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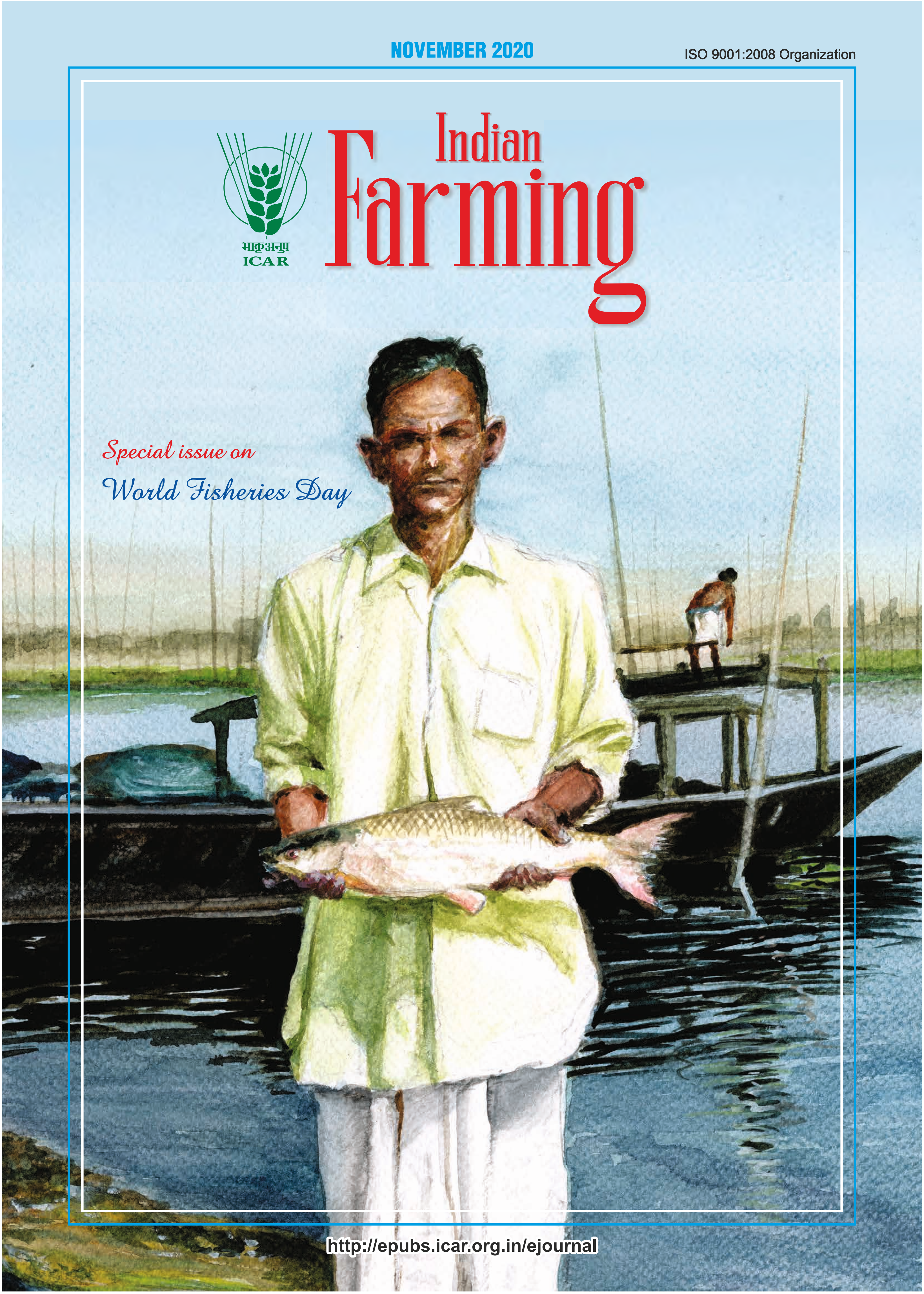
ICAR

Indian Farming

Special issue on

World Fisheries Day



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Glimpses of women in fish marketing

Arnala Fish Market
Maharashtra

Frazergunz
West Bengal

Leh Ladakh

Mangalore Fishing Harbour,
Karnataka

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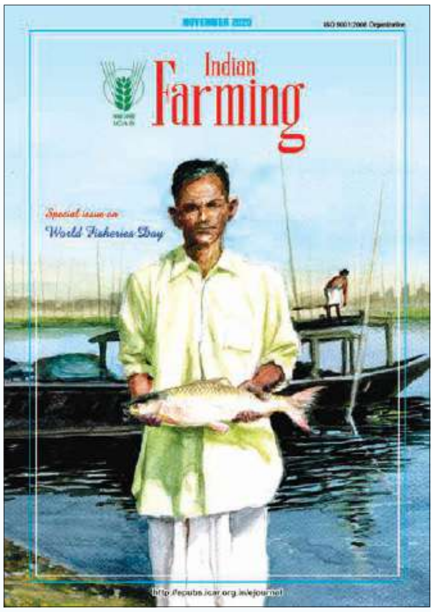
Indian Farming



Cover I : 'Happy Fisher' - A fish farmer from Bangaigoan, Asom

Cover IV : 'Big Catch' - A fisherwomen from Mangalore, Karnataka

Photo Courtesy Cover I-IV : Dr Pravin Puthra ADG (Marine Fy)

In This Issue

For editorial queries contact
Ravindra Verma
Editor (*Indian Farming*) ICAR-DKMA
011-2584 1004
e-mail: editorijans@icar.org.in

For Subscription and Advertisement contact:
S K Joshi
Business Manager, DKMA, ICAR
Krishi Anusandhan Bhavan I, Pusa
New Delhi 110 012
Telefax: 011-2584 3657
e-mail: bmicar@icar.org.in, businessunitficar@gmail.com

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Fisheries Sector in India

With a total fish production of 13.76 million tonnes at present, the fisheries sector in India has been registering an impressive annual growth rate of 6-7% during the last four decades. The phenomenal eighteen-folds growth in production in the last 70 years has been largely due to the significant increase in production in aquaculture, especially from the freshwater aquaculture sector. Such growth in fish production not only has been able to meet the increasing domestic demand but has also contributed significantly towards export earnings of over ₹ 47,000 crores from fish and fishery products. The growth in coastal shrimp farming with a production of about 0.7 million tonnes has largely contributed to such export growth. The freshwater aquaculture, largely contributed by Indian major carps, has been the major contributor of domestic demand. Aquaculture in recent years also has seen great thrust in species and system diversification in all systems, i.e. freshwater, brackishwater and open-sea. Considering the available resource potential of the country, technological advancements made over the years and the increased thrust of the Government in recent years, the sector projects accelerated growth performance also in the coming years.

Recent years have witnessed increasing adoption of different scientific aquaculture technologies, not only targeting higher production but also for the production of diversified finfish fish and shellfish species having higher market demand. Technologies have been developed for breeding and seed production of more than 60 commercially-important finfish and shellfish species, thereby providing greater choice to the farmers for adoption of the technologies. To have an assured supply of quality seed for aquaculture development, greater focus is also given on breed improvement of important cultivable species, and in this aspect, the development made through selective breeding is worth mentioning. Since feed forms the main input cost of fish farming, there has been a greater focus on the development of several feed formulations for different finfish and shellfish species. Considering the fact that aquaculture in recent years has witnessed the increasing threat of different diseases, it is expected that the research institutes give greater attention to fish health management. In this endevour the execution of a massive programme on fish disease surveillance with the financial support of the National Fisheries Development Board, Government of India is quite significant in the management of fish diseases in the country.

The successful demonstration of cage culture technology of seabass, cobia, pompano and groupers in open-sea has opened-up enormous scope for utilization of vast coastal resources for the production of high-value species. Similarly, the adoption of large-scale cage aquaculture in medium and large reservoirs needs special attention. Besides conventional pond-based farming, there has been increasing interest in the adoption of new technologies like re-circulatory aquaculture systems for high-value species, biofloc technology, etc., which provide increasing scope for entrepreneurship development.

In capture fisheries too, strategies are being made for the harvesting of the potential deep-sea resources and in this context, the development of new fuel-efficient crafts and appropriate gear designs by Indian research institutes is of high relevance. Greater attention is also given to resource-specific stock enhancement programmes in reservoirs for the effective utilization of the vast resources of over 3.0 million ha.

At a time, when the sector was looking to maintain the growth pace in the fish production to meet the increasing demand of both domestic and export fronts, the initiation of Pradhan Mantri Matshya Sampada Yojana of the Department of Fisheries, Government of India has been like a dream coming true. Further, with the greater convergence seen between the research institutes under the Indian Council of Agriculture Research and different programmes of the Governments, it is expected that the aspiration of the sector and also associated stakeholders would be met in coming years.

(Dr J.K. Jena)
Deputy Director General (Fisheries Science)
Indian Council of Agricultural Research
Krishi Anusandhan Bhawan-II
Pusa, New Delhi 110 012, India

नरेन्द्र सिंह तोमर
NARENDRA SINGH TOMAR

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सत्यमेव जयते

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ग्रामीण विकास और पंचायती राज मंत्री
भारत सरकार
कृषि भवन, नई दिल्ली
MINISTER OF AGRICULTURE & FARMERS WELFARE,
RURAL DEVELOPMENT AND PANCHAYATI RAJ
GOVERNMENT OF INDIA
KRISHI BHAWAN, NEW DELHI

20th **November, 2020**

MESSAGE

It gives me immense pleasure to be a part of the endeavor to bring out the special edition of the most popular farming magazine, the *Indian Farming*, being published on the occasion of World Fisheries Day. World Fisheries Day is celebrated every year on 21st November throughout the world by all stakeholders associated with the fisheries to highlight the importance of maintaining the world's fisheries. The World Fisheries Day in India received special focus in the year 2019 which extends up to the year 2022 with the theme "2022 ka Hai Sapna, Kisan Ki Aay Ho Dugna – Sankalp Se Siddhi".

In recent years the fisheries sector has emerged as one of the fast-growing segments of agriculture. It has made rapid strides in increasing food supply, raising the nutritional level, generating livelihood and earning foreign exchange. However, the challenges of population growth and climate change compounded by the growing instability associated with land and water resources are coercing on the fisheries sector. These impediments can be contained by technological advancements and innovations in the field of fisheries and allied activities.

This special edition of the magazine, Indian Farming on Fisheries will serve as an effective platform to publish the right blend of articles that hold great focus on fishing environment and biodiversity, fishing industry and entrepreneurship, fishing technologies and innovations and many more.

I extend my warm greetings and felicitations to the editors, authors and publishers of this issue and wish the magazine a grand success.

(Narendra Singh Tomar)

Office : Room No. 120, Krishi Bhawan, New Delhi-110 001 Tel.: 23383370, 23782691 Fax : 23384129
Resi. : 3, Krishna Menon Marg, New Delhi-110001, Ph. : 011-23794697 / 98, Fax : 011-23794696

प्रताप चन्द्र षडङ्गी
ପ୍ରତାପ ଚନ୍ଦ୍ର ଷଡ଼ଙ୍ଗୀ
Pratap Chandra Sarangi

राज्य मंत्री
सूक्ष्म, लघु और मध्यम उद्यम और
मत्स्य पालन, पशुपालन एवं डेयरी
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MINISTER OF STATE FOR
MICRO, SMALL & MEDIUM ENTERPRISES AND
FISHERIES, ANIMAL HUSBANDRY & DAIRYING
GOVERNMENT OF INDIA
NEW DELHI-110011

19 November, 2020

MESSAGE

The Fisheries sector is marching ahead at a rapid pace and providing food, nutrition and livelihood to a large section of the population besides supporting the country's economy through export and trade. On account of population upsurge, climate change and changing food habits, the demand for fish has significantly increased over the last few decades, which is expected to pose newer and greater challenges for nutritional security.

Fisheries and aquaculture development needs to be managed in an environmentally responsible and sustainable fashion through multi-dimensional research support. Knowledge-based appropriate utilization of water resources, efficient management of diversified aquaculture systems and allied enterprises are expected to ensure the horizontal and vertical expansion of aquaculture.

In this context, it is good to note that the ICAR-Directorate of Knowledge Management in Agriculture (DKMA) is bringing out a Special Issue of *"Indian Farming"* on the occasion of *World Fisheries Day.* The publication is expected to address the emerging issues and share knowledge on different technological interventions in fisheries and aquaculture. I believe, the stakeholder in the sector would be immensely benefitted.

I appreciate the sincere efforts for ICAR-Directorate of Knowledge Management in Agriculture (DKMA) and wish all the best on the occasion.

19.11.20

(Pratap Chandra Sarangi)

Room No. 133, Udyog Bhawan, Rafi Marg, New Delhi-110011, Tel. : 011-23061258, 23063142 Fax : 011-23010324

त्रिलोचन महापात्र, पीएच.डी.
सचिव एवं महानिदेशक

TRILOCHAN MOHAPATRA, Ph.D.
SECRETARY & DIRECTOR GENERAL

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GOVERNMENT OF INDIA
DEPARTMENT OF AGRICULTURAL RESEARCH & EDUCATION
AND
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
MINISTRY OF AGRICULTURE AND FARMERS WELFARE
KRISHI BHAVAN, NEW DELHI 110 001
Tel : 23382629; 23386711 Fax: 91-11-23384773
E-mail: dg.icar@nic.in

MESSAGE

Indian fisheries sector represents an economically important and fast-growing production sector contributing significantly to the national economy. This sector is mainly contributing in terms of food, nutrition, socio-economic development and providing livelihood to a large section of the country. India is the second largest aquaculture producing country and among the top exporting nations of the world. The country has immense potential to harness the fishery resources sustainably to increase fish production and productivity to cater to the ever-increasing demand for fish protein in the country and the world. The fisheries research institutes in the country need to take up the challenge to usher the blue revolution in the country, and increase the income of the fisheries sector through sound management and sustainable development of the resources.

I am extremely happy that the Directorate of Knowledge Management in Agriculture (DKMA) under the Indian Council of Agricultural Research (ICAR) is publishing a Special Issue on Fisheries and Aquaculture in the magazine *Indian Farming* on the occasion of World Fisheries Day celebrated globally on 21 November 2020. Wide range of articles on fisheries and aquaculture have been covered in this special issue. This would be an excellent source for knowledge sharing to different stakeholders for the sustainable development of fisheries and aquaculture in the country.

I compliment the officials involved in the preparation of this special publication and convey my best wishes to all on the occasion of World Fisheries Day.

(T. MOHAPATRA)

17 November 2020
New Delhi

Indian Farming **70**(11): 05–09; November 2020

Expanding studies on enclosure culture (Cage & Pen)

with special focus on fish species diversification in India

B K Das[1]* and U K Sarkar[2]

ICAR-Central Inland Fisheries Research Institute, Barrackpore, West Bengal 700 120

ICAR-Central Inland Fisheries Research Institute, Barrackpore is the pioneer for the development of technology for both fingerlings raising and table fish production. Technologies developed by ICAR-CIFRI have been applied and extended successfully in many reservoirs in different parts of the country. The present article highlights the advances of enclosure culture and discusses species diversification, potentials, issues, challenges and way forward for sustainable fisheries enhancement and employment generation from reservoirs and floodplain wetland resources.

Keywords: Cage farming, ICAR-CIFRI, Loktak lake, Pen culture

FISHERIES is a sunrise sector which provides livelihood to millions of fishers and fish farmers in India. This sector has immense potential to double the fishers and fish farmers' incomes and the fish production has reached an all-time high of 137.58 lakh MT during 2018-19. The inland open water fisheries resources especially reservoirs (>3.51 million ha) and wetlands (0.5 million ha) have immense potential to produce more fish by bridging the gap between present production and potential. The fisheries management through different approaches like the adoption of stock enhancement, Culture Based Fisheries (CBF) and enclosure culture techniques like cage farming and pen farming are gaining momentum and importance, as they have proven to create more fish and thereby income and employment for the growing human resource of the country. Enclosure culture brings in new opportunities and avenues for optimizing fish production from the reservoirs and other inland open waters, and developing new skills among fishers and entrepreneurs to enhance their earnings. Inland water bodies especially reservoirs due to its vast resources have immense potential for cage culture of fast growing and highly prized freshwater fishes.

Status and potential

In India, out of 3.5 million ha water coverage under reservoirs, 2,157,318 ha are under the purview of a medium and large category of reservoirs. Already there are 20,000 cages in Indian reservoirs of 20 States producing approximately 50,000 MT of fish. Commercial scale cage culture in India at present is mainly restricted to Pangas and GIFT Tilapia and an average production of 2-3 MT/cage is achieved. By using a mere 0.1% of the total area under large and medium reservoirs, 2,157 ha will be available to be covered under cage culture. There will be 400 cages to be accommodated in 1 ha area at a size group of 6×4 or 5×5 m^2 and thus, a total of 8.62 lakhs cages could be installed in these bodies.

In recent years, enclosure fish farming in reservoirs either for stocking materials or for the production of table size fish has attracted the attention of researchers, developmental agencies, entrepreneurs and policymakers across the nation. The growth of cage fish farming in reservoirs has gained further momentum during 2010-12 with financial support from National Fisheries Development Board (NFDB), Government of India, NMPS etc. In 2011, CIFRI ventured into raising table-fish of economically important species through cage culture by installing cage facilities with durable galvanized iron frames in Maithon Reservoir, Jharkhand (Figs 1 & 2). This paved the way for the adoption and popularization of this technology in several reservoirs belonging to more than 20 States in 'Mission Mode' through various schemes and programmes. Jharkhand, Chhattisgarh, Madhya Pradesh, Maharashtra have widely adopted this technology and scaling up is in progress in many states.

Fig. 1. Haul of Bata and Singhi harvested from cages at Maithon reservoir, India

Potential candidate species

The selection of species for cage culture shall be customized based on market demand and market value, hardy and tolerant nature of the species, and acceptance to external sources of food under confined conditions. It is preferable to culture species with high market value as the cage culture venture is capital and operational cost-intensive. The species selected should also be hardy and tolerant of confined, crowded conditions and to the rigors of handling during net changes, net cleaning, fish transfers etc. Since the reservoirs are mostly oligotrophic and fishes are stocked at higher densities, the external source of feed is a necessity and identified fish must be able to accept external sources of feed for higher growth and survival.

Economically viable cage culture of *Pangasianodon hypophthalmus* is practiced in reservoirs of the country. However, cage culture of more species drawn from the indigenous species pool needs to be encouraged. Considering the consistent demand for species of high economic and nutritive value, and the regional preference for some species, the following indigenous species need to be inducted into the cage culture domain subjected to seed availability: *Labeo bata, L. rohita* (Jayanti rohu), *Osteobrama belangeri* (Pengba), *Systomus sarana, Ompok bimaculatus* (Pabda), *Heteropneustes fossilis, Etroplus suratensis, Macrobrachium* sp. etc. Apart from *Pangasianodon hypophthalmus* and GIFT tilapia, no other exotic species (including illegally introduced fishes) are strictly prohibited for cage culture in inland open waters.

Pen culture

Pens are areas along the periphery of water bodies, enclosed generally on three sides by means of bamboo or net fencing or a combination of both, with the fourth side being contiguous with shoreline. In case of unproductive floodplain wetlands, where external fertilization is not feasible; cage and pen culture are perfect management options, wherein an area can be demarcated for enclosure culture. It is best suited for weed choked and productive wetlands as it help to overcome the issue of gear restriction and catchability. Table size fish production through pen farming could be a viable option for conflict management for fisheries development. In States deficient in stocking material (>10cm) suitable for open waters, seed raising in pens and subsequent stocking will enhance the fish production. Thus useful in meeting seed requirement for culture-based fisheries which in turn increase the fish yield.

Fig. 2. Haul of Jayanti rohu and Prawn harvested from cages at Palair reservoir, Telangana

Pen culture in Loktak lake, Manipur: Success story

Fifty fishers residing in the vicinity of Loktak lake undertook pen culture by taking an area of 0.5 ha each under lease from the Department of Fisheries, Govt. of Manipur with an annual lease value of ₹ 5,000 per year. Advanced fingerlings were stocked @ 5-7 nos.m^{-2} constituting grass carp (60-70%) and IMCs (30-40%). Locally available aquatic weeds were fed to fishes. Fish production from an individual pen was in the range of 3,000-4,000 kg/ha in one year. The mean monthly income after the adoption of the technology (₹ 9,250) was significantly higher than that before adoption (₹ 6,183). The adoption of pen culture resulted in an increase of 49.6% in the mean monthly income of the fishers and benefit-cost ratio (BCR) ranged from 1.54-1.87.

Successful demonstration of climate resilient pen system (CRPS)

Although a number of fish species have been documented in various wetlands, their potential for inclusion in enclosure culture has not been evaluated except for IMC and a few minor carps. Recent trials have revealed the potential for diversification from the indigenous fish pool. Besides pen culture with indigenous fish, there are other potential shellfish suitable for pen culture. The black clam, *Villorita cyprinoides* was successfully reared in climate resilient pen systems installed in Vembanad lake, Kerala and production of more than 2 MT was achieved through community participation. Studies using local indigenous fish species such as *Amblypharyngodon mola, Systomus sarana, Mystus tengra, Ompok bimaculatus, Gudusia chapra* and *Labeo bata* were also undertaken in pens installed in wetlands of Assam and West Bengal. The adoption of these systems can help to restore the vulnerable species and increase the adaptive capacity of wetland fishers and their income.

Recent developments

ICAR-CIFRI has developed and refined a number of technologies and management strategies for inland open water fisheries development during the last seven decades. Recently, the institute has commercialized CIFRI GI cage, CIFRI HDPE Pen and Cage Grow Feed (low cost).

CIFRI GI Cage

Standardized the cage culture technology of *Pangasianodon hypophthalmus* in reservoirs and an average production of 2-3 MT/GI cage of 5m×5m×4m has been achieved in different states (Fig. 3). Commercialised CIFRI GI CAGE can be used for both fish seed raising and table fish production. Owing to immediate need for diversification for increased adaptability and profitability, the feasibility of several commercially important indigenous fish species viz. *Labeo rohita* (Jayanti), *Ompok bimaculatus*, *Laebo bata*, *L. gonius*, *Barbonymus gonionotus*, *Systomus sarana* in different agro-climatic zones were evaluated and standardized their stocking density for production in cages.

CIFRI Pen HDPE

Developed and commercialised CIFRI Pen HDPE (one unit: 0.1 ha) which can hold fish and prawn as captive stock in open waters either for producing table size fish or for raising stocking material (fingerlings). It is a fixed enclosure with sides of HDPE netting in which the bottom is in the bed of the water body (Fig. 4). Seed production or table fish production through pen culture can help overcome threats and risks associated with open water fish production to a great extent. Seed production through pen culture could be befitting counterparts for stocking enhancement technology by ensuring timely availability of seeds of required species, number and size. The HDPE made pen has been tested in several multi-location trials with Indian

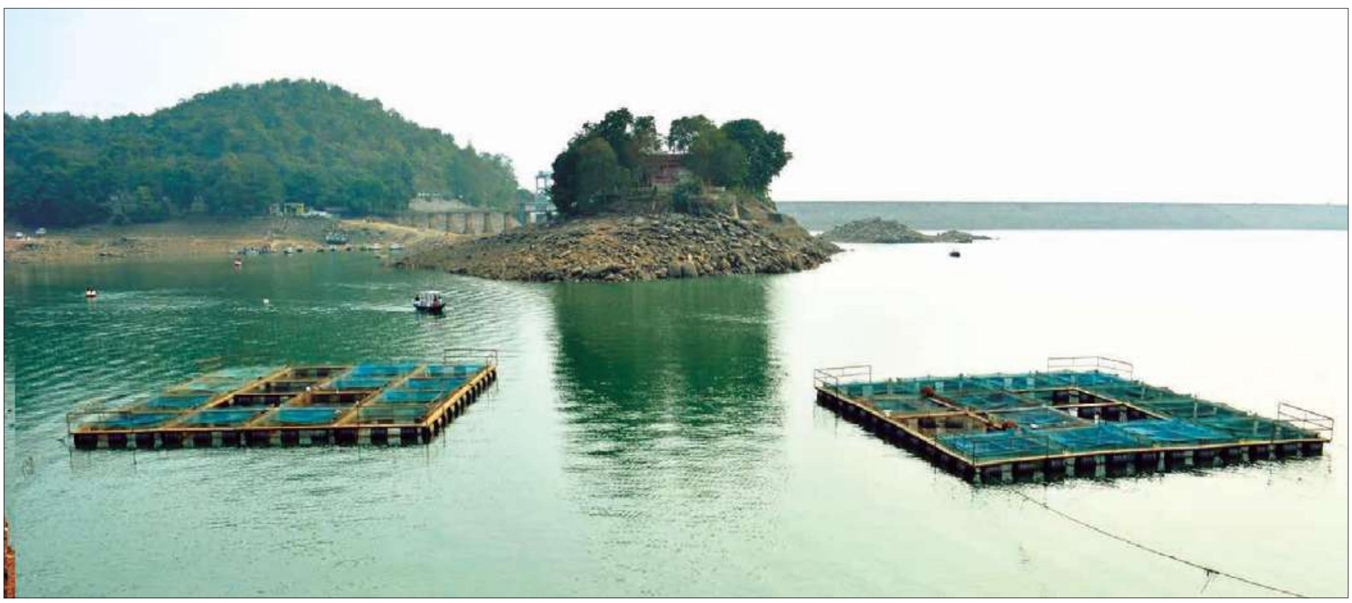

Fig. 3. CIFRI Cage Farm at Maithon reservoir, Jharkhand

Fig. 4. CIFRI HDPE Pen installed in a floodplain wetland, West Bengal

Major Carps, minor carps and minnows. The CIFRI pen culture technology has been adopted by the States of West Bengal, Bihar, Uttar Pradesh, Assam, Manipur, Meghalaya, Odisha and Kerala in wetlands and reservoirs for fish seed raising and table fish production.

New initiatives on species diversification in inland open water fisheries

Owing to the immediate need for diversification for increased adaptability and profitability of cage culture, studies were carried out by the Institute on the feasibility of several commercially important indigenous fish species and developed their production technology in GI cages installed in reservoirs and wetlands (Table 1). Stunted fingerlings of Pabda were reared at Maithon reservoir and an average size of 50-62 g was achieved in seven months. The *L. bata* stocked at the rate of 30/m^3 in GI cages in at Maithon reservoir, Jharkhand attained an average weight of 52 g in 120 days. Growth performance of stunted fingerlings of *Pangasianodon hypophthalmus* revealed a stocking density of 45/m^3 for optimum for growth in Maithon reservoir, Jharkhand.

Advance fingerlings of *L. rohita* (Jayanti) stocked in Salia dam, Odisha exhibited significantly high growth at a stocking density of 10/m^3. Advanced fingerlings of *Systomus sarana* achieved an average weight of 150 g in 90 days. Incorporation of a 10% level of

Table 1. Diversified fish species cultured in cages in different reservoirs by ICAR-CIFRI

Species	Reservoir	Achievement/findings
Labeo bata	Maithon reservoir, Jharkhand	Attained average weight of 52 g in 120 days.
Labeo rohita (Jayanti)	Salia reservoir, Odisha Palair reservoir, Telangana	Significantly high growth achieved at stocking density of 10/m^3. Achieved an average size of 1-1.2 kg in 10 months.
Pangasianodon hypophthalmus	Maithon reservoir, Jharkhand	Stocking density of 45/m^3 found to be optimum for growth.
	Gobindsagar and Pong reservoir, Himachal Pradesh Palair reservoir, Telangana	An average production of 1.9 MT/cage was achieved in Pong reservoir. A total of 102.85 tonnes of fish was harvested from 48 cages. Produced a total of 75.9 MT of Pangas and generated a revenue of 59 lakhs.
Ompok bimaculatus	Maithon reservoir, Jharkhand	An average size of 50-62 g was achieved in seven months.
Systomus sarana	Salia reservoir, Odisha	Achieved an average weight of 150 g in 90 days.
Labeo gonius	Samaguribeel, Assam	Stocking density of 40 fingerlings/m^3 was found to be optimum for growth.
Macrobrachium rosenbergii	Palair reservoir, Telangana	Achieved an average size of above 32 g in 6 months.

herbivore fish (rohu) was found to effectively control the biofouling organism growth in the commercial grow out *P. hypophthalmus* cage farming. Stocking density of 40 fingerlings/m³ and 30/m³ was standardized as optimum for the production of table-sized *L. gonius* and *L. bata* in cages in the beels of Assam.

