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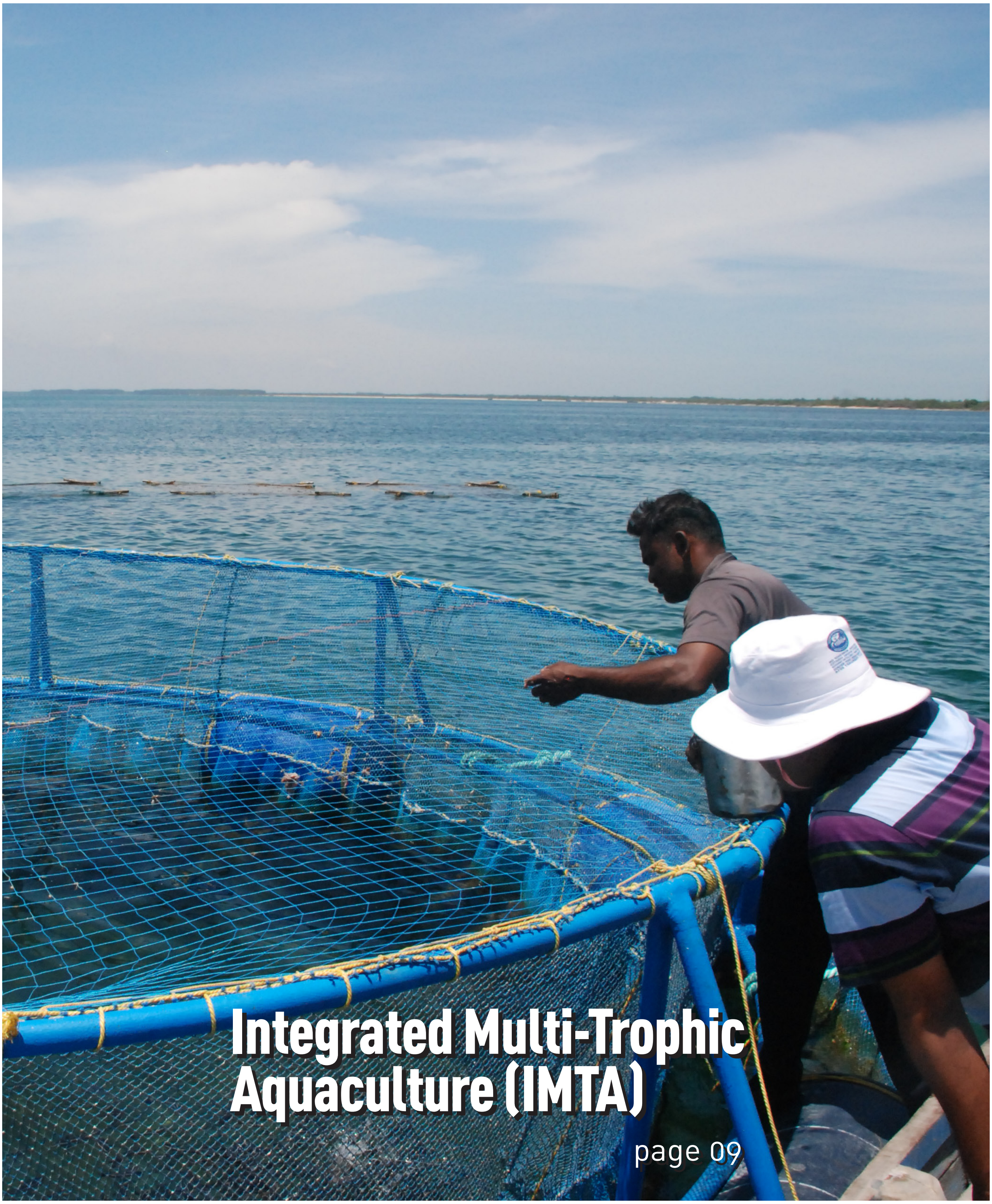

Integrated Multi-Trophic Aquaculture (IMTA)

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INTEGRATED MULTI-TROPHIC AQUACULTURE (IMTA)

A technology for uplifting rural economy and bio - mitigation for environmental sustainability

