

Income of tiger shrimp (*Penaeus monodon*) and milkfish (*Chanos chanos*) polyculture farmers with mangrove-integrated and non-mangrove ponds in Sungai Meriam Village, Anggana District, Kutai Kartanegara Regency, East Kalimantan

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ABSTRACT

Traditional brackishwater ponds in Sungai Meriam Village, in the Mahakam Delta, are used for the polyculture of tiger shrimp (*Penaeus monodon*) and milkfish (*Chanos chanos*), and some ponds retain mangroves on a central mound. This study compared the annual net income of polyculture farmers with mangrove-integrated ponds and with non-mangrove ponds and identified the constraints they face. A survey was conducted from January 2024 to June 2025 among 50 farmers selected by purposive sampling (25 per pond type). Income was analysed as total revenue minus total cost, and the difference between groups was tested with the Mann–Whitney test because income was not normally distributed (Sig. = 0.003 and 0.000). Mean net income was Rp 186,452,028 per year for farmers with mangrove-integrated ponds and Rp 167,620,477 for those with non-mangrove ponds, a difference of Rp 18.8 million (11.2%). The difference was not statistically significant (mean ranks 28.00 and 23.00; asymptotic Sig. 2-tailed = 0.225). The higher gross revenue of mangrove-integrated ponds came almost entirely from tiger shrimp, and roughly two-thirds of that gap reflects a higher implied shrimp price rather than a larger harvest. The main constraints were dry-season salinity and temperature stress, which weakened shrimp and stunted milkfish, and burrowing belitung snails that damaged pond bottoms. Mangrove-integrated ponds were therefore at least as profitable as non-mangrove ponds in this sample, and no income penalty from retaining mangroves was detected, although the small sample limits the power to detect a modest difference.

INTRODUCTION

Kutai Kartanegara Regency covers 27,263.10 km² between 115°26' and 117°36' E and between 1°28' N and 1°08' S, and is divided into 18 sub-districts (BPS Kutai Kartanegara, 2023). Anggana Sub-district comprises eight villages, including Sungai Meriam. The village covers 11,654 ha, lies in the lower Mahakam River close to the sea, and had 652 people engaged in pond aquaculture, 166 in inland open-water fisheries and 30 in marine capture fisheries (BPS Kutai Kartanegara, 2023). Most pond farmers in the village practise traditional polyculture of tiger shrimp (*Penaeus monodon*) and milkfish (*Chanos chanos*).

Traditional ponds are earthen and are managed through a sequence of drying, bottom preparation, pest control, fertilisation, water exchange, stocking of post-larvae, rearing and harvest (Rusmiyati, 2010). The ponds are built on clay soil near a brackish water source. In Sungai Meriam, two pond types are found: non-mangrove ponds, which have no mangrove vegetation, and mangrove-integrated ponds, in which a central earthen mound supports mangrove growth. Polyculture is the joint rearing of several species in one system so that they benefit one another, and shrimp and fish are a combination that can support each other when reared together (Mangampa and Burhanuddin, 2014).

Integrating mangroves into brackishwater ponds, known as silvofishery or wanamina in Indonesia, is promoted as a way to combine farm income with mangrove conservation in the Mahakam Delta, where mangrove cover has declined sharply (Susilo et al., 2018). In a survey of 284 farmers in the delta, Susilo et al. (2018) found that silvofishery adoption had a positive effect on annual income per hectare. They also noted that farmers sometimes cut back mature mangroves because shading and leaf tannins can reduce pond productivity. Whether retaining mangroves in ponds costs or benefits the farmer is therefore a practical question, and evidence at the village level is limited.

This study compares the income of tiger shrimp–milkfish polyculture farmers with mangrove-integrated ponds and those with non-mangrove ponds in Sungai Meriam Village. Its objectives were (1) to calculate the investment, costs, revenue and net income of both groups, (2) to test whether net income differs significantly between them, and (3) to identify the constraints farmers face.

METHODOLOGY

Study area and survey

The study was conducted from January 2024 to June 2025 in Sungai Meriam Village, Anggana Sub-district, Kutai Kartanegara Regency. A survey method was used, with primary data collected directly from respondents through questionnaires and face-to-face interviews (Ruslan, 2004). Primary data covered respondent identity, business profile (years of operation and source of capital), business performance (initial capital, investment cost, production cost, harvest, and selling price) and the problems encountered. Secondary data came from published and unpublished reports and archives of BPS Kutai Kartanegara, covering the general condition of the area, aquaculture production, and the social and economic situation of the population.

