The status of Asian red-tailed catfish (*Hemibagrus wyckioides* Fang & Chaux, 1949) cage culture in An Giang province, Vietnam

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Abstract. Asian red-tailed catfish (*Hemibagrus wyckioides* Fang & Chaux, 1949) reared in cage culture was studied in An Giang province, the upstream region of the Mekong Delta, Vietnam. The aim is to identify technical aspects, financial aspects and analyze the cage owners' advantages and disadvantages. The study was carried out on the cage systems on the main and the branch rivers within the province from June to December 2022 by surveying 60 households. Results found that each household has 1-5 cages, the volume of each cage is 90-120 m^3, and the cage volumes per household were classified into 3 groups: small group (S-group) < 100 m^3 household^{-1}, medium group (M-group): > 100-500 m^3 household^{-1}, and large group (L-group) > 500 m^3 household^{-1}. The culture period was 16±2 month harvest^{-1}. The price of the marketable fish was 2.5-3.5 USD kg^{-1}. The profit was from 25 -73.2 USD m^{-3}, but over 50 % of households had losses and no profits. Feeding accounts for 70-80 % of total costs. The households in the L-group often stock larger fingerling, but the density stocking was the lowest with 53.4±32.7 ind m^{-3}, and the yield was 29.3±18.0 kg m^{-3}. The yield of the cages in the main rivers was higher than in the branch rivers.
Key Words: branch river, cage owner, freshwater, main river, nursing.

Introduction. Asian red-tailed catfish (*Hemibagrus wyckioides* Fang & Chaux, 1949) is a native omnivorous freshwater fish that lives at the bottom of large rivers in the Mekong River Basin (Prasertwattana et al 2005; Termvidchakorn & Hortle 2013), notably in Thailand, Laos, Cambodia, and Vietnam (Rainboth 1996; Hee & Rainboth 1999). This species is commonly cultured in cages in large rivers and reservoirs in Asian countries (Petrakis & Stergiou 1995), where it has high commercial value because of its white meat, low fat and bone content, and good taste, which make it popular with consumers (Sahoo et al 2010). This species also grows rapidly in culture and its body weight can reach 80 kg ind^{-1} (Hee & Rainboth 1999; Amornsakun 2000), making it an attractive species for farmers to culture.

In 2010, a small number of farmers began cage culture of Asian red-tailed catfish in An Giang Province, an upstream area in the Vietnamese Mekong Delta (VMD, Figure 1). Farmers stocked cages with hatchery-produced fingerlings at stocking densities of 20-40 ind m^{-3} and obtained high profits. This encouraged others to follow and nowadays cage culture of Asian red-tailed catfish is widespread in both on the main river (red line in Figure 1) and smaller secondary tributaries (blue lines in Figure 1) of the Hau River in An Giang Province. However, flow rates and water quality vary greatly depending on the width and depth, on the proximity to the main river, and on agricultural practices (mainly rice production) on local floodplains (MRC 2020). Very little is known about the extent to which these factors affect survival rates and yield, the cost of production, and the profitability of Asian red-tailed catfish reared in cages in the VMD.

The objective of this research was to assess the current status of cage culture of Asian red-tailed catfish, and to evaluate the constraints and opportunities (cost – benefit) for farmers with cages in waterways with different environmental parameters.

Material and Method

Study area. An Giang (AG) is an inland province with a dense network of rivers and canals, which receive water from the upstream Mekong River via the Hau and Tien rivers (Figure 1). The average volumetric flow rate of this river system is about 13,800 $m^3 s^{-1}$ (flood season: 24,000 $m^3 s^{-1}$; the dry season: 5,020 $m^3 s^{-1}$) (MRC 2020). The study was carried out in the districts of An Phu, Phu Tan, Chau Doc, Cho Moi and Long Xuyen, which lie along the banks of the Hau river running from north-west to south-east (Figure 1).