Johnson. B.,Abdul Nazar, A. K., Jayakumar, R., Tamilmani, G., Sakthivel, M., Rameshkumar, P. Anikuttan,K.K., Amir Kumar Samaland Sankar, M.
ICAR – Central Marine Fisheries Research Institute
Mandapam Regional Centre, Mandapam Camp – 623 520, Tamil Nadu, India
Email: jsfaith@gmail.com

Introduction

The growth of aquaculture at the global level involves an increase in area under cultivation, a higher density of aquaculture installations and species cultured, with greater use of formulated feed resources. When unregulated and badly managed, aquaculture creates negative impacts on the environment. This necessitates engineering new aquaculture systems that offer increased environmental sustainability, economic stability, lower production costs, multiple species culture options, societal acceptability and risk reduction while ensuring improved outputs. The EAA (Ecosystem Approach for Aquaculture) promotes the efficient use of nutrient resources, as well as the opportunity of diverse products and benefits while reducing impacts, and therefore integrated aquaculture becomes a very important practical way to implement EAA (FAO, 2008). Beneficial environmental effects to bio mitigate waste production and to utilise resources effectively by farming multiple species will increase the resilience of the operation with reduced risks.

Integration of fish with aquatic plants and vegetable production has been practised for centuries. In 1970s, John Ryther reignited the interest in IMTA (Integrated Multi-trophic Aquaculture) systems in which advantages of synergistic interactions among species and environment was appraised. He is considered as the grandfather of modern IMTA for his seminal work;' "Integrated waste-recycling marine polyculture systems", for combining polyculture, integrated mariculture or aquaculture, ecologically engineered aquaculture and ecological aquaculture. Later in 2004, Jack Taylor combined integrated aquaculture and multi- trophic aquaculture into the term integrated multi-trophic aquaculture.

IMTA can be applied to open-water or land-based systems, marine or freshwater systems, and temperate or tropical systems. Choices in the design of the IMTA systems can vary on different climatic, environmental, biological, physical, chemical, economic, historical, societal, political and governance conditions, prevailing in the parts of the world where they operate (Chopin, 2013). Culture organisms must be chosen from different trophic levels based on their complementary functions in the ecosystem, as well as economic potential. Usually, fed species such as finfish or shrimp are cultivated with extractive species, such as seaweeds and aquatic plants that recapture inorganic dissolved nutrients, and shellfish and other invertebrates that recapture organic particulate nutrients for their growth. There is tremendous opportunity to use marine macroalgae as bio-filters, and to process them and produce products with commercial value. However, only a few countries are doing IMTA in a commercial scale and globally, most of the seaweed culture is taken up as open water monoculture in Asia, South America, South Africa and East Africa.

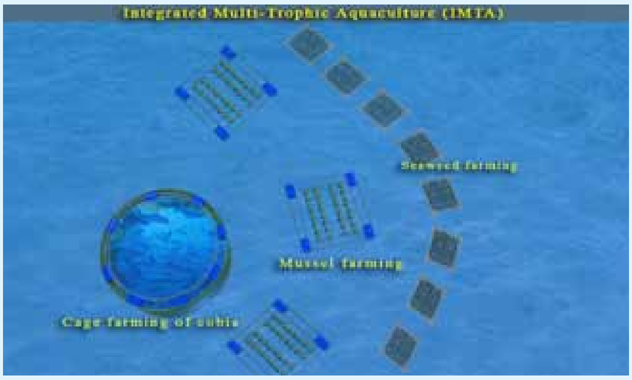
CMFRI Technology - Sea cage farming of cobia

In recent years, the availability of high value fish from sea is declining mainly due to over-exploitation of stocks. However, the demand for marine fish is increasing by the year, as it is an important source of protein, fatty acids and provides essential nutrition to growing world population. Mariculture is the only option through which this continually increasing requirement of sea fish can be met. The **Mandapam Regional Centre of Central Marine Fisheries Research Institute** (CMFRI) has been in the forefront in developing technologies for the seed production and farming of several high value marine finfishes. One such technology is sea cage farming of cobia-*Rachycentron canadum*.

