcal/g whole body for protein, lipid and carbohydrate, respectively.

2.4. Statistical analysis

The data were coded and analysed for descriptive statistics and analysis of variance using Microsoft Excel and Minitab (Version 16.0). Statistical analysis was conducted at 95% confident level ($P = 0.05$).

3. Results and Discussion

3.1. General information of farmers raising tire track eels

The interviewed tire track eel farmers were predominantly male and most of them owned the farms (Table 1). Most of them were over 30 years old with predominant from 30 - 50 years old. Males were responsibile for doing farm works.

Table 1. Educational backgrounds, sources of technological skills and other occupations of small scale fish farmers involved in the interview (Figures in table indicate % of the interviewees for each province) (n = 90)

Components	Descriptions	Provinces			
		An Giang	Dong Thap	Hau Giang	Kien Giang
Gender	Male	94.1	100	83.9	69.2
	Female	5.9	0.0	16.1	30.8
Year old	Under 30	11.8	6.9	0.0	0.0
	30 - 50	41.2	51.7	77.4	69.2
	Over 50	47.1	41.4	22.6	30.8
Role in farm	Owner	88.2	93.1	74.2	84.6
	Spouse of owners	0.0	0.0	19.4	0.0
	Child of owners	5.9	3.4	3.2	0.0
	Hired labor/technician	5.9	3.4	3.2	15.4
Education levels	Primary school (grades 1 - 5)	5.88	0	9.68	7.69
	Secondary school (grades 6 - 9)	52.9	51.7	71.0	69.2
	High school (grades 10 - 12)	0.00	20.7	9.68	7.69
	College, University	41.2	27.6	9.68	15.4
Technical skills learnt from	Own experiences	5.88	3.45	0.00	0.00
	Neighbors	88.2	75.9	38.7	61.5
	Workshops/training/school	0.00	0.00	9.68	0.00
	Media	5.88	13.8	45.2	7.69
	Neighbors & media	0.00	0.00	0.00	30.8
	Neighbors & training	0.00	6.90	6.45	0.00
Training (general)	Yes	11.8	6.9	74.2	76.9
	No	88.2	93.1	25.8	23.1
Living of the interviewees	Living in the farm	94.1	89.7	100	100
	Living in another place	5.9	10.3	0.0	0.0

In general, the educational levels of the interviewed farmers were relatively low with 5.56% and 61.1% at primary and secondary schools, respectively. The interviewees holding college or university degrees accounted for 22.2% and they lived mainly in An Giang and Dong Thap (Table 1). Most of the interviewed farmers directly lived in their farms to manage all farming activities.

Tire track eel is a new cultured species which was raised in farms recently after the artificial propagation of this species was succeeded (Loan, 2010; Trung, 2010), so most farmers did not have their own farming experiences. They learned farming techniques from each other, from their neighbors, from the mass media (e.g. YouTube, journals, newspapers, and so on), from Department of Agriculture and Rural development, agricultural extension station, production cooperative group, especially in An Giang and Dong Thap provinces.

3.2. Characteristics of the fish farms

Table 2. Type of fish farms in four different provinces in Vietnam (Figures in table indicate % of the interviewees for each province)

Descriptions	Provinces			
	An Giang	Dong Thap	Hau Giang	Kien Giang
Fingerling	17.7	13.8	61.3	0.00
Marketable sizes	64.7	72.4	32.3	69.2
Both fingerling and marketable sizes	11.76	3.45	3.23	0.00
Integrated with other species	5.88	10.34	3.23	30.8

Most of the interviewed farms raised marketable fish, especially in Dong Thap province with 72.4% farms (Table 2). Beside, some of farms raised the tire track eel in combination with other species such as freshwater prawn (*Macrobrachium rosenbergii*), marble goby (*Oxyeleotris marmoratus*), redtail botia (*Botia modesta*), siamese giant carp (*Catlocarpio siamensis*), and carp (*Cyclocheilichhthys enoplos*). Hau Giang was the province that has more fingerling farms involved in the interviews than other provinces.

