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Evaluation the bioeconomic impact of trash fish and artificial feed on production and profitability of Mangrove Red Snapper (*Lutjanus argentimaculatus*) cultured in pond

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Abstract This study examined the effects of feeding mangrove red snapper (*Lutjanus argentimaculatus*) with trash fish (T1) and artificial feed (T2) on bioeconomic performance and profitability in 400 m² grow-out ponds over a 6-month period. The findings revealed significant variations in fish growth after the first month, with T2 consistently exhibiting slower growth throughout the rearing period ($P<0.05$). Survival rate, FCR, and yield for T1 were 96.0%, 5.26, and 262.7 kg/pond, respectively, while T2 achieved 97.5%, 2.25, and 170.0 kg/pond. The total costs of rearing fish in T1 and T2 were 91.8 and 85.4 THB/m², respectively. Total revenues were 183.9 THB/m² for T1 and 119.0 THB/m² for T2, resulting in net cash returns of 92.0 and 33.6 THB/m², respectively. Both feeding strategies covered operational costs, as indicated by NPV, BCR, and IRR analyses. However, investing in T2 carried relatively higher risks, particularly in scenarios where costs increased by 20% and benefits decreased by 20%, leading to a BCR of 0.95 and a negative IRR. Overall, rearing red snapper in earthen ponds fed with trash fish appeared to be a more suitable investment option, but further study and development of artificial feed for this fish are needed for sustainable farming practices.

Keywords: Economic return, Feed efficiency, Growth rate, Red snapper culture, Survival rate

Introduction

Aquaculture stands out as one of the fastest-growing economic sectors worldwide. Presently, Asia accounts for approximately 90% of the global aquaculture output (FAO, 2022). Nevertheless, the rapid expansion of aquaculture has sparked concerns regarding its environmental sustainability, economic feasibility, and social ramifications (Tran *et al*., 2022). Bioeconomic analyses of aquaculture provide valuable insights into these concerns by exploring the intricate relationships among biological processes, economic

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considerations, and environmental factors within aquaculture systems (Llorente and Luna, 2016, Tran *et al*., 2022).

The bioeconomic and profitability considerations of fish farming were complex and influenced by various factors, such as management practices, environmental conditions, production costs, and market demand (Boyd *et al*., 2020, Nie and Hallerman, 2021). The mangrove red snapper (Lutjanus argentimaculatus) is a significant commercial marine fish species and an excellent candidate for mariculture. Numerous countries have actively engaged in fish farming in sea cages and associated research (Chi and True, 2018, Muyot *et al.*, 2021, Asiandu and Malayudha, 2022, Mosequera *et al.,* 2023). However, there is limited research on rearing this fish in grow-out ponds, especially regarding its bioeconomic and profitability aspects. Achieving success in cultivating aquatic animals requires a comprehensive grasp of both bioeconomic principles and factors influencing profitability (Nie and Hallerman, 2021). By measuring these impacts, aquafarmers can develop strategies to reduce bioeconomic and profitability challenges and improve the sustainability of their operations. Additionally, fish feed represents the most significant variable cost in any aquaculture operation, and is considered a crucial factor directly influencing the bioeconomic and profitability aspects of fish farming (Boyd *et al*., 2020). Therefore, this study examined how trash fish and artificial feeding affect the bioeconomic aspects and profitability of cultivating mangrove red snapper, with the goal of optimizing production.

Materials and methods

Study site and source of experimental fish

In September 2023, a sample of 500 fingerlings of mangrove red snapper (*Lutjanus argentimaculatus*) at about 55–60 days post-hatch (dph) was transferred to the hatchery of the Klongwan Fisheries Research Station, Prachuap Khiri Khan province, Thailand from the hatchery of the Phang Nga Coastal Aquaculture Research and Development Center, Department of Fisheries, Phang Nga province, Thailand. The fish were reared in an indoor concrete tank (2.0 m × 1.5 m ×1.2 m, with 1 m water depth) at a density of 50 fish/m^2. They were fed with floating artificial feed (commercial marine fish feed: 42% protein, 6% fat, 4% fiber, 12% moisture) to satiation twice a day at 9:00 a.m. and 15:00 p.m. for 2 weeks (age about 75–80 dph) to allow them to acclimate to the experimental ponds.