Successfully demonstrated *in situ* fish seed raising and table fish production of *P. hypophthalmus, L. rohita, L. rohita (*Jayanti variety), *Labeo catla* and *Macrobrachium rosenbergii* in 64 numbers of GI model cage installed in Palair reservoir. A total of 106 MT of fish was harvested from cages and generated a revenue of 96 lakhs benefitting 40 fishers.

Demonstration of pen culture in Takmu pat (a part of Loktak lake), located at Bishnupur district, Manipur in collaboration with the Directorate of Fisheries, Govt. of Manipur yielded good growth performance of the fish *Osteobrama belengeri* showing technological feasibility. The pen culture system was found to be economically viable with a benefit-cost ratio of 1.37.

Issues

The appropriate adoption of enclosure culture technology offers enormous scope for enhancement of fish production. There are several key issues to be addressed such as species diversification, seed production of diverse species, development of low-cost environment friendly feed, development of a package of practices, estimation of carrying capacity, the environmental impact of cage culture etc. for ensuring the sustainability of enclosure culture in inland open waters. Diversification of fish species based on regional preference, nutritional value and local acceptability will ensure the popularization and profitability of culture practices.

Conclusion

Inland open waters are potential resources that are ideal for augmenting production through the adoption of refined technologies viz. cage and pen culture. The Govt. of India has prioritized increasing fish production from reservoirs and wetlands through various schemes and programmes under the ambitious PMSSY. The diversification of fish species is very crucial in maximising the profit from inland fisheries and also for better adoption of technology. Hence, the inclusion of potential value added species from the indigenous pool may be encouraged with technological backstopping from ICAR institutes. The involvement and linking of FPO's in promoting inland fisheries and exploring opportunities for the value chain will open up new avenues. Ensuring quality seed availability, development of suitable feed and dissemination of package of practices coupled with capacity building, fund flow will ensure better adoption of open water inland fisheries to meet the increasing demand for quality fish and thereby better income, nutritional security and employment generation.

[1]Director, [2]Principal Scientist, ICAR-CIFRI, West Bengal. *Corresponding author's e-mail: basantakumard@gmail.com

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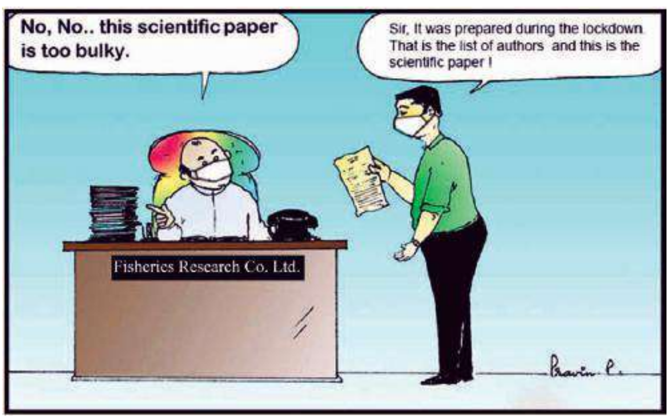
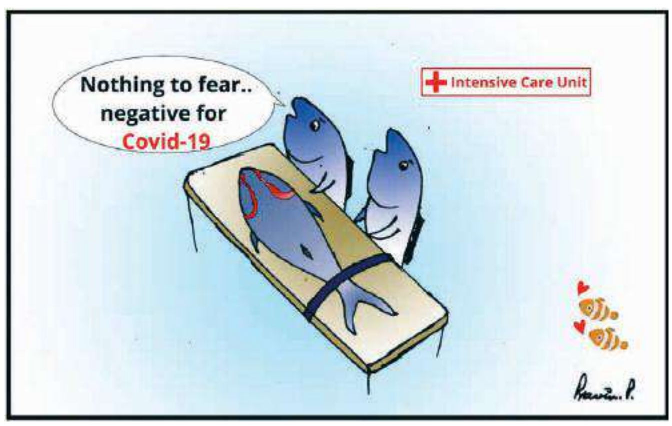




Indian Farming **70**(11): 10–13; November 2020

Canals in Indian Sundarbans:

Opportunities towards livelihood improvement through fisheries intervention

P Gogoi[1], P K Parida[1], A Sinha[2], T Tayung[1], V R Suresh[3] and B K Das[4*]

ICAR-Central Inland Fisheries Research Institute, Barrackpore, Kolkata, West Bengal 700 120

Canals in Indian Sundarbans are still underutilized in terms of sustainable fish production. Erection of barriers in these canals is a common practice for catching fishes. This may lead to intensive fishing of innate fishes and also barring natural recruitment into the canal. To rejuvenate and augment fish productions from canals, a degree of management is required for these resources. ICAR-CIFRI has initiated the staggered stocking of IMC in six freshwater canals of Sundarbans. It was reported that the practice of simple release of Indian Major Carps (IMC) in these canals produced 800 kg/ha/year of table sized fish without supplementary feeding. Similarly, in net partitions the maximum size recorded for catla, rohu and mrigal was 1.2, 1.0 and 0.80 kg respectively after six months of culture period. Stock enhancement in canals may be one of the noble options for sustainable fish production as well as support of the livelihood of rural poor fishers in Sundarbans. Attention has to be given to this pre-existing habitat to save water needed for farming and conservation of sustainable fish production.

Keywords: Canal, Fisheries, Sundarbans

CANALS are the second most important (26%) source of irrigation covering 17.0 million ha in India. Major States under canal irrigation are Andhra Pradesh, Assam, Haryana, Jammu & Kashmir, West Bengal, Punjab, Rajasthan, Bihar, Karnataka, Tamil Nadu and Uttar Pradesh. The plains of North India are canal irrigated including some parts of peninsular India where two types of canal exist *viz*., inundation canals and perennial canals. In inundation canals, water is taken from large rivers when water level is high enough, especially during monsoon. On the other hand, perennial canals are connected with dams and barrages for providing water round the year for irrigation. The total length of the canal in India is 1,26,334 km which can support various levels of fish productions practices at a time, these are hitherto not scientifically utilized for fisheries.

World scenario on canal fisheries

Literatures revealed that various countries are producing fish from irrigations canals. It is estimated that almost 16% of the freshwater fishery production comes from Nile and its irrigation canals in Egypt. while in Sudan, the fish biomass in minor canals of Geizira irrigation system is on an average 660 kg/ha/year. The practice of simple release of species *Oreochromis* spp., *Channa striata* and *Puntius gonionotus* into irrigation canals resulted in reproduction of 350 kg/ha/year without supplementary feeding in Thailand. It is reported that channelization or irrigation canals exhibit lower species diversity than nearby static water bodies which is influenced by temperature and low primary producers. Fish biomass is 31% lower compared to an unchannelized stream and that reduced 78% in macro-invertebrate biomass. In Thailand, extensive culture of bighead carp, grass carp and Nile tilapia in irrigation canals used for vegetable crops has been successful. In Myanmar, the rearing of snakeheads and climbing perch in irrigation channels is practicing by *Chan myaung* (irrigation canal, locally known as) owners in

Table 1. Canal resources in South 24 Paragans district

Name of block	Area in acres
Sagar	59
Patharpratima	287.87
Kakdwip	35.83
Namkhana	16.39
Mathurapur I	9.40
Mathurapur II	215.46
Kultali	112.39
Joynagar	214.69
Canning I	20.55
Canning II	7.0
Basanti	161.05
Gosaba	1,055.99
Bhangore II	15.20
Kulpi	30.05

Source: Adapted from Mukharjee (2016).

Ayeyarwady Delta, assistance provided by the World Fish.

Canal resources in Sundarbans

Indian Sundarbans, an important mangrove chunk in the world and an extremely fragile ecosystem inhabits considerable amount of threatened and vulnerable fish species. An area of 4,200 sq km of reserve forest located in India is a tide dominated low lying coastal wetland. The area experiences annual rainfall between 1,600-1,800 mm and severe cyclonic storms. The biodiversity of Sundarbans includes numerous species of phytoplankton, zooplankton, micro-organisms, benthic invertebrates, mollusks, amphibians and mammals. It has been inscribed as a World heritage site by International Union for Conservation and Nature (1987) and included as Biosphere Reserved under United Nations Educational, Scientific and Cultural Organization (UNESCO) Man and the Biosphere (MAB) programme list (2001). Recently, in February 2019, the Indian Sundarbans have also been designated as 'Wetland of International Importance'. Indian Sundarbans are rich in canal systems which covers an area 907.33 ha (Table 1&2) and exist highest at Gosaba block (427.34 ha). The natural forms of these resources are excavated for freshwater by erection/ setting up of sluice gate in the connecting channel of the parent river. Human settlements are prominent in both the banks of these canals in Indian Sundarbans. Industrialization and consequent urbanization in this era has brought environmental degradation and stress on coastal ecosystems of India, which adversely impact their inherent biota, physico-chemical profile of water and productivity. Sundarbans is not an exception from these anthropogenic pressures thereof. Large numbers of canals in Indian Sundarbans are fed by the tidal water through connecting channels (Fig. 1). Naturally, fish enter into these canals and some fish species form natural populations. Yet, information on trophic status of canal habitat, biotic community structure and hydrographical characters are lacking. Hence, ICAR-CIFRI initiated the investigation on trophic status of canal habitat, biotic community structure on three canals; *Bhetkimari* (21°44'29.7"N 88°15'06.7"E) and *Bherua* canal, (21°36'38.0" N 88°15'21.1"E) in Namkhana and *Bishalakhi* canal (21°46'47.3"N 88°05'30.6"E) in Sagar Island of Indian Sundarbans.

Table 2. Total Inland water resource and area under culture of West Bengal

Resources	Area (in lakh ha)	Area under culture (in lakh ha)
Open water systems		
Rivers	1.64	-
Canals	0.80	-
Reservoirs	0.28	0.13
Estuaries	1.50	-
Enclosed water bodies		
Tanks and ponds	2.88	2.61
Floodplain lakes/ derelict water bodies	0.42	-
Beels and Boar	0.42	0.21
Sewage fed fisheries	0.04	0.04
Brackish water fishery	0.60	0.59

Source: Adapted from Mahapatra *et al.* (2015)

Physico-chemical properties of soil and water in selected canals of Sundarbans

The preliminary investigations of ICAR-CIFRI in selected canals (Namkhana and Sagar Island) of Sundarbans revealed that canals are generally experienced with 8-10 feet

Fig. 1. A typical view of a canal in Sundarbans

depth during peak monsoon season (Fig. 2). Salinity is one of the important criteria in these canals where it fluctuates from 0.02 ‰ (monsoon season) to 18.76 ‰ (pre-monsoon season). The salinity levels are highest during pre-monsoon due to high rate of evaporation and lowest during monsoon season owing to high precipitation. Concurrently, low level of tidal influx is also a cause of increased salinity in some of the canals in Sundarbans. It is imperative to mention that the freshwater dominated canals are reaching maximum salinity up to 6.0% during pre-monsoon season (e.g. *Bherua* canal, *Shivpur*) which may be favorable for carp culture practice. Water temperature of the investigated canals ranged from 25.8-34.2°C round the year. Water pH found to be neutral to alkaline (7.60-8.35) with optimum range of dissolved oxygen (5.7- 6.23 mg/l) which is the most critical limiting factor for normal growth and survivability of fishes. Total alkalinity (107-188 mg/l) indicated productive nature of the canals. Water transparency (Secchi disc) in the canals recorded lowest during monsoon (28.8 cm) and highest during pre-monsoon season (45.2 cm) with average phytoplankton production 145.0 mgC/m^3/hr in the selected canals.

Soil quality is an important factor in aquaculture productivity as it maintains the bottom stability. Soil texture of the Sundarbans canal is sandy-loam (67.33%). Soil pH was alkaline in nature. Organic carbon acts as source of energy for microbes that release nutrients through biochemical processes. It was low to medium (0.38-0.60%), which indicated there was no organic matter accumulation at the bottom of the canals. In general, soils under brackish water contain good amount of available phosphorous which is beneficial to the growth of fish food organisms. Accumulation of good quantity of available nitrogen and phosphorus in canal soils are considered to be productive environment.

Fig. 2. Field visit of trainees/ fishers to ICAR-CIFRI experimental site, Bherua Canal, Shivpur

Biotic communities

The assemblage of biotic community indicates the productivity of water body. Phytoplankton population, the biological wealth of an aquatic ecosystem, responsible for wide assemblage of biotic community and regulate the food web. Zooplankton, being the primary consumer in food chain, plays an important role in transfer of energy to the higher trophic level. Zooplankton is also fed upon by many juvenile and adult zooplanktivorous fish species and hence it can be termed a key factor in the control of fish stock sizes. The occurrence of these organisms largely depends on the seasonal variations of physico-chemical parameters, physiographic factors and flow characteristics of the water body.

Phytoplankton and zooplankton populations in the selected canals exhibited significant variations in abundance in seasons. Cyanophyceae excelled as a major microfloral component (>35%) followed by Bacillariophyceae (>28%) and Chlorophyceae (>17%). Other algal groups (Coscinodiscophyceae, Euglenophyceaea, Trebouxiophyceae, Mediophyceae, Xanthophyceae, Conjugatophyceae, Synurophyceae) contributed partially and fluctuated much in seasons. Dinophyceae contributed least (<1%) contribution to the algal community. Diatoms were the most diverse group across the seasons in these canals. Compositions of zooplankton represented; Crustacean nauplius> Rotifera> Copepoda> Copepod eggs > Cladocera> Ostracoda in the stated order. Richness and Shannon-Weiner diversity index with a calculated value >2.95 in the studied canals indicated moderately rich phytoplankton diversity in the systems. Similarly, Pielou's evenness index also calculated with a mean value 0.88 showed the evenly spatial distributions of phytoplankton in the studied canals.

Periphyton is the heterogeneous group of community assemblage that attached in plants, woods, stones and various other substrates. It has great importance as primary producers together with phytoplankton and macrophytes which provides foods to many aquatic organisms. The periphytic associations in the selected canals of Sundarbans showed the dominance of six groups which represented as Bacillariophyceae > Cyanophyceae > Coscinodiscophyceae > Chlorophyceae > Conjugatophyceae > Nematoda. Diatoms invariably constituted the bulk of the population (> 66%) of the total periphytic community attached in the natural substrates. Macrobenthos; *Pila virens, Bellamya bengalensis, Pila globossa, Meiniplotica scabra, Tarebia granifera, Thiara lineata* were very common irrespective of seasons in the canals.

Small indigenous fishes (SIFs) are the major catch in these canals contributing >75% (showed percentage on the basis of studied canals) of the total catch. *Amblypharyngodon mola, Puntius* *sophore, Pethia ticto, Parambassis ranga, Chanda nama, Trichogaster* spp., *Anabas testudineus, Macrognathus pancalus, Glossogobius giuris, Channa punctata, C. marulius, Salmophasia bacaila, Notopterus notopterus, Mystus gulio, Mystus* spp. *Chelon parsia, C. tade* were the major catch. Penaied and non-penaied prawns also contributed a good amount of share (<10.0%) to the total fish catch.

Canal fisheries development in Sundarbans

A degree of management stocks to be required to maintain a more productive sustainable fishery. With this view, since 2017, ICAR-CIFRI associated in staggered stocking of Indian major carps in various fresh water canals of (Bali and Gosaba block) Sundarbans with local village development team in a participatory approach. Need-based capacity building programmes are being organized in selected areas to promote canal fisheries as a livelihood options. Interventions are made by simply release of Indian major carp fingerlings in 6 canals of Sundarabans (Bali and Kalitala area) where fish production was obtained up to the tune of 800 kg/ha/year of table sized fish without supplementary feeding. Fish production can further be increased by following proper management strategies. Stocking of right size fish seed at right time and maintaining of water depth/ volume are the two major crucial factors for the fish production/ enhancement in these canals.

Recently, ICAR-CIFRI has initiated trial in 'net partition systems' for 'carp polyculture' in selected freshwater canals of Sundarbans (Bherua and Bishalakhi canal) where stocked IMCs are resulting good growth (ongoing). It was reported that after 6 months of culture period, the maximum size recorded for catla, rohu and mrigal was 1.2 kg., 1.0 kg and 0.80 kg respectively; which may encourage the local community to culture fish in canals. Experiment on culture practices with diversified fish species is urged to do on these canals and perennial irrigation canals in particular existed in various states. Systematic net partition systems covering large area with suitable low-investment fish culture practice/ enhancements in canals is one of the noble option for enabling fish productions and livelihood support of local people.

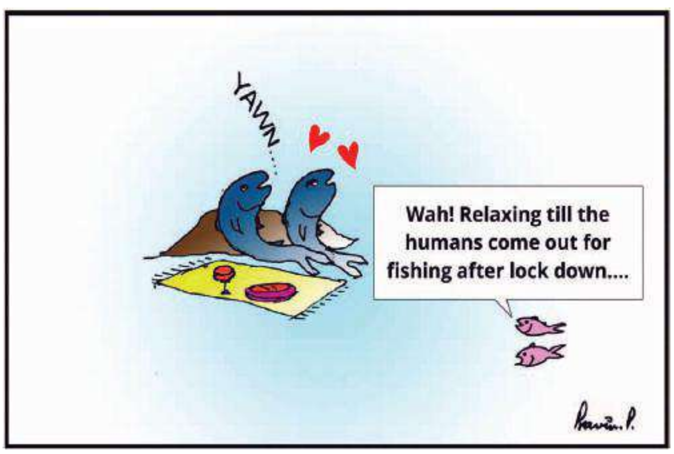
Lessons learned

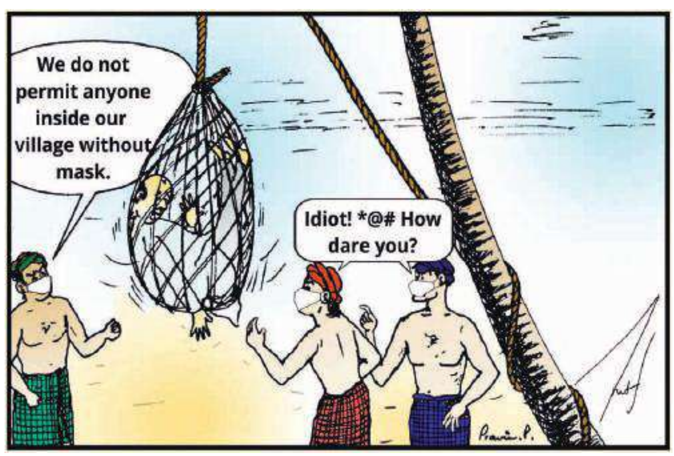
- Advanced fingerlings (more than 80 mm) to be stocked in the canals to escape themselves from the predatory wild stocks available in the resources.
- A small portion can be utilized for *in-situ* raising of advanced fingerlings as stocking material for enhancement in canals.
- As canals are long stretch of water body, poaching is a major issue and need to be addressed. Creation of ownership among stakeholders for the canal fisheries is important.
- The inlets and outlets of the canals need to be covered with nets to prevent escape of fish from the canal and *vice-versa*.
- Capacity building of the stakeholders on canal fisheries is necessary to increase fish production.
- Governance is the prime issue as canals are common property resource.

SUMMARY

The study discussed about the potential culture practice/ enhancement in canals of Indian Sundarbans. It is understood that the canals or modified irrigation systems can supply additional livelihood support through fisheries to rural poor provided attention is given to this pre-existing habitat. Restoration of productive fisheries in canals needs management regimes to save water needed for farming and conserve sustainable fish stocks. Governance of canals is the major issues due to the conflict of interest between agriculture and fisheries as these are common property resource. At the same time, the probable impact on biodiversity and ecological integrity are concern, which needs more cutting-edge research on these resources. For successful management and development in this sector, it is essential to have the appropriate understanding of these ecosystems with site-specific suitable methodologies/ enhancement practices for fish production and also plausible guidelines which can maintain the role of canal fisheries as a social "safety net" along with promotion of fishers in the locality.

[1]Scientist, [2]Principal Scientist, [3]HoD and Principal Scientist, [4]Director, ICAR-CIFRI, Barrackpore, *Corresponding author's e-mail: basantakumard@gmail.com





Closed sub-surface drainage to ameliorate waterlogging and salinity in a canal command area

Tushar Umedbhai Patel*

Navsari Agricultural University, Navsari, Gujarat 396 450

Reclamation of saline, saline-alkali and waterlogged soils formed due to the intrusion of flood waters can effectively be done by the closed sub-surface drainage (CSSD) technology. The CSSD technology is appropriate under the salinity and water logging conditions to leach out the excess and harmful salts with excess water from the root zone to provide a better environment to the plants to grow. In south Gujarat, CSSD technology was installed in Patel's farm situated at Virpor and Ghala village, Taluka Choriyasi, District Surat of Gujarat in the command of Surat branch under Ukai Kakrapar (UKC) irrigation project. With successful operation of the system installed during 2012-13 at farmers filed, the water logging problem has reduced and average water table has been lowered from 36.5 to 50.0 cm. The soil salinity has been reduced from 6.7 to 3.5 Ds/m. The sugarcane yield has increased from 58 to 96 t/ha i.e. *65.5 % higher than areas not adopting CSSD technology. The farmers are happy and express the satisfaction over the performance of dual purpose subsurface cum irrigation system.*

Keywords: Closed sub-surface drainage, PCV pipe, Soil salinity, Sugarcane, Waterlogging

IRRIGATION projects play a pivotal role in enhancing the crop productivity, livelihoods of the farmers and prosperity to the area. However, if the irrigation facility developed is not properly utilized, then the natural resources viz., soils and crops/vegetation may be deteriorated to such an extent that they become unproductive. Though drainage is envisaged in project document of each and every command, seldom it receives due attention after commissioning of the project. The introduction of irrigated agriculture, however, has resulted in the development of the twin problems of water logging and soil salinization. Farmers apply huge quantities of canal water assuming more irrigation could bring more yield. Furthermore, the introduction of canal irrigation not only brings the much needed water, but also imports salts as irrigation water contains considerable amounts of salt. In many canal commands, there has been a rise in the water table and consequent degradation of soils through water logging and secondary salt build-up. Further the impact of irrigation over many years have caused the ground water table to rise into root zones in these command areas, which led to reduction in crop yields. The time required to appear these problems and their severity vary with soil type, cropping system adopted by the farmers, maintenance of the canals and presence of network of natural drains in the command areas.

Indiscriminate and excess use of water by farmers and faulty irrigation application system, the worst fears came true in the form of water logging and secondary salinization particularly in low lying areas of Ukai-Kakrapar Command (UKC) on river Tapi in South Gujarat. In UKC area, 15% of land is actually suffering from these problems and another 25% land is critical mainly due to high clay containing soils, adoption of faulty irrigation methods (flooding, field to field etc.) by ignoring the land irrigability classification. Besides, inclination towards high water consuming crops like paddy, sugarcane, banana etc., by neglecting suggested cropping pattern and heavy rainfall (1,400 mm).

Under these circumstances, subsurface drainage is considered as a most suitable approach for removal of excess groundwater from the crop root zone system which promotes safe environment for efficient crop growth. Moreover, subsurface drainage has been found to be the only solution for providing land reclamation on a long-term basis when salts are present in the soil and groundwater. The scientists have

Fig. 1. Installation of sub-surface drainage

planned proper drainage and other land planning initiatives. Development of efficient drainage system and its maintenance, provision of interceptor and collective surface drains, plantation of bio-drainage trees resulted into lowering of water table and farmers are able to cultivate their land. The farmers of UKC have not simply adopted the CSSD in affected area, but they are also doing some modifications in the system, so as to meet their site-specific requirement. Many farmers have been benefited with this achievement but Patel's farm at Virpor and Ghala village, Taluka Choriyasi, Surat district, Guajarat, emerged as a leader in adopting the package of technologies for reclaiming barren land due to water logging and salinity (Fig. 1 and 2), the success story is addressed here.

Farmers details: The closed subsurface drainage has been installed on the fields of Shri Morarbhai Koyabhai Patel, Head of family, Shri Balvantbhai Morarbhai Patel and Nayanbhai Morarbhai Patel are the son at Virpor and Ghala village, Taluka Choriyasi, District Surat of Gujarat state in the command of Surat branch under Ukai Kakrapar irrigation project with the technical support from Soil and Water Management Research Unit, Navsari Agricultural University, Navsari, Gujarat.

Objective: The basic objective of drainage is to remove excess water from the waterlogged fields. Further, it also helps in reducing secondary salinization/ sodicity problems from the field. The other problems related to water logging conditions are poor growth and yield of crops, land workability (preparation) and higher infestation of pest and diseases are the problems due to continuous wet condition i.e., *vapsa* condition is not attained. All these aspects have negative impact on crop growth and ultimately reduce yield. Subsurface drainage installation helps in lowering the water table below root zone by draining excess water and also reclaiming the salt affected soils.

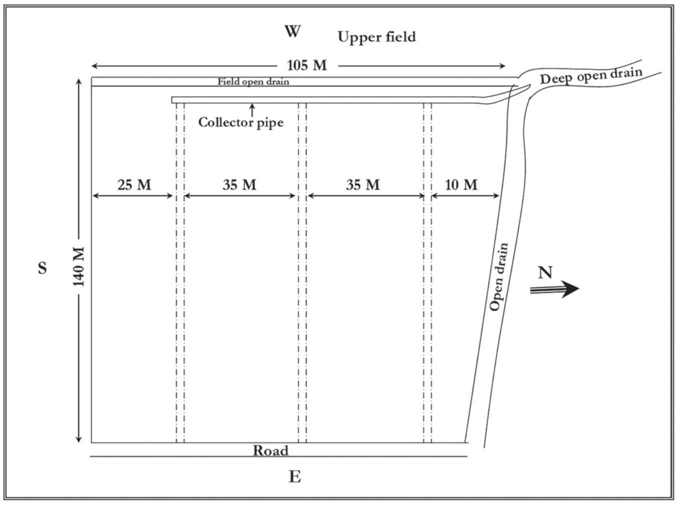
General characteristics and history of fields: The soils are heavy with more than 48% clay. The soil is moderately alkaline in reaction, and high in soil salinity. The soil salinity in most parts of the area is higher than 6.5 dS m^{-1} at all the depths. On the basis of electrical conductivity of saturation extract (ECe) of soils, most of the area has been identified as saline. The water table of this area is highly fluctuated and observed at soil surface during monsoon season and 1.5 m deep inside the ground during summer season. Rainfall is very high during mid July to August.