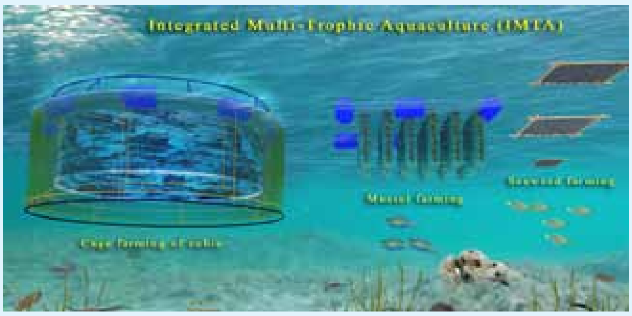
Though India is a late starter in cobia research, the Centre through its research has been able to create alternate avocation and additional income generation opportunities to fisher-folk through small scale mariculture. Cage farming of cobia was experimented for the first time in India at the Mandapam Regional Centre of CMFRI with hatchery produced fingerlings during 2011-12. The results of several demonstrations revealed that cobia is an ideal species for sea cage farming and it can reach an average weight of 2 to 3 kg in 6 months and 4 to 8 kg in one year of culture period. Cobia is a popular table fish due to its high quality meat. In India, cobia is sold as whole or as steaks in domestic market. It has a very good demand in states like Kerala, Tamil Nadu, Maharashtra, West Bengal, Karnataka and Goa. The present aquaculture production is not sufficient to meet the domestic demand. As the culture practice of the cobia is gaining in popularity, it will also have export potential in future. As a result of the initiation taken by the CMFRI – Mandapam, sea cage farming of cobia is presently being practised by over 100 fisher groups in the coastal districts of Tamil Nadu with the support of central and state government agencies.

Need for adoption of IMTA

One of the major issues foreseen while expanding the sea cage farming is the environmental degradation and consequent disease problems. In this context, the idea of bio-mitigation along with increased biomass production by integrating different groups of commercially important aquatic species which are having varied feeding habits is highly relevant. The



IMTA (Aerial view)



IMTA (Cross-sectional view)

Tying the seeded rope on the bamboo raft

ICAR-CMFRI has successfully conducted demonstration of Integrated Multi Trophic Aquaculture (IMTA) under participatory mode with a fishermen group at Munaikadu (Palk Bay), Ramanathapuram district, Tamil Nadu by integrating seaweed Kappaphycus alvarezii with cage farming of Cobia (*Rachycentron canadum*). Since, seaweed farming is being widely adopted in Tamil Nadu coast; integration of seaweed with cage farming of cobia was initially attempted.

Kappaphycus farming

The worldwide seaweed production (farming + wild collection) has substantially increased from 4 million tonnes in 1980 to about 29.4 million tonnes in 2015 (FAO, 2016). India contributes less than one per cent of global seaweed production. Among the global seaweed production, *Kappaphycus* and *Eucheuma* contributed to 41 % of the total production. India has been able to enhance its production to more than 7,000 tonnes of dry weight biomass of *Kappaphycus* in a decade between 2005 to 2015. *Kappaphycus* are used as phycocolloids (carrageenan), food, fodder & bio-fertilizer. Kappaphycus farming is being widely adopted by floating bamboo raft method in Tamil Nadu coast. The mainframe of floating bamboo raft is 12′ × 12′. Four bamboos (4′ each) are tied diagonally in four corners of mainframe. Nearly 20 polypropylene-twisted ropes along with seed materials are tied in the raft. Around 150 – 200 grams of seaweed fragments are tied at a spacing of 15 cm along the length of the rope. A total of 20 seaweed fragments can be tied in single rope. The total seed requirement per raft is 60 – 80 kgs. Fish net of 4m x 4m size is tied at the bottom of the raft to avoid grazing. The crop duration is for 45 days. An annual gross revenue of Rs. 90,000 to Rs. 1,18,000/- is being earned by a fisher family through Kappaphycus farming with a profit margin of 50-70 per cent.

Demonstration of IMTA

A total of 16 bamboo rafts (12× 12 feet) with 75 kg of seaweed per raft were integrated along with one of the cobia cages for a span of 4 cycles of seaweed farming (covering 180 days of cobia farming). The rafts were placed 15 feet away from the cage in a semi-circular manner, so as to enable the seaweed to absorb the dissolved inorganic nutrient wastes arising from the cage and which moves along the water current from the cage.