Table 3. Types of raising facilities used in small-scale tire track eel farms in the surveyed provinces (Figures in table indicate % of all farmers within each province)

Descriptions	Provinces			
	An Giang	Dong Thap	Hau Giang	Kien Giang
Earthen ponds	64.7	86.2	9.68	76.9
Pond lined with PVC	11.8	10.3	19.4	0.00
Hapas in ponds	17.7	0.00	3.23	7.69
Hapas in rivers	5.88	0.00	0.00	0.00
Tanks lined with PVC	0.00	0.00	61.3	15.4
Cement tanks	0.00	3.45	3.23	0.00

Most of the farmers in An Giang, Dong Thap and Hau Giang raised marketable fish in earthen ponds while the farmers in Kien Giang reared fingerlings in tanks lined with PVC (Table 3). Some of the farms also used cement tanks to raise fingerlings.

Table 4. Farming areas (m^2) and stocking densities (fish/m^2) of hapas, tanks and ponds at different stages in small-scale farms in An Giang, Dong Thap, Hau Giang, and Kien Giang provinces

Fish period /Types of farming	Provinces							
	An Giang		Dong Thap		Hau Giang		Kien Giang	
	Area (m^2)	Stocking density (fish/m^2)	Area (m^2)	Stocking density (fish/m^2)	Area (m^2)	Stocking density (fish/m^2)	Area (m^2)	Stocking density (fish/m^2)
Fingerlings								
Earthen ponds	450	100	500	350	-	-	-	-
Cement tanks	20	200	-	-	200	225	-	-
Hapa-in- pond-systems	48	416	-	-	-	-	-	-
Ponds lined with PVC	-	-	-	-	400	200	-	-
Tanks lined with PVC	-	-	118	500	201	257	-	-
Fingerlings and marketable sizes								
Earthen ponds	8000	3	3000	2	-	-	-	-
Ponds lined with PVC	800	31	-	-	1500	25	-	-
Marketable sizes								
Earthen ponds	7543	3.21	2600	5.52	1067	7.83	4063	2
Ponds lined with PVC	-	-	200	15	575	28.75	100	30
Tanks lined with PVC	-	-	-	-	43	31.3	-	-
Hapas in river	80	13	-	-	-	-	-	-
Hapa-in- pond-systems	1525	6.5	-	-	-	-	200	5
Cement tanks	-	-	50	20	42	5.7	-	-
Marketable sizes with other species								
Pond lined with PVC	6500	7	-	-	-	-	-	-
Hapa-in- pond-systems	-	-	-	-	100	10	-	-
Earthen ponds	-	-	2667	11.3	2500	3	5000	1.95

Fingerlings of tire track eels were raised in small areas (20 - 500 m^2) with stocking densities from 100 - 400 fry/m^2 (Table 4). The marketable size tire track eels were cultured in several kinds of facilities such as earthen ponds, ponds lined with PVC, tanks lined with PVC, hapas in river or in ponds with their areas ranged from 100 - 8000 m^2. The stocking densities of marketable fish ranged between 2 - 31 fish/m^2. The stocking density was high in ponds with aeration.

Table 5. General information of the small-scale farming of marketable tire track eels in An Giang, Dong Thap, Hau Giang, and Kien Giang provinces

Descriptions	Provinces				SEM	*P*
	An Giang	Dong Thap	Hau Giang	Kien Giang		
Sizes of fingerlings (g/head)	4.2^{b}	2.7^{b}	3.2^{b}	22.1^{a}	1.09	0.001
Price of fingerlings (USD/head)	0.28^{b}	0.24^{b}	0.26^{b}	0.44^{a}	0.0	0.001
Culture periods (months)	12.8	13.6	11.8	14.0	2.1	0.335
Harvest sizes (g/head)	421^{a}	367^{ab}	318^{b}	394^{ab}	21.1	0.018
Selling price of fish (USD/kg)	11.8^{a}	8.91^{b}	12.1^{a}	11.7^{a}	0.4	0.001
Survival rates (%)	70^{a}	40^{b}	80^{a}	70^{a}	6.0	0.001

Values are given as LS means.

Means with different superscript letters within rows are significantly different (P < 0.05).

The tire track eels in marketable farms were stocked at the sizes of 2.7 - 22.1 g/head (Table 5). The sizes of fingerlings were similar in all surveyed provinces except Kien Giang. The price of fingerlings was 0.24 - 0.44 USD/head. The price of fingerlings in Kien Giang province was the highest among the surveyed provinces. The main reason for the hishest price could be that the farmers in Kien Giang province often stocked bigger size fingerlings compared to those of other provinces.

