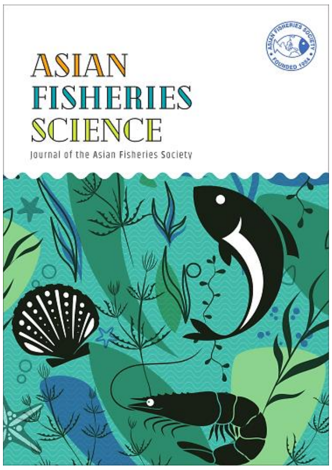

ISSN: 0116-6514
E-ISSN: 2073-3720
https://doi.org/10.33997/j.afs.2021.34.2.003

Community-Based Cobia, *Rachycentron canadum* (Linnaeus, 1766) Culture in Open Sea Cages at Olaikuda, Pamban Island, India: An Economic Analysis of Technology Transfer Initiative

G. RAJAPRABHU[1,2], R. KIRUBAGARAN[1,*], C. SURESHKUMAR[1], J. SANTHANAKUMAR[1], M.K. RASHEEDA[1], R. SENDHIL KUMAR[3], G. DHARANI[1]

[1]Marine Biotechnology, National Institute of Ocean Technology, Ministry of Earth Sciences, Government of India, Pallikaranai, Chennai 600100, Tamil Nadu, India

[2]Sathyabama Institute of Science and Technology, Rajiv Gandhi Salai, Chennai 600 119, Tamil Nadu, India

[3]Centre for Marine Living Resources and Ecology, Government of India, Ochanthuruthu, Kochi 682508, Kerala, India

*E-mail: kiruba@niot.res.in | Received: 15/03/2021; Accepted: 10/06/2021

Abstract

The Olaikuda Village of Pamban Island was chosen to demonstrate and transfer the open sea cage culture technology of cobia by the National Institute of Ocean Technology (NIOT). Olaikuda is a fishing hamlet with 1,000 traditional fishers who are primarily involved in trap fishing. An attempt was made to supplement their income under the societal development initiative of the NIOT. With the active participation of the local fishers of Olaikuda, 3,000 hatchery-produced cobia, *Rachycentron canadum* (Linnaeus, 1766) fingerlings were stocked equally in two cages with a stocking density of 4.7 fingerlings.m^{-3}. The cobia stocked in sea cages were reared with the locally available low-value fishes for 8 months. The sea farmed cobia attained an average weight of 3.3 kg resulting in an average daily growth rate of 13.5 g with a survival rate of 75 %. The fish were harvested on the 245th day of culture, which yielded 7,000 kg of marketable size cobia fish (1st cage 3,687 kg and 2nd cage 3,313 kg with an FCR of 1:5.5). The harvested fish were sold at the farm gate price of USD4.42 kg^{-1}, fetched USD30911.84. The economic analysis revealed a profit margin of USD1.26 kg^{-1}. The parameters such as cost of production, productivity, profitability, socio-economic impacts of native fishers were analysed during the study. The result of this farmer-driven attempt is encouraging the farmers across the coastal states to do cage culture farming in a big way. Similar efforts in more organised massive programs will create new jobs and reduce the fishing pressure on the natural sea stocks and considered a viable alternative livelihood for the fishers' community affected by the declining natural fishery resources and international border issues.

Keywords: finfish farming, mariculture, aquaculture, alternative sources of income, fishers' participatory approach

Introduction

The demand for seafood is increasing every day while the capture fisheries had reached maximum sustainable exploitation levels (Watson and Pauly, 2001; FAO, 2012; Ganesan et al., 2019). Scientists and researchers are trying to find alternative ways to meet the growing demand for fish foods and it can be attained only through aquaculture, especially mariculture. Mariculture has already proven itself as one of the profitable ventures compared to land-based culture systems globally. Due to the consistently growing demand for fish protein, the aquaculture industry slowly diverts its attention from freshwater to the marine sector (Kapetsky et al., 2013). Aquaculture being the fastest-growing food production sector, mariculture is widely regarded as the only means to meet the increasing demand for seafood (Pomeroy, 2016; Guillen et al., 2019). The aquaculture industry gradually expanded from the 1980s as the main seafood production system. During the last decade, aquaculture started doubling its production efficiency and presently is supplying one-third of the seafood consumed worldwide (Troell et al., 2003; Jentoft et al., 2017; FAO, 2018). While aquaculture offers livelihood security for millions, it also helps the nation increase its per capita fish protein availability (Vipinkumar et al., 2013; Pomeroy, 2016). Despite the vast pristine ocean space (76,396 km^2 of highly suitable and 84,792 km^2 suitable) available in the coastal states (Jha et al., 2017) ideal for mariculture, commercial fish farming in the country is still in its infancy. Open sea cage culture development in India is expected to bring significant social and economic benefits by improving local infrastructure and creating direct and indirect job opportunities. Cobia *Rachycentron canadum* (Linnaeus, 1766)) is one of the potential candidate species for mariculture because of its high demand in national and international markets, fetches an attractive price, fast growth, technology available for larval production and grow-out farming (Liao et al., 2004; Joan Holt et al., 2007; Benetti et al., 2010; Nhu et al., 2011; de Bezerra et al., 2016; Rodriguez, 2018).