Cage farming of cobia

Seaweed rafts without integration

Seaweed rafts (16 Nos.) integrated with cobia cage

A GI cage of 6 m diameter and 3.5 m depth with 750 cobia fingerlings was integrated with the above seaweed raft system. The fingerlings of cobia were fed @ 5% total biomass of fish with chopped low-value fishes (sardine, lesser sardine, rainbow sardine, etc.) twice a day. Cage nets were changed periodically based on the subjective assessment of fouling on the net in order to ensure sufficient passage of water through the cages. The crop period for cobia is six to seven months.

As a control, a separate set of rafts of the same number were grown in a different location without any integration with the cobia farming cages.

Economic benefits in Seaweed production under IMTA

One complete cycle of seaweed production extends over an average period of 45 days. At the end of this period, the seaweed rafts are brought close to the shore for harvesting. After retaining 75 kilogram of the yield as seed material for the next crop, the remaining stock was sun dried near the shore for three days and sold in dried form. The average dry weight of the harvested seaweed is only 10 per cent of the wet weight. Within two or three days from harvest, the rafts were seeded once again and integrated tothe cobia rearing cage. Four cycles of seaweed farming were performed in a row for a period of six to seven months. While the average yield in one raft of 12 x 12 feet size without integration per cycle was 150 kg, the corresponding yield in a similar raft integrated with a cobia rearing cage was 260 kg.

The total dried seaweed production of the integrated rafts after 4 cycles was 1280 kg, while that of non-integrated rafts were only 576 kg. Thus an additional yield of 704 kg of seaweed was achieved here through integration with cobia cage farming.

Feeding the cobia fishes

Comparison of cost and returns of seaweed cultivation by IMTA (16 rafts/ one cage/4 cycle) and non-IMTA

Particulars	IMTA	Non-IMTA	Difference
Dried seaweed production (for 4 cycle, 16 rafts)	1280 kg	576 kg	704 kg
Price of dried seaweed (Rs.per kg)	37.50	37.50	-
Revenue (Rs.)	48,000	21,600	26,400
Costs (Rs.)	16,000	16,000	-
Net Profit (Rs.)	**32,000**	**5,600**	**26,400**
Profit Margin (%)	**67**	**26**	**41**

The rafts integrated with cobia culture had an added advantage as there were an increased number (average 90-100 nos.) of newly emerged apical portion/tips in a bunch of harvested seaweed, due to effective organic waste utilization. For the rafts that were not integrated, the apical tips were lesser (average 30- 40 nos.). The bunches having more numbers of newly emerged apical portion/tips, when used for replanting, are ready for harvest within 40 days, whereas the seaweed with less numbers of apical portion/tips, when used as seed, reach harvest sizes in a duration of around 54 days.

There was an additional revenue generation/additional net profit of Rs. 26,400 with an increased profit margin of 41 percent through integration of seaweed rafts to cobia cages with same operational cost for the rafts.

More numbers of newly emerged apical portion/tips from integrated rafts

Comparison of seaweed yield both non-integrated (with cobia cage) (L) and integrated farming (R)

Economic benefit through increased cobia production under IMTA

The integration of cobia cage with seaweed rafts generated favorable returns for the farmers with respect to the finfish production also. In a six month production cycle of cage farming of cobia under IMTA (along with 4 cycles for the integrated seaweed), an average yield of 1,220 kg was achieved whereas in the non-integrated cobia cage the yield was only 960 kg. The gross revenue generated from the cobia yield (with an average weight of 2.2 kg/ fish and at the rate of Rs. 290/ kg) was Rs. 3,53,800 for the integrated and Rs. 2,78,400 for the non-integrated cages. An additional net operating income of Rs. 75,400 was realized from the integrated cage.