It often took 12 - 14 months to grow tire track eels to marketable sizes and was similar in all provinces, although Kien Giang province had larger fingerling and longer culturing time but harvesting sizes are almost similar to that of the other provinces. It can be effected by ecological environment conditions in Kien Giang, is one of the coastal provinces, not located directly on the main braches of Mekong river which can effect to the culture environment.

The harvesting sizes ranged from 318 - 421 g/head with the highest size in An Giang and lowest size in Hau Giang. Dong Thap sold the fish with the lowest price among the four provinces, that may be related with an abundance of wild fish for consuming in this area.

The survival rates of tire track eels ranged from 40 - 80%, in which the survival rates of fish in Dong Thap was the lowest. The average survival rate and rearing period from fry to fingerlings were 55.7% and 2.5 months, respectively. The average selling price of fingerling was approximately USD 0.23/head (around 3 g). The fingerling price of this fish is always higher than other fish species in the Mekong Delta.

3.3. Feeds and feeding

Tire track eels were typically fed twice per day (8:00 in the morning and 18:00 in the afternoon) during the grow out period, and 3 - 5 times per day during the fingerling stages. Feeds used in Tire track eel farming were mainly commercial pellets produced typically for other fish species such as snakehead fish, shrimp, barramundi, etc. Feeds were added with 40% water to soften for about an hour. Then vitamin C, probiotics, binder were added and shaped into balls with the average weights of 100 g. Besides, some farms also added earthworms, golden apple snails into the feed balls. This feed balls were put into feeding trays with feeding ratios of 3 - 10% the fresh fish body weights. This feeding strategy would raise environmental concerns. It can cause a negative affect on the farming system because of its difficulty in manage the feed. The feed balls were in a moist form, and feed ingredients would easily dissolve into the water, affecting the farming process. This practice needs improvement to make the fish farming more sustainable.

Results from chemical composition analysis show that the feeds used in different provinces significantly varied in their contents (Table 6). Because the farmers used various feed types, brands, and also added with different ingredients. The crude protein and crude lipid contents in feeds were 39.5 - 45.5% and 7.7 - 12.7%, respectively (Table 6). Feed conversion rate for grow-out periods of tire track eels ranged from 2 to 5.

Table 6. Chemical compositions of different compound feeds for tire track eels in An Giang, Dong Thap, Hau Giang, and Kien Giang provinces (5 samples/province)

Chemical compositions (%)	Provinces							
	An Giang		Dong Thap		Hau Giang		Kien Giang	
	Median	Range	Median	Range	Median	Range	Median	Range
Dry matters	91.2	89.7 - 91.6	90.1	89.3 - 92.1	92.6	92.1 - 93.1	90.3	89.8 - 91.1
Crude proteins	42.4	40.1 - 44.9	40.1	39.5 - 42.2	44.2	42.1 - 45.5	42.7	40.1 - 45.2
Lipids	10.2	7.7 - 10.5	10.3	8.0 - 11.8	11.8	9.6 - 12.1	11.1	9.1 - 12.7
Ashes	14.2	11.6 - 15.1	14.1	12.3 - 14.7	13.0	12.1 - 15.4	15.2	13.9 - 15.3
Crude fibres	3.7	3.1 - 4.6	4.2	3.1 - 5.6	3.3	2.8 - 4.4	2.3	2.0 - 3.9
Amino acids (g/kg)								
Arginin	56.1	44.4 - 60.1	46.7	42.6 - 59.7	62.5	43.6 - 63.7	60.4	44.2 - 62.1
Alanine	24.6	20.3 - 24.7	21.8	20.2 - 24.9	24.5	20.1 - 25.2	21.0	20.4 - 24.4
Isoleucine	17.6	16.9 - 21.5	20.1	17.8 - 10.6	22.1	19.4 - 23.1	20.6	17.2 - 20.8
Leucine	34.8	30.2 - 35.8	34.4	30.8 - 35.9	32.8	31.4 - 34.7	31.3	30.9 - 35.2
Lysine	21.7	20.6 - 25.8	23.4	20.9 - 31.0	29.6	20.7 - 30.5	26.7	20.4 - 28.1
Methionine	7.7	6.6 - 8.2	8.3	5.1 - 9.7	7.2	6.2 - 8.3	8.1	6.2 - 8.2
Phenillalanin	21.2	18.8 - 24.1	22.4	19.7 - 23.5	20.9	19.7 - 24.3	19.9	17.9 - 22.8
Threonine	14.8	14.2 - 19.4	19.9	14.5 - 20.1	16.2	15.3 - 18.9	13.7	13.1 - 18.9
Tryptophan	5.2	5.0 - 5.9	5.9	5.1 - 6.1	5.6	5.2 - 6.1	5.6	5.0 - 6.2
Valin	25.5	19.3 - 26.2	24.2	19.3 - 25.7	23.6	19.0 - 25.1	23.6	19.8 - 23.9
Cystin	24.2	10.1 - 25.9	18.3	12.6 - 19.5	23.5	12.6 - 14.2	16.0	12.0 - 25.9
Tyrosin	10.7	10.2 - 16.5	13.6	12.1 - 15.4	13.6	10.2 - 15.4	15.2	10.5 - 16.5