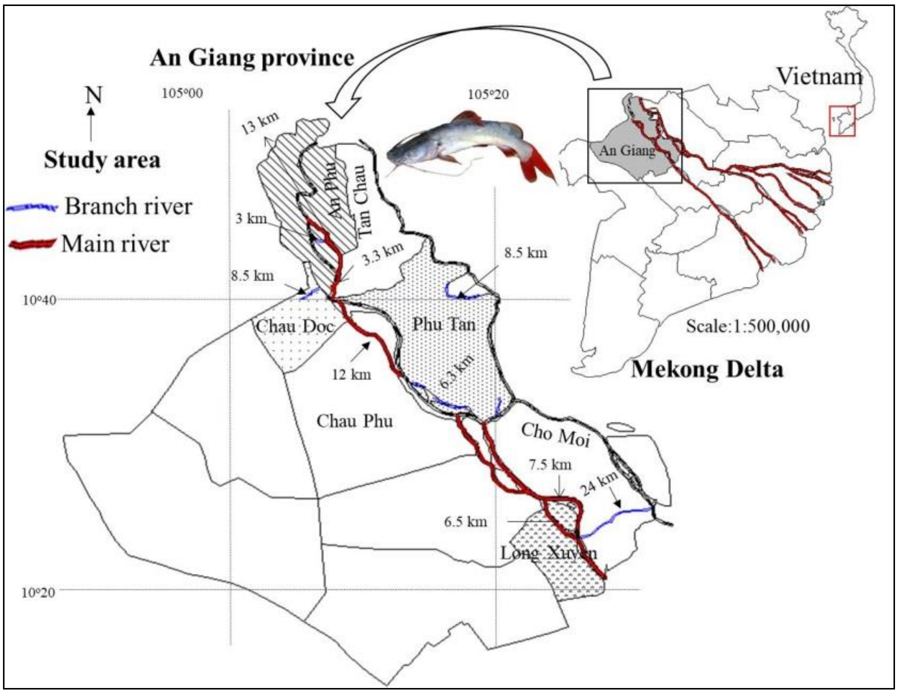

Figure 1. Study area on the map of An Giang (red line: the main rivers; blue line: branch rivers) (map generated using ArcView GIS 3.1).

Data collection. The study was carried out from June to December 2022. The primary data was collected over the period June to December 2022, using a questionnaire involving 60 households (accounting for 85% of all households engaged in cage culture of Asian red-tailed catfish) in An Phu, Phu Tan, Chau Doc, Long Xuyen and Cho Moi districts (Figure 1). The following procedure was used to select households for the questionnaire. First households were classified into three groups based on the total volume of all their cages, a small cage group (S-group, with a total cage volume of < 100 m^3), a medium cage group (M- group with a total cage volume of 100-500 m^3), and a large cage group (L-group with a total cage volume of > 500 m^3). The actual size of individual cages was very similar for each group (90-120 m^3), so the group into which a household was placed depended on how many cages they had. Households in each group were selected randomly across the main river channel and branch river channels. The number of households selected in each group was based on the relative proportions of households in each group, so fewer households were surveyed in the group containing the smallest number of households (L-group; n=15, Table 1), and more households were surveyed in the group containing the largest number of households (M-group; n=27, Table 1).

The data collected included: volume of the cages per household (m^3 household^{-1}), the number of cages per household (cage household^{-1}), the stocking density (ind m^{-3}), the yield (kg m^{-3} harvest^{-1}), typical feeding rates, fingerling length (total length cm), fish size at harvesting (kg ind^{-1}), and the period of culture (months harvest^{-1}). Also collected were data on costs such as: variable costs, which include the cost of feeding, the price of seedlings, and other variable costs; fixed costs like cage costs; income and net profit were calculated per m^3 of cage volume and on a household basis. All monetary values were converted to USD using an average rate of exchange of 1 USD ~ 23,000 Vietnamese dong (VND) for 2022.

Data analysis. The following parameters were calculated (Mahruzal & Khaddafi 2020):
Gross profit margin (GPM) = the rates of the net return on the costs divided by total costs (USD m^{-3} $harvest^{-1}$);
Net return on costs = total income - total costs;
Total fixed costs (USD) = cost of cage investment spread over a 20 year time frame;
Total costs (USD $harvest^{-1}$) = total variable costs + % of total fixed costs;
Total income = sale price of fish (USD kg^{-1}) x kg of fish harvested (kg m^{-3} $harvest^{-1}$).

$$Gross\ profit\ margin(GPM)(\%) = \frac{Net\ return\ on\ the\ costs}{Total\ costs} \times 100\%$$

A 1-way ANOVA was used to test the significance of differences in yields and production between the three cage volume groups, and a t-Test was used to test for differences between the main and branch rivers. The statistical tests were perfomed with Microsoft Excel and R software (www.r-project.org).

