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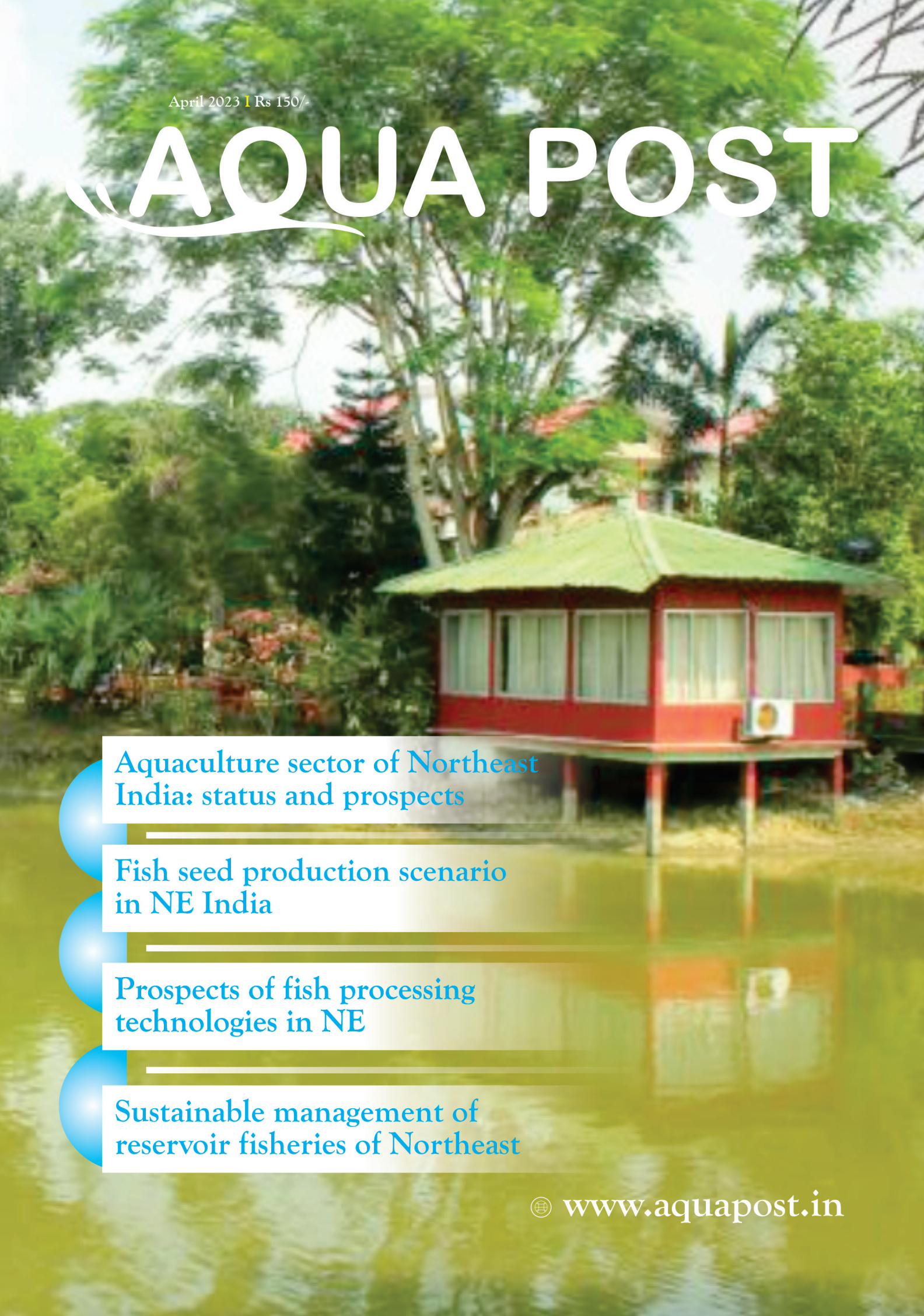

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Sales & Marketing
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+91-8882667803
+91-9971262410
aquapostnews@gmail.com, www.aquapost.in

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Editor: Pravash Chandra Pradhan

Website: www.aquapost.in

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Fisheries and Aquaculture Potential in Northeast India

The Northeastern region of India comprising of eight landlocked states viz., Arunachal Pradesh, Assam, Manipur, Meghalaya, Nagaland, Sikkim and Tripura is one of India's richest regions in terms of natural resources and biodiversity. The region has vast and varied fisheries resources in the form of reservoirs, tanks and ponds, beels, oxbow lakes and other derelict waters covering 4.18 lakh ha water-spread area, excluding rivers and streams which is estimated at 20,875 km.

The two main river systems in the region are the Brahmaputra in the north and the Barak, running through the southern edges, together with their numerous tributaries. The region is rich in freshwater fish species and is regarded as one of the world's hotspots for freshwater fish biodiversity. As many as 422 fish species from northeast India, belonging to 133 genera and 38 families, including indigenous and exotic species, have been reported. These beautiful resources make tremendous contributions towards overall fish production in the region.

Fisheries and Aquaculture sub-sector has immense potential for providing employment opportunities to youth, livelihood to rural masses and economic development as a whole for the region. There is a growing demand for fish and fishery products in the region due to increasing population, per capita income, urbanization and changes in food habits. There is a tremendous scope for development of fisheries and aquaculture in the region, but lags behind the rest of the country in fully harnessing its potential.

The region is deficient in fish production; it depends on others to fulfil its demand. Hence, there is an urgent need to increase fish production from these available resources to fill the gap. To achieve this goal, there is a need to utilize these fisheries resources of the region in a sustainable manner.

The articles in this special issue of the magazine cover different aspects of fisheries and aquaculture development in the North Eastern Region.

Pravash Pradhan

aquapostnews@gmail.com

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Enhancing fish productivity and sustainability in Aquaculture production systems of North-East India

S. Munilkumar
K. Arambam,
R. D. Singh
M. M. Meitei ...✍

ICAR-CIFE, Mumbai

The two main river systems in the region are the Brahmaputra in the north and the Barak (Meghna), running through the southern edges, together with their numerous tributaries.

Introduction

The north-eastern region is the easternmost region of India, located between latitude 1°57″ and 29°30″ N and longitude 89°46″ and 97°30″ E. Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura are eight landlocked states that together make up one of India's richest regions in terms of biodiversity and natural resources; though the soils are slightly acidic in nature. The region shares international boundaries with Bhutan, China, Myanmar, and Bangladesh. It has an area of 2.62 lakh sq. km, representing 7.9% of the country's total geographical area. This region is drained by the Brahmaputra River System in Assam, Meghalaya, Tripura, and some portions of Mizoram, Manipur, and Nagaland, as well as the Ganga River System in the north and north-eastern section of Bengal. The Chindwin river system drains the eastern portion of Manipur, which includes the central plain, and Nagaland, while the Koladyne river system drains the southern portion of Mizoram. Physio graphically categorized the area into the Patkai, Brahmaputra, and Barak valley plains, as well as the Eastern Himalaya. With the prevailing Brahmaputra and Barak river systems and their tributaries, the area has a primarily humid subtropical climate with hot, humid summers, strong monsoons, and mild winters. From the upland plains of the Imphal valley in Manipur to the primarily hilly regions of Meghalaya, Mizoram,

Nagaland, Tripura, and Sikkim, with elevations ranging from 200-900 m above mean sea level, the region has rich and diverse aquatic resources in different topographical and climatic conditions. Around 60% of the territory is covered by forest, and the annual rainfall in the area surpasses 2,000 mm. The Himalayan peaks in the northern border region with India and China have the coldest winters in Arunachal Pradesh, with lows below freezing and considerable snowfall. Altitudes of more than 2,000 meters have cold summers and snowfall in the winter. Winters below 2,000 meters above sea level are cold, with daytime highs of 15°C (59°F) and plummeting below zero at night, while summers are cool with mean highs of 25°C (77°F) and mean lows of 15°C (59°F).