In India, land-based freshwater aquaculture is well established and secured second place in the global fish production sector (FAO 2012). However, no coordinated effort exists to develop mariculture in the country due to the lack of adequate seed and feed availability for many marine species. A few government agencies such as Central Marine Fisheries Research Institute (CMFRI), Central Institute of Brackishwater Aquaculture (CIBA), Rajiv Gandhi Center for Aquaculture (RGCA) and the National Institute of Ocean Technology (NIOT) have conducted a series of demonstration programs on open sea finfish farming. The NIOT, with its vast experience in cage culture, has successfully reared six different finfishes (sea bass *Lates calcarifer* (Bloch 1790), cobia, *Rachycentron canadum* (Linnaeus 1766), pompano, milkfish, *Chanos chanos* (Forsskal 1775), parrotfish, *Scaurs ghobban* (Forsskal 1775) and rabbit fish, *Siganus javus* (Linnaeus 1766)) in sea cages. Out of the six different species, cobia culture showed good economic returns and successfully harvested fish with an average weight of 3.25 $kg.fish^{-1}$ in 245 days. NIOT has conducted culture demonstration with the active participation of the Olaikuda fishers, who were otherwise trapped fisher. The participatory approach gave exposure to the local fishers on finfish rearing in sea cages besides skill development in the relatively recent farming techniques. The present study also attempted to assess the socio-economic benefits of the beneficiaries involved in this novel approach.

Materials and Methods

Study area description

Olaikuda is a relatively small fishing hamlet situated on the northern coast of Pamban Island (Lat. 9°18'39.62"N, Long. 79°19'40.98"E) which is 2.0 km away from the iconic Rameshwaram Temple in Tamil Nadu. This site offers favourable sea conditions for small scale mariculture operations, such as relatively calm and clear water, pollution-free environment. The total population of this village is 1,000 and only 40 fishers own motorised country crafts (less than 10-meter draft length). The majority of fishers from this village practice trap fishing using small catamarans and the woman folks participate in the seasonal seaweed culture (*Kappaphycus* sp.). In contrast, others are daily wagers in mechanised trawlers. The villagers' income depends on their trap fishing activity only. These villagers frequently face legal issues and loss of lives due to crossing of Indo-Sri Lankan maritime border. So they are eagerly looking forward to an alternate livelihood option. A group of 30 fishers from Olaikuda were engaged in the present cage culture activity. The result of this experimental culture aspired another team of 20 fisher folks from the neighbouring village who came forward to take up cage culture with their own financial resources. The local fishers, with the technical support from NIOT formed a self-help group named "Olaikuda Mithavaikoondu Meen Valarpu Sangam" to take up the open sea cage culture. People with a mixed age group of 21 to 55 years became members of this society and took part in fish farming in sea cages.

Culture system (cages)

The 9 m (ø) high-density polyethylene (HDPE) cages with a culture volume of 320 m^3 were designed locally and deployed off Olaikuda coast. The cages are positioned in a sub-surface grid firmly connected with multipoint mooring system (Jayapal et al., 2017). The NIOT spent USD326.40 for deploying four cages at Olaikuda, costing USD25.50 m^{-3}. The cost can be further reduced by using more local cage components and optimising the size of the cages which NIOT is doing. The durability of these cages is time tested and is in use for more than 10 years with a minimum maintenance cost. Hence, the capital cost spent on cage fabrication works is approximately USD2.72 m^{-3} per crop, which is much cheaper than any contemporary cage models. At estimated productivity of 10 $kg.m^{-3}$, the cage cost adds only USD0.27 kg^{-1} in the production cost, which is only 10 % hike in the production expense. The juvenile fish were stocked in pregrow-out cages with knotless nets (polyamide) having the mesh size of 8 mm until the fish reaches 500 g (100 days of culture) after which the nets were changed to 16 mm mesh size net. To retain the cylindrical shape of the cage, ballast weights were added at the bottom of the net.

Physicochemical parameters

Regular monitoring of physicochemical parameters of the rearing environment such as salinity, water temperature, pH and dissolved oxygen (DO) was measured using water quality probe (563A, YSI, USA) daily. Nutrients such as ammonia, nitrite and nitrate were also analysed using the standard methods (Grasshoff et al., 1999).