Earlier, farmers used to grow cotton and pigeon pea in this area. However, they shifted to sugarcane with the availability of Ukai Kakrapar irrigation. the said farmer with the 10 acres of fertile land, recalled the happiness of his elders when canal water was made available to their land. Patels were very happy to irrigate their field and getting good yield of sugarcane and their family was prospering. The number of irrigations varied from 12 to 14 times during the entire crop growth period of sugarcane crop. The canal water has a salinity of 0.3 dSm^{-1}, thus an irrigation gift of 1,600 to 2,000 $mmyr^{-1}$ added 3.5 to 4.0 t ha^{-1} of salts to the soil profile. He was irrigating their field as much as possible but slowly he realized that problem of waterlogging (within 1 to 1.5 m below ground level) building up in their land due to low lying topography, over irrigation and low permeability of soil. Moreover, seepage of canal contributed major share of this water and the whole area

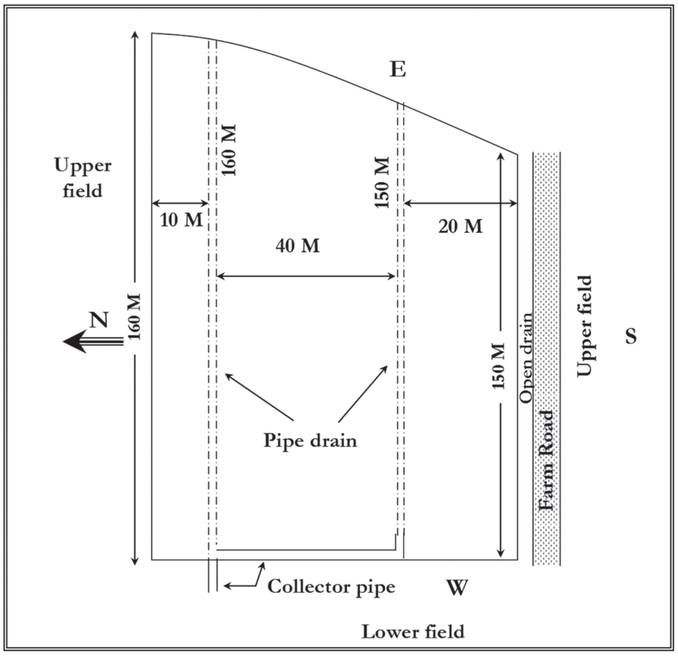
Fig. 2. Crop after installation of CSSD

became muddy and there was no way to drain out the excess water. The natural drains were choked with weeds like *Typha, Lantana* and *Ipomea*. Unable to get the proper yield, he was very worried and realized that over irrigation and unscientific practices have made his land barren. Meantime, the farmers heard some technology about drainage and consequently they visited the Soil and Water Management Research Unit, NAU, Navsari. They interacted with the scientists and were happy to know about the subsurface drainage technology which can get rid of the water logging as well as salinity and sodicity of their field. As suggested by the scientists, the farmers followed the guidelines for reclamation in their own lands. With full enthusiasm and motivation, he helped the scientists in all respects and he was happy that the drainage which earlier was choked with weeds was cleared with the use of herbicides as suggested by the scientists. The University recommends subsurface drainage for waterlogged and salt-affected lands besides addition of organics (manures and green manure). Farmers themselves bore the expenditure on the subsurface drainage system. Now, they realize the importance of maintaining the proper drainage in the field.

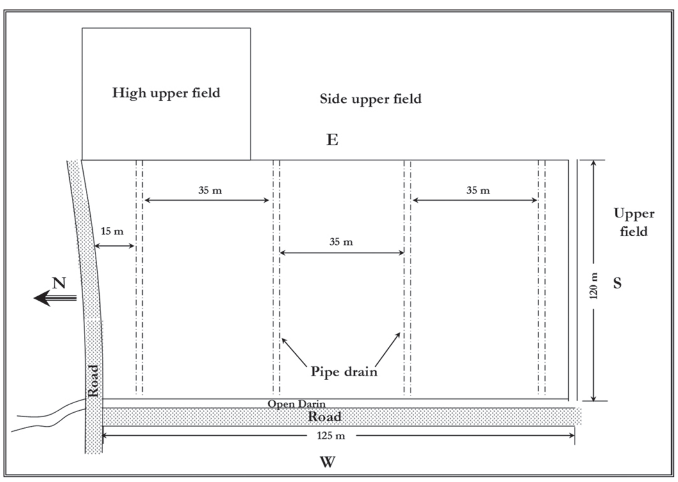
Fig. 3. Closed sub-surface drainage system layout



Farmer's name: Morarbhai Kalidasbhai Patel, *Village:* Virpor, *Taluka:* Mandvi & *Dist. :* Tapi, Block No. 184, Area. 1.47 ha.



Farmer's name: Nayanbhai Morarbhai Patel, *Village:* Ghala, *Taluka:* Kamrej & *Dist. :* Suarat, Block No. 314 Area. 2.40 ha.



Farmer's name: Balvantbhai Morarbhai Patel, Village: Ghala, *Taluka:* Kamrej & *Dist. :* Suarat, Block No. 314 Area. 1.50 ha.

Drainage technology technical details

Corrugated PVC pipes with a diameter of 80 mm were used for the field drains and rigid PVC pipes with diameters of 180 mm for the collector drains (Fig. 3). Subsurface drainage with PVC corrugated pipes were laid at 35-40 m between two drains and at an average depth of 1-1.5 m. Price of PVC corrugated pipe was around ₹ 85/m. The cost include excavation trench using JCB, labour cost for laying of pipe corrugated pipe and refilling on trench, cost and laying of PVC pipe as conveyance connecting corrugated pipe to nallas outside field was around ₹ 25,000 to 30,000 per ha.. Overall, cost of the system was around ₹ 40,000 to 55,000 per ha.

The system works by gravity and drainage water disposed in to the stream, which ultimately carries it to the Tapi River, about 1.2 km away from the farmers' fields. At one of the main closer drainage, farmers have made provisions to drain surface water into it, in the event of surface stagnation due to excess rainfall. The collector pipe thereafter is of rigid PVC pipe. Whenever required, fresh water is pumped from the stream/nala and put into rigid collector through pump stand. The collector line is used as lift irrigation pipeline to irrigate the fields. Thus, farmers are using collector line for surface drainage, subsurface drainage and irrigation. Because of multiple uses of the system they are also taking care of the system themselves.

Increase in sugarcane yield and economics

Sugarcane yield from the closed subsurface drainage system were from 87 to 105 t ha^{-1},

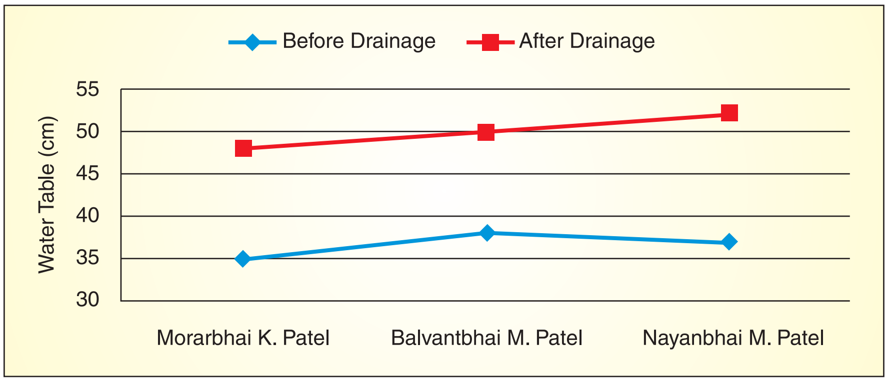


Fig. 4. Impact of Closed Sub-Surface Drainage System on ground water table

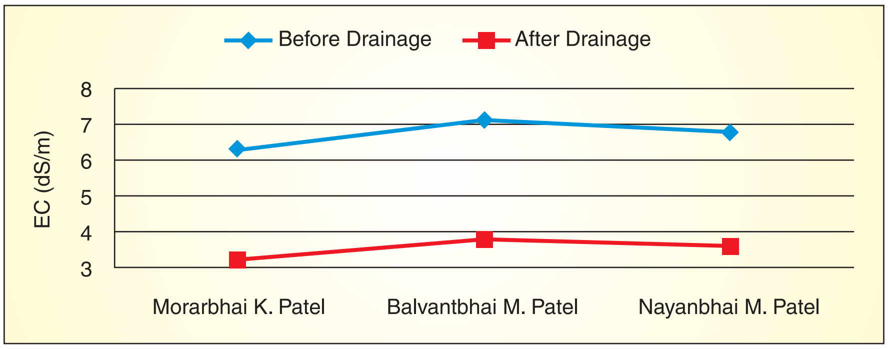


Fig. 5. Impact of Closed Sub-Surface Drainage System on soil salinity

Table 1. Impact of CSSD System on sugarcane crop production and economics

Farmers name	Crop	Crop yield ($t\ ha^{-1}$) Drainage installation Before	After	Increase in yield (%)	Cost of cultivation (₹/ha)	Net income (₹/ha)	BCR
Morarbhai K. Patel (Head)	Sugarcane	62	96	54.8	126,000	220,800	1.75
Balvantbhai M. Patel (Son)		60	105	75.0	130,000	241,500	1.86
Nayanbhai M. Patel (Son)		52	87	67.3	125,000	200,100	1.60
Average		58	96	65.5	127,000	220,800	1.74

Note: Sugarcane: ₹ 2,300/tonne (average of three year)

however, average yields obtained under closed subsurface drainage systems were noticeably significant i.e. 96 t ha^{-1} that was 65.5% higher compared to areas without installation of CSSD system areas that produced only 58 t ha^{-1}. Subsurface drainage drain excess soil water and salt from the rhizosphere, that keep the soil moisture and aeration and favours the crop growth. Quantifying the influence of this system on the salinity of drainage water indicated that electrical conductivity (EC) and total salt load decreased markedly. Looking to the performance of sugarcane cropyields, it was increased with the installation of subsurface drainage system. The results showed direct relationship between improvement of system performance and increasing in sugarcane yield, followed by a rise of the economic returns. An economic analysis showed that the cost of installing subsurface drainage systems was readily justified by annual increase in sugarcane yield.

Reduction in ground water table due to Closed Sub-Surface Drainage System

The mean water tables observed goes lower from year to year as expected. The water table range from 35–38 cm (average: 36.5 cm) below ground level before CSSD was lowered down that reached at 47-52 cm (average: 50.0 cm) in the post-drainage situation indicating significant improvement in ground water table (Fig. 4). By improving the soil conditions for water movement and also increasing drain water discharges, the performance of deep drainage systems improved. The main causes of the rise in water table are precipitation, excess irrigation, leaching water, seeps from higher land or irrigation canal and ditches and groundwater under artesian pressure that reduced by subsurface close drainage technology by removing excess groundwater from the crop root zone system which promotes safe environment for efficient crop growth that reflect on higher crop yield.

Reduction in Soil Salinity due to Closed Sub-Surface Drainage System

There was considerable reduction in soil salinity. Graph was drawn to observe the changes in ECe before and after the installation of the system (Fig. 5). Overall effect was positive and three years after installation, ECe has been reduced. Before the installation of drainage systems, ECe ranged from 6.3 to 7.1 (average: 6.7 dSm^{-1}) and after installation of drainage systems, it was observed 3.2 to 3.8 (average: 3.5 dSm^{-1}), respectively. The upper layers are reclaimed at a faster rate than the deeper layers. Within three years after installation of drainage systems, sub surface drainage technology can also be effectively used in the saline and sodic soils to remove the salts in huge quantities from the profile in shortest possible time. Establishment of sugarcane crop was good after installation of drains and general yield increase was 55 to 75%.

Conclusion

Adoption of sub-surface drainage system was found highly effective in reclamation of water logged and salt affected lands. Water table and ECe of soils were improved by 52.2 and 36.9%, respectively. Ultimately, sugarcane crop yield increased by 65.5%.

Scientist, *Corresponding author's e-mail: tushagri.ank@nau.in

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Impact of Epizootic ulcerative syndrome

on small-scale fish farmers and its management

P K Pradhan, Anutosh Paria, Gaurav Rathore and Neeraj Sood

ICAR-National Bureau of Fish Genetic Resources, Lucknow, Uttar Pradesh 226 002

Epizootic Ulcerative Syndrome (EUS) caused by Aphanomyces invadans *is one of the most destructive pathogens of freshwater fishes. The disease is a major problem is culture-based capture fisheries practiced mainly by small-scale farmers with limited resources. The losses due to the disease have significant impact on the livelihood particularly food and nutritional security. To date, there is no effective treatment for this disease. Therefore, there is a need to develop treatment measures which can be easily affordable for the farmers. ICAR-NBFGR under the All India Network Project on Fish Health has developed formulation which has been found to be quite effective in treatment of this disease.*

Keywords: *Aphanomyces invadans,* Epizootic Ulcerative Syndrome, Small-scale farmers, Treatment

EPIZOOTIC ulcerative syndrome (EUS) is a serious disease of freshwater and estuarine fish, and more than 160 fish species are known to be susceptible to this disease. It is the first disease which has spread internationally with major impacts, especially in the developing world. The disease has a complex infectious aetiology and it is clinically characterised by the presence of *Aphanomyces invadans* and necrotising ulcerative lesions leading to a pathognomonic granulomatous response. In early stages, the gross lesions are characterised by pinhead-sized red spots on the body surface including head and fins, caudal peduncle, dorsum or operculum with no noticeable haemorrhages or ulcers. In the intermediate stage, the lesions are represented by small (2-4 cm) dermal ulcers, with associated loss of scales and haemorrhages. In the advanced stage, lesions appear on other parts of body of the fishes and expand into large necrotic open ulcers; resulting eventually in death.

Given the wide geographical area, and the diverse range of habitats in which EUS-affected fish occur, a particularly diverse mix of microbiological agents have been recovered from affected fish. Some of these agents may significantly contribute to the disease complex in a particular outbreak but it is important to distinguish them from the factor(s) essential in all EUS outbreaks. However, research works have confirmed that *Aphanomyces invadans* is the primary causative agent of the disease. In an expert consultation on Epizootic ulcerative syndrome (EUS) held during the Fifth Symposium on Diseases in Asian aquaculture, Australia in 2002, majority of the experts supported a new name for the disease i.e. Epizootic Granulomatous Aphanomycosis. However, as the old name epizootic ulcerative syndrome is familiar, till date the disease is called as EUS. It is important to note that the World Organization for Animal Health (OIE), in its Aquatic Animal Diagnostic Manual and Code mentions the disease as 'Infection with *Aphanomyces invadans*' like other OIE-listed diseases, suggesting that *A. invadans* is the causative agent.

A. invadans is a water mould (Omycete) which includes other important fish pathogens, such as species of *Saprolegnia* and *Achlya*. This group of pathogens although look-like fungi but are not true fungi. Unlike fungi, oomycetes do not have chitin-based cell walls; instead their cell walls are composed of cellulosic compounds and glycan, and the nuclei within the filaments are diploid, rather than haploid as is the case in fungi. For this disease, secondary zoospores of *A. invadans* are considered as the infective stages that germinate upon attaching themselves to fish skin that has been damaged and subsequently leading to severe necrotising granulomatous lesions.

Impact of the disease

The most notable epidemiological characteristic of the disease is its vast host range which includes highest number of documented host aquatic animal species susceptible to clinical disease. As reported earlier, over 160 fish species are affected and they belong to 54 families under 16 orders. Such a wide host range has special relevance in the tropics and sub-tropics, where culture-based capture fishing is most common. It is important to mention that in one of

Fig. 1. Mortalities due to Epizootic Ulcerative Syndrome in culture-based capture fisheries in Lakhimpur Kheri district of Uttar Pradesh

the studies, it was observed that even after more than three decades of its first occurrence in the country in the year 1988, a prevalence of ~ 69% was recorded and 13 fish species were found to be infected in Lakhimpur Kheri district of Uttar Pradesh (Fig. 1). Interestingly, EUS was observed in seven new species for the first time in these natural outbreaks. In addition, there have been several reports of EUS from Northeast India where rice-fish culture is practised in some parts. Moreover, many cyprinids, the dominant human food species in India, are susceptible to EUS. Notably, fish has high concentrations of bio-available vitamins and minerals (such as vitamin B12, calcium, iron and zinc), essential fatty acids and animal protein. In addition, small indigenous fish species often caught by such farming communities are typically eaten whole and can make a significant contribution to the micronutrient intake of their families. Therefore, the importance of culture-based capture fisheries for the rural poor is much greater where fisheries are a key protein and nutrient source and occurrence of EUS can significantly affect fish catches. Hence, the potential impacts of the disease on fisheries, aquaculture and ecosystems can be serious.

Management of EUS

In the regions, where the disease is endemic, attempt should be made to eradicate *A. invadans* from an already infected area. Removal of all susceptible fish from ponds prior to stocking, drying and liming of ponds, disinfection of contaminated equipments/nets could be considered for eradication programmes. Once eradicated, the pathogen from a culture facility, the goal should be to prevent its re-introduction. It is likely that infections may be spread by affected/carrier fish, contaminated water, equipment, net etc. Therefore, obtaining seed and brood from EUS-free farms, obtaining water from disease-free source, using screen to remove wild fish, treatment of water with disinfectants etc. can be considered under exclusion strategies. After eradication and preventing reintroduction, using the epidemiological evidences, intervention strategies and special management measures should be adopted during periods of high EUS risk. In one of the epidemiological studies undertaken in an Indo-UK research project in the Maharajganj district of Uttar Pradesh at ICAR-NBFGR, it has been observed that high stocking densities and poor water qualities are associated with fish mortalities during winter seasons which coincide with EUS season. Therefore, during high risk periods, keeping the stocking densities as low as possible, avoiding stress, maintaining good water quality, preventing skin damage caused by ectoparasites and bacteria, harvesting of susceptible fish before the high risk period are some of rational approaches. In addition, the general health and the EUS status of susceptible fish should be monitored regularly. This will help to take appropriate actions if EUS is observed.

Although a number of chemicals have been evaluated for their efficacy for treatment of EUS but as on date, there is no effective treatment for EUS-infected fish. It may be noted that infection with *A. invadans* is usually observed in extensive aquaculture systems which are practised mainly by small-scale farmers with limited resources. Therefore, there is a need to develop treatment measures which can be easily applied. Keeping the same in consideration, ICAR-NBFGR under All India Network Project on Fish Health funded by ICAR, carried out detailed investigation to determine the concentration-specific therapeutic efficacy of 11 compounds with antifungal properties against three different life-stages (zoospore production, germination of zoospores and growth of hyphae) of *A. invadans*. Based on the results of *in vitro* studies, two compounds were further evaluated in 38 farms at three different locations in Assam, West Bengal and Uttar Pradesh. The affected fishes in the above farms had typical lesions due to oomycete infection. Following single application of the formulation, the fishes in all the affected farms showed significant reduction in lesions. In addition, the formulation has also been used for treatment of 12 disease cases diagnosed with oomycete infection alone or co-infection with bacteria. In all the cases, the formulation also had significant effect in resolution of the lesions. This formulation would help in significantly reducing losses due to EUS and thereby helping the farmers to improve their food and nutritional security.

Corresponding author's e-mail: pradhanpk1@gmail.com

Rainbow trout fish farming in upland hilly regions

– A game changer for the small farmers

Vinod Kumar Bist[1]* and Mitali Ghosh Roy[2]

National Bank Staff College, NABARD, Lucknow, Uttar Pradesh 226 012

Trout, a common name for a number of species of cold freshwater fishes is available and cultured in the upland catchments of many tropical and sub-tropical countries including India. Introduced in the country mainly to encourage sport fisheries initially, it also has lot of commercial value and being used as important table fish. Introduction of trout has helped the fish to become established in most of the cold water aquatic bodies of the country.

Keywords: Hilly region, Rainbow trout, Small farmers

IN trout farming, the farmers from Jammu and Kashmir, and Himachal Pradesh have done much better than most of their counterparts. Considering the larger picture, trout cultivation in the hilly regions of the country right from Jammu & Kashmir, Himachal Pradesh, Uttarakhand and also other Himalayan states can be a game changer for especially the poor small and marginal farmers. This is true, especially for those who can source supply of water in their farm land from the natural *nallahs* by constructing water channels.

Some of the essential as also limiting factors required for cultivating trout in the upland regions are as under.

- Requirement of higher dissolved oxygen content and temperature range between 10 and 20°C.
- Availability of clean, clear, cold and continuous flow of water is the most crucial deciding parameter for selection of site for setting up of the rainbow trout farm.
- Proper selection of site for trout farm is primary requirement as the site should receive water which must be free from silt.
- Besides the water quality, the water flow rate in the trout ponds or raceways is also important. A minimum water flow of about 2-3 litres per second (lps) is required.
- Availability of adequate and timely supply of quality trout fish seed is important limiting factor coming in its success.
- While cultivating the trout fish, it is required to be given protein rich feed in the raceways.

Trout farming has proved to be a money spinner and boon for small farmers in the hilly regions of the country. For sustainable development of rainbow trout farming in the country, constant support and cohesion of policy makers, research organizations and concerned line departments is equally important. There is also a need to include more components in the existing scheme of the Government of India.

The distant hilly district of Mandi in the state of Himachal Pradesh is endowed with rich cold water resources. Shri Rajeev Jaswal of village Shanan, a person in his mid-forties was unemployed and struggling to make his ends meet before the year 2000 (Fig. 1). Inspired by one of his close relatives, he utilized the natural water source flowing through his hilly farm land and started cultivating carp fishes. Initially, he started with a Chinese carp variety of fish called as common carp by cultivating them in rectangular *kutchha* pond. Soon he realized that the cultivation was not a success as the fish growth suffered due to intense cold temperatures. Jaswal did not lose heart and next year initiated cultivation of rainbow trout, an exotic cold water fish well acclimatized to the hilly regions of the Himalayas.

Trout, a common name for a number of species of cold freshwater fishes is available and cultured in the upland catchments of many temperate tropical and sub-tropical countries including India. Introduced in the country mainly to encourage sport fisheries initially, it also has a lot of commercial value and being used as important table fish. Introduction of trout has helped the fish to become established in most of the cold water aquatic bodies of the country.

Taking support of the Department of Fisheries, Jaswal converted the rectangular carp fish pond into a raceway pond of 8 × 2 × 1.5 m size and started cultivating rainbow trout in 2001. Besides the one-time cost spent on construction of raceway, major expenses were incurred on procuring 2,000 rainbow trout seeds and protein rich feed costing ₹ 45/kg. He could harvest a crop of about 250-300 kg of rainbow trout in 13 months giving him approximately an income of ₹ 55,000. Overwhelmed with this success and also subsequently the support received under various Government of India programmes viz. Rashtriya Krishi Vikas Yojana and the Blue revolution scheme, the farmer constructed thirteen cemented raceways of varying size in the next few years. At present, the farmer can produce about nine tonnes of rainbow trout from his farm comprising of 13 raceways constructed in an area of about 800 sq meter within 14-15 months. The farm gate price of the fish is presently more than ₹ 500/kg. To sum up, small farmers in upper hilly region can dream of earning a substantial amount of money from small pieces of land provided they utilize the water resources judiciously and by selecting proper economic activity like that of trout farming.

In trout farming, the farmers from States and UT like Jammu & Kashmir and Himachal Pradesh have done much better than most of their counterparts. Considering the larger picture, trout cultivation in the hilly regions of the country right from Jammu & Kashmir, Himachal Pradesh, Uttarakhand and also other Himalayan States can be a game changer for especially the poor small and marginal farmers. This is true especially for those who are having a good source of perennial water supply in their farm land from the natural nallahs by constructing water channels. Some of the essential points as also limiting factors required for cultivating rainbow trout (Fig. 2) in the upland regions are as given under.


Fig. 1. Rainbow trout Farm of Shri Rajeev Jaswal at Shanan, Himachal Pradesh

- It grows well in waters with a higher dissolved oxygen content and temperature range between 10 and 20°C. The fish may not survive at temperatures above 25°C, hence, it is imperative to culture the fish only in the higher hills. As the temperature rises and dissolved oxygen in the water decreases, fish begins to experience stress. Stress begins to set in well before the water temperature reaches the lethal limits (above 20°C).
- Availability of clean, clear, cold and continuous flow of water is the most crucial deciding parameter for selection of a site for setting up of the rainbow trout farm. The fish can be cultured only in flow through ponds popularly called as raceways. Continuous flowing water ensures clear and highly oxygenated waters in the raceways which is essential for the fish.
- Proper selection of site for trout farm is primary requirement as the site should receive water which must be free from silt. The water supply from the natural *nallahs*/drains till the trout ponds or raceways can be channelized by constructing a cemented channel.
- Besides the water quality, the water flow rate in the trout ponds or raceways is also important. A minimum water flow of about 2-3 litres per second (lps) is required. This also helps in maintaining the desired level of oxygen.
- Availability and timely supply of quality rainbow trout fish seed is very important for success of a trout farm. At present most of the trout seed hatcheries are located in remote areas of the hilly states and it often becomes difficult for the farmers to get quality trout seeds on time.
- Protein rich fish feed is the other essential input for the trout. Good quality, energy rich and nutritionally balanced feed is very essential especially when the size of the fishes are small.

The fish attains table size in about 12-14 months (about 250-300 gm). It is well adapted to supplementary feed and culture in raceway ponds. In recent years, farmers have shown greater interest in commercial rainbow trout farming. Requirement of technological advances in the form of improved feed having higher food conversion ratio (FCR), farm design with greater efficiency, optimization of stocking density, brood stock maintenance and hatchery practices are necessary for the future development of trout farming in India.

The fish although fetches a good farm gate price for the farmers (₹ 500-600 per kg), however, in future, with more farms coming up, marketing network needs to be strengthened. Since farms are located in remote areas in the hills with poor transportation facilities, access to the market may be a challenge. Rainbow trout being a high value low volume fish and highly perishable commodity, the produce needs to be transported in shortest possible time under refrigerated condition to fetch good price. In the absence of cold chain facilities and reliable market linkage, expansion of rainbow trout farming on a commercial scale may be difficult. Value addition of the final produce may also be thought of in future to increase its sales and consumption.


Fig. 2. Rainbow trout

Although rainbow trout farming activity is highly remunerative for the small as well as large farmers in the hilly regions, it is also fraught with some risks. Some of them are listed below:

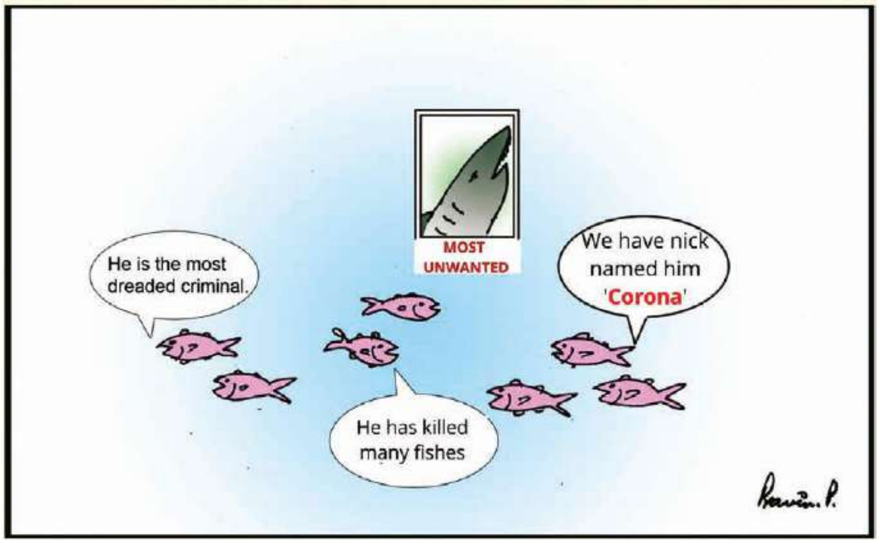
- Timely availability of quality seeds for stocking
- Timely availability of quality feed in desired quantity
- Maintenance of clean and continuous water flow in the raceway
- Proper watch and ward facilities
- Arrangements for marketing of fish.

Rainbow trout farming in the upper hilly regions can be a highly remunerative activity and can easily be adopted by the small farmers. For this, the farmers need to be suitably trained from the respective Fisheries Departments on aspects related to raceway construction, seed stocking, feeding and rearing management. The rainbow trout fish requires a continuous flow of cold, clear and clean water. Timely availability of quality seeds in sufficient quantities and protein rich formulated feed are very important aspects of trout farming. Although, the farm gate price of the harvested fish is quite high, more number of farmers and production in the coming years may become a cause of concern. For promoting the culture of rainbow trout, even Government of India is providing fair amount of subsidy to the interested farmers.