With only about 39 million people, the area is one of India's least densely populated regions. From ancient times, fish has played a significant role in the lives of the inhabitants of northeast India. Most indigenous residents of the region have valued fish as a staple diet. Fish provides wholesome food and forges a strong bond with the local people's culture, religion, and traditions. Fish consumption accounts for more than 95% of the population, so a significant imbalance exists between supply and demand. In addition to unreported imports from Bangladesh and Myanmar, the region also imports fish from other Indian states, like Andhra Pradesh, to meet the region's rising demand for fish.

Northeast India's water and fisheries resources

The two main river systems in the region are the Brahmaputra in the north and the Barak (Meghna), running through the southern edges, together with their numerous tributaries. The Irrawaddy, a third river that flows through Myanmar at the region's easternmost flanks, also drains a portion of it, mainly through some of its tributaries like the Chindwin. The Brahmaputra and Barak Rivers, with their tributaries and basins, account for over 50% of the water resources in the country. The area is rich in freshwater fish species and is regarded as one of the world's hotspots for freshwater fish biodiversity. About 422 fish species from northeast India, belonging to 133 genera and 38 families, including indigenous and exotic species, have been reported. The maximum diversity is observed in the family Cyprinidae, which is represented by 154 species. Food fish, ornamental fish available as well as water resources in the different states of Northeastern India is described in Table 1 & 2.

Table 1. State-wise fish species diversity with their value as food fish and ornamental fish

State	No. of species	Food fish	Ornamental fish
Arunachal Pradesh	271	112	159
Assam	311	131	180
Manipur	325	142	183
Meghalaya	231	95	136
Mizoram	202	97	105
Nagaland	210	94	116
Sikkim	194	95	99
Tripura	199	101	98

Table 2. State-wise water resources (Handbook of Fishery Statistics, 2020)

State	Rivers/canals (km)	Reservoirs (ha)	Ponds/Tanks (ha)	Wetlands (ha)
Arunachal Pradesh	10,957	136	29,122	3,227
Assam	4,820	1,096	77,250	1,54,650
Manipur	14,788	2,142	11,622.8	24,433
Meghalaya	4,200.87	717.53	3,465.37	284.78
Mizoram	1,750	8,010	5,492	–
Nagaland	1,600	2,258	3,474.13	1,110
Sikkim	1,600	850	1,466	–
Tripura	2,975.8	3,049.34	18,530.12	–
Total	42,691.67	18,258.87	1,50,422.5	1,83,704.8

Fisheries play an important role in the region's economic development and livelihood security. According to the Handbook of Fishery Statistics (2020), the sector employs over 26.3 lakh people. The average annual fish production in the region is estimated to be 1.5 MT/ha. Up until 2004-2005, the region produced only 2,39,790 MT of fish annually. However, it has now increased to 5,18,380 MT/annum with systematic approaches and integrated strategies, which is around 5% of India's total inland fish production. The supply and demand for fish still fall short by 43000 MT, and to fill the gap, fish is imported from Bangladesh and other states. Table 3 shows the State-wise fish production trend during 2015-16 to 2019-20 in the region, with Assam being the major producer.

Table 3. State-wise production trend

	(in Lakh Tonnes)				
States	2015-16	2016-17	2017-18	2018-19	2019-20
Arunachal Pradesh	0.04	0.04	0.04	0.05	0.05
Assam	2.94	3.07	3.27	3.31	3.73
Manipur	0.32	0.32	0.33	0.32	0.32
Meghalaya	0.11	0.12	0.12	0.13	0.14
Mizoram	0.07	0.08	0.08	0.07	0.07
Nagaland	0.08	0.09	0.09	0.09	0.09
Sikkim	0.05	0.04	0.04	0.04	–
Tripura	0.69	0.72	0.77	0.70	0.78

(Values in parentheses indicate the absence of data)

Diversity of farmed species in the region

The Indian major carps (IMCs) and Chinese carps form the major species cultivated in the region and contributed maximum to the production (Table 4). Mahseer and trout are two more notable coldwater species that are cultured. The three cultivated species of carp, Silver carp, Grass carp, and Common carp, are said to operate best in a composite culture system under conditions of moderate altitude.

Table 4. Species-wise fish production in the region during 2019-20 (in Lakh Tonnes)

States carps	Major carps	Minor carps	Exotic	Murrels	Catfishes	Other freshwater fishes
Arunachal Pradesh	0.01	–	0.02	–	–	0.02
Assam	1.44	0.48	0.27	0.25	0.40	0.89
Manipur	0.10	0.01	0.20	–	–	0.01
Meghalaya	0.06	0.02	0.05	–	–	0.01
Mizoram	0.03	–	0.04	–	–	–
Nagaland	0.05	–	0.04	–	–	–
Sikkim	–	–	–	–	–	–
Tripura	0.51	0.08	0.17	–	0.01	0.01

(Values in parentheses indicate the absence of data)

Farmers in the private sector produce fish seeds from 11–12 different species. In addition, Manipur and now Meghalaya produces seeds of an endangered minor carp, Pengba, Osteobrama belangeri, in small quantities. Tripura also produces seeds of Pabda, Ompok bimaculatus and Macrobrachium rosenbergii. The local stock of Common carp (Cyprinus carpio var. communis) has various shortcomings viz. early maturation and poor growth. Thus the ICAR-NEHR first introduced the genetically superior variety of common carp i.e. Amur (Hungarian strain) during 2010 in Meghalaya after extensive on-station and on-farm experiments to improve fish production in the region. Only a few months (June to August) are restricted for fish breeding in the mid-hill region. All of India's exotic and major carps have been successfully bred at the ICAR NEHR. Moreover, small carp like Labeo gonius, L. bata, and Puntius javanicus have been successfully raised and artificially produced to advance these species in mid-hill aquaculture. The Amur common carp and minor carps have recently been shown to be the best fish for mid-hill aquaculture. As a result, farmers in the mid-hill region always have an increasing demand for high-quality seeds, particularly for L. gonius and Amur common carp. In contrast to IMCs, both species grow to a marketable size within a year of being reared under mid-hill conditions.

The region's potential candidate species for aquaculture practice are Tor putitora (Golden mahseer), Neolissochilus hexagonolepis (Chocolate mahseer), Amblypharygodon mola, Chagunius spp., Cirrhinus reba, , L. pangusia, L. dyocheilus, L. dero, Semiplotus semiplotus etc. Despite reports of some of these species being bred artificially, there are currently no farmer-friendly methods available for the large-scale production of their seeds to support aquaculture in ponds, tanks, and other water bodies, particularly in the region.