Seed support, transportation and stocking

A total of 3,000 cobia seeds of 90 days old (size 15 to 18 cm and weight 25 to 40 g) were purchased at USD0.48 $seed^{-1}$ from Rajiv Gandhi Centre for Aquaculture (RGCA), Pozhioor, Thiruvananthapuram, Kerala. As a routine procedure, cobia fish seeds were starved for 24 h prior to the transportation to avoid build-up of ammonia, carbon dioxide and metabolic end products which could cause stress and mortality during transport. The seeds were thus transported in two 1.5 ton HDPE tanks with filtered seawater. Tanks were aerated continuously using oxygen cylinders and transported with a biomass ratio of 1 kg per 60 L approximately one fingerling per litre of water. Earlier, cobia fingerlings were treated with a broad-spectrum antibiotic (Oxytetracycline, 20 $mg.L^{-1}$) to avoid bacterial (gill) infections (Benetti et al., 2007) during transportation. Water temperature was maintained at 16 °C using ice bags to lower the rate of metabolic activity. The DO levels, pH and salinity were continuously monitored and maintained at ~8 $mg.L^{-1}$, 7.5 and 34 ppt, respectively. Seeds were transported during night hours (350 km from Pozhiyoor hatchery to cage culture site) to avoid the rise in water temperature (Lim et al., 2003).

Stocking of seeds in cages

Cobia fingerlings were stocked in the early hours of the following day of transport using plastic buckets. Fingerlings were released slowly into the indigenously designed nursery cages (2 m ø) deployed inside the grow-out cages. Low-value fishes collected from the vicinity of the culture site were used as feed for rearing the fish in sea cages which are a common practice in community-based fish farming across Asian countries (Liao et al., 2004; Nhu et al., 2011; Brett D Glencross, 2015; de Bezerra et al., 2016). The fingerlings were fed at a rate of 4–5 % of their body weight with chopped low-value fishes, anchovy *Stolephorus indicus* (van Hasselt, 1823) and *Sardinella* sp., until they attain 100 g of size. After 40 days of nursery rearing in these nursery cages, fingerlings were released into the grow-out cages at a stocking density of 3.8 m^{-3} (1200 $fingerlings.cage^{-1}$).

Feeding and cage maintenance

The fishes were fed twice daily at 4 % body weight (40 % at 0630 h and 60 % at 1430 h). The feed quantity was gradually increased based on the total estimated fish biomass fortnightly. After feeding, the fishes were closely monitored by skin diving to take stock of the fish health (Fig. 1). The dead fish, if any, were immediately removed from the cage and were documented. The net, HDPE frame, and brackets were periodically cleaned as part of the maintenance protocol to keep them devoid of fouling and ensure proper water exchange in cages.

Fig. 1. Cobia, *Rachycentron canadum* in sea cages closely monitored by skin diving to take stock of the health status.

Growth performance

Once every 15 days, random sampling was made using a knotless scoop net during the entire culture period to assess the growth rate of the fishes with a sample size of 20 fish and recorded the total length (TL) and weight. Absolute growth (AG), absolute growth rate (AGR), relative growth (RG), relative growth rate (RGR) and specific growth rate (SGR) were estimated and documented.

The per cent weight gain (PWG) was assessed using the formula:

$$\mathrm{PWG}\ (\%) = \frac{\mathrm{W2} - \mathrm{W1}}{\mathrm{W1}} \times 100$$

where W2 = Mean final fish weight, W1 = Mean initial fish weight.

Growth of the fish was expressed as the specific growth rate ($SGR.day^{-1}$) using the formula below (Schram et al., 2009):

$$\mathrm{SGR} = \frac{\mathrm{InW2} - \mathrm{InW1}}{\mathrm{Days}}$$

where W2 = Mean final fish weight, W1 = Mean initial fish weight

Feed conversion ratio (FCR) was further computed from the results to show the food conversion efficiencies of these species. This was calculated as follows (Naylor et al., 2009):

$$\mathrm{FCR} = \frac{\mathrm{TFI}}{\mathrm{WG}}$$

where TFI = Total feed ingested, WG = Weight gain.

Results

The water quality parameters were observed daily from the day of stocking until harvest. Graphical representation of results is shown in Figure 2. The average water temperature was 28.3 ± 1.3 °C, salinity 30.8 ± 0.41 PSU, DO 6.07 ± 0.52 $mg.L^{-1}$ and pH 8.14 ± 0.23, ammonia (0.02–0.34 $mg.L^{-1}$), nitrate (0.20–0.86 $mg.L^{-1}$) and nitrite (3.26–12.52) during the study period. Water temperature plays a significant role in the growth and development of cobia seeds during the culture period (Sun and Chen, 2014).