Rainbow trout farming has proved to be a profitable venture and a boon especially for the small farmers of the hilly regions of the country. For sustainable development of rainbow trout farming, constant support and cohesion of policy makers, research organizations and concerned line departments are equally important. There is a need to include some of the essential cost components like cost of construction of sedimentation tank, bird protection net, construction of channel from water source till raceway of the farmers etc. in the existing schemes of the Government of India.

This will be great incentive for the small and marginal trout farmers, as presently, they have to spend a lot money on these components. The existing guidelines also compels the farmers to construct the minimum standard size of raceway viz. 51 cubic meters. In view of smaller land holding of the farmers and land being highly undulated, the farmers may be allowed to select the size of the raceway as per the land available with them. All these measures will go a long way not only in enhancing the production of the highly priced rainbow trout fish in the upland regions but also will turn out to be a major source of self-employment in the hilly states.

[1]General Manager/Faculty Member, [2]Chief Technical Officer, DKMA, ICAR New Delhi, *Corresponding author's e-mail: bistvinod64@gmail.com



Indian Farming **70**(11): 23–26; November 2020

Success Story

Fisheries enhancement through stocking of fingerlings in Indian reservoirs

for doubling fisher's income and livelihood security

U K Sarkar[1]*, Lianthuamluaia[2], Mishal P[3] and Suman Kumari[4]

ICAR-Central Inland Fisheries Research Institute, Barrackpore, West Bengal 700 120

Fingerling stocking and culture-based fisheries (CBF) is one of the major fisheries enhancement strategies practiced in reservoirs. In the recent years, the reservoir productivity in the country has improved through adoption of culture based fisheries coupled with financial assistance from National Fisheries Development Board (NFDB), Govt. of India and technical guidance from ICAR-CIFRI. The present study deals with the assessment of impact of fingerlings stocking on the major carp production in selected reservoirs in three different states. Successful adoption of CBF in 83 small reservoirs of Odisha led to the increase of fish yield to 204-323 kg/ha/yr. Similarly in Chhattisgarh the fish yield increased significantly from 48-160 kg/ha/year after scientific stocking of fingerlings in 34 reservoirs. The fish yield increased from 1.1 kg/ha/yr in 2004-05 to 43.46 kg/ha/yr in 2017-18 due to adoption of fish stock enhancement strategy in large reservoir of Madhya Pradesh. Stocking and management of fingerlings in these reservoirs resulted in increased availability of fish, enhanced food security, livelihood opportunities and increased farmer's income.

Keywords: Fingerling stocking, Fisheries enhancement, Livelihood, Small reservoir

IN India, the area under reservoir was estimated at about 3.5 million ha having enormous potential for inland fisheries development. Presently, stocking of fish in reservoir or culture based fishery is the most important strategy for sustainable enhancement of fish production. Enhancement of fish production through stocking was recorded in many reservoirs of India and other parts of the globe. Scientific assessment of the actual impact of stocking on the fish yield is lacking which is essential for fixing of the optimum stocking density and refining the stocking management for sustainable enhancement of fish production from the reservoirs.

The reservoirs of India are situated in tropical region with high nutrient turnover favouring natural productivity. The fish production in India is low due to poor adoption of scientific stocking strategy and agro-climatic factors. Initially, in absence of scientific guidelines, the Indian reservoirs were stocked arbitrarily. Fish seed Committee of Government of India (1966) recommended stocking rate of 500 fingerlings/ha (40-150 mm). Despite of the recommendations, reservoirs were understocked owing to unavailability of quality seed and inadequate fund availability. After the boost in fish seed production in the country through induced breeding of carps coupled with financial assistance from National Fisheries Development Board (NFDB) after its formation in 2006, the stocking rate has increased over the years which has reflected in the increased fish yield from these water bodies. The stocking recommendations were later revised to 500 fingerlings/ha, 1,000 fingerlings/ha and 2,000 fingerlings / ha for small, medium and large reservoirs, respectively.

The information on impact of stocking on fish yield in reservoir of India is sparsely and irregularly available. Although different states have their own stocking program but no recent systematic assessment has been carried out and documented properly in the recent years. Impact assessment of stocking was carried out only for selected reservoirs of India. As information on the impact of stocking is needed for development of stocking strategies for enhancing fish production in reservoir, an attempt for updating the information is highly needed. The Government of India is emphasizing on second blue revolution from eastern India particularly from the inland open waters. In this background, the present study attempted to assess the impact of stocking on the fish yield i.e. the fish catch per unit area per unit time (kg/ha/yr) from selected reservoirs of India and discusses issues and suggests management measures and way forward for sustainable fisheries enhancement and livelihood security of fishers.

Methodology for assessment of impact of stocking

The data on stocking and production of Indian reservoirs were collected from respective state department of fisheries to assess the impact of stocking of Indian Major Carp (IMC) i.e. *Catla catla*, *Labeo rohita* and *Cirrhinus mrigala* fingerlings. Impact of stocking were statistically assessed by comparing the change in fish production between the initial year of stocking and the year after stocking of fish using suitable statistical tools such as student t-test. The pattern of stocking and fish yield and their relationship were shown using suitable graphs.

Impact of stocking of fingerlings on fish yield in Indian reservoirs

In India, NFDB and other organizations in collaboration with state fisheries department, stocking of fingerlings of IMCs was executed in reservoirs of different states of India. However the impact of stocking on fish yield was not properly assessed. The impact of this stocking programme on fish yield was highly necessary to find the optimum stocking density for maximum sustainable production. The fish yield has increased from 11.4, 12.3 and 49.9 to 33, 94, and 174 kg/ha/yr from large, medium, and small reservoirs respectively as a result of adoption of culture based fisheries and management practices through NFDB (Fig. 1 and 2).

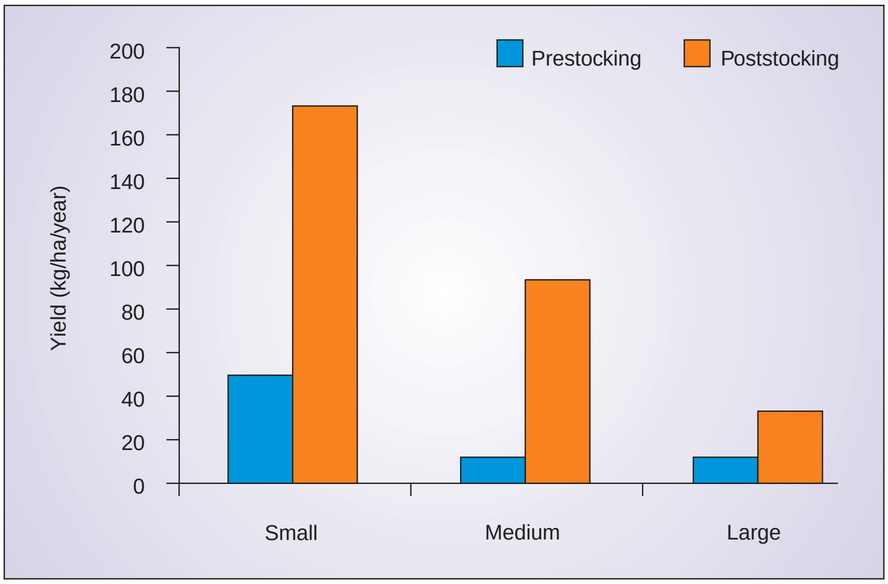


Fig. 1. Impact of stocking on small, medium and large reservoirs of India. *Source:* Adapted from Sarkar *et al.* 2018.

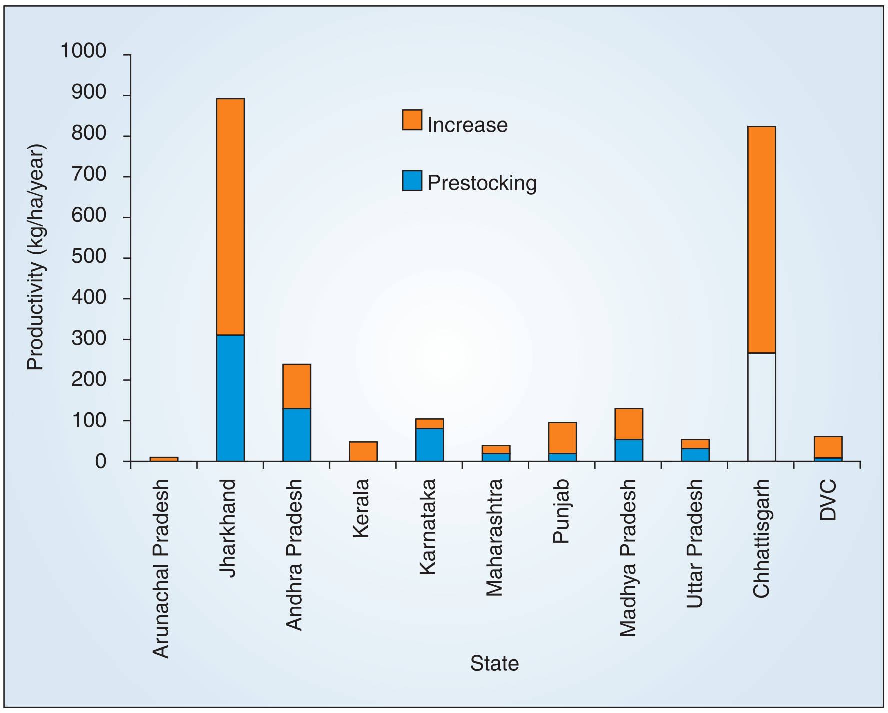


Fig. 2. Impact of stocking in reservoirs of different states of India. *Source:* Adapted from Sarkar *et al.* 2018.

Success stories of culture based fisheries in small reservoirs of Odisha

The basic data on reservoirs, fish stocking details and fish catch information were collected for the year 2012-13 and 2013-14 from Department of Fisheries, Odisha, India to assess the impact of stocking of Indian Major Carp (IMC) i.e. *C. catla*, *L. rohita* and *C. mrigala* fingerlings stocked in 83 small reservoirs from 19 districts during 2012-13 and 2013-14. The stocking programme was implemented with the financial assistance from ST & SC Development Department, Government of Odisha.

The mean production level of small reservoirs of Odisha increased significantly ($P<0.05$, t-test) from 32.46 MT during 2012-13 (initial year of stocking) to 48.69 MT (after stocking) during 2013-14. It was observed that the fish yield of small reservoirs under this program was increased significantly ($P<0.05$, t-test) from 204 kg/ha/yr during the 2012-13 to 323 kg/ha/yr during 2013-14. The per capita fish production was increased from 398 kg/fisher/year during 2012-13 to 702 kg/fisher/year during 2013-14. The visible change in per capita fish production was noticed in

Fig. 3. Fish harvest using gill net from reservoir

Mayurbhanj district.

Culture based fisheries/stock enhancement in Chhattisgarh

A total of 34 reservoirs of Chhattisgarh have been assessed for assessing impact of fingerling stocking. Highest fish yield of more than 300 kg/ha/year was recorded in Kirna reservoir. Fish yield increased significantly ($P<0.05$) from 48 to 160 kg/ha/year after scientific stocking of fish seed in reservoirs of Chhattisgarh (Fig. 3, 4 and 5).

Impact of fish fingerling stocking in Indirasagar reservoir, Madhya Pradesh

Indirasagar reservoir is located in Khandwa district at the heartland of India, Madhya Pradesh. The reservoir of Indirasagar Dam a multipurpose key project was built on the holy Narmada river near Punasa village. Indirasagar reservoir is the largest water reservoir with an area of 91,348 ha at full reservoir level (FRL). Impact of stocking was assessed for 14 years (2004- 2018) based on the data of fish stocking and yield. The fish yield increased from 1.1 kg/ha/yr (Stocking Density: 86 fingerlings/ha/yr) in 2004-05 to 43.46 kg/ha/yr (Stocking Density: 304 fingerlings/ha/yr) in 2017-18 due to adoption of fish stock enhancement strategy (Fig. 6).

Recommendations and way forward

- The carrying capacity of the water body must be considered while formulating stocking strategy as the fish yield potential varies from reservoir to reservoir and region to region.
- Stocking of advanced fingerling (~120 mm) would ensure better survival especially in reservoirs dominated by the large predatory fishes. Also, efforts should be made to remove large predatory fishes through repeated netting or with hook and line.
- Some reservoirs covered under the study were struggling with low

Fig. 4. Fish catch from reservoirs for marketing

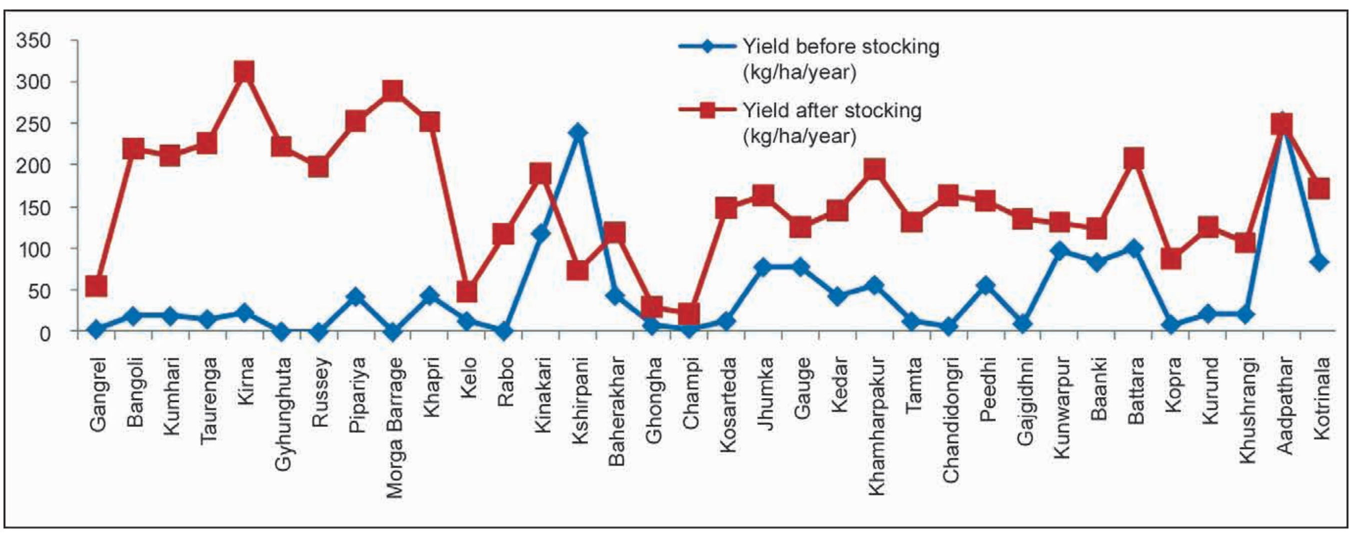


Fig. 5. Impact of fish stocking and yield of 34 reservoirs of Chhattisgarh

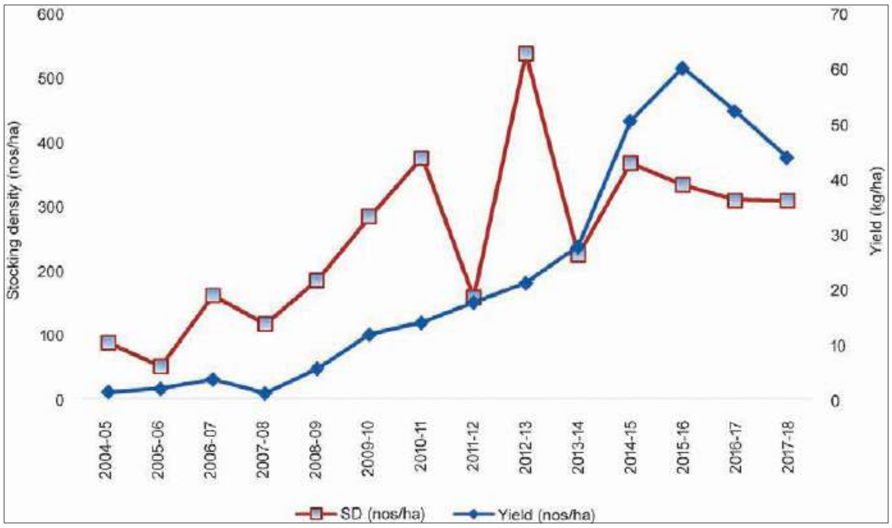


Fig. 6. Trends of fish stocking and yield in Indirasagar reservoir, Madhya Pradesh

Fig. 7. Sensitization of culture based fisheries to the fishers of reservoirs

water level during summer and were frequently affected by the extreme climatic events like flood and drought. Hence, reducing water diversion, adoption of deep pool refuge, late stocking, early harvesting etc. can be used as adaptive management strategies.

- Onsite nursery rearing in cutoff pools, cages, pens etc. by the Primary Fishermen Cooperative Society (PFCS) should be promoted and replicated to the other reservoirs, where adequate quantity and optimum sized fingerlings are not available for stocking.
- Systematic records on stocking, harvesting, gear operated, catch per unit effort (CPUE), fisher's income etc. should be maintained by DoF to quantify the impact of the launched developmental schemes. Moreover, time series data on stocking, environmental and climatic conditions prevailing will help in estimation of weather pattern influences on fish yield.
- Application of remote sensing for delineating the effective water area will optimize the stocking rate as fluctuating water levels may cause massive mortality of the stocked species.
- Impact assessment of climate variability and extreme climatic events on culture based fishery of reservoirs should be done to devise appropriate strategies to mitigate negative impacts in future and to ensure livelihood of fishers (Fig. 7).
- For sustenance of the CBF in small reservoirs, the PFCS should be strengthened to take up such kind of enhancement programs independently in respective reservoirs with no or minimal financial assistance in future.
- Ecosystem based model for estimation of optimum density for sustainable fish production in reservoirs.
- Understanding of ecosystem functioning of the tropical reservoirs for development of climate resilient reservoir fisheries.
- Knowledge based management practices with adequate budgetary support in participatory mode.
- Development of region specific management protocol by utilizing the information of ecological status and fisheries information.

Conclusion

CBF is a stock enhancement practice suitable for water bodies that do not support sustainable fisheries through self-recruiting fish populations. The present findings clearly indicated that stocking rate (1,000 nos./ha/yr) recommended by National Fisheries Development Board, India enhanced the fish yield, however, the impact on fish yield depends on habitat quality, natural productivity, size and management. Estimation of the potential fish yield and generation of basic data on fisheries and ecology are needed for each reservoir for optimising the stocking density and adopting reservoir specific management strategies. Scientific record of stocking and yield data is extremely important as time series data on stocking and production are needed for generating optimum stocking density. Awareness and training for the fishers and cooperative society members are recommended for the better fisheries management of reservoirs in terms of stocking, harvesting, marketing and profit sharing etc. to support the livelihood of fishers living in and around the catchment of the reservoirs.

[1]Principal Scientist and Head of Division, Fisheries Resource Management, [2,4] Scientist, Fisheries Resource Management,[3] Scientist, Fish Nutrition and Biochemistry. *Corresponding author's e-mail: uksarkar1@gmail.com

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Hatchery and Broodstock Management

to produce quality seed in carps

Kanta Das Mahapatra[1]*, Khuntia Murmu[2] and Avinash Rasal[3]

ICAR-Central Institute of Freshwater Aquaculture, Kausalyaganga, Bhubaneswar, Odisha 751 002

The fish production is needs to be enhanced from 13.75 million metric tonnes (2018-19) to 22 million metric tonnes by 2024-25. To achieve this target aquaculture productivity should be augmented from the present 3 tonnes to about 5 tonnes per ha. The contribution of fish seed in total production cost is 5-10% and stocking of better quality seed is crucial to the expansion and progress of aquaculture sector. Inbreeding depression is observed in many of the carp hatcheries because of repeated usage of the same brood fishes without following intermittent replenishment of broodstock. There is lack of genetic norms in most of the hatcheries in India, which account to nearly 30% loss in production due to bad quality fish seed. Thus, using genetically improved seed following proper broodstock management and genetic norms in the carp hatcheries can serve as a suitable alternative to solve the problem of poor quality fish seed.

Keywords: Broodstock, Carps, Fish seed, Hatchery management

WITH the shift from wild harvest of a product to agricultural or aquaculture production, genetic improvement has always been an important developmental strategy. The first stage is usually the process of domestication. Further genetic improvement in agriculture or aquaculture typically has a focus to enhanced production, although the process of domestication for aquatic organisms is at an infant phase than their terrestrial counterparts.

The growing importance of aquaculture has propelled improvements in the technologies required for securing the initial and basic needs for higher productive aquaculture. Aquaculture presently is difficult without induced breeding of commercially cultivable fish species. The fish seed demand has increased steadily for stocking in aquaculture pond and natural water bodies such as reservoirs and rivers. The per capita fish consumption will increase largely in the developing countries in near future.

Seed is the important component for development of aquaculture sector. The rapid growth of aquaculture has been dependent on the availability of desired fish seed in required quantity to the fish farmers. Broodstock or brood fish are the base materials on which the growth of aquaculture industry depends. The availability of quality fish seed throughout the year is crucial for adoption of sustainable aquaculture by farmer. Although large quantities of seed of major cultured species is now produced in hatcheries, seed quality has remained as a major constraint for the success of aquaculture. Poor quality of seed can have a variety of causes related to both genetics and management. The quality and management of brood fish and hatchery practices that lead to inbreeding or contamination have been implicated, as has been poor husbandry during nursing, culture and transportation. Infection with pathogens to the seed may be cause for poor performance.

Issues and importance of breed improvement

Selective breeding is a novel approach to improvise the fish production. The major issues are:

- Non adoption of genetic norms in commercial carp hatcheries resulting in inbreeding depression leading to genetic erosion, loss of important alleles in the population and seed quality deterioration.
- Inadvertent hybridization of Indian Major Carps because of mixed breeding resulting to the genetic pollution in the hatcheries leading to non-availability of the pure strains of the carps.
- Genetically improved breed for desirable traits.

Broodstock is the principal and primary input of an effective and productive hatchery, while, management of broodstock is also vital for quality seed production. Success of induced breeding depends on the availability of adequate number of brood fish. Brood fish should be reared scientifically to get the matured broods during breeding season.

Fig. 1. Spawning and hatching pool for breeding

Hatchery management

For hatchery manager/owners two types of managements are required: Management of broodstock and hatchery while spawning, and Stock management through genetic norms (Fig. 1 and 2).

Management of broodstock and hatchery

To raise good quality brood fish, it is better to collect fast growing healthy yearlings from known source (genetic background) of parent fishes and keep in quarantine for 1-2 months. Stocking density is one of the important measures for assuring good and healthy brooders. The stocking density for brood carps should be at 1,500-2,000 kg/ha in polyculture system.

The prospective brood fishes are to be reared in separate ponds with rich plankton source. They should be checked for secondary infection during netting and if found they should be given prophylaxis with potassium permanganate solution (5 ppm). Two or three months prior the spawning period, water exchange should be done in the brood fish ponds. The periodic examination should be done to check the maturity status of brooders. Due care should be taken to avoid any parasitic infection or any other diseases. The surfacing of brood fish during cloudy weather is usually observed which is mainly due to depletion in level of oxygen. To overcome this it is advised to aerate the water surface.

Feed management is equally important for getting healthy brood fish. In spite of the natural food like plankton, the brood fishes required to be fed adequately with supplementary feed, @ 1-2% of the body weight. CIFABROOD™ a carp broodstock diet having 30-31% protein proved to be very good as brood fish diet for carp. Otherwise, also traditional feed or commercial pelleted feed may be given to the brood fishes. Over feeding may lead to fat deposition in the body affecting maturity adversely. With good scientific husbandry practices fishes attain maturity before onset of monsoon, which can be checked physically by free oozing of milt in male with gentle pressure and bulging belly in case of female.

Hatchery management during spawning/ fish breeding

Brood fishes transportation from the broodstock pond to hatchery is very important. They should be transported in a stress free condition. Canvass carry bags with water may be used for this purpose. After reaching the hatchery, fishes should be allowed to acclimatize in the spawning pool for 15-20 min in a showering condition. As per their body weight and species hormone injection may be applies preferably by intra-peritoneal route (Fig. 2). Over dose may lead to plugging of the female brooder.

Critical water quality parameters that hatchery managers should look for on regular basis in his hatchery are as below:

Water source

Water source should be pollution free. Water should be filtered before entering the hatching pools.

Temperature

Ideal temperature for carp breeding is 28-32^{0}C. Beyond 35^{0}C may affect breeding response.

Oxygen

Dissolved oxygen level in the hatchery pond water should be more than 4.0 ppm. Oxygen level below 2 ppm may lead to mass mortality of hatchlings.

Total alkalinity

Total Alkalinity should be less than 100. Alkalinity above 100 ppm affects the hatching process negatively. Ideal alkalinity range is 60-80.

Further following technical operations in the hatchery may be taken care by the hatchery managers for improving survival of seed.

- Egg collection should be done on a water cushion in the collection

Fig. 2. Broodstock of Jayanti rohu

Fig. 3. Indian Major Carp Seed

chamber.

- Direction of the duck mouths and speed of the water are maintained in such a way that they keep developing eggs away from both inner screen and wall of the incubation chamber.
- The water speed should be maintained at 0.4-0.5 m/sec for the first 12 h, 0.1 m – 0.2 m/sec for the next 6 h and 0.3 – 0.4 m/sec for rest of the operation.
- Reducing speed after 12 h of the operation avoids premature hatching and prolongs hatching of the developing eggs.

Stock management using genetic norms

Fish stock improvement through selective breeding is a novel approach and in the present context it is the need of hour to produce quality carp seed (Fig. 3). The primary goal of aquaculture genetics is to produce quality fish/shellfish seed. In genetic term, 'quality seed' may be defined as those having better food conversion efficiency, high growth potential, better ability for adapting to changing environmental conditions and to resist diseases. It is expected that culture of quality seed will improve over all aquaculture production of the country. The focus of hatchery operator should be to maximize the effective population size to reduce adverse effects of inbreeding depression. Production of pure breed is equally important so following suggestions may be considered to improve brood fishes with genetic norms:

- Avoid spawning of all Indian major carps in single spawning pool to protect the genetic purity of carps' gene pools. Spawning should be done separately for each species to avoid unintended hybridization between these species.
- To increase the heterozygosity different lines of fishes may be crossed. Separate lines of fish can be maintained by keeping the record of the families of different strains bred in the hatchery.
- Improved varieties of fish like Jayanti rohu and improved catla may be taken for broodstock development in the hatchery for producing quality seed for the farmers.
- Significance should be given to own broodstock production in the hatchery. Seed from different times of breeding may be taken for own stocking rather than from same day spawn for own broodstock production.
- Equal sex ratio for male and female (1:1) may be maintained and same ratio may be used for breeding purpose.
- Female breeder of 3-5 years of age and male of 2-5 years may be used in the breeding program. Broodstocks of different age groups should be bred together. This helps in reducing the chance of loss of some valuable alleles due to genetic drift.
- Replacement of broodstock from different sources i.e. rivers, hatcheries and crossing between them may be done for seed production. Natural stocks may be included in the breeding nucleus to increase the heterozygosity level of the domesticated hatchery stock. Networking of hatcheries can be made for exchange of brooders between hatcheries to improve the quality by crossing between the stocks.
- The mating between same year class, parent offspring, sibs and repeated use of same breeder may be avoided.
- To improve the quality of carp seed cohort breeding protocol may be practiced.
- To reduce pond space required for the male broodstock raising in the hatchery cryopreserved milt may be used.
- Hatchery operator should maintain the pedigree record by various means (tagging, fin clipping, dye marking) to avoid the inbreeding in the hatchery.
- Other aquaculture management practices such as water, feed and disease management are also crucial for quality seed production.