Results

The technical patterns of Asian red-tailed catfish culture in the study area. Each household had 1-5 cages (Table 1). The volume of each cage ranges from 90-120 m^3 and the cage can be used for 20-30 years. The frame of cages is made from wood, and they are covered with a net with a mesh size of 1.5-3.0 cm, depending on the cage site and the fingerling size at stocking. All farmers purchased fingerlings with a length in the range of 2 - 5 cm from hatcheries. The cage owners often buy small fingerlings and nurse them themselves to save costs. These fingerlings are nursed in small cages installed in areas with less current. The mesh size of the cages used for nursing is smaller to ensure the fingerlings cannot escape. Fingerlings are nursed for 2-3 months to a length of 8.5-12.5 cm before stocking in grow out cages. The period of culture and the seedling length of S- and M-groups at the time of stocking were not significantly different (p>0.05), whereas the fingerling length at stocking was signficantly longer for the L- group (p<0.05), because reared larger fingerlings at lower stocking rates in order to reduce the period of culture. In practice, the decision on when to harvest depends on market demand, and farmers can harvest fish of about 1.0-1.5 kg ind^{-1} earlier if market conditions are favorable (Figure 2a).

Table 1

Technical parameters of the cage owners on the different cage volume group

No	*Items*	*Volume of cage*		
		<100 m^3 (n = 18) (S-group)	*100-500 m^3 (n = 27) (M-group)*	*>500 m^3 (n = 15) (L-group)*
1	Number cages $household^{-1}$	$2.1±0.9^a$	$2.7±1.7^b$	$5.7±4.4^c$
2	Period of culture (months $harvest^{-1}$)	$16.3±2.5^a$	$16.0±2.0^a$	$14.7±1.7^b$
3	Density stocking (ind m^{-3})	$85 ±27^a$	$78.5±30.0^b$	$53.4±32.7^c$
4	Seedling length (cm)	$2.9±1.5^a$	$3.4±1.5^b$	5.5±2.3c
5	Body weight of seedling (g ind^{-1})	$0.02±0.01^a$	$0.02±0.01^a$	$0.03±0.02^b$
6	River depth (m)	$11.4±2.5^a$	$12.1±1.7^a$	$11.4±2.1^b$
7	Cage depth (m)	$3.8±0.6^a$	$4.5±0.7^b$	$4.1±0.9^b$
8	Harvesting size at selling (kg ind^{-1})	$1.5±0.3^a$	$1.6±0.4^b$	$1.6±0.3^b$
9	Cage volume (m^3 $cage^{-1}$)	$90±10^a$	$95±13^b$	$94±16^b$
10	Production (kg $household^{-1}$)	$3,609±1,894^a$	$14,487±9,557^b$	$25,614±22.772^c$
11	Yield (kg m^{-3} $harvest^{-1}$)	$52.9±11.1^a$	$62.6±27.5^b$	$29.3±18.0^c$

Note: Means ± SD different letters in the same row show significantly different (p<0.05).

There were significant differences in yields (kg m^{-3} $harvest^{-1}$) between cage groups ($p<0.05$) (Table 2), the M-group having the highest yields, with the lowest yields in the L-group (Table 1). However, yields within all three obtained by all cage volume groups fluctuated greatly, and this coupled with problems such as limited markets and unstable market prices at harvesting means that farmers of this species are exposed to significant financial risk. This is exacerbated by hard to manage water quality in the rivers, due to pesticides, herbicides, fertilizers and other chemicals used in rice farming, and the discharge of domestic waste into rivers.

Yields (kg m^{-3} $harvest^{-1}$) and production (kg $household^{-1}$) of cages in the main rivers were both a little higher than those in the branch rivers; although the differences were small, they were neverhtheless statistically significant (Table 2). For the most part there was no significant difference in other parameters shown in Table 2 between main rivers and branch rivers, although main rivers tended to be deeper than branch rivers, and likewise cages were generally a little deeper in main rivers than in branch rivers (Table 2).