At the end of the culture period, fingerlings stocked at an average weight of 30 ± 0.5 g in the cages, at stocking density of 140 ± 1$g.m^{-3}$ gave a final biomass

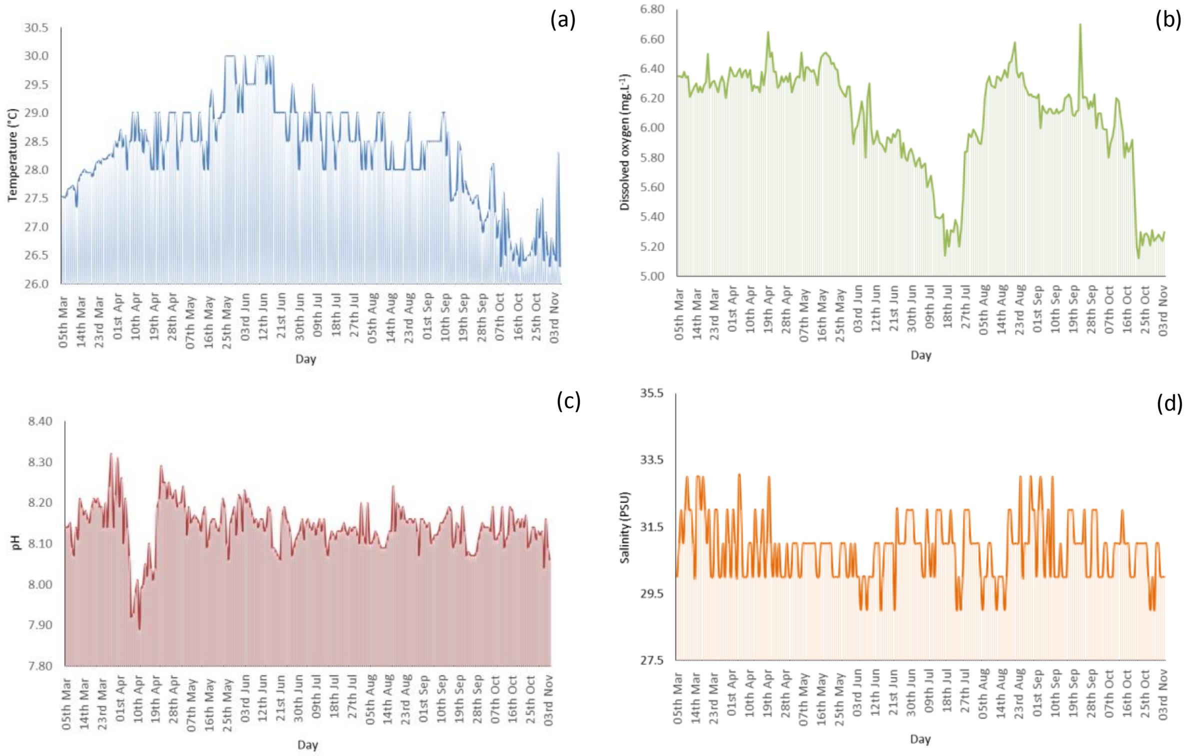

Fig. 2. Water quality parameters taken daily at the cobia, *Rachycentron canadum* cage culture. (a) Temperature; (b) Dissolved oxygen; (c) pH; (d) Salinity.

density of 11.52 ± 1.31 kg.m^{-3} and 10.35 ± 0.92 kg.m^{-3} in cage 1 and 2, respectively. The individual fish weight varied between 1.8 ± 0.16 and 4.5 ± 0.15 kg at the time of harvest (Fig. 3). The harvested fish were sold at the farm gate price of USD4.42 kg^{-1}, fetched USD30911.84. The total culture operation cost (seed, seed transportation, feed boat charges, labour cost and harvesting charge etc.) was around USD22066.30. Final fish production cost USD3.16 kg^{-1}. The profit obtained was USD1.26 kg^{-1} fish.

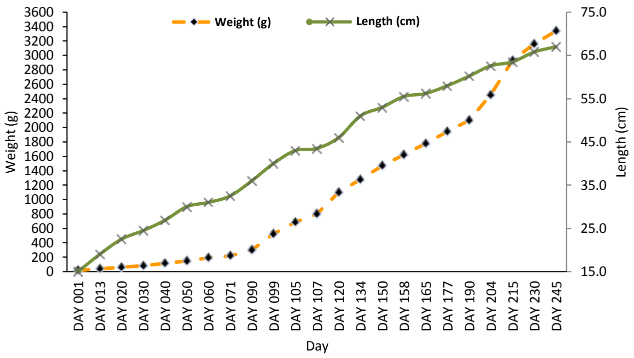

Fig. 3. Growth performance of cobia *Rachycentron canadum* in sea cages.