Sampling

A sample is a part of the population under study and should share its characteristics (Arikunto, 2006). Respondents were selected by purposive sampling, in which participants are chosen according to predetermined criteria (Bernard, 2002). The criteria were that the respondent (1) is a resident of Sungai Meriam Village and owns a tiger shrimp–milkfish pond business, (2) has an active business, (3) operates a pond with mangroves or without mangroves, (4) uses the same stocking number, and (5) has the same pond area. The sample comprised 50 farmers: 25 with mangrove-integrated ponds and 25 with non-mangrove ponds.

Data analysis

Income was calculated from costs and revenue. Total cost (TC) is the sum of fixed cost (FC) and variable cost (VC) (Suratiah, 2015):

$$TC = FC + VC \quad (1)$$

Total revenue (TR) is production multiplied by price (Soekartawi, 2003):

$$TR = P \times Q \quad (2)$$

Income (I) is total revenue minus total cost (Andrianingsih and Asih, 2021):

$$I = TR - TC \quad (3)$$

where TC, FC, VC, TR and I are in Rp per year, P is price (Rp/kg) and Q is quantity (kg per year). Fixed costs consisted of annual depreciation of the assets listed in Table 1, calculated by dividing each asset's cost by its service life. Variable costs were seed, fertiliser, ice, fish poison and diesel.

The normality of income in each group was assessed, and the decision rule was that data are normally distributed if the significance value is greater than 0.05 (Sugiyono, 2017). Because parametric tests cannot be used when normality is rejected, the difference in income between the two groups was tested with the Mann–Whitney test (Mann and Whitney, 1947), a non-parametric test for two independent samples. The significance level was 0.05.

RESULT AND DISCUSSION

Results

Investment and depreciation

Farmers financed all investments from their own capital. The assets used were the pond itself, a guard house, a harvest house, sluice gates, boat hulls and engines, fibre boats, cork pontoons, fibre and plastic crates, headlamps, tarpaulins, generators and julu traps. Mean investment per farm was Rp 275,857,890 for mangrove-integrated ponds and Rp 254,550,720 for non-mangrove ponds, a difference of 8.4% (Table 1). The pond was the largest item in both groups (Rp 126,000,000 and Rp 123,880,000), and tarpaulins were the smallest (Rp 131,200 and Rp 164,400). Mean annual depreciation was Rp 27,117,856 and Rp 22,809,147, respectively, 18.9% higher in the mangrove-integrated group.

Table 1. Mean investment cost and annual depreciation per farm of tiger shrimp–milkfish polyculture ponds (Rp).

Asset	Investment, mangrove	Investment, non-mangrove	Depreciation, mangrove (per year)	Depreciation, non-mangrove (per year)
Pond (earthen)	126,000,000	123,880,000	11,108,714	9,229,347
Guard house	30,620,000	27,340,000	2,795,333	2,305,833
Harvest house	7,640,000	7,400,000	726,857	559,857
Sluice gate	35,200,000	28,880,000	2,628,857	2,243,237
Boat hull	31,640,000	28,720,000	2,984,333	2,671,904
Boat engine	21,700,000	20,800,000	2,505,000	2,277,500
Fibre boat	3,609,090	2,166,000	433,376	418,342
Cork pontoon	234,000	234,000	90,920	90,920
Fibre crate	8,940,000	6,360,000	871,095	567,714
Plastic crate	5,280,000	3,840,000	1,028,571	567,713
Headlamp	345,600	372,320	109,600	132,000
Tarpaulin	131,200	164,400	131,200	164,400
Generator	3,368,000	3,304,000	554,000	490,380
Julu (bamboo trap)	1,150,000	1,090,000	1,150,000	1,090,000
Total (mean per farm)	275,857,890	254,550,720	27,117,856	22,809,147

Variable costs

Variable costs were nearly identical between groups (Table 2): Rp 13,051,160 per year for mangrove-integrated ponds and Rp 13,233,200 for non-mangrove ponds. Tiger shrimp seed was the largest item in

both (Rp 5,608,000) and fertiliser the smallest (Rp 399,600 and Rp 404,800). Seed costs for shrimp and milkfish were identical in the two groups, consistent with the equal stocking criterion.

Table 2. Mean annual variable cost per farm (Rp).

Variable cost item	Mangrove	Non-mangrove
Tiger shrimp seed	5,608,000	5,608,000
Milkfish seed	2,462,400	2,462,400
Fertiliser	399,600	404,800
Block ice	802,200	809,200
Fish poison	1,288,000	1,210,000
Diesel	2,490,160	2,738,800
Total (as reported)	13,051,160	13,233,200

Source: primary data, processed (2025). The reported totals are used as given; the mangrove items sum to Rp 13,050,360.