Table 2

Technical parameters in the main rivers and the branch rivers

No	*Items*	*Main rivers (n=37)*	*Branch rivers (n=23)*
1	Number cage $household^{-1}$	$2.9±1.7^a$	$2.9±2.8^a$
2	Period of culture (month)	$15.5±1.8^a$	$15.1±2.4^a$
3	Fingerling length (cm)	$3.1±1.7^a$	$3.2±2.0^a$
4	Body weight of seedling (g ind^{-1})	$0.02±0.01^a$	$0.02±0.01^a$
5	River depth (m)	$12.1±1.8^a$	$11.4±2.2^b$
6	Cage depth (m)	$4.5±1.2^a$	$4.2±0.9^b$
7	Cage volume (m^3 $cage^{-1}$)	$95±8.2^a$	$94±7.6^a$
8	Size of fish at selling (kg $ind.^{-1}$)	$1.5±0.5^a$	$1.5±0.3^b$
9	Production (kg $household^{-1}$)	$12,536±8,922^a$	$11,574±9,353^b$
10	Yield (kg m^{-3} $harvest^{-1}$)	$53.2±26.7^a$	$37.0±26.8^b$

Note: Columns with different letters in the same row are significantly different ($p<0.05$).

Costs, income and profitability of Asian red-tailed catfish culture in the study area. The total cost of production for the S-group and M-group was almost twice that of the L-group, mainly because of higher fingerling and feeding costs associated with higher stocking densities, compared to the L-group (Table 3). Chemical costs were about 20% higher for the L-group compared to the S- and M-groups (Table 3). Despite the lower operating costs for L-group, the total income and net profit from cages in the L-group was only about one-third to one-half that of cages in the S- and M-groups (Table 3; Figure 2b), presumably partly because of the lower stocking density and yield in the L-group compared to the other two groups (Table 1). Cages in the L-group also returned lowest gross profit margin (GPM), whereas M-group returned the highest (Table 3).

Table 3

Cost, income and profitability of Asian red-tailed catfish culture for three different cage volume groups

No	*Items*	*The cage volume group*		
		< 100 m^3 (S-group)	*100-500 m^3 (M-group)*	*> 500 m^3 (L-group)*
1	Total cost (USD m^{-3})	$141.5±89.6^a$	$148.4±63.9^b$	$60.3±10.7^c$
2	Seedling cost (USD m^{-3} $harvest^{-1}$)	$13.3±6.7^a$	$12.8±6.9^b$	$8.8±4.9^c$
3	Feeding cost (USD m^{-3} $harvest^{-1}$)	$86.3±37.6^a$	$96.5±43.9^b$	$48.4±7.4^c$
4	Chemical costs (USD m^{-3} $harvest^{-1}$)	$3.4±0.6^a$	$4.5±0.7^b$	$6.1±0.9^c$
5	Price of marketable fish (USD kg^{-1})	$2.5±1.5^a$	$2.0±1.6^a$	$2.1±1.5^a$
6	Total income (USD m^{-3})	$175 ±69^a$	$206.6±90.7^b$	$75.5±22.7^c$
7	Net profit (USD m^{-3} $harvest^{-1}$)	$45.3 ±52.7^a$	$73.7±73.2^b$	$25.7±7.7^c$
8	Gross profit margin - GPM (%)	$0.6±0.6^a$	$0.73±0.72^b$	$0.5±0.3^c$

Note: Columns with different letters in the same row are significantly different ($p<0.05$).

Net profit was marginally higher in main rivers, both in terms of USD m^{-3} and USD $household^{-1}$, compared to branch rivers, and this was reflected in the GPM (Table 4). There was no difference in the market price of fish in the main and the branch rivers (Table 4).