Fish seed production

With more than 500 units, traditional "Hapa" breeding continues to dominate the seed production sector. And the most typical large-scale seed production technique is the Chinese hatcheries. Assam, Manipur, and Tripura produce surplus seeds and export them to other states. While states like Arunachal Pradesh and Mizoram still import a significant amount of seed from other states. The state-wise seed production during 2015-16 to 2019-20 is shown in Table 5.

Table 5. State-wise fish seed production in NE India during 2015-2020 (in Lakhs Fry)

States	2015-16	2016-17	2017-18	2018-19	2019-20
Arunachal Pradesh	55	65	70	–	–
Assam	56,780	67,580	80,000	98,930	95,190
Manipur	2,190	2,150	2,500	4,060.8	2,494.8
Meghalaya	110.7	75.6	97	–	3
Mizoram	300	310	426	406.6	400
Nagaland	478	480	481	760	795
Sikkim	20.2	23.2	6.5	16.25	16.25
Tripura	2,987.	3,137	4,350	–	–

(Values in parentheses indicate the absence of data)

Fish mortality is highest early stage, making nursery-growing fish spawning to the appropriate fingerling size difficult. To address this, low-cost pond-based cage culture under the National Agricultural Innovation Project (NAIP) was successfully demonstrated for the first time to achieve superior growth and survival of juveniles in the Garo hills of Meghalaya.

Small-scale integrated aquaculture practice as a sustainable approach

The majority of rural tribal farmers in the region's hill states are impoverished, yet many of them keep livestock for domestic needs. The small-scale integrated aquaculture employing available on-farm resources has significant promise due to the limited size of fish ponds in the hill areas, primarily rain-fed and seasonal. Also, the fish's growing period is brief, lasting approximately 7-8 months owing to the cold climate. Hence, small-scale integrated aquaculture is a great choice for the food security and economic advancement of rural farmers in the region. Under an innovative Assam

Fish mortality is highest early stage, making nursery-growing fish spawning to the appropriate fingerling size difficult.

Rural Infrastructure and Agricultural Service Project, a first attempt was made in Assam, India, to implement a farmer-participatory small-scale aquaculture research and extension program in 3 tribal villages of Assam. The project showed an annual production of 1800 kg/ha from small seasonal homestead ponds through integrated utilization of locally accessible biological resources.

Paddy-cum-fish culture

A significant activity that is common in various parts of the region is rice-fish cultivation, with reported yields ranging from 250 to 1200 kg/ha of fish and 2100 to 2300 kg/ha of rice. Arunachal Pradesh has the traditional rice-fish cultivation known as Aji gnui assoni, which yield around 500 kg/ha annually. And in Nagaland, rice-fish culture constitutes the state's second major resource for fish production. The indigenous inhabitants of the northeast use shifting cultivation and paddy-cum-fish farming. Cyprinus carpio var. specularis, C. carpio var. communis and C. carpio var. nudus are generally cultivated. Thus, it is imperative that efforts may be made to increase the expansion of the farming practices in the region.

Integrated Multi trophic Aquaculture Systems

The region is bestowed with indigenous freshwater molluscs with many local food and economic value. It would pave the way for their utilization as ecological engineers, especially organic extractives in freshwater-integrated multi-trophic aquaculture (FIMTA) systems. Species like Pila globosa, Bellamya bengalensis, Melania tuberculata, and Lamellidens spp may be incorporated into the system along with the native aquatic plant species like duckweeds (Wolffia sp, Lemna sp) and water mimosa (Neptunia prostrata). Integrated multi-tropic aquaculture using rohu as fed species, Wolffia as inorganic extractives and mussel as organic extractives have shown promising results in an experiment in Tripura.

Pen and cage culture in floodplain wetlands

Northeastern India's floodplain wetlands are a significant fisheries resource. Wetlands must be utilized to develop ecologically benign aquaculture systems. The yield of fish in floodplain wetlands is 100-200 kg/ha/year. This can be boosted up to their potential production range of 1000-2000 kg/ha/year by employing pen and cage aquaculture. Pen culture is a promising technique to raise fish from seed and stock them to grow to marketable size. Cage culture is currently underexploited in the region. Aquaculture intervention using pen and cage culture is potential, given that the majority of the open water in this region is underutilized. Pen and cage culture in the wetlands of NE region, is being actively taken up by the ICAR-Central Inland Fisheries Research Institute, Guwahati centre.

Introduction of genetically improved carps

To assist the farmers, genetically enhanced carp species have been introduced. Jayanti rohu developed by CIFA, has been tested in the region and is reported to give 20-40% better growth compared to normal rohu. Amur strain of common carp also reported 20-30% higher growth than the local strain.

Constraints in enhancing fish production

- Inadequate transfer of technology,
- Lack of private entrepreneurship,
- The low temperature and low pH, which doesn't favour the culture of IMCs,
- Insufficient quality infrastructural facilities,
- Non-availability of quality seed,
- Difficulty in giving financial assistance for the system due to the complicated land ownership patterns and small, fragmented land holdings.

Future strategies for increasing aquaculture productivity

- Expanding aquaculture practices like paddy cum fish culture and integrated multitrophic aquaculture system (IMTA).
- Prioritization of indigenous species for diversification
- High-altitude fish farming
- Culture of air-breathing fishes and other small indigenous fishes
- Expansion of enclosure culture systems
- Exploring possibility of using Biofloc technology, Re-circulatory aquaculture system and Aquaponics.

Conclusion

Northeast India is a 'global hotspot' for aquatic biodiversity and resources. Presently, the potential of these resources is being underutilized in many areas, resulting in fish yield that is much lower than the national average and a local fish supply that is insufficient to meet the needs of the population. Most fish farmers still lack information about scientific fish farming, which would allow aquaculture activities to be expanded and intensified. As more than 95% of people in the Northeast consume fish, there is a significant possibility of choosing fisheries as a possible source of income, employment, and business growth. Thus, it is essential to focus on the sector's integration with allied sectors like agriculture, horticulture, animal husbandry, etc., to produce a variety of food items and raise the living standards and socioeconomic security of those involved in the sector. The government should also make policy decisions to establish brood banks of appropriate species to provide high-quality brood stock to the selected fish seed producer in the region. ◆◆◆

To assist the farmers, genetically enhanced carp species have been introduced. Jayanti rohu developed by CIFA, has been tested in the region and is reported to give 20-40% better growth compared to normal rohu.

Role of ICAR-CIFRI in open water fisheries development in NE India

B.K. Bhattacharjya[1]
B.K. Das[2]
P. Das[1]...

[1] ICAR-CIFRI Reginal Centre, Guwahati

[2]ICAR-CIFRI, Barrackpore

The prioritized areas were identifies in an inception workshop on "Scientific fisheries management of wetlands and reservoirs of NE Region" on June 20, 2012 held at the CIFRI Regional Centre, Guwahati.