Rearing fish in grow-out ponds

The fish from the indoor concrete tanks were transferred to earthen ponds with a surface area of 400 m^2 at a density of 1 fish/m^2. They were divided into two experimental groups based on the type of feed used: one group was fed trash fish (mixed species of marine fish), referred to as T1, and the other was fed floating artificial feed, referred to as T2. Fish were fed daily at 9:00 a.m. at approximately 5% of their biomass. Rearing was carried out for 6 months, during which the total length (in centimeters, from the point of the nose to the end of the caudal fin) and body weight (in grams) of a subset of 10 randomly selected fish from each pond were measured at the start of rearing and once monthly thereafter. To maintain good water quality, approximately one-half of the water was exchanged weekly, and water quality parameters were monitored twice a week. Salinity was determined using a refractometer (Prima Tech), pH was measured using a portable pH meter (Cyber Scan pH 11), and dissolved oxygen concentration (DO) and water temperature were measured using an oxygen probe (YSI 550A). Total ammonia, nitrite, and alkalinity of the water were determined using the indophenol blue method, colorimetric method, and titration method, respectively (APHA, AWWA & WEF, 2017).

Data collection

For bioeconomic considerations, at the end of the rearing period, the number of surviving fish was counted and about 5% of the total fish from each pond was weighed to assess its final body weight. The survival rate, absolute growth, average daily growth (ADG), specific growth rate (SGR), feed conversion ratio (FCR), gross yield and net yield were calculated using Equations 1, 2, 3, 4, 5, 6 and 7, respectively:

(1) Survival rate (%) = 100 × (number of fish survived / number of fish stocked)
(2) Absolute growth (g) = final BW – initial BW
(3) Average daily growth (g/day) = (final BW - initial BW) / t
(4) Specific growth rate (%/day) = 100 × [ln (final BW) - ln (initial BW)] / t
(5) Feed conversion ratio = total feed given / total fish weight gain
(6) Gross yield (kg/pond) = fish production (kg) / pond (400 m^2)
(7) Net yield (kg/m^2) = fish production (kg) / m^2

where BW is the mean body weight, t is the growth periods in days and ln is the Napierian logarithm.

For profitability factors, total cost of fish farming was divided into two components that is fixed cost (FC) and variable cost (VC). In this study, FC includes tools and equipment cost for grow-out pond construction (approximately per 400 m^2 pond). VC was partial budget, that is seed, feed, transportation and other miscellaneous cost. Net return (NR) or profit means the total monetary sales value derived by deducting total cost from gross return of mangrove red snapper production at different feeding, it was calculated using Equation 8:

(8) $NR = (P \times Q) - (TFC + TVC)$

where P is price per unit of fish (THB/kg), Q is total quantity of fish (kg), TFC is total fixed costs and TVC is total variable costs.

In addition, this component shows financial indicators that measure the profitability of the project (Chucheep, 2001). Mainly was the net present value (NPV), the benefit-cost ratio (BCR) and the internal rate of return (IRR) including the sensitivity analysis concerning was done to assess the financial risk of fish farming operation, using a switching value test of cost (SVT_C) and benefit (SVT_B). The NPV, BCR, IRR, SVT_C and SVT_B were calculated based on Equations 9, 10, 11, 12 and 13 respectively:

(9) $NPV = \sum_{t=1}^{n} \frac{(Bt-Ct)}{(1+r)^t}$

(10) $BCR = \sum_{t=1}^{n} Bt\,(1+r)^{-t} / \sum_{t=1}^{n} Ct\,(1+r)^{-t}$ or $BCR = PVB / PVC$

(11) $\sum_{t=1}^{n} \frac{(Bt-Ct)}{(1+r)^t} = 0$

(12) $SVT_C = NPV / PVC \times 100$

(13) $SVT_B = NPV / PVB \times 100$

where PVC is present value of costs, PVB is present value of benefits, t is time period of the project (1 year), Bt is benefit of project at time t, Ct is cost of project at time t and r is discount rate (7.5% per year).

For the sensitivity tests, in this study to examine the changes of cost and benefit of the investments were estimated in three scenarios: (I) where costs increased by 20% and benefits remained fixed, (II) with benefits decreased by 20% and fixed costs and (III) where costs increased by 20% and benefits decreased by 20%. It is often used in financial modeling, risk assessment, and decision-making processes to understand the effect of uncertainty and variability in input variables on the output (Chucheep, 2001, Wechakama *et al.*, 2012, Oniam *et al.,* 2018).

Data analysis

Statistical analysis was performed using the IBM SPSS Statistics for Windows software (version 21.0; IBM Corp.; Armonk, NY. USA). Differences between groups were analyzed using independent samples t-test at the 95% level of confidence. Some statical measures like average, percentage and ratios were calculated in tabular form for measuring economic characteristic and financial profitability and the quantitative method was used to assess profitability.