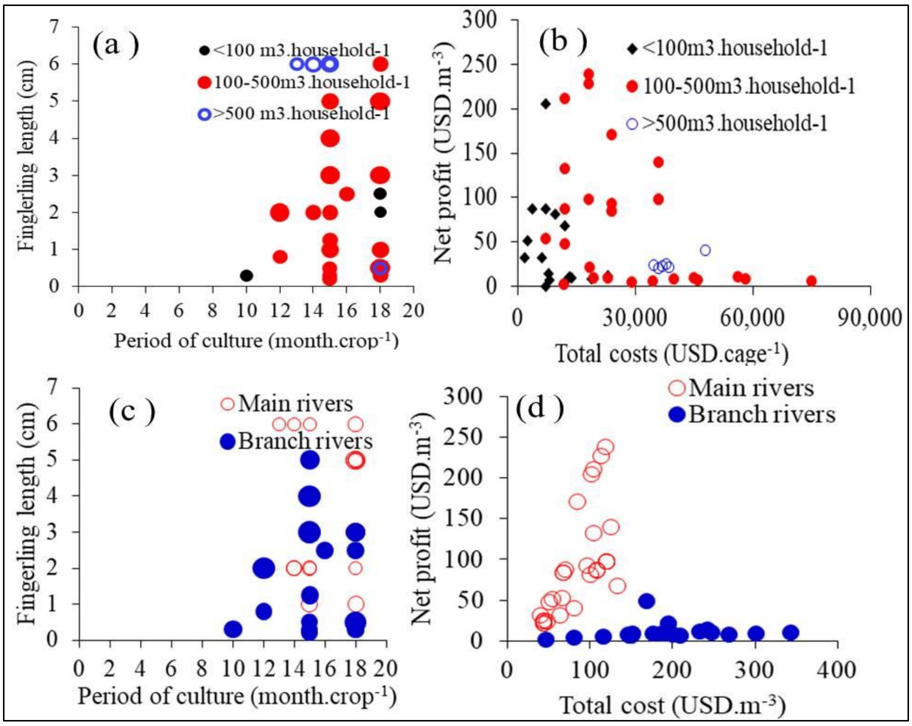

Figure 2. (a) The relation between fingerling length (cm) and the period of culture (month) with the harvesting size circle point size ranges from minimum (1.0 kg ind^{-1}) to maximum (2.0 kg ind^{-1}); (b) Relation between the net profits (USD m^{-3}) and the total costs (USD $cage^{-1}$) for different cage volume groups; (c) Relation between fingerling length (cm) and the period of culture (month) based on the cage volume by the harvesting size (circle size points range from minimum: 1 kg ind^{-1} to maximum: 2 kg ind^{-1}); (d) Relation between the net profit (USD m^{-3}) and the total cost (USD $household^{-1}$) based on the main and the branch rivers.

Table 4

Market price of fish, net profit and gross profit margin for cage owners on main rivers and on branch rivers

No	Items	Main rivers	Branch rivers
1	Price of marketable fish (USD kg^{-1})	3.3±0.5^a	3.3±0.5^a
2	Net profit (USD $household^{-1}$ $harvest^{-1}$)	12,097 ±12,879^a	10,851 ±13,391^b
3	Net profit (USD m^{-3} $harvest^{-1}$)	63.9 ±66.8^a	60.1 ±64.1^b
4	Gross profit margin (%) - GPM	0.7±0.6^a	0.6±0.7^b

Note: Columns with different letters in the same row are significantly different ($p<0.05$).

Total costs and the net profit per household are shown in Figure 3a, and fish harvest size and production are shown in Figure 3b.

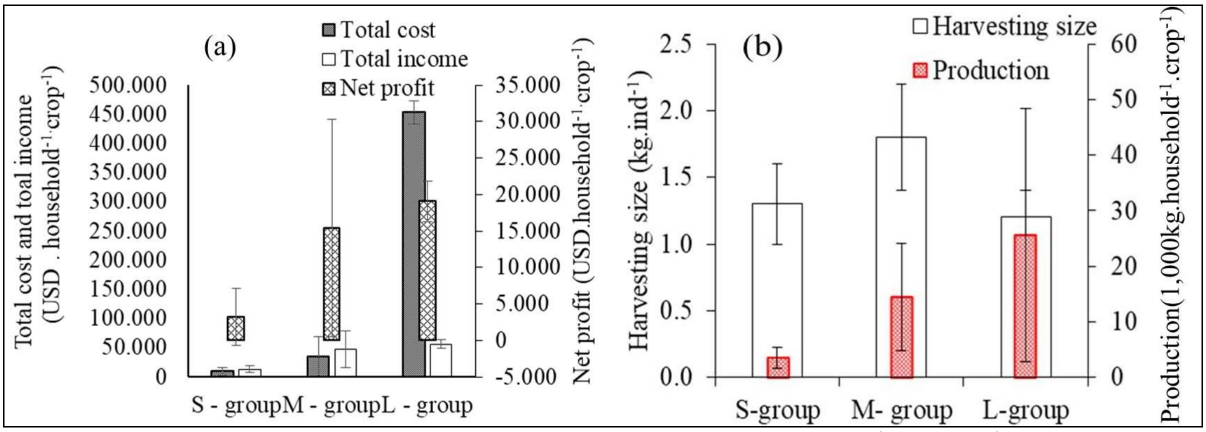

Figure 3. (a) Total costs, total income and net profits (USD household^{-1} harvest^{-1}) for each cage volume group; (b) Size of fish at harvest, and production (kg household^{-1}) of each cage volume group.