Conclusions

Genetic basis of broodstock management and use of genetic norms in hatcheries are highly essential in the present context. Increase in production as well as purity of stock is also equally important. From all states effort should be made to implement the genetic norms in their hatcheries for quality seed production.

*Corresponding author's e-mail: kdmahapatra@yahoo.co.in

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Doubling Farmers' Income

through Carp Seed Rearing

Himansu Kumar De[1]*, Manoj Kumar Das[2] and Kalyan Sundar Das[1]

ICAR-Central Institute of Freshwater Aquaculture, Kausalyaganga, Bhubaneswar, Odisha 751 002

Farmer FIRST Programme, an innovative extension approach, focuses on enriching knowledge and interpreting technologies in the farmers' condition. ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar has implemented this project during 2016-19. According to the authors view doubling of farmers' income through carp seed rearing is possible and the project has significantly contributed towards livelihood improvement of the beneficiaries.

Keywords: Carp seed rearing, Doubling farmers' income, Farmer FIRST Programme

FARMER FIRST Programme is an approach which focuses enriching knowledge and integrating technologies in the farmers' conditions and to enhance farmer-scientist interface. Emphasis is given on farmer's farm, innovations, resources, science and technology. Small holders, landless and farm women are specially addressed through technology integration modules. Strong partnership with farmer for developing location specific, demand driven farmer friendly technology option is the guiding principle.

The project has covered 4 villages in Khordha district i.e. Kantia Talasahi, Kantia uparasahi, Jagannathpur (Block-Balianta) and Dorbanga (Block-Balipatna) involving more than 400 small and marginal farmers belonging to SC & ST categories and women. Modules on improved technologies on crop, horticulture, livestock and fishery are demonstrated. Skill training and technical backup are provided to the beneficiaries. The project was operated by ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar in 2016-19.

Integrated nutrient management in paddy, powdery mildew resistant variety of green gram var. TARM 1, photo insensitive variety of cauliflower var. Fujiyama, bitter gourd var. VNR, backyard poultry farming var. Vanaraja, composite carp culture, minor carp farming etc. technologies are demonstrated in the adopted villages. Fish based integrated farming system was established in 3 adopted villages for increase in income of farm household through integration of different enterprises.

Component I: Enhancing Farmers-Scientist Interface

For enhanced capacity building regular farmers-scientist interfaces were conducted. Need based trainings, visits, workshops,

Fig. 1. Carp Seed rearing

Table 1. Technology assessment and module application 2018-19

Crop/Variety/Technology/Methodology	No. of Farmers	Area Covered (ha)	Yield before FFP (t/ha)	Yield after FFP (t/ha)
Integrated Nutrient Management in paddy	38	15.2	4.0	4.5
Green gram in Rice fallow	155	18.6	0.375	0.625
Improved variety of Bitter gourd var. VNR	20	2.5	-	30
Introduction of Cauliflower var. Fujiyama	10	1.2	15	20
Introduction of Bush type French bean var. Falguni	10	0.4	-	8
Backyard Poultry Strain (Kaveri/Vanaraja)	150	1500 nos	-	3-3.5 kg body weight gain and 20-25 egg per month after 6-7 months maturity
Composite Carp Culture	280	5.33	1.6	3.0
Introduction of Minor carp in Backyard ponds	14	0.36	-	350 g after 6-7 months
Total	677			

interfaces, extension activities etc. were carried out at regular interval. Demonstrations of new technologies in the adopted villages were also carried out. In the year 2018-19 thirteen field days and five farmer-scientist interfaces were organized from which 414 and 191 farmers were benefitted respectively.

Component II: Technology Assemblage, Application and Feedback

Recommended technologies from various sources like ICAR-CIFA; OUAT, Bhubaneswar; Odisha State Seeds Corporation Limited; Central Poultry Development Organisation etc. were demonstrated in the adopted villages as per suitability.

i. Integrated Nutrient Management in paddy was demonstrated in 15.2 ha of land during 2018-19 *Kharif* season. Under INM, the following practices were carried out to reduce the use of chemical fertilizer.
   - Application of Zinc Sulphate @ 25 kg/ha and FYM @ 12.5 t/ha.
   - Green manuring with Dhaincha (25 kg seed/ha)
   - Seed treatment with fungicides e.g. Thiram 42% @ 3 g/kg seed
   - Demonstration of Cono weeder
   - Use of green manure and FYM reduced the application of chemical fertilizer into half of the recommended dose.
   - Leaf colour chart developed by ICAR-NRRI, Cuttack used for efficient nitrogen management in paddy

ii. Green gram was demonstrated as rice fallow to utilize the available soil moisture after harvesting of rice. Before planting green gram seeds were inoculated with Rhizobium, Phosphobactor @ 250 gm each/10 kg of seed and Trichoderma @ 10 gm/10 kg of seed. Seed dressing was done with Gaucho (Imidaclorpid) @ 1.5 ml/kg of seed. A powdery mildew resistant variety (TARM 1) was demonstrated which provides yield of 0.625 t/ha.

iii. Composite carp culture was practiced in 6 community ponds having an area of 5.33 ha. Lime was applied on the basis of soil and water test. Supplementary feeding was given @ 2% of total biomass. Bigger and healthier fingerlings were stocked after proper acclimatization with the pond environment. Potassium permanganate was also applied as disinfectant to the fingerlings to protect them from different diseases. Fish health was checked through sampling at regular interval.

iv. VNR variety of bitter gourd was also demonstrated in the villages and the highest yield of 30 t/ha was recorded.

v. Photo insensitive variety of cauliflower (Fujiyama) was introduced for growing in off season. The cultivar gave an

Carp seed production for doubling farmer's income

Shri Gadadhar Pradhan (65) of village Giringo, District Khordha, a beneficiary of Farmer FIRST Programme was introduced to Carp seed rearing. The farmer was involved in different farming practices like cereal, horticulture, livestock and fisheries. He has holding size of 1 ha. The farmer also owns 3 cattle and 30 sheep. He has a pond of area 0.15 ha where he used to practice carp culture.

Shri Pradhan gets around 5 quintal of table fish production in one year from the pond (3.3 tonne/ha) which he dispose at ₹ 120/kg in the local market. After spending ₹ 24,700 for pond cleaning, fertilization, renovation and for procurement of raw materials like fish seed, feed, lime, labour etc., he earned ₹ 60,000. This gave him a profit of ₹ 35,000 in a year.

After receiving training and technical guidance from the project, he switched over to carp seed rearing in his pond in 2017-18. By adopting ICAR-CIFA technology package, the farmer was able to grow a good crop and harvested fingerlings in three and half months' time. He had stocked 7,00,000 carp spawn and was able to produce 2,40,000 carp fingerlings. He spent ₹ 28,000 for pond cleaning, liming, fertilization and for procurement of spawn, feed, labour, etc. Sale proceeds from carp seed was ₹ 84,000. After selling seed the pond was utilized for grow out culture for the rest of the season. He harvested 3 quintal of table fish with a monetary return of ₹ 36,000 without any further expenditure. From fish seed rearing as well as grow out culture he earn a profit of ₹ 75,000 which is 2.15 times higher than his previous enterprise.

Fig. 2. Enhancing Farmers-Scientist Interface: Workshop on farmes' feedback

average yield of 17.5 t/ha.

vi. Fish based Integrated Farming System with dairy, poultry, horticulture crops on the pond embankments have been established in Jagannathpur.

Increased access to advanced technologies and support provided by the project has enabled the farmers to adopt the improved practices.

Component III: Partnership and Institution Building

Under this project Self Help Group for schedule caste and landless women were mobilized for poultry farming. Training on technologies related to one day old chicks brooding, poultry feed and vaccinations were provided to the beneficiaries. Seven SHGs were involved from 3 villages for this intervention. Facilitated formation of Bhargabi Fish farmers Producers Company Ltd. in Balipatna block. This company was incorporated on 27.03.2019. Technical back up and training were provided to the shareholders of this FPO through the project.

Component IV: Content Mobilization

- *Website developed for the project:* Complete information including location, beneficiaries, villages adopted, intervention, photo gallery, publications, contact us etc. are there. Further, link is provided to Institute's publications for better access. Details of available technologies of the Institute (www.cifa.nic.in) are linked with the project website (www.farmerfirstcifa.in).
- An episode of "Chaupal Charcha" by DD Kisan, New Delhi was prepared on Farmer FIRST Programme of ICAR-CIFA, Bhubaneswar. This was telecast on 4 February 2019 at 09:00 AM.
- A bilingual leaflet "Carp seed rearing can double aquafarmers' income- technical intervention of Farmer FIRST Programme proved it" is developed and is being distributed to farmers and other stakeholders to apprise them about the scope of the project as well as expectations from the stakeholders.

Other Activities

- On-site input production and management like vermi-composting, nursery of planting material, seed production, residue management etc.
- Five beneficiaries of Farmer FIRST Programme attended the national workshop on "Let's listen to farmers: A workshop on farmers' feedback on doubling farm income by 2022" organized at ICAR-NAARM during December 22-23, 2017 (Fig. 2). The farmers shared their feedback and ideas on how to double their income by 2022.
- An exposure visit was organised under which 27 beneficiary farmers from Jagannathpur (Block-Balianta) and Dorbanga (Block-Balipatna) village participated and visited 3 ICAR institutes like ICAR-NRRI, Cuttack; ICAR-CHES and ICAR-CTCRI regional centre, Bhubaneswar on 31 August 2018.
- A field day on carp seed rearing was organised at Giringo village.

Impact FFP on livelihood of farmers

Under Farmer FIRST Programme a study was conducted to assess the impact of improved agricultural practices on livelihood of adopted farmers. Data was collected from 87 randomly selected beneficiaries. A structured interview schedule based on DFID framework (1999) was developed and data was collected by personal interview method. The same interview schedule was introduced before i.e., in 2016-17 and after the intervention i.e., in 2019-20. The impact on livelihoods of farmers was measured through finding comparative position of physical, social, financial, human and natural assets of the farmers before and after adoption of the interventions. The mean value of overall standard of living of adopted farmers derived through addition of the index values of five assets was worked out to be 2.84 in post-adoption period against 2.41 in pre-adoption period. The gain was found maximum in the financial assets (25%), followed by natural assets (21%), human assets (19%), physical assets (15%) and social asset (14%). Overall gain in livelihood is worked out to be 18%. By applying paired t test, it was found that the project had a positive and highly significant impact on the livelihood of the beneficiaries.

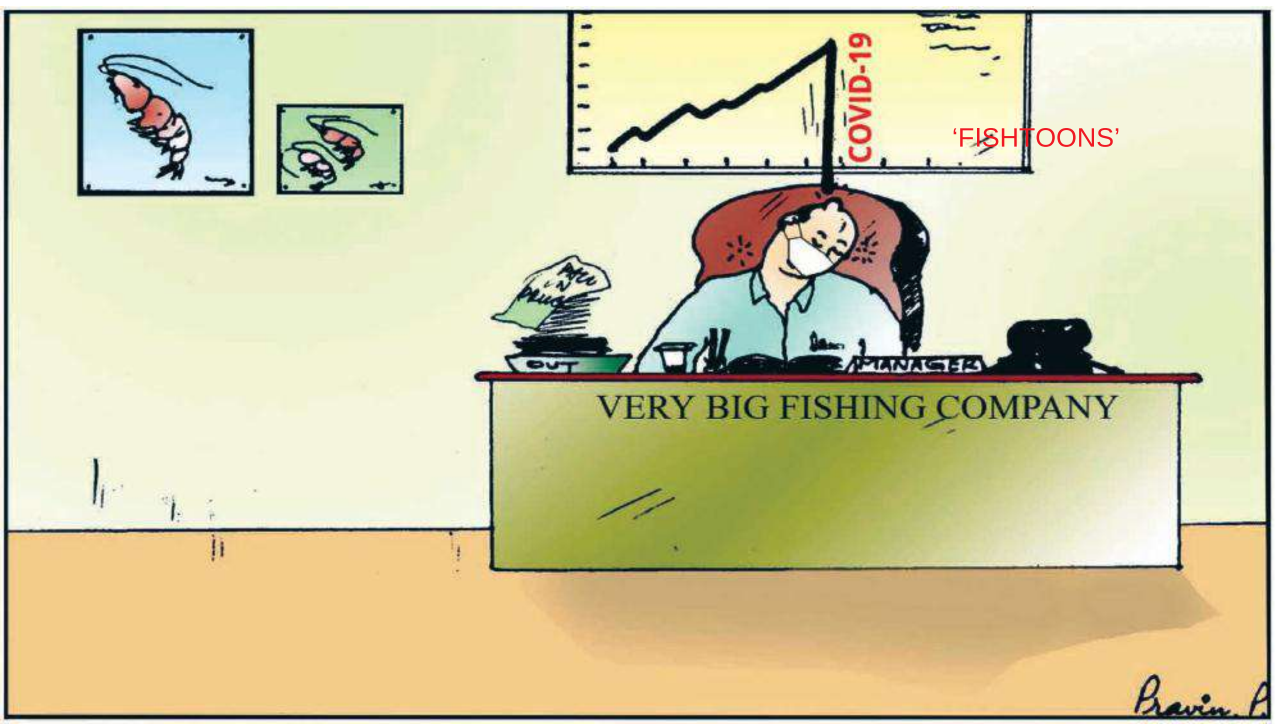
Fig. 3. Backyard poultry: Income enhancement for small farmers

It was attended by 12 farmers from nearby villages. Sri Gadadhar Pradhan who has shifted from carp culture to carp seed rearing, following ICAR-CIFA package of practices, shared his experiences. The farmers learnt about the fish seed rearing and also appreciated the profit from fish seed rearing venture.

Significant Achievements

- TARM 1 cultivar of a green gram was demonstrated which gave an average yield of 6.75 q/ha in demonstration plots (B:C ratio was 1.82). The yield of TARM 1 is 66% higher than the local check.
- Landless women farmers were trained to rear backyard poultry Kaveri and Vanaraja strain (Fig. 3). Male birds weigh upto 3-3.5 kg and female birds lay 20-25 eggs per month after 7 month of rearing. Eggs are of average weight of 55 gm. By rearing dual purpose breed, the beneficiaries got 1.79 times higher income as compared to the local breed.
- Composite fish farming gave an average yield of 3.0 t/ha. Higher yield led to enhanced per capita consumption of fish by the farmers. Application of lime, soil and water testing and supplementary feeding at regular interval and demonstration of advanced technologies controlled fish mortality and thereby minimized loss.
- Photo insensitive variety of cauliflower var. Fujiyama gave an average yield of 15 t/ha in the demonstration plots. Farmers were benefitted financially as it was harvested in offseason at a higher price.
- Minor carp was stocked in November in the backyard ponds. Minor carp (*Puntius gonionotus*) provide intermittent income to the farmers, species diversification; maximize biomass production and thereby giving consumers a better choice.
- Bush type French bean Falguni variety was demonstrated due to its strong and bushy nature. An average yield of 8 t/ha of green pods in 75-85 days was obtained (B:C ratio was 1.91).

[1]Principal Scientist, [2]Senior Research Fellow, *Corresponding author's e-mail: bhuthnath@gmail.com



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Ornamental aquaculture

An alternative avenue for livelihood support

Saroj K.Swain*, Sunil S. Ail and M.K. Bairwa

ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar, Odisha 751 002

Ornamental aquaculture is among hobbyist farming types where aesthetic sense of human prevails. This can be taken as an addition to other farming practices like beekeeping, mushroom cultivation, etc. It can be taken up in small range of initial capital or in a large scale also. Thus, there is an ample scope for livelihood development through ornamental fish farming in villages. Ornamental fisheries involve wide area of business including culture and breeding of fishes, aquarium construction and design, culture of aquatic plants, live food culture, etc.

Keywords: Aquaculture, Backyard ornamental fisheries, ICAR-CIFA, Ornamental fish village

THE Food and Agriculture Organization (FAO) estimated the world trade of ornamental fish around US $ 20 billion. The top exporting country is Singapore followed by Hong Kong, Malaysia, Thailand, Philippines, Sri Lanka, Taiwan, Indonesia and India. The largest importer of ornamental fish is the USA followed by Europe and Japan. The emerging markets are China, South Africa and gulf countries.

Domestic trade of ornamental fisheries valued around ₹ 600 crores mainly contributing from local aquarium shops across the country. The trade is mainly concentrated at major metro cities like Kolkata, Chennai, Mumbai, Delhi, Hyderabad, Bangalore and Cochin. The key production is from small scale production units within 1 acre of land and investment within ₹ 3 lakhs. Around 50% of this trade value is mainly of imported accessories for use in urban aquariums.

Commercially important ornamental fishes

There are around 30 important fish families which constitute as ornamental fish varieties which are traded worldwide. Live bearers belonging to poecilidae is one among commercial fishes, which are easy to culture and breed in small tanks. Koi carp and gold fish belonging to cyprinidae are one of the oldest domesticated fishes and are seen with number of varieties. Tetra, angel fish, discus fish, fighter fish, gourami, barbs, catfishes, etc. are other groups which are most preferred in freshwater. Dozens of varieties of these fishes have been developed by the fish breeders in the sector. Certain varieties fetch higher price than the

Fig. 1. A mini backyard model ornamental hatchery in 400 sq. ft. area at ICAR-Central Institute of Freshwater Aquaculture for the beginners who wants to venture in ornamental fish farming.

normal fish, this is due to variation in fish colour within the species. Most of the important varieties are imported from countries like Singapore, Malaysia, Indonesia and Sri Lanka where ornamental fish breeding and culture is more than in India. There are indigenous fishes mainly from two biodiversity hotspots which are collected from the wild and exported. This has caused decline in fish stocks and threat to the natural biodiversity. Therefore, in order to conserve such important fish varieties breeding and culture of important indigenous fishes the study has to be carried out.

Backyard ornamental unit in rural areas

The major hitch among small scale farmers is the availability of land for farming. The increasing land price makes it difficult for new farmer to venture into agriculture. A minimum space of 400-600 sq.ft is needed to start the ornamental fish culture in the backyard on mini commercial scale (Fig. 1). Small rectangular or circular tanks are better for the unit because of the space constraint. Tanks made of ferrocement will last longer and is efficient to use. Tanks should be arranged in a manner that better utilizes the space and covers maximum tanks in minimum area. Such models are successful in Kerala and West Bengal, where women in their backyard venture in ornamental fish farming. Even polylining sheets can be used for preparation of backyard tanks for the culture and breeding of fishes.

During the initial days, farmers can take up production of live bearers as its breeding and rearing are relatively easy. Among live bearers, guppy (*Peocilia reticulata*) is simplest to start with as it tolerates greater variation in water quality and accept all types of foods. There are many guppy varieties available in market like, round-tail, spear-tail, fan-tail, veil-tail, pin-tail, cobra guppies, Singapore guppies, etc. Another popular live-bearer is molly of various types such as sail-fin molly, black molly, moon-tail, round-tail, chocolate molly, white molly, orange molly, balloon molly, etc. Another magnificent group of live-bearers is

Fig. 2. Ornamental Fish village in Deogarh District where women SHG involved in fish farming

sword tail (*Xiphophorus helleri*) with varieties like red sword tail, green sword tail, sunset sword tail, tuxedo tail, double-sword tail etc. Yet another common fish is Platy (*Xipophorus maculatus*) with varieties like round tail, veil tail, fringe tail, lyre tail, pin tail, etc. (Fig. 3). A sound knowledge on biology, feeding behaviour and ambient condition of a fish is a prerequisite before going ahead with breeding and culture. Production of fish food, brood stock diet and larval diet needs special attention. The broodfish needs live food like tubifex worms and larvae needs infusoria, artemia and daphnia during early stages. This necessitates a unit for continuous production of live food. Generally, breeding is easy but larval rearing needs special care.

A small space in the backyard of a home can be converted into a small breeding and rearing unit. Such backyard unit needs low investment and a farmer can avail an agricultural loan to develop such units. Basic training on the subject will be helpful before starting an ornamental fish farming. It is good to begin from small fishes like bearers or cyprinids, koi carp and gold fish (Fig. 4). Good quality and highly colour variants fish to be procured from reliable source. Good quality feed with 30-35 % protein with carotenoid pigments has to be procured and to be fed twice daily @ 3-5% body weight. Water exchange to be done @10-20% weekly. After breeding, the young

Fig. 3. Commercially important live bearers

Fig. 4. Commercially important egg layers

ones need to be separated, reared to market size for sale. Routine care and necessary management will ensure a constant business. Links should be developed with nearby pet shops for the sale of the fish. If farmer desires he can start rearing varieties like fighter fish, angel fish, rosy barb, tetras, etc. for better income.

The estimated returns of ₹ 2,500-5,000 per month can be obtained by having a backyard ornamental fish culture unit. A farmer can improve his activity as he gains experience by breeding and rearing. There is scope for venturing into egg layers also if a farmer is keenly interested to go further with additional facility. This model can also be used in urban areas for production of live bearers or rearing of small egg layers (Fig 4).

Concept of Ornamental fish village

Ornamental fish village model revolves around production of ornamental fishes in 80% of the households in a hamlet or village. This will form a large number of backyard units producing quantity equal to one large scale unit. The prototype was tested by ICAR-Central Institute of freshwater aquaculture, Bhubaneswar under National Agricultural Innovation Programme (NAIP) in Odisha where three ornamental fish villages were developed at Landijhari, Saruli and Nuagaon of Barkot block, Deogarh District. Such models will improve the market and ensure livelihood in rural areas. The villages will have facilities for providing accessories, electric supply and live food production. Basically women SHG's can co-ordinate such activities in villages where women can involve in farming along with household activities (Fig. 2). This will help in strengthening women empowerment in rural areas and also earn additional income in every household.

Ornamental fish villages can be also developed in a cluster model by identifying suitable sites and involving local community in fish culture. The cluster can be developed as public private partnership leased to the interested entrepreneurs by local governing body. This type of model can be seen in Chennai Aqua Rainbow park, where number of small ornamental units are developed and maintained by different fish breeders. Such enterprises will cater not only for domestic trade but also for export market.

Role of ICAR-CIFA to popularize ornamental fish farming

Being the premier institute in freshwater aquaculture, ICAR-Central Institute of Freshwater Aquaculture (CIFA), Bhubaneswar contributes significantly in aquaculture sector with its various promising technologies and products. ICAR-CIFA has developed captive breeding and culture of many indigenous ornamental fishes including many barb species from Western Ghats. The work for commercial level breeding and culture of these barb species is under process to popularize them. The training on ornamental fish farming to different stake holders is provided from time to time. Model ornamental fish rearing unit of different scale is developed for demonstration and training purpose. Scientists are involved in committee's of different policy matters and expert advice for national level projects in this sector. A new variety of rosy barb named 'Shining barb' was developed by this institute through mass selection technology, which was probably first improved variety of ornamental fish in India.

Contribution in blue revolution and PMMSY

Ornamental fish culture will be a boon for farmers with available water resources and are keen for expansion of their farming practices. The financial boost will help in adding up the trade value of the sector including production of accessories in India. Developmental schemes by NFDB and MPEDA in last decade has given a better shape to this industry. This was mainly focused in states like Kerala, West Bengal, and Tamil Nadu on backyard units with minimal investment. A targeted investment of ₹ 576 crores to generate 7 lakh employment for upgrading the ornamental aquaculture sector is presently set under Pradhan Mantri Matsya Sampada Yojana (PMMSY). Also additional investment of ₹ 500 crore under World Bank scheme is proposed for catering this sector. This will surely help financial needs of the sector to lift up the farming.

Conclusion

Ornamental fishery helps small entrepreneurs in ensuring their livelihood in regions like Kolkata, Chennai and Mumbai. This can be replicated in many urban cities for upbringing this industry and also to ensure employment among youths. As this sector is developing we need to attract many people towards this business and strengthen the domestic trade.

*Corresponding author's email: sarojswain2008@gmail.com

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Seafood value addition

Current trends and future prospects

Parvathy U, Binsi P K, Ashok Kumar K and Ravishankar C N

ICAR-Central Institute of Fisheries Technology, Kochi, Kerala 682 029

Value addition is the key word in the seafood processing industry as it widens the possibilities of maximum returns by foreign exchange earnings. India, being one of the fastest growing economies and the second largest consumer market in the world, offers a strong platform for processed seafood industry. Based on the market requirement, seafood value addition can be diversified. The category of value added commodities range from live seafoods to ready-to-eat convenient products. Value addition also explores new dimensions for the effective utilization of fishery by-catches. India, being adequately equipped with skilled manpower and the dominance in several agri-commodities offers advantage to make strong seafood market capture with a wide array of commodities.

Keywords: Fish Processing, Seafood Market, Surimi, Value Addition

VALUE in the context of food, is an aggregation of functional characteristics arising on account of nutritional and sensory aspects at superior quality as well as affordable price. Further, it promises utilization of the under-exploited nutrient rich resources in the most effective manner. Value added fish products are presented in a preparatory and convenient form. It can be products ranging from simple dressed/ trimmed, minced forms to advanced ready-to-eat styles. Value addition can also be in the form of a new package in eco-labelling with multiple dimensions of flavor profiles on account of added ingredients. It is one of the possible approach to raise profitability in seafood industry, which is becoming highly competitive, lucrative and increasingly expensive.

The commonly practiced processing techniques in seafood sector include curing, which includes salting, smoking, drying, pickling, canning, freezing, surimi processing, etc. Some high-end technologies, viz. minimal processing, irradiation technologies, etc. are effective but restrictedly adopted by the industry. However, most of the exports are currently limited to frozen forms, and thus not explore absolute benefits from aquatic resources. A value addition to the level of about 23% is reported for seafood in India but not beyond the level of dressed fish and deveined/ blanched shrimps. Hence, standardization of new processes and protocols have to be made for enhancing value addition and thereby effective utilization of fishery resources. In this regard, development of indigenous processing machinery is an immediate necessity in fisheries sector. At present, Indian seafood consumers prefer fresh fish and there is an increasing trend in the utilization of value added fish products as evidenced by their availability and demand in modern super markets.

Value addition: Future dimensions

Value addition in seafood sector covers a wide array of products from live commodities to ready-to-eat/serve convenience products. India, being the largest producer of several agri-commodities, offers wide possibilities of value addition and product development for the domestic as well as export market. Ethnic Indian recipes like fish/ shrimp pickle, unique dishes of various cultural populations, diverse marinated recipes, etc. offer attractive opportunities for seafood value addition. However, these captivating factors are flattened by the poor infrastructure development and capital investment affecting the development of processed seafood market of the country.

Ethnic seafood products are those that are traditional, region specific and are being prepared and consumed by different cultural community. Some of these products are preserved or processed using centuries-old indigenous knowledge of fermentation/drying/smoking, etc. Globalization has accounted for a high demand for these ethnic food products and hence approaches towards its popularization by adopting effective processing techniques can bring a huge adoption for these commodities.

Surimi and surimi based products are yet another least explored area of value addition in the country, inspite of having a number of lean varieties of species globally identified for surimi manufacturing. Surimi being a wet concentrate of myofibrillar protein, is an intermediate product for the development of highly demanded commodities such as sausage and analogue products. Globally, there is a constant search for suitable and promisive raw material for surimi production. Surimi production from farmed species shows huge potential for a variety of value added products. Furthermore, the utilisation of farmed varieties for surimi and surimi based products will strengthen the link between increased production and resource utilization.

Thermal processing is a technology of great significance in many developed countries. Though expensive, this technique leads to the production of a variety of convenience products which fetches higher margins in export market. However, the severe thermal conditions in this processing technique leads to textural disintegration, limiting the process adaptability to a few species like tuna, crab, lobster, shrimps, etc. Hence, emerging species for thermal processing is demanded which further broaden the scope of value addition.