Production and revenue

Mean annual production of mangrove-integrated ponds was 1,844 kg of tiger shrimp and 1,803 kg of milkfish, against 1,780 kg and 1,762 kg for non-mangrove ponds, i.e. 3.6% and 2.3% more (Table 3). Milkfish was sold at Rp 20,000/kg in both groups, since all respondents sold to the same collector. Revenue from tiger shrimp was Rp 212,277,920 and Rp 190,365,560 per year. Dividing revenue by production gives an implied shrimp price of about Rp 115,100/kg for mangrove-integrated ponds and Rp 106,900/kg for non-mangrove ponds. Total revenue was Rp 248,337,920 and Rp 225,605,560, so mangrove-integrated ponds earned 10.1% more.

Table 3. Mean annual production and revenue per farm.

Pond type	Shrimp (kg)	Shrimp revenue (Rp)	Milkfish (kg)	Milkfish price (Rp/kg)	Milkfish revenue (Rp)	Total revenue (Rp)
Mangrove	1,844	212,277,920	1,803	20,000	36,060,000	248,337,920
Non-mangrove	1,780	190,365,560	1,762	20,000	35,240,000	225,605,560

Costs and net income

Total cost was Rp 61,885,892 per year for mangrove-integrated ponds and Rp 57,985,083 for non-mangrove ponds (Table 4). Mean net income was therefore Rp 186,452,028 and Rp 167,620,477 per year, so farmers with mangrove-integrated ponds earned Rp 18,831,551 (11.2%) more (Figure 1). Net income was about 75% of revenue in both groups (75.1% and 74.3%). Depreciation and variable costs together came to Rp 40,169,016 and Rp 36,042,347. The remainder of total cost, Rp 21,716,876 and Rp 21,942,736, is not itemised in Tables 1–2 and is shown as a balance in Table 4.

Table 4. Mean annual revenue, costs and net income per farm (Rp).

Item	Mangrove	Non-mangrove
Total revenue	248,337,920	225,605,560
Depreciation (fixed cost)	27,117,856	22,809,147
Variable cost	13,051,160	13,233,200
Other costs (balance)	21,716,876	21,942,736
Total cost	61,885,892	57,985,083
Net income	186,452,028	167,620,477

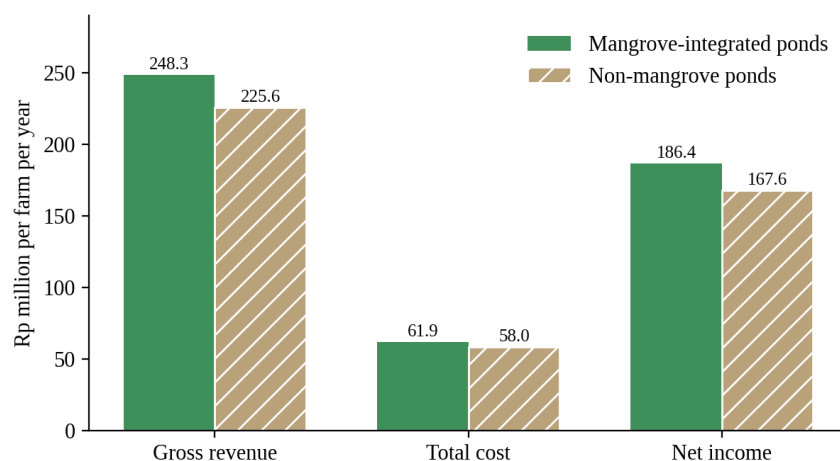


Figure 1. Mean gross revenue, total cost and net income per farm per year for mangrove-integrated and non-mangrove polyculture ponds in Sungai Meriam Village.

Statistical test of the income difference

The normality test gave significance values of 0.003 for mangrove-integrated ponds and 0.000 for non-mangrove ponds. Both are below 0.05, so income was not normally distributed in either group and the Mann–Whitney test was used. The mean rank of income was 28.00 for mangrove-integrated ponds and 23.00 for non-mangrove ponds, showing a tendency towards higher income in the former (Table 5). The difference was not significant (asymptotic Sig. 2-tailed = 0.225 > 0.05). Hence there is no significant difference in income between the two pond types.

Table 5. Mann–Whitney test of annual net income, mangrove-integrated versus non-mangrove ponds (n = 25 per group).

Statistic	Mangrove	Non-mangrove
Normality test, Sig.	0.003	0.000
Mean rank	28.00	23.00
Sum of ranks	700.0	575.0
Mann–Whitney U	250.0	
Z	−1.21	
Asymp. Sig. (2-tailed)	0.225	

U, Z and sums of ranks were derived from the reported mean ranks ($U = n_1n_2 + n_1(n_1+1)/2 - R_1$) and reproduce the reported significance value.