Results

Bioeconomic

During the study period, the monthly growth of fish reared in grow-out ponds using different feeding regimes is illustrated in Figure 1. In terms of growth, fish reared in T1 exhibited higher total length and body weight values compared to those in T2 throughout the rearing period. The highest mean final total length (35.3±1.4 cm) and final body weight (759.2±107.4 g) were recorded in T1 (P<0.05). Conversely, the final total length and body weight of T2 were 32.5±1.5 cm and 496.5±72.7 g, respectively (Figure 1). After 6 months of fish rearing, the results indicated that final body weight, survival rate, absolute growth, ADG, SGR, FCR, gross yield, and net yield are summarized in Table 1.

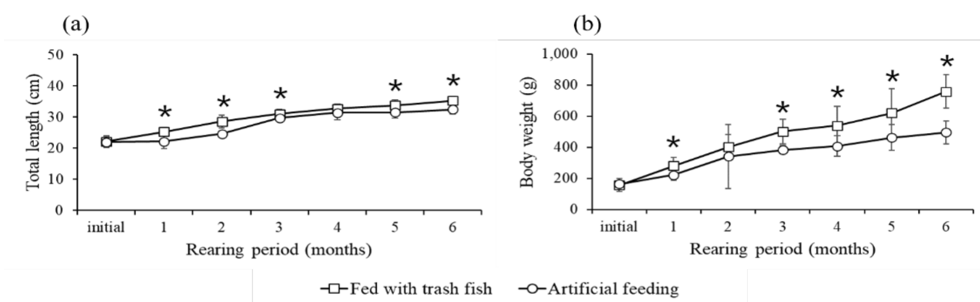

Figure 1. Total length (a) and body weight (b) of mangrove red snapper (*Lutjanus argentimaculatus*) reared in grow-out ponds at different feeding: An asterisk denotes statistical significance (P<0.05) at time point indicate different between treatments

Profitability

The expenses and profits related to rearing fish in grow-out ponds at different feeding are detailed in Table 1. The expenses and profits related to rearing fish in grow-out ponds at different feeding are detailed in Table 1. The total cost of rearing fish in T1 and T2 were 91.8 and 85.4 THB/m^2, respectively. The returns per m^2 were 204.1 and 135.5 THB, with net returns of 112.2 and 50.1 THB/m^2, respectively. When evaluating the financial returns of fish across different feeding, it was discovered that rearing mangrove red snapper at each feeding proved to be a profitable investment. This conclusion was supported by positive NPV, BCR and IRR, with NPV values of 246,015.54 and 251,921.28 THB, BCR of 2.00 and 1.43, and IRR of 122.10% and 57.73%, respectively (Table 2).

Table 1. Bioeconomic and profitability data of mangrove red snapper (*Lutjanus argentimaculatus*) rearing in grow-out ponds using different feeding over a 6-month period

Items	Fish feeding	
	Trash fish (T1)	Artificial feed (T2)
General information		
Culture area (m^2)	400	400
Density of fish (fish/m^2)	1	1
Fish juvenile cost (THB/fish)	40	40
Fish feed cost (THB/kg)	15	47.5
Rearing period (month)	6	6
Production		
Mean body weight (g)	759.2	496.5
Absolute growth (g)	601.4	332.8
Average daily growth (g/day)	3.34	1.85
Specific growth rate (%/day)	0.87	0.62
Survival rate (%)	96.0	97.5
Gross yield (kg/pond)	291.5	193.6
Net yield (kg/m^2)	0.73	0.48
Total feeding (kg)	1,382.5	382.4
Feed conversion ratio	4.74	1.97
Cost (partial budget; seed and feed costs)		
Total cost (THB/pond)	36,737.5	34,164.0
Total cost (THB/m^2)	91.8	85.4
Benefit		
Sale price (THB/kg)	280	280
Total revenue (THB/pond)	81,629.2	54,217.8
Total revenue (THB/m^2)	204.1	135.5
Net cash retum (THB/pond)	44,891.7	20,053.8
Net cash returm (THB/m^2)	112.2	50.1

For the financial sensitivity analysis and risk assessment of rearing this fish, the analysis indicated that fish reared in T1 still yielded a favorable return on investment under I, II and III scenarios. However, investing in fish reared in T2 had relatively higher risks or were not economically feasible in scenario III due to the combined increase in costs and decrease in benefits. This was evident from the BCR and IRR for fish rearing in T2 at scenario III (Table 2).