Introduction

The Northeastern (NE) region of India comprises of Assam, Arunachal Pradesh (AP), Meghalaya, Manipur, Mizoram, Nagaland, Sikkim and Tripura) and has total geographical area of 2,62,180 sq.km which is about 8% of the country's total area with a population of about 40 million. The predominantly hilly region has rich fisheries resources, which are amenable to development of capture fisheries and fisheries enhancements. People of this land-locked region have very high preference for animal protein in general and fish protein in particular. Naturally, fisheries is an important avenue for nutritional and livelihood security in the region. The NE region has vast and varied fisheries resources in the form of reservoirs, tanks and ponds, beels, oxbow lakes and other derelict waters covering 4.18 lakh ha water-spread area, excluding rivers and streams which is estimated at 20,875 km (Table 1). Assam is the largest state of Northeast India which occupies nearly 30% geographical area of the region, but has 68.2% water resources of the region excluding rivers and streams. There are 58 notable rivers (including Brahmaputra and Barak) in the region besides

numerous rivulets/hill streams, the combined length of which is 21,180 km. Rivers and their associated wetlands as well as reservoirs form the mainstay of capture fisheries resources in the region. The region has 150,422 ha of ponds and mini-barrages, most of which are privately owned and are being used for extensive and semi-intensive pond aquaculture. Floodplain wetlands/ ox-bow lakes and upland lakes are an important open water fisheries resource of the region both in terms of the resource size (1,35,975 ha) and potential for development of capture and enhancements especially in the floodplain wetlands/ ox-bow lakes (beel/ pat) covering 144,555 ha. The Northeast reportedly has 50% of the total hydel power potential of the country and a number of reservoirs covering 28,510 water-spread area (23 no.) have already been commissioned. Most of these are small reservoirs (amenable for development of culture-based fisheries) except for Gumti and Khandong reservoirs, which are medium sized ones. The region has considerable areas (1,03,211 ha) of derelict water bodies in the region, many of which were floodplain wetlands or lakes, which became swamps/ low-lying paddy fields over the years due to siltation and macrophytes infestation. These are amenable for capture fisheries, fisheries enhancements as well as developing paddy-cum-fish culture (e.g., Ukhrul district of Manipur and the Apatani plateau of AP).

Open water bodies of the region are important common property resources and are part of the diverse socio-cultural traditions of the region including community fishing. The region has considerable potential for substantial improvement both in production and yield of fishes from its open water bodies. There are many areas requiring management interventions to achieve higher fish yields. The strategy for realising this potential comprises conservation and sustainable of capture fisheries in rivers, large and open floodplain wetlands, lakes and reservoirs; adoption of suitable fisheries enhancement options including culture-based fisheries in the floodplain wetlands (small/ closed) and reservoirs and bringing more areas under paddy-cum fish culture. By following such a combined strategy, it will be possible to raise the region's fish production substantially. However, development of open water fisheries in the region did not receive due attention support from the R&D agencies. Against this background, the ICAR-Central Inland Fisheries Research Institute (ICAR-CIFRI), Barrackpore established the Guwahati research centre in 1971 for providing research support for development of inland fisheries in the region.

Open water bodies of the region are important common property resources and are part of the diverse socio-cultural traditions of the region including community fishing.

Brief account of past research work of ICAR-CIFRI in NE fisheries

Carp spawn prospecting investigation in River Brahmaputra: The Institute carried out studies on the availability of natural seed of Indian major carps from the river in late sixties. The finding of the study showed that natural seed of IMC was available in the lower stretches of the river from Guwahati to Dhuburi during the southwest monsoon season (June to September).

Fisheries and ecology rivers of NE region: Baseline studies were carried out by the Institute on fisheries and habitat characteristics of River Brahmaputra and their important tributaries during the period from 1973 to 1979 and during 1996-98. This was followed by studies on ecology and fisheries of important rivers of other NE states during 1998-2002.

AICRPs on Composite fish culture and Air-breathing fish culture: A series of experiments were conducted by the Institute on these aspects under the agro-climatic conditions of the northeastern region as part of respective All India Coordinated Research Projects during the seventies. Experiments on composite fish culture and carp seed production was conducted in the Ulubari Fish Farm of the Department of Fisheries, Assam in the seventies (1973-79). During the same period, field experiments on air-breathing fish (e.g., magur, singi, koi) culture were carried out in bamboo cages in Ghorajan and Peetkati beel of Kamrup district, Assam.

Fisheries ecology of floodplain wetlands and reservoirs: The Institute carried out baseline studies on fisheries and ecology of floodplain wetlands (beels/ pats) and reservoirs of NE India including socio-economic aspects and institutional arrangements. Thesetudies conducted by the Institute on the ecology and fisheries of floodplain wetlands of Assam, Meghalaya, AP (beels) and

Manipur (pats) have generated a large volume of scientific information. These studies have shown that the production potential of floodplain wetlands was high (1000-1500 kg ha-1yr-1).

Protocols for fish stock enhancement: The Institute developed fish stock enhancement protocols for fish stock enhancement in floodplain wetlands of Assam; adoption of these protocols by beel users led to enhancement of average fish yield of stocked beels of Assam to 534 kg ha-1yr-1 in recent years from 173 kg ha-1yr-1 in 1996-98.

Enclosure culture: The Institute developed and refined technologies for fish culture in pen and cage enclosures in wetlands. Studies by the Institute showed that pen and cage culture can be practiced as parallel activities without affecting the capture fisheries and other enhancement options in wetlands and reservoirs. For construction of pens, a manageable part of marginal areas of wetlands are encircled with split-bamboo screens (bana) lined with small meshed nets both for rearing of carp fingerlings and for growing table fishes. Pen culture is a good management option for macrophyte-choked shallow and unproductive wetlands. On the other hand, cages are installed in deeper areas of the wetland to raise fingerlings or to produce table fish. Cage culture is particularly suitable for raising fingerlings during the rainy season, when erection of pens is difficult in many open beels. ICAR-CIFRI has successfully carried out pen culture experiments in the wetlands of Assam, Manipur and AP both for rearing of carp fingerlings and for growing of table fishes, thereby contributing to additional fish production and income of fishers. Pens are being successfully used for raising fingerlings or table fish in wetlands of Northeast.

For raising fingerlings, carp fry can be stocked @ 5-15 no./m2 to raise advanced fingerlings in 4-6 months duration. For rearing table fish, carp fingerlings can be stocked @ 1-3 no./m2 and reared for 8-12 months. Polyculture of carps in pens with 40% surface feeders (catla & silver carp), 20% column feeder (rohu), 30% bottom feeders (mrigal & common carp) and 10% macrophyte feeder (grass carp) is normally practiced. Fish species with local importance such as O. belangeri (pengba) and L. gonius (kuri) performed well when stocked in net pens in Takmu pat of Manipur. L. bata, Barbonymus gonionotus and other small indigenous fishes like Puntius spp., Amblypharyngodon mola and Gudusia chapra can also be stocked along with carps for additional income from the pens. Economically important small indigenous fishes can be stocked in pens, which would reproduce in them and become a self-recruiting population providing nutritional securities to the fishers. Pen aquaculture technology developed and refined by the Institute for floodplain wetlands of NER (including use of CIFRI-HDPE pen and CIFRI CageGrow feed) led to fish production in the range of 3,000-

13250 kg ha-1yr-1 in pen enclosures.