Comparison of economics of sea cage farming of cobia with and without IMTA (for one cage & one crop of 6 months duration)

S.No	Particulars	IMTA (Rs)	Non IMTA (Rs.)	Difference
750 cobia seeds were stocked in a 6m dia and 3.5m depth GI cage				
1	Fixed cost (one cage)	61,600	61,600	0
2	Total Operating cost	1,30,000	1,30,000	0
3	Total cost of production (Six months)	1,91,600	1,91,600	0
4	Yield of farmed fish (in kg) (in six months average wt. 2.2 kg)	1220	960	260 kg
5	Gross revenue in Rs. (@ Rs. 290 per kg)	3,53,800	2,78,400	75,400
6	Net income	1,62,200	86,800	75,400
7	Net operating income (Income over operating cost)	2,23,800	1,48,400	75,400
8	Farm gate Price (Rs.)	290.00	290.00	0
9	Capital Productivity (Operating ratio)	0.37	0.47	-
10	Cost of production Rs. per kg	157	199	42
	Profit Margin (%)	85	45	40

Harvested cage farmed cobia fishes from the integrated cages

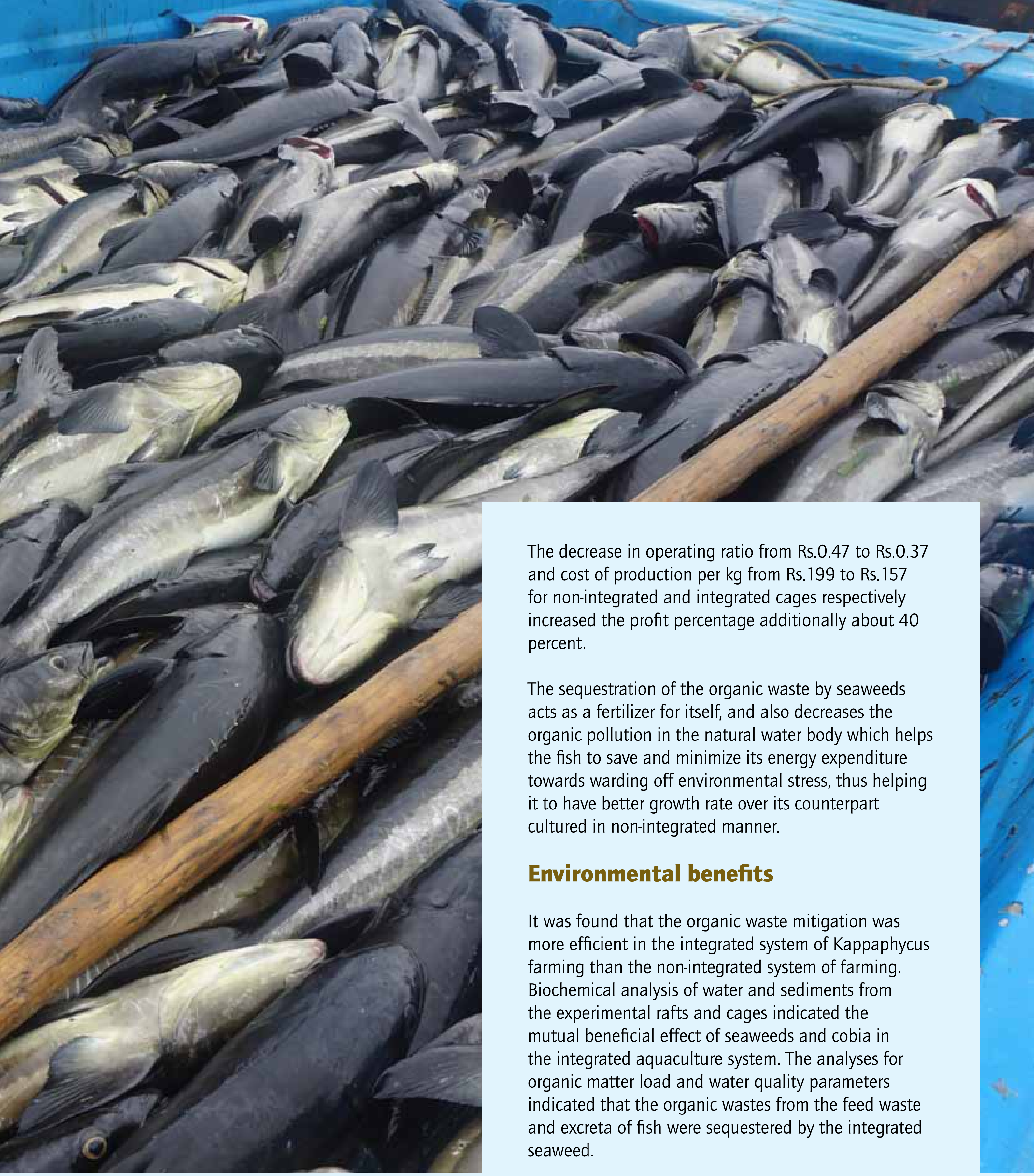
Fisherman Shri. Mohamed Noogu got State Level Best Farmer Award