Discussion

The present stocking density was marginally higher than previous attempts reported elsewhere (Paul et al., 2013). Though getting healthy fish fry and suitable feed are considered bottle-necks for the expansion of mariculture, cobia has proved to be a potent candidate for cage culture due to its remarkable growth and market preference. In cage culture, optimal stocking density for cultured organisms greatly varies according to individual species. In cages, about 30-50 fingerlings (100 g.m^{-3}) were recommended for cobia (Philipose et al., 2013). Also, quality seed is a key for better economic performance in cage culture (Islam et al., 2016). A number of studies on cobia cultured in the cages suggested that quality seed are the primary requirement for better yield than other parameters (Miao et al., 2009; Huang et al., 2011). Seawater quality is an important factor that significantly influenced the survival and growth of fish (Moreira et al., 2015).

The summary of cobia cage culture details is presented in Table 1. Out of 3,000 seeds stocked initially, 75 % survived until harvest. The mortality rate of 20 % took place in the initial days and the remaining 5 % mortality occurred between the 2nd and 4th months. A total of 38,375 kg of low-value fishes were fed to cobia until harvest. A total of 7 tonnes (1st cage 3,687 and 2nd cage 3,313 kg of cobia with an average weight of 3,340 g were harvested and sold at the farm gate price of USD4.42 kg^{-1}, fetched USD30911.84 against the investment of USD22066.30.

The cost of production was worked out as USD3.16 kg^{-1} against the sale price of USD4.42 kg^{-1} thus, giving

Table 1. Summary of the details on cobia *Rachycentron canadum* cage culture operation.

Details	Value
Cage dimension (ø)	9 m
Cage volume	320 m^3
Cultured species	Cobia
Stocking density	4.7 fingerling.m^{-3}
Production volume	10.9 kg.m^{-3}
Total fingerlings stocked	3,000
Total fishes harvested	2,250
Initial stocking size	25–35 g
Average weight of harvested fish	3.2 kg
Fingerling length (While stocking)	15–18 cm
Average total length (While harvest)	67 cm
Specific growth rate (SGR)	13.51 day^{-1}
Feed conversion ratio (FCR)	1:5.5
Per cent weight gain (PWG)	11033.33 %

a net profit of USD8845.54 from the 8 months of culture operation. The overall benefit was shared among the 30 members of the self-help group to contribute and support the culture activities (such as feeding, cleaning of cages, change of nets, purchase of low-value fish, watch and ward). At the end of the culture period, the physical contribution of each member was calculated as 32 hours.$person^{-1}$, which fetched them USD9.21 $hour^{-1}$ of their work, i.e. USD294.85 $member^{-1}$.

The successful implementation of any innovative technology lies in its economic performance. The rate of revenue return for the money invested is the ideal economic indicator that provides the incentive for investors to select an enterprise. The economic output of the cage culture trial was worked out by analysing the annual fixed costs and operational cost. By analysing operating cost and revenue, financial viability was calculated.

In this community-based mariculture, although the capital cost was not included considering the longer durability of these culture systems, the capital cost can be reduced to below 20 % of the operational cost making it a profitable venture. Table 2 shows the statistics for input costs for cobia production in sea cages. The cost of production could be classified into five categories: feed, labour, boat, harvest, maintenance and seeds (including seed transport charges). The expenditure for the above inputs was 47.3 %, 23.7 %, 10.6%, 8.9 %, and 7.8 %, respectively. Universally the feed cost remains the major and predominant expenditure and constitutes nearly 50 % of the expense in cage farming. The present attempt also shows a similar trend with 47.3 % cost for the feed which is at par with successful mariculture models of Asian counterparts (Elizabeth et al., 2014). The feed and labour expenses together constitute almost 71 % of total culture operation. During the culture period, the labour and boat hiring expenses were spent within the same village, i.e., for feeding and cage maintenance at the rate of two labourers and one diesel boat.day^{-1} for 8 months. In this model, 34.3 % of money circulated within the village and

Table 2. Details of cost inputs and their percentage in total expense in the cobia *Rachycentron canadum* cage culture farming operation.

Particulars	Quantity	Cost (USD)	Expense (USD)	% of expense
Seed	3,000	0.48 $seed^{-1}$	1426.70	6.47
Seed transport		285.34	285.34	1.29
Feed (Low value fish)	38,375 kg	0.27 kg^{-1}	10428.50	47.26
Boat charge	245 days	9.51 day^{-1}	2330.28	10.56
Cage maintenance expenditure	NA	NA	1494.64	6.77
Labour cost				
Boat labour (2 person)	245 days	5.44 $person^{-1}$	2663.17	12.07
Low-value fish cutting charges	125 days	5.44	665.79	3.02
Night watch	120 days	8.15	923.96	4.19
Cage supervisor salary	9 months	122.29	978.31	4.43
Harvest expenditure	NA	461.98	461.98	2.09
Interest	3 %	407.63	407.63	1.85
Total			22066.30	100.00

NA: Not applicable.

generated considerable employment opportunities besides the additional revenue generated through the operation.