ICAR-CIFRI attempted cage culture in Assam for the first time with air-breathing fishes like Heteropneustes fossilis (singhi) and Anabas testudineus (kawoi) in the seventies; later Channa marulius, C. striatus, C. punctatus and Clarias magur were cultured in cages. It is a good avenue for in situ rearing of fish fingerlings for stocking the wetlands or reservoirs. The optimum stocking density of Cirrhinus mrigala fry and Labeo rohita fry in net cages was standardized at 300 and 200 fry/ m3, respectively in beels of Assam. Cage culture technology has been successfully field tested in several wetlands of Northeastern India with special emphasis on Assam. The technology is also being demonstrated and tested (using CIFRI GI Cage as well as Modular cages) in Umiam lake of Meghalaya, Loktak lake, Khuga and Mapithel reservoirs of Manipur, Dumbur reservoir of Tripura and Doyong reservoir of Nagaland. Development of cage culture technology for floodplain wetlands and reservoirs of region has led to led to fish production in the range of 1.0-10.0 kg m-36 months-1. By adopting pen and cage culture technology in large open water resources of the Northeast, the region can produce significant quantities of fish reducing the demand-supply gap.

Other research activities: Indigenous ornamental fish species occurring in the NE region of India were documented by the Institute with a view to their sustainable utilization. It assessed the impact of climate change on fisheries of floodplain wetlands of the region. Field studies of fish seed hatcheries of Assam showed that alteration in the seasonal rainfall resulting in flood and drought had adverse effects on fish seed production in the area. Other important aspects of open water fisheries of the region studied by the Institute include qualitative and physiological studies of NE fishes, studies on and livelihood, Information flow and extension strategies, fisheries resource assessment through GIS application, assessment of beneficial effects of temperature on spawning of major fish species, and so on.

New initiatives in collaborative work programmes: The Institute has drawn up extensive collaborative work programmes for refinement/ pilot-scale validation of CIFRI technologies/ management guidelines in collaboration with state fisheries departments/ fisheries corporations and other stakeholders of open water fisheries in the Northeast under the NEH component in the XII FYP under the leadership of the DDG (Fy Sc) and the Director. The prioritized areas were identifies in an inception workshop on "Scientific fisheries management of wetlands and reservoirs of NE Region" on June 20, 2012 held at the CIFRI Regional Centre, Guwahati. Officials from fisheries departments of the region, Assam Fisheries Development Corporation (AFDC) ltd., scientists from ICAR-NRC on Pigs, Rani and teachers from College of Fisheries, CAU, Lembucherra and AAU, Raha participated in the workshop. The collaborative work programmes were coordinated by the Director, ICAR-CIFRI with the Head, ICAR-CIFRI Regional Centre, Guwahati acting as the Nodal Officer. The Institute conducted large-scale collaborative pen culture demonstrations in collaboration with the AFDC Ltd. (in 30 beels), Department of Fisheries (DoF), Govt. of Assam (10 beels), Bodoland Territorial Council, Kokrajhar (4 beels) and the DoF, Govt. of Manipur (2 pats) under NEH component, The Institute developed a model pig-cum-fish farming system Development of in collaboration with ICAR-NRC on Pig, Rani, Guwahati. High fish production (3,564 kg/ ha/6 months), pig production (1,656 kg) and B:C ratio (2.38) showed profitability of pig-cum-fish farming.

ICAR-CIFRI organized a Regional Consultation on "Open Water Fisheries Development in NE Region" under the leadership of the Director at Guwahati in April, 2017 to prepare a roadmap for open water fisheries development in the North Eastern Region.

ICAR-CIFRI organized a Regional Consultation on "Open Water Fisheries Development in NE Region" under the leadership of the Director at Guwahati in April, 2017 to prepare a roadmap for open water fisheries development in the North Eastern Region. The Institute prepared a policy document entitled "Roadmap for development of open water fisheries resources in NE Region" and released it at Guwahati on 16.06.17. ICAR-CIFRI also organized interactive workshops on 'Management of open water fisheries' at Agartala (January 4-5, 2019) in collaboration with DoF, Tripura followed by that at Imphal in collaboration with DoF, Manipur (Feb. 18, 2019). An interactive meeting of ICAR-CIFRI with the Principal Secretary to Govt. of Meghalaya (Fisheries) on 'Prospects

of cage culture in Meghalaya' was held at cage culture site in Umiam reservoir on 03.02.2022. The Institute and DoF, Assam also jointly organized an Interactive meeting on 'Open water fisheries development in Assam' (21.07.2022) at the DoF, Guwahati.

As a result of these initiatives for collaborative work programmes, the Institute increased its activities in NE India considerable during the past 15 years. It assessed/ monitored 34 floodplain wetlands, 3 reservoirs and 2 rivers in the region for sustainable utilization and livelihood support. The average fish yield in selected beels of Assam increased to 458.60 kg/ha/yr in 2020-21 from 372.50 kg/ha/yr during 2019-20, where supplementary stocking was carried out by ICAR-CIFRI. It showed that fish stock enhancement led to 31% increase in fish production in the selected beels.

The Institute conducted 53 pen culture trials/ demonstrations in the region with productivity in the range of 8250 to13250 (kg/ha/yr). On the other hand, 15 cage culture trials/ demonstrations were conducted during the period with productivity in the range of 1-10 kg/m3/ 6 months.

ICAR-CIFRI carried out a series of mega ranching programme "Augmenting natural stock of endemic carp, Osteobrama belangeri (pengba)" in Loktak lake during March, 2022 and for re-establishing its stocks in the wetland and released 1,30,000 pengba fingerlings in presence of the Honerable CM of Manipur. It plans to continue more such collaborative work programmes in the region in the coming years in addition to its core research programmes.

Human resource development (HRD) in open water fisheries: The Institute has been conducting a number of HRD programmes on various aspects of open water fisheries in the region for capacity building of various stakeholders. As part of this thrust, the centre conducted 58 training programmes (both on and off-campus)/ farmers' seminars over the past 15 years to train 2465 individuals (fisheries officials, fishers, fish farmers, beel lessees, academicians, etc.) of NE region, In addition, the centre conducted 37 awareness programmes, and participated in 19 exhibitions in the region.

Note:

Figures in parenthesis mentioned in 3rd column show the numbers of reservoir.s

* These are mostly upland lakes, also known as upland wetlands, but not floodplain in nature.

Source: DAHDF-GoI (2014), DoF-GoI (2019) and # Barman et al., 2013 (for Rudrasagar lake).

Table 1. Open water fisheries resources of Northeast India

State	Rivers & Canals (km)	Reservoirs (Area in ha)	Tanks & Ponds (ha)	Floodplain wetlands/ ox-bow lakes & lakes* (ha)	Derelict water bodies (ha
Arunachal Pradesh	2000	160 (1)	29,122	2505	11864
Assam	4820	2000 (3)	77,250	100815	86204
Manipur	3360	2142 (6)	11,623	24433	4728
Meghalaya	5600	8000 (5)	3,465	282	54
Mizoram	1395	8100 (4)	5,492	-	-
Nagaland	1600	2258 (1)	3,474	4700*	-
Sikkim	900	850 (3)	1,466	3000*	-
Tripura	1200	5000 (2)	18,530	240#	361
Total	20,875	28,510 (23)	1,50,422	1,35,975	1,03,211

S.K. Das ...