Discussion

Culture techniques. Since cages are generally of a similar size, regardless of the group (S-, M-, or L-Group), households in the S-group have fewer cages and therefore have significantly lower capital investment costs and operating costs. Households in this group tend to have limited finance and often select smaller, cheaper seed to nurse with their own labor in order to save on costs (Table 1). Stocking densities vary considerably within and between cage volume groups (Table 1), depending on the financial condition, technical knowledge and experience of the cage owners. In practice, cage owners in the S-group tended to use high stocking densities, expecting it to give higher production per m^3, but they had the lowest production due to small cage volume (Figure 3b). On the other hand, cage owners of the L-group who have a large number of cages usually preferred to stock larger fingerlings at low stocking density to shorten the length of the culture period to increase the frequency of harvesting (Table 1 and Figure 2a), with the aim of being able to provide marketable fish more flexibly at a good price, and they actually have the highest production per household (Figure 3b). They also have more flexibility in selling smaller fish (1.0-1.2 kg ind^{-1}) when market prices are favorable, thereby saving on costs and time, and allowing them to start the next harvest.

The stocking densities recorded in this study fall within the range previously reported, up to 60 ind m^{-3} (Ngoc 2010) and 50-80 ind m^{-3} (Quân 2020). In general, with good management, yields in kg m^{-3} tend to increase with stocking density, but stocking densities that are too high can in fact lead to high rates of mortality leading to a lower yield than expected, especially when harvesting is delayed in order to produce larger individuals attracting a higher market price.

According to farmers, the location of cages strongly influences production, and the consensus amongst farmers is that it is better to set up in rivers or canals with a strong current, such as the main rivers which are 350 - 850 m in width and have current speed of 1.2 - 2.8 m s^{-1}. However, in practice, many farmers still set up their cages in smaller branch rivers, due to a lack of space in the main rivers. In addition, yield is also affected by feeding rate and feed quality, by fingerling quality, by water quality, and by the experience of farmers (Prasertwattana et al 2005; Sahoo et al 2010; Jiwyam & Nithikulworawong 2014).

Since fingerlings are normally purchased from the hatchery when they are 2-5 cm in length, all cage owners nurse them to a length of at least 8 cm for a period of 1.5-3.2 months before stocking in the cages so that they are large enough to withstand strong currents. However, survival rates of fingerlings during the nursing stage can vary from 5% to 80%, depending on seed quality, how they are fed, the experience of farmers, and perhaps water temperature. One study, for example, found that seed nursed for 1-2 months from 3-5 cm to 8.2-12.4 cm in length had a survival rate of 73-76% in Daklak, a mountainous area in Vietnam where the temperature is lower than in the VMD (Phuc et al 2016).

The market price for Asian red-tailed catfish varies with demand in different months of the year, and is less dependent on uniform size. This is important because fish of the same cohort reaching marketable size normally range from 1 kg to 2 kg per individual (Figure 2a). This means that larger individuals within the same cage can be harvested earlier, while smaller ones can be reared for a further period of up to about 4 months before harvesting. Harvesting larger individuals as early as possible, or moving them to another cage, also avoids the risk of smaller fish being preyed upon by larger ones.

Asian red-tailed catfish is an omnivorous species, which means that it can be fed a wide range of feeds. The most widely used feed is industrially produced pellets formulated to match the nutritional requirements of fish. These are convenient for farmers, but are more expensive than other feed sources, so many farmers use pellets during the early stages of growth (3-4 months) and then replace them with alternative feed sources. Cheaper, home-made feed containing locally available materials like rice bran and trash fish, which are mixed and cooked, is usually used later in the grow out phase in order to save costs, because feed accounts for over 70% of the total cost of cage culture.