Shri. L. Mohamed Noogu holding the harvested seaweed under IMTA

Shri. L. Mohamed Noogu, a fisherman from Munaikadu, Ramanathapuram district, Tamil Nadu is undertaking seaweed farming since 2004. The Mandapam Regional Centre of ICAR-CMFRI conducted participatory farming trials on IMTA at Munaikadu during 2013-14. Initially Shri. Noogu was skeptical about the technology. Later, when he witnessed double the seaweed harvest through IMTA, he was fully convinced and is adopting the technology. He said that the seaweed production had drastically reduced in Ramanathapuram district due to heat stroke during 2013-14, but adoption of IMTA had helped him to double the yield than farming seaweed alone.

The adoption of ICAR-CMFRI technology - IMTA has paid reward to him. He obtained STATE LEVEL RECOGNITION for his accomplishments in the 'Kisan Samriddhi Mela ('Farmers Fair for Prosperity').

Shri. L. Mohamed Noogu receiving State Level Best Farmer Award from Dr. K. Ramasamy, Vice-Chancellor, Tamil Nadu Agricultural University, Coimbatore



The decrease in operating ratio from Rs.0.47 to Rs.0.37 and cost of production per kg from Rs.199 to Rs.157 for non-integrated and integrated cages respectively increased the profit percentage additionally about 40 percent.

The sequestration of the organic waste by seaweeds acts as a fertilizer for itself, and also decreases the organic pollution in the natural water body which helps the fish to save and minimize its energy expenditure towards warding off environmental stress, thus helping it to have better growth rate over its counterpart cultured in non-integrated manner.

Environmental benefits

It was found that the organic waste mitigation was more efficient in the integrated system of Kappaphycus farming than the non-integrated system of farming. Biochemical analysis of water and sediments from the experimental rafts and cages indicated the mutual beneficial effect of seaweeds and cobia in the integrated aquaculture system. The analyses for organic matter load and water quality parameters indicated that the organic wastes from the feed waste and excreta of fish were sequestered by the integrated seaweed.

The total amount of CO_2 sequestered into cultivated seaweed (Kappaphycus alvarezii) in the integrated and non-integrated rafts were estimated to be 223 kg and 100 kg respectively. Hence, there is an addition of 123 kg carbon credit due to integration of 16 seaweed rafts (4 cycles) with one cobia cage (one crop).

Harvested cage farmed cobia fishes from the integrated cages

Comparison of carbon sequestration potential of seaweed cultivation through IMTA

S.No	Particulars	IMTA	Non-IMTA
1	Seaweed production as wet weight (for 4 cycle, 16 rafts)	12800 kg	5760 kg
2	Average dry weight percentage of the harvested seaweed (%)	8.75	8.75
3	Average carbon content (%)	19.92	19.92
4	**Total amount of carbon sequestered (1)× (2)× (3)**	**223 kg**	**100 kg**

Conclusion

Integration of seaweed with cobia cages generated additional revenue through increased yields of both cobia as well as seaweed. This is evident from the increased profit percentages in either case. Presently, close to 100 fishers in Ramanathapuram district of Tamil Nadu are adopting this IMTA technology with their own investment. As the bamboo raft method is sometimes not suitable for rough sea conditions, tube net method could be better for integration of seaweeds with cobia farming cages.

IMTA is an efficient system that helps in controlling both organic and inorganic pollution in the natural open waters and thereby ensuring ecological balance. It is also an eco-friendly and sustainable option that ensures a steady income to the coastal fishers. IMTA could also emerge as one of the significant mitigating measures for the adverse impact of climate change and earn valuable carbon credit for our country.

Acknowledgement

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For Suggested readings & references, please contact the corresponding author