ICAR RC for NEHR, Umiam

Fish seed production scenario in NE India

Introduction

The Northeast India is yet to become self-sufficient in fish production although there has been a spectacular growth of fish and fish seed production sector especially in the state of Assam. Among the eight states in the northeast region, Assam and Tripura occupy the plains while the rest of the states are mostly mountainous with much rugged and inaccessible terrain. The fish production in the hill states of the region has remained almost static for past few years. The states of Tripura, Manipur and in recent times Meghalaya are making sincere efforts to improve the fish production through various Government sponsored schemes. There are several constraints in development of the fisheries & aquaculture sector in the region. In addition to difficult terrain, the non- availability of quality fish seeds in time is identified as one of the major bottlenecks in expanding aquaculture in the hilly region. Two most important basic inputs for aquaculture are Fish seeds and Fish feeds. A farmer may be good at growing fish and may provide the best environmental conditions possible, but if the qualities of the reared fish fingerlings are of genetically poor quality, performance and production will be low despite the excellent fish culture operation.

Northeast India represents approximately 33% of total 2,163 freshwater fish species of India. Goswami et al. (2012) listed 422 species belonging to 133 genera and 38 families; while recently, Vishwanath (2017) brought out a list of 318 fish species from the region. However, in the Northeast, fish seeds of about 11-12 fish species

The Northeast India is yet to become self-sufficient in fish production although there has been a spectacular growth of fish and fish seed production sector especially in the state of Assam. Among the eight states in the northeast region, Assam and Tripura occupy the plains while the rest of the states are mostly mountainous with much rugged and inaccessible terrain.

Since 1950s, scientific fish farming practices were introduced in the region with the culture of Indian Major Carp seeds procured from West Bengal. Presently, hatcheries account for 95 percent of seed source. A steady increase in fish seed production from the 1990s can be attributed to the use of Chinese type carp hatchery technology and the application of ready-to-use spawning agents.

are commonly being produced at carp hatcheries for aquaculture. In addition to the best known 03 Indian major carps, 03 exotic Chinese carps and a few minor carps, Manipur and Meghalaya (ICAR-NEHR) produce seeds of Pengba- an endemic medium carp of Manipur while Tripura is the only state to produce the seeds of Pabda and Macrobrachium rosenbergii successfully besides carps.

Since 1950s, scientific fish farming practices were introduced in the region with the culture of Indian Major Carp seeds procured from West Bengal. Presently, hatcheries account for 95 percent of seed source. A steady increase in fish seed production from the 1990s can be attributed to the use of Chinese type carp hatchery technology and the application of ready-to-use spawning agents. The fish seed production technologies being practised in plain areas are less viable in the Northeast hill areas primarily due to cold climatic conditions and lack of appropriate infrastructure facilities.

The widely cultivated three Indian major carp (Catla, Catla catla, Rohu, Labeo rohita & Mrigal, Cirrhinus mrigala) and two exotic carp (Silver carp, Hypophthalmicthys molitrix, Grass carp, Ctenopharyngodon idella) species although mature in pond condition never breed in confined environment. With the advent of the technique of induced breeding of IMC by Chaudhuri and Alikunhi (1957) through hypophysation, it became possible to obtain quality seed of major carps for aquaculture. Earlier, the carp seeds were primarily collected from rivers for aquaculture. In the past few decades the technology has been refined and with use of several synthetic inducing agents in addition to pituitary hormone, most of the carp fish species could be induced bred using hatcheries. Among the different types of hatcheries, the circular Chinese hatchery is the most commonly adopted system in the country today. During 1990's the ready-to-use fish spawning agents like ovaprim (Nandeesha et al, 1990, Das et al,,1994) revolutionized the fish seed industry in the country. Another Hungarian hormone, Ovopel was also found to be very effective in breeding of carps in Assam (Das, 2004). During late 90's several ready to use hormones for fish breeding were made available in India by Indian pharmaceutical companies. Ovatide, Ovafish, Gono-Pro are some of them. Thus, with the use of different types of farmer friendly inducing agents and establishment of hatcheries for fish breeding and egg hatching, it has become possible to produce carp fish seeds in large quantity with high survival percentage of larvae. Farmers nowadays no longer depend on riverine collection for seeds.

In the NE Region, the state of Assam recorded a phenomenal growth in fish seed production till 1989-90. One of the factors behind the phenomenal growth of fish seed production is the upcoming of the fish seed production units in private sector. As per the latest record, the fish seed production has increased in the 1st half of the decade to 1052% in the NE Region. During 2019-20 the region produced about 103,332.3 Lakh fry. There is paucity of correct and updated statistics of fish seed produced in different states of Northeast. Hill states produce very little fish seeds and largely depend on Assam for their requirement.

Over the years although the state of Assam produced a large quantity of fish seeds mostly in the private sector; the state's market fish production has not increased significantly. Genetic deterioration in the hatchery population may be one of the principal factors affecting the fish production. An attempt was made to study the effective population size of randomly selected hatcheries of the state during the year 1999-2000 (Das, S.K., 2012). The study highlighted the importance of effective population size in the carp hatcheries to reduce the genetic drift and inbreeding. Through this maiden study an effort was made to advocate proper policy instruments for sustainable development of fish seed industry in the State.

There is great potential for utilizing indigenous fish species for aquaculture in the northeast. The other potential candidate species for aquaculture in North east region are Notopterus spp, Anguilla bengalensis, Monopterus albus, M. cuchia, Amblypharygodon mola,, Bangana dero, Chagunius spp, Cirrhinus reba, , L. pangusia. However, at the moment there are no farmer friendly technologies available for mass-scale production of their seeds to promote aquaculture in ponds, tanks and in other water bodies. Although there are reports on induced breeding of some theses species, the larval rearing has remained a major challenge. Therefore we may need to develop certain criteria in choosing a suitable larval food such as easily perceived by the larvae, appropriate size to fit the mouth size of the larvae, easily digested by the larvae and satisfies the nutrient requirement and v.

available in large quantities.

Breeding of Air breathing fish in the North East

There is a tremendous opportunity for seed production of air breathing fish species as they fetch very high market price in the entire northeast region. Out of all the species , Channa sp, C. batrachus , H .fossilis , Anabas testudineus and Air breathing mud eel (M. cuchia and M albus) are the most important fish species that require immediate attention. Seed production technologies of some of these important species have already been standardized. With the successful hatchery operations in future, significant increase in farming operation can be expected in northeast. There is need to refine the available technologies for large scale seed production of these important air breathing fish species.

In past few years, the fish seed production in the mid hill areas of the NE Region has improved significantly with establishment of carp hatcheries under different programmes being supported by the state Governments and ICAR.