The chemical compositions of feed from this research showed that the farmers used high protein feeds to raise Tire track eel (from 39.5 - 45.5%) and made the feeds with a high cost. This concern needs to be solved by producing feeds for a more sustainable farming of this species in the future.

3.4. Managements the fish ponds

Many materials such as PVC tubes, chicken nets, water hyacinths, bamboo branches and nylon ropes were used as habitats for tire track eels in the pond system.

Sludge accumulated in the fish ponds was not removed during throughout each crop. Instead, the farmers used commercial probiotic products containing Bacilllus to treat the pond bottom environment for maintaining good water quality.

The water management process in Tire track eel ponds were done as the normal farms in Mekong Delta (Phan et al., 2009) that the water in the culture systems was exchanged at infrequent intervals ranging from daily to once a week. The rate of exchange at any one time ranged from 10 to 30% replenishment to ensure that all water parameters were always within the appropriate ranges for the normal growth of fish.

3.5. Advantages and challenges in farming tire track eels

The survey results show that the farmers were easy to sell their fish production. Culturing Tire track eel can give them high profit because they have high price and high market demand. In addition, the farmers reported that this species highly tolerated to the culture environment, as so obtaining high survival rate, well adapted to local natural conditions, and then the fish grows well; it can be integrated with other species to increase economic efficiency on the same farming area.

Besides, the farmers' opinion indicated that Tire track eel was one of the species for simple farming techniques, and it got less disease infection compared to other fish species raised in these provinces, such as pangasius, tilapia, snakehead fish, gourami, climbing perch, shrimp, etc. Fish only encountered a few diseases (e.g., skin, parasitic, intestinal diseases, fungus in gills, etc.), especially at small-size stages when the weather changes (e.g. rain, monsoon, etc.) or feed changes. However, the main reason of the fish deaths during farming period was mainly due to management factors such as poor water quality caused by decompositions of uneaten feed, low dissolved oxygen at high stocking density or power supply failures.

Infact, the moist feeds used in this farming would cause some water quality problems. This practice requires improvement in the future for the sustainable development of tire track eel farming.

4. Conclusions

Most of the small-scale farmers of tire track eel (*Mastacembelus favus*) were carried out in earthen pond covered with or without PVC liners, which developed and operated by self-learned experience and from neighbours' knowledge.

Fish were typically fed twice per day during the grow-out periods, and 3 - 5 times per day during the fingerling stages.

High nutrient feeds were used, specifically the crude protein and crude lipid contents in feeds were 39.5 - 45.5% and 7.7 - 12.7%, respectively. It was not a good practice while farmers used commercial pellets for other fish species such as snack head fish, shrimp, barramundi, etc to feed the tire track eel. Additionally, the current feeding strategy, which was the dry pellets were soaked with water to make large moist feed balls before feeding the fish, which needs improvement

because it would cause poor water quality.

Feed conversion rates for culturing growing-out tire track eels ranged from 2 to 5.

Commercial farming periods of tire track eels were from 11.8 - 14 months. The harvest sizes were from 318.2 - 421.4 g/head and the survival rates were from 40 - 80%.

The fingerlings were cultured around 2.5 months from the fry with a survival rate of 55.7% and were sold for USD 0.23/head (around 3 g/head).