Table 2. Cost-benefit analysis of mangrove red snapper (*Lutjanus argentimaculatus*) rearing in grow-out ponds using different feeding over a 6-month period

Iterms	Fish feeding	
	Trash fish (T1)	Artificial feed (T2)
Average cost per year (THB/1,600 m^2)	293,900.00	273,312.00
Average revenue per year (THB/1,600 m^2)	653,033.47	433,742.40
Average net cash return per year (THB/1,600 m^2)	359,133.47	160,430.40
Net present value (NPV)	246,015.54	251,921.28
Benefit cost ration (BCR)	2.00	1.43
Internal rate of return (IRR)	122.10	57.73
Switching value test of cost (SVT_C)	8.37	9.22
Switching value test of benefit (SVT_B)	4.19	6.45
Sensitivity analysis		
(I) 20% increased in cost		
NPV	312,632.87	313,872.00
BCR	1.67	1.19
IRR	84.82	28.99
(II) 20% decreased in benefit		
NPV	263,429.76	263,487.74
BCR	1.60	1.14
IRR	77.31	22.67
(III) 20% increased in cost and 20% decreased in benefit		
NPV	330,047.10	325,438.46
BCR	1.33	0.95*
IRR	46.59	-11.35*

Note: The assessment of fish culture considered two production cycles per year; * indicates unprofitable and high-risk investments.

Discussion

Aquaculture, especially the cultivation of marine species like the mangrove red snapper (*L. argentimaculatus*), plays a vital role in meeting the growing demand for seafood (Chi and True, 2018, Muyot *et al*., 2021, Asiandu and Malayudha, 2022, Mosequera *et al*., 2023). In current study, consistent with prior research demonstrating the advantages of using trash fish to enhance fish growth (Hasan and Halwart, 2009; Biswas and Yakupitiyage, 2013). Trash fish, being a natural feed, contains a variety of essential nutrients crucial for fish growth and development. Biswas and Yakupitiyage (2013) emphasized the economic advantages of using natural feeds, such as trash fish, in aquaculture. They observed that tilapia farming in grow-out ponds using natural feeds was economically viable and yielded higher returns compared to artificial feed. This supports the findings of the current study, where fish reared with trash fish showed higher profitability compared to those fed with artificial feed.

The growth performance of fish is influenced by various factors, with feed quality playing a significant role (Boyd *et al*., 2020, Nie and Hallerman, 2021). Hasan and Halwart (2009) underscored the significance of feed inputs in aquaculture and their impact on industry sustainability. They discussed the practices and consequences of using fish as feed inputs in aquaculture, emphasizing the need for sustainable feed sources to maintain the industry's long-term viability. In the current study, the utilization of trash fish as a natural feed contributed to the superior growth performance of fish in T1, highlighting the critical role of feed quality in aquaculture operations.

The economic sustainability of aquaculture investments was a critical concern for fish farmers. Tacon and Metian (2008) presented a comprehensive overview of the utilization of fish meal and fish oil in aquafeeds, discussing industry trends and future prospects. They emphasized the challenges faced by the aquafeed industry, including the necessity for sustainable feed sources and the importance of balancing economic viability with environmental sustainability. The current study's findings support the idea that investing in sustainable feeding practices, such as utilizing natural feeds like trash fish, can result in increased profitability and economic sustainability in aquaculture operations. The financial sensitivity analysis and risk assessment conducted in this study provided valuable insights into the economic viability of rearing mangrove red snapper with different feeding regimes. The analysis indicated that fish reared with trash fish (T1) remained a favorable investment under various scenarios, demonstrating its economic resilience and viability. In contrast, investing in fish reared with artificial feed (T2) was linked to higher risks and was economically unfeasible in certain scenarios. This underscores the importance of considering economic risks and uncertainties in aquaculture investments to ensure long-term profitability and sustainability. However, further research should focus on developing formulated pellet feeds for this fish species. This innovation could help reduce reliance on natural resources, such as trash fish, for aquaculture. As the use of trash fish continues to rise in the aquaculture industry, it presents challenges to resource sustainability and the future of aquaculture (Myo *et al.,* 2018).

Overall, this study has shown that rearing mangrove red snapper with trash fish is not only beneficial for the fish's growth performance but also economically viable. The use of natural feeds like trash fish can increase profitability and promote economic sustainability in aquaculture operations. However, proper management practices, including ensuring feed quality, are crucial to optimizing growth performance and economic viability in aquaculture investments. Future research should focus on further refining feeding practices and investigating alternative feed sources to enhance the sustainability of aquaculture operations. This includes developing artificial feeds with tailored nutritional profiles that meet the specific needs of this fish species.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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