Fish seed production in mid hill region

In past few years, the fish seed production in the mid hill areas of the NE Region has improved significantly with establishment of carp hatcheries under different programmes being supported by the state Governments and ICAR. Besides Indian major carps, other species cultured in the poly culture system are Silver carp, Grass carp, Common carp, Labeo bata, Labeo gonius, Puntius javanicus etc. Among all the cultured species; Silver carp, Grass carp and Common carp are reported to perform better in composite culture system in the mid altitude conditions. ICAR Research complex of NEH Region at Barapani , Meghalaya in past few years has been making a sincere effort to address the issue of seed availability in order to promote aquaculture for augmenting fish production in

themed hill region. The ICAR RC-NEHR, Barapani which is located at about 900 meter above mean sea level (MSL) has been successful in breeding of all the exotic and India major carps. In addition, minor carps, Labeo bata and Labeo gonius have also been successfully reared and induced bred for promotion of these two species in mid hill aquaculture. In recent times two more fish species, Amur common carp (-a genetically improved Hungarian Common carp) and highly esteemed Pengba, Osteobrama belangeri (- an endemic & endangered fish species of Manipur) have been introduced in Meghalaya. Amur Common carp seeds have also been introduced in Nagaland, Mizoram, Manipur, Arunachal Pradesh by the ICAR complex, Barapani for enhancing fish production under mid hill condition.

Fish breeding in high altitudes

The cold water fish farming sector especially in the high altitude has not gained much momentum. One basic reason is non-availability of adequate number of suitable fish species for breeding and culture. The important cold water species in the northeast India includes Chocolate mahseer, Neolissoceilus hexagonolepis, T. chelynoides, .T putitora (Golden mahseer) and T. tor among mahaseers and Schizothorax richardsonni and Schizothoraichthys progastus among the snow trouts. Many of these species are known as game fish and there is enormous potential to develop sport fisheries and eco-park based on these fishes. In recent years, efforts are being made to establish mahseer and trout hatchery in Assam, Arunachal Pradesh, Meghalaya and Sikkim. The state of Sikkim has already established trout hatchery and now promoting trout farming in raceways. Other hill stream fishes Poropuntius spp, Semiplotus spp, T. progenies, Barilius bendelisis could also be tried for development of breeding technologies. Breeding of different species of snow-trout viz.,Schizothoraichthys niger, S. esocinus, S. micropogon and S. planifrons and Schizothorax richardsonii has also become possible and however technologies are to be perfected for mass production of the seed under controlled farm conditions .

Assam has taken up various initiatives in improving the quality of hatchery produced fish seeds. In fact, the Assam is the first state in the country to adopt a fish seed policy based on a study conducted by College of Fisheries, AAU, Raha.

Recent initiatives in improving quality seed in Assam

Assam has taken up various initiatives in improving the quality of hatchery produced fish seeds. In fact, the Assam is the first state in the country to adopt a fish seed policy based on a study conducted by College of Fisheries, AAU, Raha. The study revealed the genetic deterioration of the hatchery produced seeds and thus conceived and prepared a policy document to submit to the Government of Assam. In the light of fish seed policy prepared, the state Government of Assam adopted it through a notification No.Fish.97/2000/90-A Dated. Dispur, the 17th Nov, 2001. The department of Fisheries, Assam has taken several initiatives at a later stage and finally to regulate the activities for quality fish seed production, the Govt. of Assam enacted Assam Fish Seed Act, 2005.

Conclusion

Seed being the basic input in any culture systems, its production has been accorded highest priority in terms of broodstock management, establishment of hatcheries, refinement of induced breeding techniques, rearing and production of quality seed. The technology of induced breeding is well known. However, there is need to develop breeding technologies for high value fishes such as Cat fish and other important indigenous and endangered fish species not only to conserve the species but also to augment the fish production of the region. There is scope to undertake research on reproductive biology of potential fish species of the region to develop seed production technologies. Further, Continuous refinement of developed technologies, domestication of other potential species for aquaculture, determination of physiological requirements for optimum reproductive performance and determination of physiological requirements of larvae/fry may be undertaken by the researchers of the region.

The Government may lay more emphasis on the infrastructure development, capacity building and facilitate finance for the enthusiastic entrepreneurs/farmer groups/NGO etc. for taking up seed production activities of important high value fish species of the region. The key player, Fish seed producers should be trained on appropriate technologies concerning selective breeding, brood stock management, hatchery management, nursery management, etc.

An overview of Coldwater fisheries developmental prospects in Northeast India

Debajit Sarma...

ICAR-DCFR, Bhimtal

Northeast India is blessed with abundant natural resources, including rich freshwater resources that support diverse aquatic life, including coldwater fish species. The region has a total water surface area of around 13,000 sq. km and includes several major rivers, such as the Brahmaputra, Barak, Subansiri, and their tributaries, which are home to several coldwater fish species.

Introduction

Northeast India is blessed with abundant natural resources, including rich freshwater resources that support diverse aquatic life, including coldwater fish species. The region has a total water surface area of around 13,000 sq. km and includes several major rivers, such as the Brahmaputra, Barak, Subansiri, and their tributaries, which are home to several coldwater fish species. In addition to these, there are several small streams and creeks that flow through the hilly terrain of the region, which are also suitable for coldwater fisheries development. Among the coldwater fish species, trout and mahseer hold a special place as it is one of the most popular food and game fish in the region. With its shimmering large colorful scales and streamlined body, mahseer (golden and chocolate mahseer) is an attractive and prized catch for anglers. In recent years, there has been a growing interest in developing rainbow trout fisheries in Northeast India as a means of generating employment opportunities. This

article aims to provide an overview of the current status, prospects and issues of coldwater fisheries development in Northeast India and the challenges that need to be addressed to ensure sustainable development. Despite the current annual production of trout is less in Northeastern states (150 tons) in comparison to Indian scenario (2500 tons), there are ample scopes for its rapid development.

Rainbow trout farming potential in Northeast India

The potential for trout fisheries development in Northeast India was first recognized in the early 1970s. The Government of India launched a program to introduce exotic trout species, such as rainbow trout and brown trout, into the uphill rivers and streams of the region. The program was aimed at boosting the economy of the region by creating job opportunities and promoting tourism. Since then, there has been a gradual increase in the number of trout fisheries developmental projects in the region, with the private sector also showing interest in this sector. Currently, there are more than 500 functional trout race ways/farms exist in Northeast India mainly in Sikkim, Arunachal Pradesh, Nagaland and Meghalaya. These trout farms are managed by the state governments and private farmers. The fisheries offer a range of activities, including farming and tourism. The development of trout fisheries in Northeast India has had a positive impact on the economy of the region. The trout farming provide employment opportunities to local people, particularly in the rural areas where jobs are scarce. They also attract tourists from different parts of the country and abroad, thereby boosting the tourism industry in the region particularly in angling of mahseer and brown trout. The quality of oxygenated water available in the stream of Northeast India makes trout farming viable round the year (14-180C).

> The Northeast region of India shares two of the 34 biodiversity hotspots listed by Conservation International, as the Himalayas and Indo-Burma region. Ichthyofaunal diversity of coldwater resources in India comprises 258 species, belonging to 21 families and 76 genera.