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

This research was funded by Vietnam National University Ho Chi Minh City (VNU-HCM) under grant number B2021-16-01.

References

Ahmad, A. B., Zaini, N., Nayan, N., Fahmi-Ahmad, M., Rizal, S. A., & Yusuf, Y. (2018). Freshwater fish diversity of Sungai Setiu, Terengganu, Peninsular Malaysia. *Malayan Nature Journal* 70(4), 499-507.

AOAC (The Association of Official Analytical Chemists). (2000). *Official methods of analysis of AOAC international* (17th ed). Maryland, USA: The Association of Official Analytical Chemists.

Jamaluddin, J. A. F., So, N., Tam, B. M., Ahmad, A., Grudpan, C., Md Sah, A. S. R., & Mohd Nor, S. A. (2021). Genetic diversity of the tire track eel *Mastacembelus favus* in Southeast Asia inferred from microsatellite markers. *Ichthyological Research* 68, 529-540. https://doi.org/10.1007/s10228-021-00807-4.

Jamaluddin, J. A. F., So, N., Tam, B. M., Ahmad, A., Grudpan, C., Page, L. M., Khaironizam, Md. Z., & Mohd Nor, S. A. (2019). Genetic variation, demographic history and phylogeography of tire track eel, *Mastacembelus favus* (Synbranchiformes: Mastacembelidae) in Southeast Asia. *Hydrobiologia* 838(1), 163-182. https://doi.org/10.1007/s10750-019-03987-3.

Knight, A. (2022). What is a smallholder farmer? *Heifer International.* Food and Waste, Retrieved December 15, 2022, from https://www.heifer.org/blog/what-is-a-smallholder-farmer.html.

Loan, P. P. (2010). *Developing an artificial seed production process for Tire track eels (Mastacembelus favus) fish in An Giang* (research report). An Giang Department of Science and Technology, An Giang, Vietnam.

Mongabay. (2020). *Mastacembelidae* (Spiny eel) family. *Tropical fish*. Retrieved from April 12, 2020, from https://fish.mongabay.com/mastacembelidae.htm.

NRC (National Research Council). (1993). *Nutrient requirements of fish*. Washington, USA: National Academy Press.

Pethiyagoda, R. (1991). *Freshwater fishes of Sri Lanka*. Colombo, Sri Lanka: Wildlife Heritage Trust of Sri Lanka.

Phan, L. T., Bui, T. M., Nguyen, T. T., Gooley, G. J., Ingram, B. A., Nguyen, H. V., & De Silva, S. S. (2009). Current status of farming practices of striped catfish, *Pangasianodon hypophthalmus* in the Mekong Delta, Vietnam. *Aquaculture* 296(3-4), 227-236.

Rainboth, W. J. (1996). *Fishes of the cambodian mekong*. Wisconsin, USA: Food & Agriculture Organization of the United Nations.

Riede, K. (2004). *Global register of migratory species: from global to regional scales: final report of the R&D-Projekt 808 05 081*. Bonn, Germany: Federal Agency for Nature Conservation.

Sokheng, C., Chhea, C. K., Viravong, S., Bouakhamvongsa, K., Suntornratana, U.,

Yoorong, Nguyen, T. T., Tran, B. Q., Poulsen, A. F., & Jorgensen, J. V. (1999). Fish migrations and spawning habits in the Mekong mainstream: a survey using local knowledge (basin-wide). Assessment of Mekong fisheries: Fish migrations and spawning and the impact of water management project (AMFC). *AMFP Report* 2, 99.

Tran, T. (2016). *U Minh peat swamp forest: Mekong river basin (Vietnam)*. New York, USA: Springer. https://doi.org/10.1007/978-94-007-6173-5_174-4.

Trieu, N. V. (2010). Study on biological characteristics of Mastacembelus armatus. *Can Tho University Journal of Science* 2010(15b), 70-80.

Trung, N. T. (2010). *Artificial propagation of tire track eel (Mastacembelus favus) (*research report*)*. Can Tho Department of Science and Technology, Can Tho, Vietnam.

Vázquez-Ortiz, F., Caire, G., Higuera-Ciapara, I., & Hernández, G. (1995). High performance liquid chromatographic determination of free amino acids in shrimp. *Journal of Liquid Chromatography and Related Technologies* 18(10), 2059-2068.