Curing and drying, even though an age-old practice, opens up new dimensions and possibilities towards value addition in domestic as well as international markets. In India, as per the estimates, about 17-20% of the total catch is converted to dried products and dry fish export contributes to about 7.86% of total fish exports. However there are several factors hindering the addition of dried fishery products to the product profile. The major one being, lack of standard operating procedures as drying is still pratice in traditional method of processing. Moreover, there is a general concept that drying is a secondary method for preserving low value varieties, which compromised quality. Attempts towards improving the handling practices right from the point of raw material harvesting till marketing, popularisation of improved packaging practices, use of hygienic energy efficient mechanical driers, and adequate extension services can facilitate better adoption of drying practice in seafood sector.

Although fermentation has traditionally been used to preserve fresh fish, especially in tropical climates, today it is used to enhance nutritive value, improve appearance and taste, destroy undesirable factors, and to reduce the energy needed for cooking. However, it takes long duration to develop the characteristic features of fermentation. Smoking of fish is done primarily for the unique taste and flavour, however, the texture of flesh may be affected during the smoking process. Hence, preparation of flavoured products with typical flavour extracts may be advised to reduce the process time and can be projected as a minimal processing protocol with product diversification scope for chilled high value fishes like sea bass, cobia, pompano, and grouper. This opens up value addition opportunities in terms of less intense flavour of cultured species owing to the difference in food chain followed in captive condition compared to the basic seaweed based food pyramid in marine ecosystem.

Recently, the global seafood market indicate diversification with increased consumer demand towards more convenient on-the-go products, having superior nutritional value. In this line, a series of intermediate/low moisture foods such as nutritional bars, meat flakes, noodles, pastas, etc. have occupied the modern domestic and export markets. They have a low water activity (0.7-0.9), stable under ambient conditions for longer duration and can be used with/ without rehydration. Techniques like food extrusion provides a great versatility for the development of such nutritious and convenient food products especially cereal-based snacks and food products. Many farmed species with whiter, and tastier flesh are found to best suited for these innovative products. Further utilization of underutilized fishery resources for the formulation of such products are also highly recommended.

Value addition of secondary raw materials

A considerable quantity of waste is being generated from seafood processing operations about 70% of raw material which is alarming, and is costly to dispose. The proteinaceous nature and richness in biomolecules with medicinal and therapeutic value has upgraded the value of fish processing waste, classifying it as ‘a certified waste’. Process discards, primarily composed of head, viscera, scale, skin, bone, fins, eyes, gills, etc. is a major source of high value by-products which are nutritious as well as possess immense bioactivity. These include protein and bioactive peptides, PUFA, collagenous matter, chitin, chitosan, glucosamine, minerals, pigments, etc. Cost effective bulk reduction technologies may be adopted for the conversion of these valuable discards to high efficiency products ranging from farm supplements such as manure, fertiliser, foliar spray, aquaculture and animal feeds etc. to high end products having human food and nutraceutical applications. Successful waste management programmes can be implemented by strengthening the baseline data which includes information on waste generation and disposal, local facilities, and major stakeholders involved. Lack of clear legal classification of secondary products in the international market, lack of unified protocols for quality assurance and most importantly, limitations in know-how with regard to the value generation possibilities from process discards are the major factors affecting the development of this sector. Development of efficient means of networking and establishing inter-industrial linkages between potential stakeholders, generation of pilot facilities for testing and demonstration of innovative technologies, encouraging more partnership programmes, initiating and framing public policies against seafood process discard dumping, and its effective utilization are a few measures that can improve the current scenario in the sector.

Value added products: Market potential

Seafood processing and marketing has become highly competitive that the exporters are shifting towards value addition for increased margins. Marketing of value added products is highly capital intensive, dynamic, sensitive and complex, unlike traditional seafood trade. Intense market studies coupled with attractive presentation by innovative and attractive packaging techniques and advertisement are mandatory for the successful launch of a new food commodity. This in turn, creates confidence to the consumers to experiment with a new product launched in the market. Most of the market channels currently used is not suitable to trade value added products. An effective approach in this regard would be a proper chain, linking consumer markets directly to the source of supply.

SUMMARY

Seafood product diversification by value addition of main and rest raw material can augment marketing of these commodities in food and nutraceutical sector. Simultaneously, it leads to reduced post-harvest losses contributing to global economic growth and nutritional security. Technology up-gradation remains to be the key element in value addition domain, supported by minimal processing options, innovative smart packaging concepts, intelligent quality monitoring systems. Innovative concepts and product development addressing niche markets is an important strategy for improving farm income. Developing such technologies with a feasible business model has immense industrial potential assuring additional income to the entrepreneurs. Inevitably, value addition in seafood sector upgrades seafood chain, as well as development of intelligent and smart transportation techniques for increased product quality and stability.

Corresponding author's e-mail: directorcift@gmail.com

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Seaweed farming in India

Progress and Prospects

Johnson, B[1] and Boby Ignatius*[2]

ICAR-Central Marine Fisheries Research Institute, Mandapam Camp, Tamil Nadu 623 520

Seaweeds are exploited commercially for their cell wall polysaccharides such as agar, algin, carrageenan and for manure, fodder and bioactive metabolites. Seaweed also represents an excellent source of fatty acids, vitamins and minerals. It is marine macrophytic thallophytes consisting of taxonomically distinguished groups of green (Chlorophyta), brown (Phaeophyta) and red (Rhodophyta) seaweeds. These seaweed resources grow best in the tidal and inter-tidal waters along the peninsular coastline, Andaman-Nicobar and Lakshadweep Archipelagos. India is bestowed with more than 0.26 million tonnes (potential yield) wet harvestable biomass of seaweeds belonging to 700 species. Of these, nearly 60 species are economically important for their polysaccharides and secondary metabolites. Approximately 20,000 tonnes (wet weight; i.e., 4,000 tonnes dry weight) of these resources are harvested annually from the wild in India.

Keywords: Agar, Bamboo raft, Cadalmin™ GAc, ICAR-CMFRI, Integrated Multi-Trophic Aquaculture, Livelihood, Seaweed

THE ICAR-Central Marine Fisheries Research Institute (CMFRI) has been working on seaweed mariculture and seaweed utilization in India since 1972. Mandapam Regional Station of CMFRI has developed the technology for commercial scale cultivation of *Gracilaria edulis*, an agar yielding red algae, using raft, coir-rope nets/spore method. This Station has also developed a cottage industry method for the manufacture of agar from *Gracilaria* spp. and alginic acid from *Sargassum* spp. during 1980s and demonstrated the agar and algin production to many farmers and entrepreneurs. These demonstrations have paved ways for development of many small-scale agar industries at Madurai, Tamil Nadu.

Seaweed Farming: Current Status

Seaweed farmers in India are generally small-scale farmers, produce crops of (mostly) red algae in small patches of intertidal sand flats. The main culture methods involve either vegetative propagation using fragments from mother plants or by different kinds of spores.

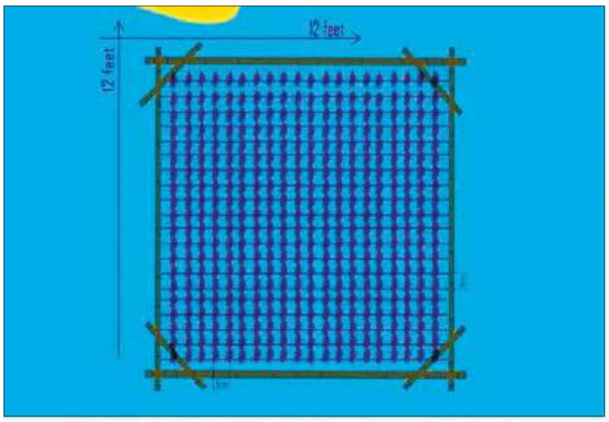
In places which are calm and shallow, raft method (12 × 12 feet bamboo poles) is ideal. Vegetative fragments inserted ropes are tied to the floating raft. In places characterized by moderate wave action, shallow depth and the presence of less herbivorous fishes, longline or monoline method is ideal. Seaweed inserted ropes are tied to the posts planted in the sandy and muddy bottom of the intertidal regions. First harvest can be made in 45-60 days depending on the species. The tube net method is being adopted in places with higher wave actions. It is a recent method in which long sleeves (10/25 m long and 6/10 cm dia.) made of nylon nets (1-1.5 cm mesh) are seeded with vegetative bits that appear like "net tubes". Both the ends are then tied and allowed to float in seawater. Anchors are used at each end to hold the tube nets steady in the water column. Harvesting is generally done after 60 days.

Though started in 1972, seaweed mariculture (agarophytes *Gracilaria edulis* and *Gelidiella acerosa*) in India remained in low key until the year 2000. Seaweed cultivation with native species has been shown to be beset with problems such as grazing of seed material and grown up plants by fishes, longer culture duration and slow growth rate of species like *Gelidiella acerosa*. Large scale, commercial sea-farming of *Kappaphycus alvarezii*, a *kappa* carrageenan yielding seaweed started in 2000 with a backup by PepsiCo India Holdings Ltd. in the coastal waters of Tamil Nadu, Odisha, Gujarat and Daman and Diu with technical support from CSIR - Central Salt and Marine Chemicals Research Institute (CSIR-CSMCRI), Bhavnagar. It is reported that with the contract farming of *Kappaphycus alvarezii* by the fisher folks of east coast of India, more than 46,600 tonnes wet biomass of *Kappaphycus* was produced in a decade during 2005 to 2015. The market price during this period found to increase from less than ₹ 4.5 to 35/kg (dry weight). The present market price is about ₹ 50/kg (dry weight). However, the production sharply declined after 2013 due to mass mortality as a result of "ice-ice" disease and the average production of cultured *Kappaphycus alvarezii* in recent years is only to the tune of 200 t (dry weight)/year. At present, commercial farming is carried out following three techniques, namely floating bamboo raft, tube net (net sleeves), and long lines; of which the former two are widely practiced (Fig. 1).

The economics of *Kappaphycus alvarezii* farming as analysed by ICAR-CMFRI is as follows:

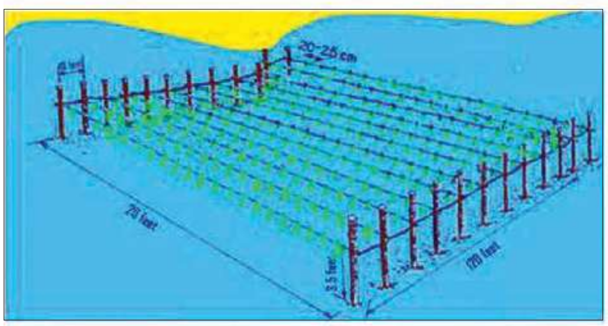
- Seaweed production: 1,000 kg/raft/yr- 240 kg as seed material for 4 crops/yr = 760 kg
- Price of seaweed: ₹ 8/kg (wet weight)/raft or ₹ 50/kg/dry weight (Dry weight = 10%)
- Total revenue generated: ₹ 6080/year/ raft @ ₹ 8/kg/wet weight
- Total cost of production (including capital cost): ₹ 1500/raft/yr
- Net profit: ₹ 4580/raft/year (₹ 6080 minus 1500)
- One family (2 person) can handle average 30 rafts (12 × 12 ft)
- Total Net profit (30 rafts) in fresh weight = 30 × ₹ 4580 = ₹ 1,37,400/yr
- One hectare can accommodate 400 rafts (12 ft × 12 ft) of seaweeds
- Total production per ha = 760 kg × 400 rafts = 304 tonnes (wet weight)
- Net profit per hectare= 4580 × 400 = ₹ 18,32,000/-

Considerable research has been carried out on various aspects of Indian seaweeds by ICAR-CMFRI.



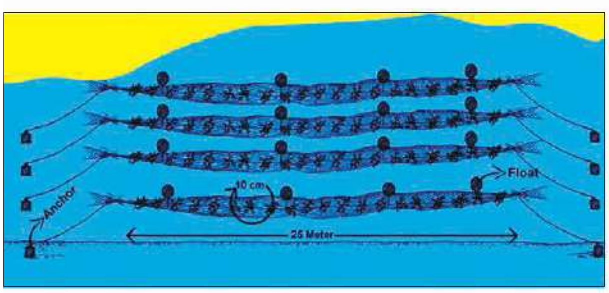
Schematic view of floating bamboo raft method


Field view of floating bamboo raft method



Schematic view of longline or monoline method


Field view of longline or monoline method



Schematic view of tube net method


Field view of tube net method

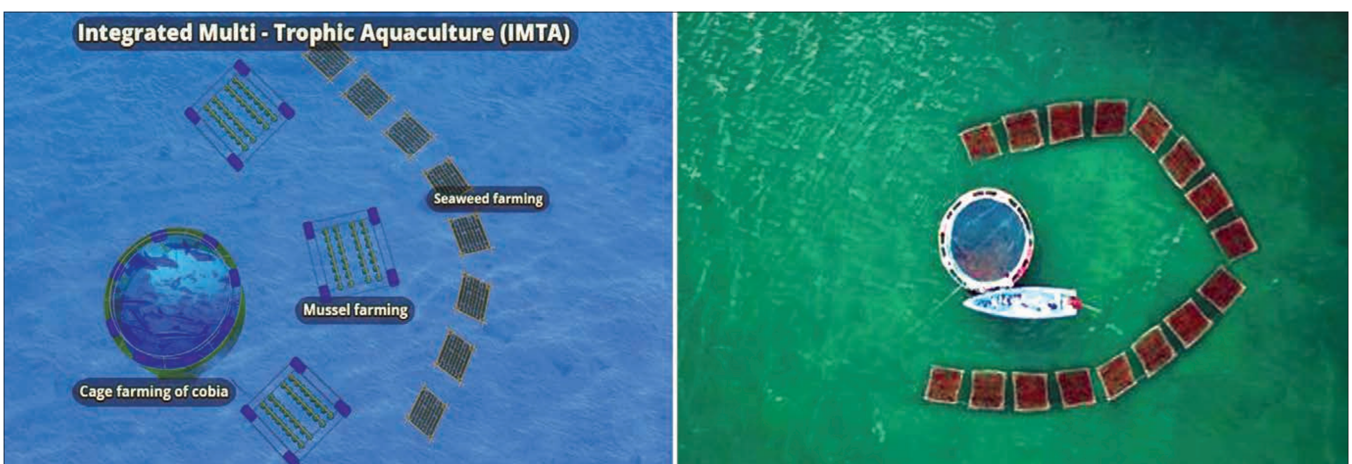
Fig. 1. Seaweed cultivation

Fig. 2. View of harvested farmed Kappaphycus alvarezii

Survey of the seaweed resources on the coasts of Tamil Nadu, Goa, Maharashtra, Gujarat, Andhra Pradesh, Odisha, Kerala and Lakshadweep has been completed and the estimates of total standing crop of these areas and, in particular, the harvestable quantities of agarophytes and alginophytes had been made (Fig. 2). Annual seaweed harvest estimation (wild collection) from Indian Coast as well as production through farming in the sea along the east coast of India is being enumerated periodically by this Institute with which potential yield was estimated.

Integrated Multi-Trophic Aquaculture (IMTA)

The bio-mitigation along with increased biomass production in mariculture activity can be achieved through Integrated Multi-Trophic Aquaculture (IMTA) by integrating different groups of commercially important aquatic species, which are having varied feeding habits (Fig. 3). Seaweeds are excellent bio-remediating agents and capable of improving water quality by uptake of dissolved minerals, nitrates, ammonia and phosphates. In this context, the ICAR-CMFRI has successfully conducted demonstration of Integrated Multi Trophic Aquaculture (IMTA) by integrating seaweed *Kappaphycus alvarezii* farming with cage farming of Cobia (*Rachycentron canadum*). A total of 16 bamboo rafts (12 × 12 feet) with 60 kg of seaweed per raft were integrated for a span of 4 cycles along with one cobia stocked cage (6 m diameter and 3.5 m depth with 1,000 cobia fingerlings). Seaweed rafts integrated with cobia stocked cage had a better average yield of 320 kg per raft while in the non-integrated raft, the yield was 144 kg per raft. An addition of 176 kg of seaweed per raft was achieved due to the integration with the cobia cage farming. The total amount of carbon sequestered into the cultivated seaweed (*Kappaphycus alvarezii*) in the integrated and non-integrated rafts was estimated to be 357 kg and 161 kg, respectively. Hence, there is an addition of 196 kg carbon credit due to integration of 16 seaweed rafts (4 cycles) with one cobia stocked cage (one crop). The presence of inorganic extractive components contributes to the periphyton to the aquaculture area



IMTA (Schematic Aerial View) | Seaweed rafts (16 Nos.) integrated with cobia cage

Fig. 3. Integrated Multi-Trophic Aquaculture (IMTA)

as well as offer habitat for planktons to settle. Seaweeds are known to release 30-39% of their gross primary production as dissolved organic carbon (DOC) to the ambient water.

Seaweed mariculture for combating climate change impacts

It is estimated quantitatively that seaweeds are capable of sequestering dissolved CO_2 at the rate 80.5 mg/g wet weight/day while their rate of emission through respiration is only 10 mg/g wet weight/day. Large scale seaweed mariculture has been recognized as one of the climate resilient aquaculture techniques to mitigate ocean acidification. Being highly autotrophic, seaweed vegetation can utilize the carbon dioxide for photosynthesis which can remove the dissolved CO_2 from the seawater. Seaweed beds and seaweed farms are considered significant CO_2 sink and can play active role in mitigation and adaptation of climate change. It is estimated that the seaweed biomass alone along the Indian coast is capable of utilizing 3017 t CO_2/day against emission of 122 t CO_2/day indicating a net carbon credit of 2,895 t/day.

In experiments involving the culture of seaweed (*Kappaphycus alvarezii*) in ICAR-CMFRI it was estimated that specific rate of sequestration of carbon dioxide (CO_2) by the *Kappaphycus* is estimated as 19 kg/day/tonnes of dry wt. of seaweed. Hence, large scale mariculture of seaweeds preferably red seaweeds would definitely be helpful to check ocean acidification, which indeed is a green technology without the involvement of energy, fertilizers and chemical inputs and is not a labour-intensive avocation.

Seaweeds as prospective resources of pharmacologically active metabolites, nutraceutical products and functional foods

Seaweeds constitute a major share of marine flora, and they were reported to possess structurally diverse compounds of various bioactivities with potential pharmacological significance. Novel secondary bioactive metabolites from the seaweeds are attracting attention because of the growing demand for new compounds of 'marine natural' origin, having potential applications in pharmaceutical fields, and concerns about the toxic effects by synthetic drugs. Considering the importance of the group, ICAR-CMFRI and ICAR Central Institute of Fisheries Technology (ICAR-CIFT) developed research programme to systematically search these candidate seaweed species for the development of promising bioactive molecules for human health and medication. The active ingredients in the nutraceutical products are in the concentrated form of the purified compounds, and not the crude extract (350 mg active principle capped in the hydroxypropyl methyl cellulose capsules). Optimized methods were developed to prepare the concentrated form of the active ingredients from the crude seaweed extract, and the active principles were stabilized with the natural additives and stabilizing agents. The nutraceutical products were found to have no side effects (LD_{50} > 5,000 mg/kg BW) as proved from the preclinical and acute/long term chronic toxicity studies on experimental subjects (animal models) in the DSIR recognized hospitals/institutes.

The research work carried out at ICAR-CMFRI developed natural anti-inflammatory supplements enriched with lead molecules as nutraceutical Cadalmin™ Green Algal extract (Cadalmin™ GAe) from seaweeds to combat rheumatic arthritic pains. This product has been out-licensed to the biopharmaceutical company for commercial production and marketing in India and abroad. The research efforts to isolate the lead molecules with action against type-2 diabetes led to the development of a nutraceutical product Cadalmin™ Antidiabetic extract (Cadalmin™ ADe) from marine algae that has been out-licensed to a leading Biopharma Company. Cadalmin™ Antihypercholesterolemic extract (Cadalmin™ ACe) and Cadalmin™ Antihypothyroidism extract (Cadalmin™ ATe) developed from seaweeds to combat dyslipidemia and hypothyroid disorders, respectively. These products were also out-licensed to a pharmaceutical company. Cadalmin™ Antihypertensive extract (Cadalmin™ AHe), Cadalmin™ Antiosteoporotic extract (Cadalmin™ AOe), and Cadalmin™ Immunoboost extract (Cadalmin™ IBe) from seaweeds are under commercialization (Fig. 4).

The ICAR-CIFT has developed and commercialized many aqua-nutraceuticals in line with the regulatory compliances to address the felt demand of the consumers keeping eye on their healthcare and nutritional requirement and established its prominence in the aqua- nutraceuticals domain. The products like *FucoidanExt*, *FucoTeaExt, FucoxanthinExt, Seaweed NutriDrink*, *Seaweed Cookies*, *Seaweed Yoghurt*, *Seaweed Sanitizer* are some of the promising seaweed based products developed by the institute.

The Way forward

Seaweed for livelihood: Seaweed mariculture is an economically viable livelihood option for the coastal fishing community especially for the fisherwomen. The seaweed cultivation requires no land, no fresh water and no fertilizer or pesticide. The large-scale cultivation will enhance rural employment

Fig. 4. Cadalmin™ Antihypercholesterolemic extract (Cadalmin™ ACe)

opportunities and improve rural economy. It was found that the Benefit Cost Ratio (BCR) is above 2.0, which signifies the profitability of the activity and it can double the fisher's income.

Need for marine spatial plans and leasing policies: Currently, the growth of seaweed farming is constrained primarily by lack of proper marine spatial plans. Areas suitable for seaweed farming in three coastal states (Tamil Nadu, Gujarat and Andhra Pradesh) have been identified by ICAR-CMFRI. Large-scale expansion of the seaweed cultivation will necessitate a more complete understanding of the changes that the farming activity may bring in the ecosystem. Most Indian seaweed cultivation is located in near-shore waters, and to overcome inshore challenges an alternative farming strategy including expanding to offshore culture systems is recommended.

Enhancing availability of planting materials/seeds: Traditional seaweed farming techniques involving vegetative propagation require a large amount of seed stock biomass. An average of 10-20% of harvested material needs to be recycled during seeding procedures. To improve production of *Kappaphycus* in India, developing *in vitro* cell culture techniques is crucial as it facilitates year-round mass supply of seed materials maintained under controlled conditions. Development of new and improved strains of *Kappaphycus* through strain development and hybridization and through protoplast fusion techniques are envisaged for production of fast growing, productive, high-temperature-tolerant and fouling- and disease-resistant strains. Challenges faced by seaweed farming include difficulty in obtaining quality seed materials of native species such as *Gracilaria dura*, *G. debilis* especially after monsoon rains, natural calamities such as cyclonic weather and grazing by herbivores fishes. Import of high-yielding species/varieties and establishment of seed banks for improving the availability of quality seed material to support farming activities may be given top priority.

Meeting the requirement of seaweed products and augmenting self-sufficiency in production: The Indian requirement of agar and alginate is about 400 tonnes per annum and 1,000 tonnes per annum, whereas only 30% and less than 40% respectively of it has been produced indigenously. The Indian requirement of carrageenan is 1,500-2,000 tonnes per annum. The food sector accounts for nearly 70% of the world market for carrageenan. Taking the demand on agar, alginate and carrageenan, the total annual seaweed requirement in dry weight basis is 4,000 tonnes of agar yielding algae; 5,000 tonnes of alginate yielding algae and 4,500-6,000 tonnes of carrageenan yielding algae. Hence to improve self sufficiency in seaweed-based products, large scale farming needs to be promoted.

Policies and institutional support: Seaweed cultivation can be taken up by fishermen/fisherwomen co-operatives and self-help groups (SHGs) of the coastal areas. A minimum price for the farmed seaweeds and opening of marketing channels for seaweeds also should be considered before taking up large scale farming of seaweeds in the country. Promotion of seaweeds as healthy food for human consumption apart from its use as raw materials for the extraction of bioactive compounds and phyco-chemicals may also be attempted. National fisheries development agencies like NFDB can promote seaweed consumption through awareness campaigns and seaweed food festivals organised throughout the country. Hence, large scale mariculture of seaweeds which is a green technology for their nutraceuticals and other secondary metabolites is a dire necessity which can help mitigate major greenhouse gas and can check ocean acidification, while the seaweed farmers can make a living out of the harvest. Appropriate financing and insurance cover against crop losses due to natural calamities are also the need of the hour to further promote seaweed farming in Indian waters.

More nutraceuticals and bio-active molecules from seaweeds: Considering the diversity of chemical constituents present in seaweeds that are capable of exerting wide range of bioactivities, a growing trend is developing across globe to include seaweeds in nutritional and biomedical applications. The future programmes envisages in developing high value pigments and omega-3-fatty acids from seaweeds as cardioprotective and antidiabetic supplements. It is also proposed to develop novel seaweed liquefaction technology to produce seaweed products, which can be used as animal feed, soil conditioners, bio-pesticides, and plant growth promoting foliar spray. Work on seaweed-enriched extruded snack foods, soup powder, protein powder, pasta, seaweed tuna jerky, noodles, seaweed based composite scaffolds and membranes for medical application, seaweed based edible and biodegradable packaging materials, carrageenan-based ointment, seaweed incorporated fish feed, are underway and are in different stages of development.

SUMMARY

Seaweed farming offers immense scope as a livelihood opportunity and for developing a large number of by-products with several applications. Seaweed farming has the advantage of low capital input, as it is a primary producer requiring no inputs. Expansion of seaweed farming in the country will improve the socio-economic status of coastal fishermen/farmers and will be helpful in mitigating the negative effects of climate change while protecting the marine ecosystems from ocean acidification and ocean de-oxygenation. Establishment of seed banks, processing and marketing units, marine spatial planning, policies and institutional support are essential for sustaining seaweed farming.

[1]Scientist, [2]Principal Scientist, ICAR-Central Marine Fisheries Research Institute, Kochi, Kerala. [1]Corresponding Author: Regional Centre of CMFRI, Mandapam Camp P.O., Tamil Nadu. Corresponding author's e-mail: jsfaith@gmail.com

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Wetlands are important carbon sink

in the context of global warming and climate change

Subir Kumar Nag*, Bandana Das Ghosh and U.K. Sarkar

ICAR-Central Inland Fisheries Research Institute (CIFRI), Barrackpore, West Bengal 700 120

Climate change is a truth now as available evidence is undeniable. The emission of greenhouse gases is increasing globally leading to an increase in mean annual temperature which has several consequences. There are mainly two-pronged strategies to cope with this event of GHG emission and global warming i.e. by reducing the emission and/or increasing the capture and removal of carbon from the atmosphere. Wetlands, one of the most productive ecosystems on earth, are a huge carbon sink. So, proper management, restoration of existing wetlands and creation of new wetlands can reduce the carbon footprint and mitigate climate change to some extent.

Keywords: Carbon sequestration, Climate change, Global warming, Wetlands

THE mean global temperature has increased by approximately 1°C above the pre-industrial level with a likely range of 0.8-1.2°C and Global Warming is likely to reach 1.5°C from 2030-2052 if it continues to rise in the same pace. A recent United Nations report has warned that the world is heading for an average temperature rise by 3.2°C by 2100 which would bring more disaster of climate change and this can happen even if all current commitments under Paris Agreement are implemented. The main reason for this warming is the changes in the Earth's radiative forcing caused by greenhouse gases (GHG), the most importantly carbon-di-oxide (CO_2) and other major non-CO_2 gases viz., CH_4 and N_2O. Both CO_2 and CH_4 along with N_2O contribute to the extent of 90% of direct radiative forcing of long-lived GHGs. The concentration of CO_2 in the atmosphere has increased by 48%, from 280 ppmv in 1,750 to 415 ppmv in 2019 due to emissions caused by human activities. Atmospheric CH_4 has increased from 700 ppb to 1,866 ppb over the same period accounting 167% increase. A similar trend was also found in the case of N_2O.