In India, there is a lack of connectivity between the technical know-how and fishers except for a few seaweed farming initiatives to improve the economics of fishers. In a case study (Ganesan et al., 2019), economical viable *Lates calcarifer* (Bloch, 1790) was cultured in HDPE cages and the annual rate of return for the investment was estimated as 119 % (Ramachandran, 2009). Compared to the freshwater fish farming segment which reports only an average profit margin of USD0.068 to 0.27 kg^{-1}, the present net profit of USD1.26 kg^{-1} assures a promising business opportunity.

Every year during April and May, the Indian Government enforces a fishing ban on the east coast to protect the fishery resources (Gunakar et al., 2017; Jentoft et al., 2017). Expansion of mariculture would provide an alternate job opportunity to the fisherfolk even during the fishing ban and considerably reduce the fishing pressure on the wild stock which is already overexploited.

Conclusion

A well-coordinated community-based mariculture seems to be one of the long-term solutions for raising the standards of coastal fishers. This community-based low-intensity fish farming benefits the marginal fishers to increase their revenue without disrupting their routine activity. A couple of extra work hours daily will fetch them a considerable additional income enhancing their livelihood status significantly. During this study, fisherfolk realised the importance of an alternate avenue to boost their income generation capabilities and cage culture seems to be one such option and wholeheartedly supported the idea of expanding the activity. The culture practice can be organised to harvest the cultured fishes during the fishing ban season, to enhance their income many folds and regulate the availability of fishes throughout the year. However, to meet the huge capital requirement, the fishers expect financial support from government agencies to invest in fish culture as a full-time business.

It was felt that more fishers participation in similar efforts will ensure the input availability (feed and seed) and infrastructure creation required for mariculture and thereby enhance the profit margin in the coming years. The culture of cobia operation focused on fishers' community dynamics as a trait of the self-help group. The model provides an opportunity for individuals to collaborate as a group and contribute their experience and skills. This technology transfer program provided the much-needed confidence to the Olaikuda fisherfolk to ensure they can successfully conduct cage culture on their own. While sustainable small scale farming with the cooperation of coastal fishers leads to the creation of employment opportunities, additional income and foreign exchange for the country. There is also a need for supporting such programs on a much bigger scale. It is estimated that a 9 m diameter cage with a production capacity of 6 to 8 tons of fish can maintain 20 % of the fishers in a fishing hamlet like Olaikuda with a population of 1000 individual.

The program will require 65 to 70 such cages, 1 million fish seeds and 105 tons of formulated diet to support a venture of this magnitude resulting in the production of 65-70 tons of fish annually. However, considering the limitations in the community-based approach, it may not be possible to expand the activity beyond a certain level unless the farmers are ensured the availability of formulated diet and hatchery-reared seed when required. It is also important for the farming community to continuously monitor and coordinate these efforts and do multi-species culture to avoid the dominance of single species. This is to avoid loss of the market preference and thereby reduction of profit margin. Perhaps a more organised cooperative or a government agency should coordinate the fishers to take up such ventures in a well-planned manner that will ensure availability of inputs and the market for the fish.

Conflict of interest: The authors declare that they have no conflict of interest.

References

Benetti, D.D., O'Hanlon, B., Rivera, J.A., Welch, A.W., Maxey, C., Orhun, M.R. 2010. Growth rates of cobia (*Rachycentron canadum*) cultured in open ocean submerged cages in the Caribbean. Aquaculture 302:195–201. https://doi.org/10.1016/j.aquaculture.2010.02.021

Benetti, D.D., Orhun, M.R., O'Hanlon, B., Zink, I., Cavalin, F.G., Sardenberg, B., Palmer, K., Denlinger, B., Bacoat, D. 2007. Aquaculture of cobia (*Rachycentron canadum*) in the Americas and the Caribbean. In: Cobia aquaculture: Research, development, and commercial production, Liao, I.C., Leano, E.M. (Eds.), Asian Fisheries Society, Manilla, Philippines, World Aquaculture Society, Louisiana, USA, The Fisheries Society of Taiwan, Keelung, Taiwan, and National Taiwan Ocean University, Keelung, Taiwan, pp. 57–77.