Constraints faced by farmers

Two main constraints were reported. The first was the dry season, when high air temperatures increase evaporation from the ponds and raise salinity as freshwater supply falls. Water temperature is high by day and low at night, and farmers reported that these sudden changes stress the shrimp and make them weak (locally “teler”), that shrimp then fail to survive, and that milkfish do not grow large. The second was pests, chiefly the belitung snail (keong belitung), which burrows into the pond bottom to nest. Respondents reported that if left unchecked, the bottom is damaged and the pond gives off a foul odour, which harms the health of the shrimp and milkfish.

Discussion

Income of mangrove-integrated and non-mangrove ponds

Farmers with mangrove-integrated ponds earned 11.2% more on average, but the Mann–Whitney test did not show a significant difference. The result should be read as no detectable income penalty, not as proof that the two systems are equal. With 25 farmers per group and income that was not normally distributed, the test has limited power to detect a difference of this size. The mean ranks (28.00 versus 23.00) nevertheless point in the direction of the mangrove-integrated ponds, which is consistent with the positive income effect of silvofishery reported for the Mahakam Delta by Susilo et al. (2018), although that study measured income per hectare with a matching design and is not directly comparable.

The source of the revenue gap deserves attention. Tiger shrimp accounted for about 96% of the Rp 22.7 million revenue difference (Rp 21.9 million), while milkfish contributed only Rp 0.8 million. The shrimp harvest was only 3.6% larger in mangrove-integrated ponds, whereas shrimp revenue was 11.5% higher. A decomposition using the implied prices indicates that about two-thirds of the shrimp revenue gap comes from price and about one-third from volume. Price differences between ponds were not recorded directly, and may reflect shrimp size or grade, harvest timing or the buyer's terms, none of which were analysed. Farmers' statement that all respondents sell to the same collector at the same price is therefore difficult to reconcile with the implied shrimp prices and should be checked against the raw data. The finding that mangrove-integrated ponds did not yield less, even though part of the pond is occupied by the central mound, suggests that mangroves and shrimp–milkfish polyculture can coexist without a visible production loss in this sample.

Mangrove-integrated ponds also required more capital. Mean investment was 8.4% higher and annual depreciation 18.9% higher, and total cost was 6.7% higher, which absorbed part of the revenue advantage (Table 4). The investment gap was spread across most assets rather than concentrated in the pond itself (the pond accounts for only Rp 2.1 million of the Rp 21.3 million difference), with the largest differences in sluice gates, guard houses and boat hulls. This pattern suggests that farms in the mangrove-integrated group may operate at a somewhat larger scale or with more equipment, even though equal pond area was a sampling criterion. Pond area was not recorded as a variable, so income per hectare could not be computed.

Constraints

The constraints reported are consistent with the physical setting of traditional ponds that depend on rainfall and tidal exchange. In the dry season, evaporation and reduced freshwater inflow raise salinity, and large daily temperature swings add stress, which can explain the weak shrimp and the stunted milkfish that farmers described. No salinity or temperature measurements were taken in this study, so these links rest on farmers' reports and general reasoning. The belitung snail is regarded as a pest because its burrowing damages the pond bottom and causes odour, but the extent of the losses was not quantified. Neither constraint was analysed separately for the two pond types, so it is not known whether mangroves moderate or aggravate them.

Limitations

The study is cross-sectional and based on 50 purposively selected farmers, so the results cannot be generalised beyond Sungai Meriam. Pond area was not recorded, shrimp prices are implied rather than observed, and part of total cost is not itemised. Income was measured in money terms only and excludes the ecological services of mangroves, such as coastal protection and carbon storage. Future studies should record pond area and mangrove cover, measure salinity and temperature over the year, use a larger sample, and report income per hectare.

CONCLUSION

Mean annual net income was Rp 186,452,028 for farmers with mangrove-integrated ponds and Rp 167,620,477 for farmers with non-mangrove ponds. The Mann–Whitney test showed no significant difference between the two (asymptotic Sig. 2-tailed = 0.225), so retaining mangroves in tiger shrimp–milkfish polyculture ponds did not reduce income in this sample. The higher revenue of mangrove-integrated ponds came from tiger shrimp and was partly offset by higher investment and depreciation. The main constraints were dry-season salinity and temperature stress, which weakened shrimp and stunted milkfish, and burrowing belitung snails that damaged pond bottoms and produced odour. Management support for dry-season water management and snail control would benefit farmers in both pond types.

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