Strategies for mitigation of global warming

There are mainly two approaches to mitigate the global warming caused by GHGs, one by reducing or avoiding the emissions from different sources, and another by increasing the removal of atmospheric carbon. Governments of different countries, NGOs and scientific communities feel that the mean global annual temperature should not increase beyond 2 °C above the pre-industrial value, which is very challenging. To achieve this, the global greenhouse gas emissions should be reduced by 40-70% by mid-century compared with the level in 2010, and to near-zero by the end of this century. Capturing and storage of atmospheric carbon for a long duration through natural or artificial techniques are one of the important strategies to lower CO_2 concentration in the atmosphere.

Wetlands

Wetlands are 'areas of marsh, fen, peatland, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, or salty, including areas of marine waters, the depth of which at low tide does not exceed six meters' (Ramsar Convention, 1971). They provide many beneficial ecosystem services to humankind like harbouring wide and diverse types of plants, animals, and microbes (biodiversity) and protection of wildlife; source of livelihood; fisheries and aquaculture; carbon sequestration; ecotourism, recreation, and aesthetics; water quality improvement; groundwater recharge; flood mitigation; coastal line protection, etc.

Soils in the wetland as a huge carbon sink

Of the major carbon pools, the pedologic pool is the third largest one after the oceanic pool and geological pool (fossil fuel). Carbon stored in soils exceeds the amount of carbon stored in biomass worldwide. The pedologic pool consists of soil organic carbon (SOC) and soil inorganic carbon (SIC). SOC pool is estimated at 1,550 Pg and SIC at 950 Pg up to 1 m depth. Soils of wetlands are particularly rich reserves of carbon. Wetlands and associated soils constitute a large pedologic pool estimated at approximately 450 Pg which is about one-third of total SOC stored in soils. Wetland soils may contain 200 times more carbon than the associated vegetation.

Soils of wetlands play an unusual role in the global carbon cycle. Carbon accumulates in wetland soils because of high rates of plant productivity and low rates of decomposition in these ecosystems. The net primary productivity (NPP) of freshwater wetlands is very high compared to various ecosystems including tropical forests. Due to these facts production usually exceeds decomposition in wetlands and results in the net accumulation of organic matter and carbon.

Factors affecting carbon accumulation and sequestration in wetland

The accumulation of carbon and its subsequent sequestration in sediments of different wetlands vary as it is controlled by several factors like wetland type, climatic cycle, topography and landscape position, primary productivity, macrophyte diversity and coverage, depth into the sediment, temperature, hydrology, oxidation-reduction potential, salinity, land use, etc. The carbon sequestration rate in gram carbon per square meter area per year (g C $m^{-2}y^{-1}$) of different types of wetlands around the world is given in Table 1.

Aquatic plants have a very important role in carbon accumulation in a wetland. Plants use atmospheric CO_2 for photosynthesis and after their death and decay, organic matter is added to the wetland bottom. This has a profound effect on carbon sequestration in wetland soil. It has been observed through experiments that carbon assimilation of many wetland plants (eg., *Phragmites* sp.) is increased due to the elevation of CO_2. Thus, carbon sequestration in wetland soil could be enhanced if the primary productivity of the aquatic plant is increased.

Wetlands are also a source of GHGs

Although wetlands can sequester carbon and store it in sediments for a very long period, at the same time they can also act as a source of GHGs, particularly methane (CH_4) which is 21 times more potent in global warming than CO_2. Wetlands are considered as the largest natural source of CH_4 which results from methanogenesis occurring in the sediments. They contribute 109-145 Tg CH_4 y^{-1} i.e. 20-25% of global CH_4 emission. Wetlands can also act as a source of CO_2 when decomposition of organic matter outpaces production. In addition, seasonal wetlands and those which are occasionally drained for agricultural and other purposes in many parts of the world can also become a significant source of atmospheric CO_2.

However, in spite of the release of carbon through the emission of CH_4 and CO_2, the net sequestration of carbon takes place over time in wetlands. Therefore, in the context of the above discussion, it is quite apparent that appropriate management strategies should be adopted to maintain and further enhance the carbon reserve in wetlands for the sake of protecting the earth from global warming and climate change.

Management practices to protect C-stores in wetland

- Conservation of wetlands and their sustainable use as natural habitats
- Restoration of degraded wetlands and creation of new wetlands
- Control drainage and other land and water management practices which lead to dewatering of wetlands and oxidation
- Control fires including deep burns
- Allow natural revegetation to occur
- Control peat harvesting and other removals of carbon from wetlands
- Public awareness and legal protection

Indian scenario

India has a vast area under wetland. The flood plain area covers around 0.55 million ha. Besides, there are about 0.72 million ha upland lakes. The flood plain wetlands are mostly spread in Uttar Pradesh, Bihar, West Bengal, Assam and few other North-Eastern states like Arunachal Pradesh, Manipur, Meghalaya, and Tripura. The soils of most of these wetlands have a high concentration of carbon (~4-10%) as compared to agricultural/upland soils.

As part of an adaptation and mitigation strategy for climate change due to global warming, at our institute we attempted to find out the carbon sequestration potential of different wetlands by measuring primary carbon capture and ultimate carbon accumulation in soils of different wetlands in West Bengal and Assam through our work under National Innovation on Climate Resilient Agriculture (NICRA)

Table 1. Carbon sequestration in different types of wetlands

Wetland type	g C $m^{-2}y^{-1}$	Reference
General average for peatlands	12-25	Malmer (1975)
General range for wetlands	20-140	Mitra *et al.* (2005)
Peatlands (North America)	29	Gorham (1991)
Peatlands (Alaska and Canada)	8-61	Ovenden (1990)
Boreal peatlands	15 -26	Turunen *et al.* (2002)
Temperate Peatlands (North America)	10-46	-do-
Thoreau's Bog, Massachusetts	90	Hemond (1980)
Thoreau's papyrus wetland, Uganda	480	Saunders *et al.* (2007)
Created temperate marshes, Ohio	180-190	Anderson and Mitsch (2006)
Prairie pothole wetlands, North America Restored (semi-permanently flooded)	305	Euliss *et al.* (2006)
Reference wetlands	83	
Tropical wetland, Indonesia	56 (24000 yr) 94 (last 500 yr)	Page *et al.* (2004)
Flow through freshwater wetlands		Bernal and Mitsch (2008)
Ohio (temperate)	124-160	
Costa Rica (humid tropical)	250-260	
Sewage fed wetland, Kolkata	124.5-249.05	Nag *et al.* (2019)

project. The studied wetlands were seasonally open or closed system floodplains, excepting one which was a sewage fed Ramsar site in East Kolkata. The net algal primary productivity of these wetlands varied from 150–880 mg-C/m^3/h which can add 4.21-24.67 Mg-C/ha/year (tonnes/ha/year). The seasonal average aquatic macrophytes coverage in these wetlands was between 10–40% which has the potential of adding 18.8–75.3 kg C/ha/year. Carbon dissolved in water is also an input source of carbon into the soil. The ground water recharge helps incorporation of dissolved carbon into sediments and soil. The average dissolved carbon content in the wetlands under our study varied from 14–51 ppm, which can add 90–327 kg C/ha/year. However, as organic matter decomposition and microbial respiration occurring simultaneously in the system, total amount of carbon from all these input sources will not be incorporated into the sediments or soils. But only a fraction of it, depending on biogeochemical, microbial and other factors, would be accumulated in sediments and soil and remain there for a considerable time as sequestered carbon. It is observed that 49-157 Mg-C/ha were accumulated up to 0.3 m depth into soils in different wetlands. The corresponding figures in reference upland sites was in the range of 26-49 Mg-C/ha, which clearly indicates that wetland soils can store 2-4 times or even higher amount of carbon than the upland terrestrial soils. However, capacity of the wetlands to capture and store carbon in soil varies depending on their nature. The macrophyte abundance and diversity has been found to have a positive impact of carbon accumulation is wetland soils.

Conclusion

Wetlands are one of the most important and useful resources gifted by nature to us. They do have the best capacity among the different ecosystems to capture, sequester and retain carbon through permanent burial. Sequestration of atmospheric CO_2 into soil organic carbon could be very significant in stabilizing the concentration of this GHG in the atmosphere and in achieving the target of the Kyoto Protocol set by the United Nations in 1997 which was set into effect in 2005. Therefore, we need to take all measures for protection, conservation, and creation of wetlands for the better future of our next generation.

*Principal Scientist (Agricultural Chemistry), Corresponding author's e-mail: nagsk_67@rediffmail.com

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Coldwater fish farming

in Indian Himalayan region: Challenges and opportunities

Debajit Sarma and Suresh Chandra

ICAR-Directorate of Coldwater Fisheries Research, Bhimtal, Uttarakhand 263 136

*Indian Himalayan region is abounds in innumerable rivers, streams and lakes. Of these, upland aquatic resources and mid-Himalayan region laying in the states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, part of West Bengal, Sikkim, Arunachal Pradesh, Nagaland and Meghalaya in the Himalayan range and Western Ghats like the Munnar high ranges in Kerala, Nilgiri hills in Tamil Nadu and Bababudang hills in Karnataka are some of the potential areas offering enough resources for coldwater fish farming in the country. Under the influence of lower temperature regime, the farming of selected cold water fast growing species i.e. rainbow trout (*Oncorhynchus mykiss*), exotic major carps i.e. grass carp (*Ctenopharyngodon idella*), silver carp (* Hypopthalamichthys molitrix*) and common carp (Cyprinus carpio) and few exotic ornamental fishes and minor carps are in practice among the people of Indian Himalayan region.*

Keywords: ICAR-DCFR, Polytask, Rainbow trout, Recirculating aquaculture system, Trout raceway

Rainbow trout farming in raceways

Among all the coldwater cultivable fish species, rainbow trout has been considered as a promising candidate species in hill fish farming and its large scale seed production and culture is being carried out in several fish farms in Kashmir, Himachal Pradesh, Uttarakhand, Arunachal Pradesh and Sikkim (Fig. 1). The basic requirement for establishing a trout farm is availability of good quality and quantity of snow fed spring water where temperature throughout the year is below 20^{0}C. There are about 35 small and big trout hatcheries with an estimated eyed ova production capacity of 15 million are present in the country which have been mostly established by the various state governments and also with the assistance of central government schemes. The states of Jammu and Kashmir and Himachal Pradesh are forerunner in promoting rainbow trout farming in private sector. The highest trout producer states in India are Jammu and Kashmir with a table size trout production of 700 MT and 13.4 million trout ova production. Himachal Pradesh is the second highest producer (650 MT) in the country. DCFR is further giving technical support and conducting demonstration program for expanding trout culture activities in Leh- Laddak, Sikkim, Arunachal Pradesh, Nagaland and also in high reaches of Uttarakhand. Seed production of trout is mainly in Jammu, Kashmir, Himachal Pradesh and Uttarakhand in central Himalaya. However, with the DCFR's tiring efforts, seed production of trout has further been extended in Sikkim and of late in Arunachal Pradesh. At present the trout production in the country is over 1,500 tonnes (2018-19). The rainbow trout is a highly expensive fish to cultivate in the farms and as a luxury food beyond the reach of the common man is still holding well amongst the fisheries planners. Being a low volume high value commodity, the trout has good potential for domestic consumptions as well as foreign export. Presently the rainbow trout has been established in Indian water and is a

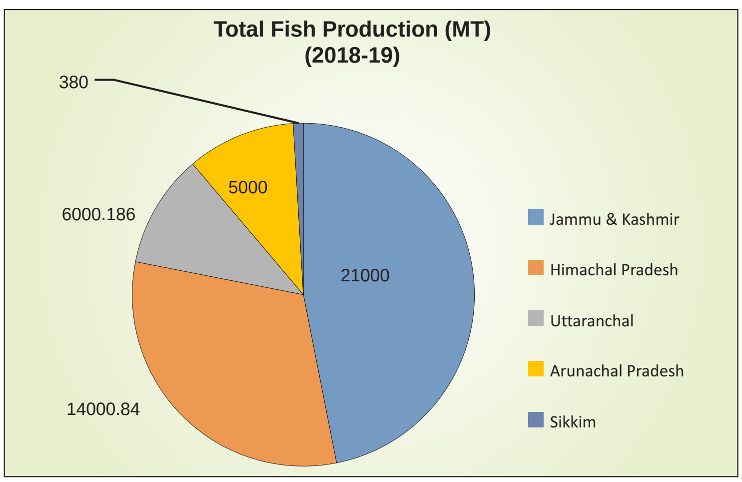

Fig. 1. Total fish production from Himalayan States is 46,381 MT

Fig. 2. Trout raceways

cultivable species with cool, clean and well oxygenated flowing water (Fig. 2). Cool, clean and well oxygenated flowing water is the prime need for the successful culture of rainbow trout. Raceways of 30-150 sq m with depth of 1 m used for the production of table sized trout fish (300-400 g). This system is feed based culture in continuous flowing water known as raceway farming. The stocking density is also dependent on quality and quantity of available water volume. Healthy seed is stocked at the rate of 5-10 fingerlings/sq m under suitable water temperature and sufficient good quality protein rich (40%) feed supply, trout attains 300-500 g size after 10-12 months with stocking of advanced fingerlings. Technology is farm based and eco-friendly to achieve production of 10-15 kg/sq m. There is ample scope for enhancement of trout production in hill states through participatory approach. The present trout production of the country is around 1500 MT which may be enhanced upto 10000 MT easily with the adoption of recent technology and with the help of best management practices. Trout has good potential for domestic consumptions as well as foreign export. It provides an excellent opportunity for utilizing the abundant aquatic upland resources and for livelihood and nutritional security to the hill community through fetching of a very good market price restaurants.

Rainbow trout farming in re-circulating aquaculture system

Rainbow trout farming has been a promising and remunerating livelihood opportunity in Indian uplands due to the abundance of cold freshwater sources. Nevertheless, with changes in the demographic pattern and competition for resources, huge amount of water required in conventional flow-through raceway system trout farms (FTRS), makes the activity unsustainable in the long-term. To illustrate, to maintain 1000 kg of trout at a stocking density of 25 Kg/m^3 in an FTRS, a water flow rate of 600L/minute is required. As such, 50-200 m^3 of water (depending on the different methods of calculation) is required to produce 1 kg of rainbow trout in FTRS, which is apparently not sustainable with diminishing water resources and limits rainbow trout farming activities to an only specific region of Indian uplands. Therefore, it is time to adopt climate-resilient and intensive farming practices, which involves maximum utilization (reuse) of available land and water resources, to facilitate the blue revolution fish production targets by 2030. It is important to note that scientific advances in Recirculating Aquaculture Systems (RAS) have reduced the water requirement in trout culture by several folds (less than 1 m^3 of water per kg fish production), with stocking densities as high as 100 Kg/m^3. Comparison of the environmental impact of FTS and RAS suggests that RAS reduces water dependency by 93%, eutrophication potential by 26-38%, and improves food conversion ratio by 27%. Even the bottom side of high energy requirement in RAS (16 kWh per kg fish) can be overcome by strategically reducing energy usage to a significant extent by optimizing water re-circulation and oxygenation requirements. Besides, clean energy sources (e.g. solar energy which is adequately available in hilly regions) and biogas produced from fish waste sludge can be utilized to make RAS based rainbow trout farming more sustainable. Further, by controlling water temperature in RAS, it is possible to reduce crop duration to 5-6 months (as compared to the 12-14 months cycle in FTS) and augment production per unit time.

In this regard, ICAR-Directorate of Coldwater Fisheries Research, Bhimtal has initiated a study for the feasibility of RAS for rainbow trout in the Indian context. ICAR-DCFR designed and installed a RAS, consisting of four 7 m^3 large culture tanks for grow-out production and 18 (0.5 m^3 each) juvenile rearing and experimental tanks with available rearing volume of 33 m^3 (Fig. 3). The system consists of radial flow separators and mesh screen drum filter to remove settable and suspended solids and two moving-bed biological filter to remove ammonia and nitrite, and a UV filter for disinfection. The water is re-circulated with the help of water pumps continuously. With the current pilot-scale RAS set up, it is possible to produce 1.2 MT of trout per crop cycle (2.4 MT per year, at the stocking density 40 kg per m^3). The production can be increased to ~5.0 MT per year with the help of pure oxygen for oxygenation and

A pilot scale rainbow trout Recirculating Aquaculture System

Harvesting rainbow trout from RAS

Fig. 3. Rainbow trout farming at ICAR-DCFR, Bhimtal

addition of CO_2 stripper and protein skimmer to system. In the trial, ~ 250kg of rainbow trout are harvested and sold from two of the grow-out tanks, and observation indicates that growth rates are much faster in RAS compared to FTRS (100 g to 800 g in four months) due to controlled water parameters. Currently, we are testing the system for complete production cycles and economic feasibility of the RAS system for rainbow trout farming in the Indian scenario. RAS system can significantly contribute to increase in trout production due to the fact that the RAS farming practices can be done from nearly anywhere in the Indian upland region with limited water availability and lower land footprints which otherwise impossible with current farming practices in flow through raceways. Moreover, ICAR-DCFR is also working on development of affordable and economically viable prototypes for small scale RAS trout production systems which can be operated by small scale farmers and will be disseminating soon to the Indian hill fish farmers.

Polyculture of exotic carps

In the upland waters, Chinese carps are commonly cultured in the mid-Himalayan region as the candidate species for polyculture. The culture of Chinese carps were introduced in the polytanks/ irrigation tanks in the mid altitude regions. The technology provided opportunities for conservation of water for irrigation and fish culture. The use of polytanks has shown enhanced growth of fish. Around 76 farmers in the Champawat and Almora districts of Uttarakhand have already adopted the technology. Recently, DCFR imported improved Hungarian strain of scale carp and mirror carp and the farm raised improved strain of common carp was propagated for aquaculture promotion in hill states which gave very promising results having 35-40% better growth over the existing old stock of introduced common carp. In the upland waters the Indian major carps do not grow well, due to the low thermal regime. Therefore, Chinese carps were taken as the candidate species for polyculture. Seed in the form of fry is being used for stocking grow-out ponds, which require 12 months to get the table size fish (>1 kg). The average fish production in the existing system is 2.6 t/ha which can be doubled through technological support, quality seed, feed and improved management practices. Crop duration may be reduced to half with the practice of stocking of stunted fish of 50-80 g. However, provision of seed banks is required for round the year availability of stocking material to the farmers. The carp culture practice may also be integrated with dairy, poultry and horticulture keeping the fish pond as nucleus in view of increasing productivity, reducing risk and production cost.

Composite culture of rohu, catla, mrigal, grass carp, silver carp and common carp in earthen ponds of the size of 0.1-0.4 ha is advisable for the foot hill region (800-1000 msl). Raw cow dung (RCD) @ 9000 kg/ha/yr is applied to ensure consistent growth of plankton. Stunted fish of the size of 50-80 g are stocked at the rate of 5000-6000 fish/ha with species ratio of 40:30:30 for catla and silver carp (surface feeder), rohu and grass carp (column feeder) and mrigal and common carp (bottom feeder), respectively. Supplementary feed, prepared from locally available ingredients such as oil cake, rice polish/bran is given @ 2-3% of the body weight. Vegetable waste/ terrestrial grass is used for grass carp feeding. Two crops of 6 months each can be achieved with average production of 2.5-3 t/ha (total annual production- 5-6 MT/ha). With an expenditure of ₹ 2,700/100m^2, a gross income of ₹ 7,200/100m^2 has been achieved with a net return of 167%. Profitability (₹ 4,500/100m^2). There is great scope for disseminating this promising technology in sub to mid Himalayan belt in order to upgrade the socio-economic conditions of the inhabitants. There is a need of introduction of large scale farming to bring the country on International scenario. The linkage of public and private sector is mandatory in order to further development of this technique. The farmers in the hill region have integrated type of farming pattern. Fish can serve as an additional source of income if integrated with the hill agriculture.

Polyculture in polyline tanks

The Chinese carp based mixed culture have shown positive results fetching average 340 g/m^2 in an extended culture period of over one year. However, this limited production can further be raised up to 700 g/m^2 by adopting multi-tier model for integrated fish farming using polytanks. These plastic (silpaulin) film lined ponds are suitable for rainwater harvesting in uplands where scarcity of water becomes major bottleneck in agricultural production or diversification from poorly remunerative production to scientifically recommended production considering local climatic and soil advantages. In Himalayan hilly tracts, such ponds are being used for rainwater harvesting or storing the water from low discharge springs which otherwise cannot be directly used for irrigation purposes.

The following steps are involves in the preparation of polytank

Digging of the pond (100 m^3 from 80 to 100 m^2 land area), removing sharp edge material (stone pieces) embedded on the walls and the bottom of the pond. Plastering the inside wall and bottom by using a mixture of fine soil and water mixture to smooth them. Lining the pond's walls and bottom with polythene/silpaulin (200-250 g per meter). Advanced Fingerlings (20-25 g) of silver carp, grass carp, improved common carp and minor carp are stocked at the rate of 3-4 fish/m^3. Vegetable waste/terrestrial grass is used for grass carp feeding @ 20% of total fish biomass daily. Waste of grass carp in the form of faecal matter acts as manure in pond water and enrich the plankton production which is the natural feed for silver carp. Some part of the faecal matter is directly eaten by common carp. Stored water in the poly tanks also acts as buffer stock and is used for the irrigation of horticulture crops. This water remains rich in nitrogen content and also acts as manure for horticulture plot. In hills, the agriculture is mainstay of the inhabitants but the average land holding is 700-900 m^2 compared to national average 1370 m^2. The soil productivity is less due to marked water shortage during the summer in the streams of hills, soil is gravelly and porous that has low water holding capacity which limits the production cycle and farm activities. This is the main cause of migration of the young people to the plains for earning their livelihood. In this context, this model has a lot of scope to intensify in the mid hills for increasing the productivity of the land that can help in ensuring nutritional and livelihood security in the hills which ultimately, would decrease the pressure on the metropolitan cities since this would check the migration from hills to plains. There is great scope for disseminating this promising technology in sub to mid Himalayan belt in order to upgrade the socio-economic conditions of the inhabitants. With an expenditure of ₹ 3,000/100m^3 a gross income of ₹ 11,200/100m^3 was achieved with net return of 273%.

Ornamental fish farming in hills

The demand of ornamental fishes is increasing remarkably due to their important role in the world trade for fish and fishery production. The export of ornamental fishes from India is worth only US$ 0.2 million, which is not sufficient with regard to the rising demand of these beautiful coloured species in the world ornamental fish market. The Potential ornamental fishes of the coldwater resources are *Barilius* species, *Namacheilus* species, *Botia* species, *Puntius* species *Garra* species and also few exotic species are unique for aqua gardening. This diversity is yet to be explored for breeding and culture practice which may have great coldwater ornamental fish value.

A germplasm repository of seven cold water ornamental fish species like *Barilius, Tor chilinoides, Garra, Schistura, Nemacheilus* including exotic gold and koi carp have been established in DCFR, Bhimtal campus. The focus of the technology is to establish culture and breeding of ornamental fishes in the backyard or Kitchen garden in upland rural areas. Depending upon the space and available resource, the unit is established. For establishing a 30 sq feet with 5 feet deep UV resistant polylined tank including labour and input cost is about ₹ 2,500. Total about 350 fishes can be stocked with a survival of 300 with a sale value @ ₹ 25/piece in hills is about ₹ 7,500 with an approximate net income of ₹ 5,000 per year. The small landholding in the hills with marginal agricultural and allied activities is directly affecting the economic status of the population (Fig. 4). The intervention of ornamental fish culture in the tribal regions will help in upbringing the livelihood opportunities. Ornamental fish keeping in house, hotels, offices are the general practices by much reason (fascination/recreation/aesthetic value) which will create livelihood opportunities in the hill areas.

Upland rice-fish culture

The rice-fish wetlands are important resources in the state of Arunachal Pradesh, Nagaland, Meghalaya, Manipur and parts of Assam. A large area in Apatani plateau in Ziro valley of Lower Subansiri district of Arunachal Pradesh, several districts of Nagaland and other Northeastern states is being cultivated under rice-fish culture (Fig. 5 and 6). The fish production in these fields is at present

Fig. 4. Ornamental fish farming in hills

Fig. 5. Upland rice-fish culture

is low (215-290 kg/ha) and scientific intervention is required to enhance the productivity. Higher productivity from rice-fish plots can be achieved by stocking bigger size (3-4") of quality fingerlings at appropriate density of fish (1-2 fish/m^2) and redesigning proper sized trenches in the field for providing shelter to the fishes. Of course, nutrient and natural fish food available have to be taken into account to decide the practices of organic fertilizers and supplementary feed. There are possibilities to enhance the productivity to 3-4 times. Never the less, large sections of upland population including women are dependent of rice fish culture in NE region and it gives livelihood and nutritional security to the particular tribes of Indian Himalayan region.

Challenges in coldwater fisheries development

The constraints of coldwater fish farming are low productivity of upland waters due to comparatively slow growth rate in almost all fish species except rainbow trout, coupled with low fecundity in fishes. Further, poor landing and marketing facility are also obstacles in the development and expansion of coldwater fish production.

The major constraints are cost intensive activity, slow growth rate leading to less output, lack of infrastructure (e.g. Raceways, Hatcheries, and Transport *etc*.), costly inputs (less availability of seed, feed for culture), habitat destruction, lack of commercial/cluster approach for farming, non-adaption of fisheries as main stream profession by local population and lake of organised market for selling high value fish like trout.

The key strategies to be adopted to address the challenges and tap the opportunities are:

- Promotion of trout farming in areas above 1,500 msl having temperature range of 4-12.
- Poly culture in hill regions between 700 and 1,500 msl with suitable land and water resources for carp culture.
- The eco-climatic conditions of the foothills and river valleys located up to 500 MSL are suitable for composite culture of carps. Such sites are available in the catchments of the Himalayan and peninsular rivers, streams and their tributaries. The carp farming would be, therefore successful in the valleys and peripheral regions located in the temperature range between 15 to 25°C.

Fig. 6. Traditional rice fish culture in Ziro valley, Arunachal Pradesh

Future Scope

Under scientific management and through application of modern techniques, significant scope exists for promoting trout farming, which in long run, will have both domestic and export demand. There is also a great potential for sport fishery development and ecotourism in hill regions. Ornamental fish culture for small scale enterprises in the hills can provide an alternative source of employment. Presently DCFR has different available technologies for the hill aquaculture, resource management and conservation. Three ponged fish farming has been standardized and also disseminated to the farmers of different hill states of the country. Chinese carp based polyculture technology has been popularized and also adopted by farmers in Arunachal Pradesh, Manipur and Uttarakhand. Trout farming and seed production technology has also been introduced in the state of Sikkim and Arunachal Pradesh. Aquaculture diversification is the key of fish production enhancement in the hill states and also one of the most important needs of the hour. It is believed that the introduction of Recirculatory Aquaculture System for rainbow trout farming will definitely be a game changer for improving the status of coldwater fish production in the country and will play a significant role in improving the livelihood and nutritional security of the upland population of Indian Himalayan region.

Corresponding author's e-mail: director.dcfr@icar.gov.in

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Pradhan Mantri Matsya Sampada Yojana to bring "Aatma Nirbhar Bharat"

in fisheries and aquaculture

Rajeev Ranjan[1]

Department of Fisheries, Ministry of Fisheries Animal Husbandry and Dairying, Government of India

Fisheries and aquaculture is a sunrise sector in India, which is the fastest growing and the most profitable among agriculture and allied sectors that made impressive strides in achieving a robust average annual growth rate of 10.88% in the last five years. The sector provides vital livelihood directly to over 2.8 crore fishers, fish farmers, fish workers and fish vendors and indirectly to several crore people along the entire value chain. Apart from providing gainful employment, the sector contributed about 1.24% to National Gross Value Added (GVA) and over 7% to the agricultural GVA during 2018-19.