Brett, D., Glencross, E.H.P. 2015. Recent changes in the bioeconomic of finfish mariculture in Vietnam. Journal of Aquaculture Research & Development 6:1000311. https://doi.org/10.4172/2155-9546.1000311

de Bezerra, T.R.Q., Domingues, E.C., Maia Filho, L.F.A., Rombenso, A.N., Hamilton, S., Cavalli, R.O. 2016. Economic analysis of cobia (*Rachycentron canadum*) cage culture in large- and small-scale production systems in Brazil. Aquaculture International 24:609–622. https://doi.org/10.1007/s10499-015-9951-2

Elizabeth, H.P., Tran, D.L., Dam, T.C., Vu-Anh, Tran, Q.B., Le Van, T., Brett, D.G. 2014. Bio economics of cobia *Rachycenton canadum* culture in Vietnam. Aquaculture Economics & Management 18:28–44. https://doi.org/10.1080/13657305.2014.855953

FAO. 2012. Fisheries and Aquaculture Department, Food and Agriculture Organization of the United Nations, Rome. http://www.fao.org/3/i2727e/i2727e00.pdf

FAO. 2018. Fisheries and Aquaculture Department, Food and Agriculture Organization of the United Nations, Rome.

http://www.fao.org/state-of-fisheries-aquaculture/2018/en
Ganesan, M., Trivedi, N., Gupta, V., Madhav, S.V., Radhakrishna Reddy, C., Levine, I.A. 2019. Seaweed resources in India - Current status of diversity and cultivation: Prospects and challenges. Botanica Marina 62:463–482. https://doi.org/10.1515/bot-2018-0056
Grasshoff, K., Kremling, K., Ehrhardt, M. 1999. Methods of seawater analysis. 3rd Edition. Wiley-VCH Verlag, Germany. 600 pp. https://doi.org/10.1002/9783527613984
Guillen, J., Natale, F., Carvalho, N., Casey, J., Hofherr, J., Druon, J.N., Fiore, G., Gibin, M., Zanzi, A., Martinsohn, J.T., Wr, L.V.K., Lim, L.C., Dhert, P., Sorgeloos, P., Philipose, K.K., Loka, J., Damodaran, D., Lim, L.C., Dhert, P., Sorgeloos, P., Wr, L.V.K., Guillen, J., Natale, F., Carvalho, N., Casey, J., Hofherr, J., Druon, J.N., Fiore, G., Gibin, M., Zanzi, A., Martinsohn, J.T., Bank, W. 2019. Global seafood consumption footprint. Ambio 48:111–122. https://doi.org/10.1177/156482650402500108
Gunakar, S., Jadhav, A., Bhatta, R. 2017. Protections for small-scale fisheries in India: A study of India's monsoon fishing ban. In: The small-scale fisheries guidelines, Jentoft S., Chuenpagdee R., Barragán-Paladines M., Franz N. (Eds.). MARE Publication Series, vol 14. Springer, Cham. pp. 291–311. https://doi.org/10.1007/978-3-319-55074-9_14
Huang, C.T., Miao, S., Nan, F.H., Jung, S.M. 2011. Study on regional production and economy of cobia *Rachycentron canadum* (Linnaeus, 1766) commercial cage culture. Aquaculture International 19:649–664. https://doi.org/10.1007/s10499-010-9391-y
Islam, G.M.N., Tai, S.Y., Kusairi, M.N. 2016. A stochastic frontier analysis of technical efficiency of fish cage culture in Peninsular Malaysia. SpringerPlus 5:1127. https://doi.org/10.1186/s40064-016-2775-3
Jayapal, S., Kumar Ramaiyan, S., Gopal, D., Kothalia, R., Manambarakat, V., Ramalingam, K. 2017. Blue barred parrot fish (*Scarus ghobban* Forsskal, 1775) culture in sea cages at Rameshwaram Island, Southeast coast of India. Indian Journal of Geo Marine Sciences 46:1614–1620. http://nopr.niscair.res.in/handle/123456789/42518
Jentoft, S., Chuenpagdee, R., Barragan-Paladines, M., Franz, N. 2017. The small-scale fisheries guidelines: Global implementation. MARE Publication Series. Volume 14. Springer, Netherlands. 850 pp. https://doi.org/10.1007/978-3-319-55074-9
Jha, D.K., Rajaprabhu, G., Kirubagaran, R., Sendhil Kumar, R., Dharani, G., Das, A., Gopinath, G., Santhanakumar, J. 2017. Estimation of potential zones for offshore mariculture in the Indian sea using geographical information system as a management tool. Journal of Coastal Conservation 21:893–902. https://doi.org/10.1007/s11852-017-0556-y
Joan Holt, G., Faulk, C.K., Schwarz, M.H. 2007. A review of the larviculture of cobia *Rachycentron canadum*, a warm water marine fish. Aquaculture 268:181–187. https://doi.org/10.1016/j.aquaculture.2007.04.039