Chemicals are also used when really necessary. These are often mixed with the feed, especially when starting with a new feed, to prevent intestinal problems or health problems related to water exchange. They are also used to treat skin conditions and diseases linked to scratching and aggressive behavoir in cages with high stocking densities. Popular drugs include vitamin C and proprietary drugs for treating digestive problems. When fish are stocked at high density in a cage, their sharp spines on the pectoral and dorsal fins can cause injuries to other individuals. This frequent contact and scratching can lead to skin irritation, and specific treatments are used. The types of chemicals used by farmers are heavily influenced by advice from representatives of aquatic veterinary medicine companies, which provide feeds and veterinary products for aquaculture. However, their benefits are uncertain, and some may pose a risk to human health or have adverse environmental impacts.

An Giang has favorable hydrological conditions for cage culture, owing to strong water currents in the downstream tributaries of the Mekong River. However, AG is also a key rice growing area with 2-3 crops of paddy rice per year. Intensive rice production with its heavy use of fertilizer, pesticides, herbicides and other agrichemicals has adversely affected water quality in the waterways, including the main rivers. These impacts are exacerbated by the discharge of urban and industrial wastewater and solid wastes into waterways. With a grow-out period of 10-16 months in the cages, fish are highly vulnerable to the impacts of poor water quality, which can lead to lower growth rates, greater stress and higher mortality, especially during the earlier stages of grow out. Thus, water pollution poses a significant risk to the livelihoods of households engaged in cage culture of Asian red-tailed catfish and to the longer term success of this activity in the VMD.

Economic aspects. The design of cages and the materials from which they are made are very similar for all cage owners. A typical cage is 7-8 m long, 4-6 m wide, and 3.5-5 m deep. These are usually built with the help of professional services at a cost of 25,000-35,000 USD per cage. The materials used to construct cages are usually quite durable, so the cage frame can be used for 20-30 years before it needs to be replaced. However, the net around the cage may need to be replaced more often. It is also possible for farmers to purchase secondhand cages at price equal to 30-60% of that of a new cage of the same size.

Total costs per household are different among cage volume groups (Figure 3a). The L-group had the highest total costs and net profits (USD household^{-1} harvest^{-1}), because they have more cages and thus more flexibility in meeting market demand and selling at higher prices. Over 50% of L-group households had high investment and a flexible and professional business model because they buy marketable fish from cage owners in the S- and M-groups at lower prices and then keep them in their own cages for sale when market prices are higher. In contrast, while cage owners in the S- and M-groups had lower costs and net profits per household per harvest, around 50% of them lost income, because of low investment in feed. According to cage owners, feeding has an important role in culture because it affects survival rates and growth rates. For optimal survival and growth, this species requires pelleted feed containing around 44% protein (Junming et al 2011). However, at a price of 1.0-1.3 USD kg^{-1}, it is costly for farmers (Prasertwattana et al 2005). Thus, in order to save cost, farmers in the S- and M-groups use mainly home-made feed in the later stages of harvesting and the proportion of pellets fed is 10-60% of the total feed requirment.

The gross profit margin (GPM) was highest in the M-group and lowest in the L-group (Table 3 and Figure 2d), and GMP of the cages in the main river was higher than in the branch rivers (Table 4). What is very clear, however, is that the relationship between net profit and total costs is highly variable, within cage groups, between cage groups, and between cages in the main rivers and branch rivers (Figure 2b, 2c). This high variability is further illustrated by standard deviations that are larger than the average (Table 3 and Table 4). This could be due to poor and unpredictable water quality, to disease outbreaks, to fluctuating market demand and prices, and to the level of technical knowledge and experience of the cage owner. This implies that cage culture of Asian red-tailed catfish is currently a high risk activity, and a better quantitative understanding of these risks is necessary for the industry to develop.

Conclusions. Asian red-tailed catfish (*Hemibagrus wyckioides*) should be reared in cages with a volume of 100-500 m^3 per household, ideally in main rivers with strong currents. Proper attention to the quality of feeding in these conditions can significantly increase yield and net profits. However, this practice carries high risks, including low prices for harvested fish, limited market demand, high feeding costs, and challenges in managing survival rates at all stages.

Conflict of interest. The authors declare that there is no conflict of interest.

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