Keywords: Aatma Nirbhar Bharat, DARE-ICAR, Nutrients, Ornamental fisheries, PMMSY, Seaweed

INDIA is the second-largest fish producing country in the world and shares 7.58% of global production. Fish production in India has registered an average annual growth of 7.53% during the last five years and stood at an all-time high of 141 lakh tonnes during the year 2019-20. Since 2017, India has become the 4th major exporter of fish and fishery products, boosted by a steep increase in farmed shrimp production spearheaded by *Littopenaeus vannamei*. The major commodity of the export basket is frozen shrimp, which accounts for about 70% in terms of the value of the total fish and fishery product exports. Moreover, India has become the top country in the export of frozen shrimps all around the world, accounting for around 24.9% of the total global shrimp exports.

Recognizing the immense potential of the fisheries and aquaculture sector and acknowledging its significance to the economy, the Government of India has approved a new flagship scheme, the Pradhan Mantri Matsya Sampada Yojana (PMMSY) under Aatma Nirbhar Bharat Package at an estimated investment of ₹ 20,050 crores in order to drive sustainable and responsible development of the sector while ensuring socio-economic welfare of fishers, fish farmers, fish workers and fish vendors. PMMSY, with the highest ever investment in the history of the fisheries sector, will be implemented in all States and Union Territories over a period of 5 years, from 2020-21 to 2024-25 as an 'umbrella scheme'. Further, the scheme intends to promote focused fisheries development in strategic areas such as Jammu and Kashmir, Ladakh, North-East Region and Aspirational Districts by identifying community needs, leveraging local knowledge and building on area-specific strengths and capabilities.

In an endeavour to consolidate the fisheries' sectoral gains and boost economic growth, PMMSY sets out ambitious goals for the next five years which include increasing fish production up to 220 lakh tonnes, increasing aquaculture productivity from the current national average of 3-5 tonnes per ha, doubling exports from ₹ 46,589 crores (2018-19) to ₹ 1,00,000 crores, generating sustainable employment for over 55 lakh people and doubling fishers and fish farmers' incomes.

Scope for Aatma Nirbhar Bharat in the fisheries sector

Through the promulgation of the Aatma Nirbhar Bharat or Self-Reliant India, the honourable Prime Minister of India envisions the revival of the country's socio-economic circumstances that got severely affected due to the COVID-19 Pandemic. Rebuilding India by making it self-reliant will be a critical task for India, since being the nation with the world's second-largest population size, where more than 65% of the population encompasses the rural Indians. As the food production sectors are the backbone of the nation, strengthening the sectors like agriculture, animal husbandry and fisheries would have their pivotal roles to play to achieve the targets of Aatma Nirbhar Bharat in the coming years.

Over the years, fisheries and aquaculture have evolved from an informal and fragmented sector, to become a pivotal engine of the Indian economy due to the remarkable intervention of the Government during the last decades, in form of policy and financial support under various schemes such as Centrally Sponsored Scheme- Blue revolution (CSS-BR, during 2015-20), Fisheries and Infrastructure Development Fund (FIDF-launched during 2018-19), *Kisan Credit Card* (KCC) to fishers and Fish farmers.

However, achieving Aatma Nirbhar in the Fishery sector in the country needs more focused attention on its various subsectors which are detailed below.

Aquaculture of food fishes

Presently, the Indian aquaculture is dependent on a few species of major carps and prawns, though there are a number of species in line for which the mass production methods are yet to be commercialized. Freshwater aquaculture is centered around the major carps, whereas the brackishwater aquaculture is almost synonymous to the shrimp aquaculture, exceptionally dominated by the exotic, Pacific white shrimp, *Littopenaeus vannamei*. The *L. vannamei* at present, contributes around 90% of the total cultured shrimp production in the country. Therefore, developmental strategies through PMMSY gives due attention towards diversification of aquaculture through indigenous varieties of finfish and shellfish species for furthering self-reliance in the farming sector.

Apart from species diversification, scaling up of production is the need of the hour, which is another crucial aspect, that the government is looking for, through the focused interventions under PMMSY. Recent estimates show that, there is a gap of about 30-35% existing between the actual seed requirement and availability in the Indian aquaculture sector. PMMSY addresses the stumbling blocks in upscaling the fish production throughout the country by the establishment of adequate number of brood banks, hatcheries, seed rearing units, feed mills and ensuring indigenous production of specific pathogen-free/ resistant seed as well as genetically improved broodstock.

Fish consumption and Value chain development

India is witnessing a huge challenge in addressing the food security and malnutrition issues, scaled up by the population size and the huge proportion of around 60% of which resides in rural India. The existing production systems, as well as value chain may not be sufficient to ensure the availability and equitable distribution of nutritious food to the growing population. Fish is a superior and affordable source of protein to other animal source foods, and it is rich in essential nutrients such as vitamins and minerals. These are precisely the nutrients essential to prevent wasting and stunting of the human body. It is for that reason that the global initiatives have recently made pleas to put fish higher on the agenda targeting malnutrition.

Therefore, it is the Government through the interventions under PMMSY, envisages to increase the average per capita fish consumption in the country in the tune of 11-12 kg/ person/year from the current levels of 5 kg/ person/year. The attempts will direct towards the mission of alleviating hunger and ensure food security in the coming years through support for sustainable aquatic food production. PMMSY also targets a reduction in post-harvest losses from 25% to 10% in the coming years. The Government is working for achieving these targets by creating conducive environment in terms of food fish production systems, popularizing the health benefits of fish consumption and ensuring the fish availability all over the country. Along with increasing production to meet the domestic demand in the coming years, emphasis is also be laid on addressing critical gaps in the value chain through technology infusion, improved quality, hygiene of fish and fish products, value addition, demand-based branding and marketing.

Ornamental fisheries

Ornamental fisheries sector in the country has a huge potential in terms of unique varieties of fishes with high ornamental value and the increasing number of aquarium hobbyists in the country particularly in the urban areas. It is estimated that, if the number of aquarium hobbyists in the country could be raised to approximately 3% of the urban households from the current level of 1.25% by 2025, the domestic aquarium trade can be raised manifold. As far as the aquarium industry is concerned, the ornamental fish contributes only about 20% to total domestic aquarium trade in India. It is mainly the aquarium and aquarium accessories that constitutes about 63% to domestic aquarium trade. But, the major requirement of aquarium accessories (about 90%) is met through imports.

The Government of India has recognized that, technological advancements in indigenous ornamental fish breeding and the accessories manufacturing sector and financial support to small and medium scale units in the country, could potentially scale up the production of quality offspring's combatable to trade and bring in more indigenous units of aquarium accessory manufacturing in the country. The intervention will result in a significant reduction in import of high value ornamental fishes as well as aquarium accessories and there by achieving self-reliance in the sector. Therefore, under the Pradhan Mantri Matsya Sampada Yojana (PMMSY), an investment of ₹ 576 Crore is proposed exclusively for the development of ornamental fisheries in the country in coming five years.

Seaweed cultivation

Seaweed farming is another area which has high potential in terms of mass employment generation and demands self-reliance in its various stages along the value chain. Seaweeds are the marine algae which are one of the potential renewable resources of the oceans. The utility offered by the seaweed bio-resources are mainly attributed by the phyco-colloid industries. Agar, algin and carrageenan are the three polysaccharides obtained from seaweeds, which have over 200 identified extensive industrial uses. Out of the global seaweed production of 32.4 million tonnes of fresh weight, India does not contribute much at present. Although there are number of seaweed-based industries in India, which are not functioning up to their rated capacity due to short-supply of raw materials. It has been estimated that, only about 30% of the annual domestic agar requirement and 40% of alginates has been met by indigenous production. Rest of the domestic demand is still met by imports and present situation demands more self-reliance in the sector to align towards the slogan of Aatma Nirbhar Bharat in terms of seaweed-based industry and value chain.

It is therefore under PMMSY, envisaged to revolutionize the seaweed farming and value chain in the country with an increase in production manifold from the current levels to about 11.2 Lakh tonnes of wet weight in the coming 5 years. Under PMMSY, a total investment of ₹ 640 crores is exclusively earmarked for the development of seaweed cultivation and value chain in the country. Moreover, being an agricultural economy, products such as plant growth stimulant (liquid fertilizer) developed from fresh seaweed biomass have huge domestic demand in India. Biofertilizer and growth stimulant business currently represent 1,500-1,700 crore market in the country, where the lion's share of sea weed extracts required for the industry are imported annually. Hence, the targeted hike in the seaweed production under the PMMSY will result in a significant reduction in the imports in the biofertilizer and growth stimulant industry in India. Seaweed biomass is gaining prominence in food and nutraceuticals industry, wherein new emerging application in several bio-based and high value edible commodity products especially functional food is being developed. The ICAR – Central Marine Fisheries Research Institute (CMFRI) has successfully developed a series of Nutraceutical products indigenously for use against various life style disorders. Scaling up of production and industrialization of such products offer large scope in the coming years.

Deep sea fisheries

Given the low level of harnessing of deep-sea fisheries resources in EEZ and High seas, by our indigenous fleet and artisanal fishers, support under PMMSY will be provided to traditional fishermen for acquiring deep sea fishing vessels, promotion of technologically advanced fishing vessels and fishing gear for fishermen/fishermen groups through State/UT governments. Training and capacity building for undertaking deep-sea fishing will also be supported under PMMSY, in collaboration with other important maritime nations.

Mobilization of Human resource and support to entrepreneurship in fisheries

The Government is considering the fact that scaling up production and making the sector self-reliant require engaging more new people in its various sub-sectors and capacity building of existing work force, that needs some levels of training, knowledge and exposure for achieving better results. Therefore, under PMMSY, special focus is given accorded for training, awareness, exposure and capacity building of beneficiaries which includes fishers, fish farmers, entrepreneurs, fish workers/vendors and fishery officials. A comprehensive action plan is being drawn up to train about 1.5 lakh beneficiaries with an amount of ₹ 100 crore under PMMSY.

Apart from the conventional subsidy-oriented support system, the PMMSY strives to create a conducive environment for private sector participation and promote the dynamic development of innovative entrepreneurial ventures and viable business models in the fisheries sector.

Collaboration with DARE/ICAR in training and capacity building

Most recently, the Department of Fisheries proposed to undertake a massive outreach program, in collaboration with ICAR, Department of Agricultural Research and Education (DARE) for disseminating the PMMSY scheme not only among fishers, fish farmers, fish workers, fish venders and entrepreneurs but also among agriculture farmers, who undertake aquaculture activities as allied activities for additional income generation. The proposed program is envisaged to reach out to over 10 lakh fishers and farmers through web-based training and awareness in a fixed time frame. Towards this end, 150 Fisheries potential districts including all 77 coastal Districts are proposed for taking up in the first phase by drawing the expertise of ICAR- fisheries Institutes, KVKs and Fisheries Universities/ colleges.

Strategies for Implementation

Committed to attaining its targets, PMMSY works in the domain of cooperative federalism, built on a structured and robust implementation framework which inter-alia includes institutional mechanisms for establishing Program Units, State level Approval and Monitoring committees in all States/UTs along with District and Sub-district level units for preparation of Integrated Fisheries Development Plans and fast-tracking approvals. Apart from that, PMMSY establishes effective linkages between farm production and retail chains, strengthening Fisheries SHG's and Cooperatives, Collectivizing fishers and fish farmers through Fish Farmer Producer organizations (FFPO's) to enhance competitiveness of the sector and increasing bargaining power of fish farmers leading to higher incomes and economic prosperity.

To the extent possible, PMMSY will adopt a 'cluster or area-based approach' integrating requisite forward and backward linkages to facilitate economies of scale, accelerate growth and expansion of the sector in an organized manner. It is also envisaged to encourage convergence with the schemes or programs of other Ministries/ Departments to facilitate holistic development and thus, amplify outcomes.

Through need based financial support to various sub-sectors, training and capacity development of large number of rural population and align them towards fisheries and aquaculture related lively hood activities, it is expected that PMMSY can significantly contribute towards the *Aatma Nirbhar Bharat Abhiyan*.

[1]IAS, Secretary, Ministry of Fisheries Animal Husbandry and Dairying, Govt. of India

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Responsible fishing and sustainability

Leela Edwin* and Saly N Thomas

ICAR-Central Institute of Fisheries Technology, Kochi, Kerala 682 029

Marine fishing globally has undergone significant structural transformation from artisanal focus to technology intensive and advanced fishing systems. This, however has resulted in an undesirable trend of excess capacity and overexploitation of resources. This emerging trend demands enforcement of sustainability standards as per the FAO Code of Conduct for Responsible Fisheries. While India, as a member country is keen on following the FAO standards, the concept of 'green fishing' encompassing energy conservation and minimization of environmental impact gain accelerated relevance.

Keywords: Bycatch reduction devices, Energy conservation, Green fishing, Responsible fishing, Trawl

INDIA has expanded its fish production during the last six decades with an 18-fold increase in production. With its highly productive fishing area, the country's fish production has grown from 0.74 million tonnes in 1950 to 13.42 million tonnes in 2018 with the share of marine catch at the level of 3.71 million tonnes. The structural transformation of the fishing system in India was from an exclusively artisanal sector dependent on manual labour, into a mechanized system depending on engine power for vessel propulsion and/operation of the fishing gear. The fishing systems today comprises of motorized and mechanized vessels using large versions of gears such as trawls, purse seines, gillnets, lines and traps. The artisanal non-motorized is slowly being phased out. Increase in fish production, over the years, has been the result of increased number of fleet and availability of large and more efficient gear systems, and developments in electronic, navigational and acoustic detection equipment that help to enhance overall capabilities.

Challenges of sustainability

Structural change implies negative consequences as well. At present, there are about 1,99,141 fishing vessels in India, of which nearly 72,749 are mechanized vessels (36.5%), 73,410 are motorized (36.9%) and the rest 52,982 non-motorized (26.6%). These are in excess of the optimum that the fishery system can sustain; motorized vessels thrice and mechanized vessels five times higher than the optimum. This means, over exploitation of the resources bycatch, high energy use and over capitalization especially in terms of indicators such as vessel and gear size, and engine power. Sustainability concerns, therefore demand corrective measures. As a signatory of multinational conventions, following the global codes of conduct is the best policy option that India can think of. The global thinking today is towards an integrated approach to sustainable fishing practices under the 'Responsible Fisheries' framework.

FAO Code of Conduct and Responsible Fishing Approach

A Code of Conduct for Responsible Fisheries (CCRF) came from the FAO in December 1995. It sets out the principles and international standards of behaviour for responsible practices to ensure long term sustainability of living aquatic resources, with due respect for the ecosystem, biodiversity and environment. Article 8 of the Code covers key principles including use of conservative management approaches when the effects of fishing practices are uncertain; avoiding overfishing and preventing or eliminating excess fishing capacity; minimization of bycatch and discards; prohibition of destructive fishing methods. India has been keen on adopting CCRF for sustainable exploitation of the resources. As a member country, India's responsible fishing initiatives for sustainability include, development of efficient fishing vessel designs, responsible fishing gears, measures for bycatch reduction, energy conservation and minimizing negative impact of fishing gears.

Responsible Fishing ensures sustainability of the system by using gears in a responsible way so that overfishing is reduced and fish stock is protected. At the operational level, selective fishing is the deployment of gears which capture target resources without having any adverse impact on the resources and the ecosystem. Such gears ensure selective exploitation of resources according to criteria on size, shape, age or species. Optimum mesh size and other selectivity characteristics for different gears like trawls, purse seines and gillnets for selective exploitation of commercially important fishes. These strategies and measures would enable sustainable fishing by avoiding juveniles, bycatch etc.

Demersal trawls which contribute maximum towards the marine fish production of India are non-selective and a large number of non-target species and juveniles are landed during trawling, in addition to its impact on benthic communities. Off bottom trawl system (CIFT-OBTS) is an alternative to demersal trawl in the small-scale mechanized trawler sector. Unlike conventional demersal trawl which is dragged along the seafloor, off bottom trawl operates at a little distance above the bottom. This makes off bottom trawl an eco-friendly gear with significantly lower bottom impact than demersal trawls. Besides, it comes out as a responsible alternate trawl system for harvesting less exploited large demersal and semi-pelagic species as the shrimp and other demersal resources targeted by bottom trawls are rather over exploited.

Most fishing gears, while targeting a particular fish or group of fishes, non-targeted ones also are caught unintentionally and is termed as bycatch. Bycatch problem mostly happen when the gear used is non-selective and not designed to exclude non-targeted fish. Devices used to exclude the bycatch of non-targeted species including endangered species like turtle are collectively known as Bycatch Reduction Devices (BRDs). These devices are developed taking into consideration the variation in the size, and differential behaviour pattern of fish, shrimp and other animals inside the net.

Among the different types of fishing, shrimp trawling accounts for the highest rate of bycatch, of which a significant portion is constituted by juveniles that are generally discarded. Square mesh netting is the simplest BRD used in trawl codend as a conservation measure. Meshes in the square mesh codend remain open under tension during trawling unlike the diamond mesh codend in which the mesh lumen closes under tension. In square mesh, water flow and filtration will be efficient and resultant drag will be comparatively less which minimizes fuel consumption. As the mesh lumen remains open, it is easy for small fishes and juveniles to escape through the meshes which reduces the quantum of bycatch. Gujarat Marine Fishing Regulation Act (GMFR Act-2003) has prescribed the use of 40 mm square mesh codends in the trawl nets. Most recently the Govt. of Kerala has adopted 35 mm square mesh codend for fish trawl and 25 mm cod end for shrimp trawl through amendment of the Kerala Marine Fisheries Regulation Act.

Incidental catches of marine turtles which are endangered species have been reported in the trawl landings of India particularly from West Bengal, Odisha, Andhra Pradesh, Tamil Nadu and southern parts of Kerala. Turtle excluder device (TED) is a BRD incorporated in trawl nets to facilitate escape of turtles incidentally caught in trawl nets. Its use by small and medium mechanized trawlers operating in Indian waters ensure 100% escapement of the turtles while exclusion of fish and shrimp is at the minimum possible level.

Trawl fishermen in India and other tropical fisheries depend on both finfish catches and shrimp catches to keep the commercial operations economically viable. The sorting of the shrimp and the finfish from the catch is time consuming. A unique solution for this issue is a Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD), which retains mature shrimp in the bottom portion of the net while allowing juvenile shrimp to swim out through the mesh unharmed. The device also retains mature finfish in the upper codend of the device, while allowing small sized fish of low commercial value and juveniles of commercial species to be safely excluded. The sorting of the shrimp and the finfish between the lower and upper parts of the net enhances profitability by reducing the sorting time and by preventing the shrimp from becoming crushed under the weight of fish which increases the shrimp's market value.

Though not as dominant as in trawls, bycatch is an issue in other gears like gillnets, purse seines, hooks and lines, and traps. Bycatch in drift gill nets include marine mammals, sea turtles and sea birds, in addition to non-targeted fish species. Use of optimum mesh size and hanging coefficient as well as by judicious deployment of gill net considering the depth and area of operation and season would avoid gear interaction with non-targeted species and minimize bycatch in gill net fisheries.

Accidental pursing of juvenile shoals is the main reason for bycatch in purse seine. Selection of optimum mesh size, proper choice of fishing area, depth and season could lead to better selectivity and reduction of bycatch in purse seines. Use of *Medina panel*, section of fine mesh which form a type of escape panel, prevents dolphins from becoming entangled in the gear, and back down manoeuvre have been deployed to prevent capture of dolphins in purse seines. Choice of hook design and size, bait type and size, selection of space and time of fishing are approaches for mitigation of bycatch issues in hook and line fisheries and minimize gear interaction with other species. Provision of escape windows for juveniles and non-target species in the design side and appropriate choice of bait type, fishing area, fishing depth, fishing time also help to minimize juvenile catch in traps.

Green fishing

The concept of 'Green Fishing' encompasses energy conservation and minimization of environmental impact of fishing gears.

Energy conservation in fishing

Motorized and mechanized fishing operations are dependent on fossil fuels, which are non-renewable and limited. Fossil fuel produces increased levels of carbon dioxide in atmosphere contributing to green house effect and other pollutants which are detrimental to the environment and human health. Greenhouse effect leads to irreversible climatic and oceanographic changes. Moreover, spiraling oil prices may severely affect the economic viability of fishing as a means of food production. World capture fisheries consumes about 50 billion litres of fuel annually (1.2% of the worldwide fuel consumption) releasing an estimated 134 million tonnes of CO_2 into the atmosphere at an average rate of 1.7 tonnes of CO_2 per tonne of live-weight of landed product. Annual fuel consumption by the mechanized and motorized fishing fleet of India has been estimated at 1220 million litres which formed about 1% of the entire fossil fuel consumption in India in 2000 (122 billion litres) releasing an estimated 3.17 million tonnes of CO_2 into the atmosphere at an average rate of 1.13 tonnes of CO_2 per tonne of live-weight of marine fish landed.

Introduction of innovative designs of fuel-efficient fishing vessels can reduce the fuel consumption by the fishing sector. By modifying the hull form and reducing vessel weight, fuel consumption can be reduced to a significant level there by reducing carbon footprint. Carbon footprint can also be reduced through introduction of new generation fishing gear materials such as Ultrahigh Molecular Weight Polyethylene (UHMWPE). Use of solar panel for navigation lights reduces the fuel burning and helps reducing pollution in the same vessel.

Utilization of solar energy in fishing is an innovative idea to curtail the increasing fuel consumption by the fishing industry and also to reduce pollution. Solar powered FRP vessels are introduced successfully in reservoirs, small rivers, and aquaculture ponds. These can also be used for recreational fishing activities. The vessels are capable of running for 2.5 to 3.0 hours after full charge and attain a speed of nearly 4.0 knots in calm waters. Considering the 240 days of fishing in a year the fuel saved compared to an equivalent diesel powered vessel is about ₹ 48,000 per year. The vessel has wider space, a canopy for protection from rain and sun, low rolling characteristics during fishing, and also has provision of navigational lights to facilitate fishing in the night.

Minimizing environmental impact of fishing gears

Dragged gears such as bottom trawls, particularly when they are heavily rigged, could cause severe damage to benthic fauna and flora, which occupy the bottom substratum and contribute to the productivity of the region. Use of off-bottom trawls reduce the impact of trawling on the bottom biota.

Plastics constitute 91% of the global marine debris of which 10% is contributed by the fishing sector. Lost fishing gears entangle and kill target and non-target organisms, damage habitats and become hazard to human navigation. Lost/derelict fishing gear include nets, lines, traps, and other recreational or commercial fishing equipment that has been abandoned, lost, or otherwise discarded (ALDFG). The first study on ALDFG relating to gillnets and trammels nets in Indian waters in 2017 showed that this is a serious problem requiring strict monitoring and control. Further to this initial assessment, detailed assessment of fish and gear loss in gillnet and trammel net sectors of India identifies a loss rate of 24.8% of the total fishing gear per gillnetter per year in the country which is quite alarming. Ghost fishing is a problem associated with lost fishing gears. Fishing net becomes 'ghost net' when the operational control of the gear is lost and a fish or an animal, is trapped in the net and mortality occurs. Ghost fishing is estimated to cause a loss of 7% of total fish catch which goes unreported and unaccounted for. Such studies have to be conducted in Indian waters.

Marking of fishing gear

Illegal, Unregulated and Unreported (IUU) fishing is a major area of concern in sustainable exploitation of fish resources. Gear marking is a possible measure to regulate both legal and illegal fisheries. FAO has brought out voluntary guidelines for gear marking. A well-marked gear with proper identification would be useful for enforcement agencies checking on illegal gear and operation. The basic purpose of gear marking is to determine ownership and to trace back information regarding the gear. ALDFG and ghost fishing are related to IUU. Gear marking enables in reducing ALDFG by avoiding interaction with other vessels and entanglement with other gears. It also helps the state to take effective action against defaulters in case of ALDFG. As far as India is concerned, there is no system to mark gears/ gear materials and accessories. For the first time in the country, marking of fishing gear is incorporated in the Marine Fishing Regulation Act amendment 2018 of Govt of Kerala.

SUMMARY

'Responsible Fishing' signifies the way forward in harnessing the potential of India's 'Blue Economy'. Research on design, development and operation of fishing vessel and fishing gear form the first stage of this strategy. India has a wide range of technologies for bycatch reduction, minimizing environmental impact and energy conservation based on FAO-CCRF. Creating awareness among stakeholders with suitable incentives will result in faster adoption of such technologies. Beyond these, policy changes and creation of appropriate legal and Institutional framework also need examination.

*Corresponding author's e-mail: leelaedwin@gmail.com

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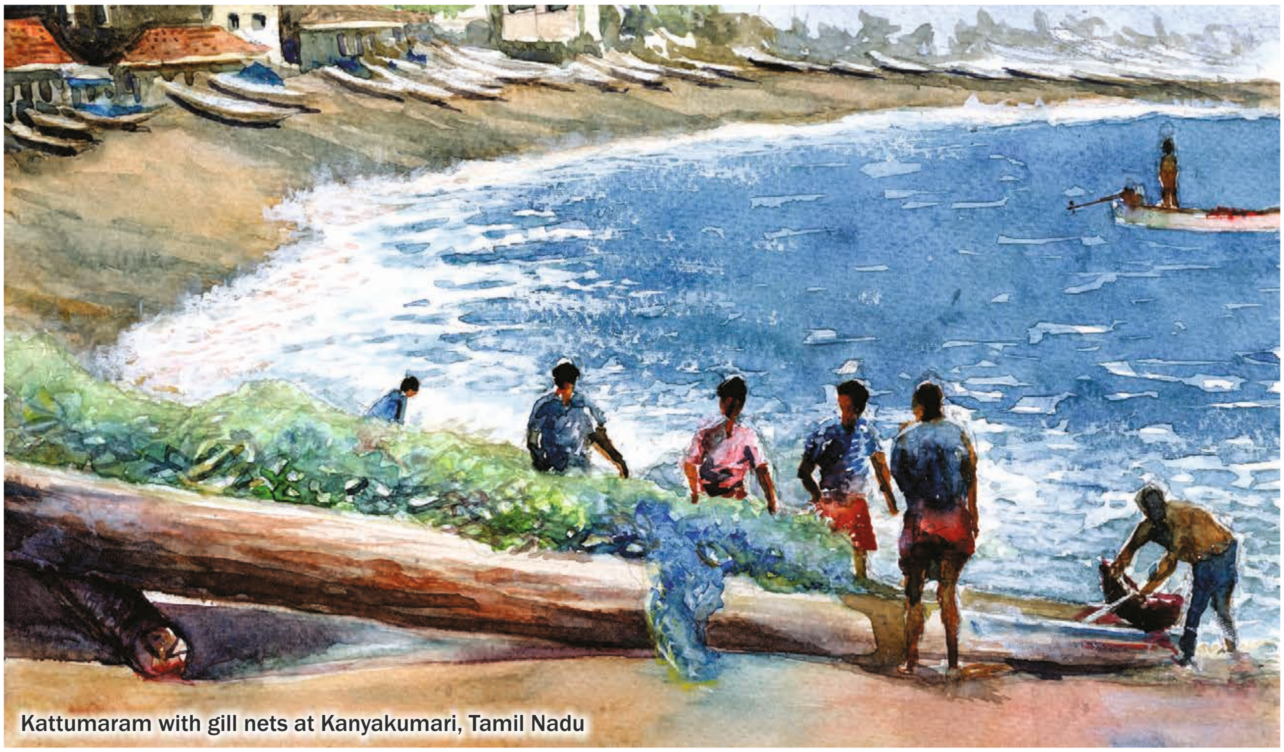
Glimpses of fishing craft & gears in the fisheries sector



Kattumaram with gill nets at Kanyakumari, Tamil Nadu

Fishing Canoe with Trammel nets at backwaters Cochin, Kerala

Coracle with drift gillnets at, Cochin, Kerala

Motorized Fishing Boat with gillnets at Mangalore, Karnataka

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