Kapetsky, J.M., Aguilar-Manjarrez, J., Jenness, J. 2013. A global assessment of potential for offshore mariculture development from a spatial perspective. FAO Fisheries and Aquaculture Technical Paper. No. 549. FAO, Rome. 181 pp. http://www.fao.org/3/i3100e/i3100e00.htm
Liao, I.C., Huang, T.S., Tsai, W.S., Hsueh, C.M., Chang, S.L., Leaño, E.M. 2004. Cobia culture in Taiwan: Current status and problems. Aquaculture 237:155–165. https://doi.org/10.1016/j.aquaculture.2004.03.007
Lim, L.C., Dhert, P., Sorgeloos, P. 2003. Recent developments and improvements in ornamental fish packaging systems for air transport. Aquaculture Research 34:923–935. https://doi.org/10.1046/j.1365-2109.2003.00946.x
Miao, S., Jen, C.C., Huang, C.T., Hu, S.H. 2009. Ecological and economic analysis for cobia *Rachycentron canadum* (Linnaeus, 1766) commercial cage culture in Taiwan. Aquaculture International 17:125–141. https://doi.org/10.1007/s10499-008-9185-7
Moreira, C.B., Rombenso, A.N., Candiotto, F.B., Tsuzuki, M.Y. 2015. Feeding frequency affects growth of juvenile cobia *rachycentron canadum* (Linnaeus, 1766) cultured in near-shore cages. Boletim do Instituto de Pesca 41:219–226. https://www.pesca.sp.gov.br/41_2_219-226.pdf
Naylor, R.L., Hardy, R.W., Bureau, D.P., Chiu, A., Elliott, M., Farrell, A.P., Forster, I., Gatlin, D.M., Goldburg, R.J., Hua, K., Nichols, P.D. 2009. Feeding aquaculture in an era of finite resources. Proceedings of the National Academy of Sciences of the United States of America 106:15103–15110. https://doi.org/10.1073/pnas.0905235106
Nhu, V.C., Nguyen, H.Q., Le, T.L., Tran, M.T., Sorgeloos, P., Dierckens, K., Reinertsen, H., Kjørsvik, E., Svennevig, N. 2011. Cobia *Rachycentron canadum* (Linnaeus, 1766) aquaculture in Vietnam: Recent developments and prospects. Aquaculture 315:20–25. https://doi.org/10.1016/j.aquaculture.2010.07.024
Paul, S. W., Charles,R. W., Richard, M.B,. Marty, A.R. (2013). Evaluation of commercial marine fish feeds for production of juvenile cobia in recirculating aquaculture systems. North American Journal of Aquaculture 75:178-185. https://doi.org/10.1080/15222055.2012.750635
Philipose, K.K., Loka, J., Sharma, S.R.K., Divu, D., Rao, K.S., Sadhu, N., Dube, P., Gopakumar, G., Rao, G.S. 2013. Farming of cobia, *Rachycentron canadum* (Linnaeus 1766) in open sea floating cages in India. Indian Journal of Fisheries 60:35–40. http://eprints.cmfri.org.in/id/eprint/9811
Pomeroy, R. 2016. A research framework for traditional fisheries: Revisited. Marine Policy 70:153–163. https://doi.org/10.1016/j.marpol.2016.05.012
Ramachandran, C. 2009. Open sea cage culture in India- A sociological perspective. In: Course manual: National training on cage culture of seabass. CMFRI & NFDB, Kochi, pp. 94-98. http://eprints.cmfri.org.in/id/eprint/6089
Rodriguez, U. 2018. (Cobia) *Rachycentron canadum* (Linnaeus, 1766) datasheet. Aquaculture Compendium, Invasive Species. CABI (Centre for Agriculture Bioscience International), UK, pp. 1-51.
Schram, E., Verdegem, M.C.J., Widjaja, R.T.O.B.H., Kloet, C.J., Foss, A., Schelvis-Smit, R., Roth, B., Imsland, A.K. 2009. Impact of increased flow rate on specific growth rate of juvenile turbot (*Scophthalmus maximus*, Rafinesque 1810). Aquaculture 292:46–52. https://doi.org/10.1016/j.aquaculture.2009.03.020
Sun, L., Chen, H. 2014. Effects of water temperature and fish size on growth and bioenergetics of cobia (*Rachycentron canadum*). Aquaculture 426-427:172-180. https://doi.org/10.1016/j.aquaculture.2014.02.001
Troell, M., Halling, C., Neori, A., Chopin, T., Buschmann, A.H., Kautsky, N., Yarish, C. 2003. Integrated mariculture: Asking the right questions. Aquaculture 226:69-90. https://doi.org/10.1016/S0044-8486(03)00469-1
Vipinkumar, V P and Meenakumari, B and Jayasankar, P and Shanthi, B. 2013. Gender mainstreaming paradigm in the context of Indian marine fisheries sector: elucidation of success cases. Discovery Agriculture 1:12-25. http://eprints.cmfri.org.in/id/eprint/9592
Watson, R., Pauly, D. 2001. Systematic distortions in world fisheries catch trends. Nature 414:534–536. https://doi.org/10.1038/35107050