Challenges of rainbow trout farming

However, the development of trout fisheries in Northeast India is not without its challenges. The major challenges include the lack of infrastructure, inadequate training and support for local people. Infrastructure is a major challenge in developing trout fisheries in Northeast India. The region is characterized by difficult terrain and poor connectivity, which makes it difficult to transport equipment and supplies. In addition, many of the rivers and streams in the region are located in remote areas, which make it challenging to provide basic amenities such as electricity and water supply. The lack of infrastructure hampers the growth of coldwater fisheries and makes it difficult to take a rapid growth.

Another challenge is the lack of training and support for local people. Trout fisheries require skilled labor, which is often not available in the region. The local people need to be trained in various aspects of fisheries management, such as breeding, feeding, and disease control. In addition, they need to be provided with technical support and access to finance to set up their own trout raceways. Without these, it is difficult for local people to benefit from the development of trout fisheries.

In the natural water bodies, overfishing is another major threat to the sustainability of brown trout fisheries in Northeast India. Overfishing can also lead to the destruction of the natural habitat of the fish, which further affects their population. Therefore, it is important to regulate fishing activities and promote sustainable practices to ensure the long-term viability of trout fisheries in open waters (viz., Yargyap Chu river of Mechuka is a home for brown trout).

Strategies to develop coldwater fisheries in NE India

To develop the coldwater fisheries in Northeast India, various strategies can be adopted, including improving the breeding and hatchery techniques, enhancing the fish feed formulation, and promoting sustainable fishing practices. Trout farming can be an important source of livelihood for people in Northeast India, as it has the potential to generate employment and boost the economy since it is a fast growing fish. From single race way (trout growing pond) of size 45 m2, it is possible to produce 1000 kg of rainbow trout in a year. It is also a high value fish. It generally fetches Rs. 500 per kg in the market. So, over all, trout farming is a high income generating farming practices in coldwater fisheries sector. While developing a sustainable and profitable trout farming industry, it requires careful planning and implementation.

A few important steps that can be taken for the development of trout farming in northeast India are:

Conduct a feasibility study: Before investing in trout farming, it is important to conduct a feasibility study to determine whether the region has the necessary resources (water availability and quality of water required for trout farming, 600 L/m water flow per raceways; DO more than 6ppm) and infrastructure to support successful trout raceways. This study should also assess factors such as availability of feed and market demand for trout.

Establishment of hatcheries: The success of trout farming operation depends largely on the quality of the fish stock. To ensure a consistent supply of high quality fish seed, it is important to establish hatcheries that can produce healthy fingerlings for stocking in the raceways along with the trout farm.

Development of raceways: Once suitable land has been identified, raceways should be developed to provide a suitable habitat for the fish. The design of the tanks should take into account factors such as water flow, depth, and oxygenation to ensure optimal growing conditions for the trout.

Provide adequate feed: Trout require a diet that is high in protein and energy (Protein 40-45%). Commercial fish feed can be purchased from the local authorized distributor which is available in the country.

Monitor water quality: Water quality is critical for the health and growth of the trout fish. Regular monitoring of water quality parameters such as dissolved oxygen, pH, and ammonia levels is essential to ensure that the fish are living in a healthy environment (To produce 1 kg of trout in a flow through raceways 1-2 lakh L of water is required).

Implement bio-security measures: Disease can be a major problem in trout farming operations. To prevent the spread of disease, it is important to implement bio-security measures such as quarantine procedures for new fish stock, regular disinfection of equipment and facilities, and strict control of water sources.

Establish a marketing strategy: Once the fish are ready for harvest, it is important to have a marketing strategy in place to sell the product. This may involve developing relationships with local restaurants and markets, or exporting the fish to other regions.

Provide training and support: To ensure the success of trout farming operations, it is important to provide training and support to local farmers. This may include training on fish husbandry practices, disease management, and marketing strategies.

Researchable areas

There are few researchable areas which are needed to be carried out by the institutions of the region for promotion of coldwater fish farming in northeast India. They are:

1. Identification of suitable site, habitat suitability assessment.
2. Feed formulation and feeding practices.
3. Disease management.
4. Market demand and value chain analysis.
5. Government policy and support.
6. Breeding and larval rearing
7. Environmental sustainability.
8. Technology and innovation.
9. Socio-economic impacts.
10. Policy and governance.

Coldwater eco-tourism

Important points to understand for the development of coldwater eco-tourism in northeast India are:

Identification of potential sites: The first step in developing coldwater ecotourism is to identify potential sites that are suitable for tourism activities. This could include pristine rivers, streams, and lakes that have unique biodiversity, scenic beauty, and recreational potential.

Infrastructure development: Once potential sites have been identified, there is a need for infrastructure development to provide basic facilities for tourists, including accommodation, food, transportation, and recreational activities. This could involve the construction of eco-lodges, campsites, hiking trails, fishing and boating facilities.

Community involvement: The success of coldwater ecotourism depends on the involvement of local communities, who can act as guides, provide hospitality services, and share their knowledge of the local environment and culture with tourists. There is a need for

community based ecotourism initiatives that provide economic benefits to local communities while preserving their cultural heritage and natural resources.

Capacity building: Developing the skills and knowledge of local communities and tour operators is critical for the success of coldwater ecotourism. There is a need for training programs on hospitality management, tour guiding, environmental conservation, and sustainable tourism practices.

Marketing and promotion: Effective marketing and promotion are critical for the success of coldwater ecotourism. This could involve the development of brochures, websites, and social media campaigns that highlight the unique biodiversity, scenic beauty, and cultural heritage of Northeast India's coldwater habitats.

Coldwater fishes of Northeast India

The Northeast region of India shares two of the 34 biodiversity hotspots listed by Conservation International, as the Himalayas and Indo-Burma region. Ichthyofaunal diversity of coldwater resources in India comprises 258 species, belonging to 21 families and 76 genera. Out of these, the maximum of 255 coldwater fish species are recorded from Northeast Himalaya, 203 from the West and Central Himalaya and 91 from the Deccan plateau. A systematic account of 213 species of fishes from the state of Arunachal Pradesh was also recorded. All these fish species recorded have commercial importance in terms of food, ornamental and sports value.

Future scope

Under scientific management and through application of modern techniques, significant scope exists for promoting coldwater fisheries particularly trout farming, which in long run, will have both domestic and export demand. There is also a great potential for sport fishery development and eco-tourism in Northeast regions. Ornamental fish culture for small scale enterprises in the NE India can provide an alternative source of employment. Trout farming and seed production technology has been geared up in the state of Sikkim and Arunachal Pradesh. There are scopes for its rapid development in other Northeastern states viz. Nagaland, Meghalaya and Manipur. Aquaculture diversification is the key of fish production enhancement in the NE states and one of the most important areas for upscaling. Promotion of paddy cum fish culture will play a major role in the enhancement of livelihood security of the farmers. 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 Northeastern states as well as in the country which will play a significant role in improving the livelihood and nutritional security of the population of Northeastern region.

Conclusion

The aquatic resources in mountains are quite valuable for the development of fishery for food, sport, recreation and employment but scientific management of these resources is quite necessary to achieve the objectives. It is being realized and demonstrated that coldwater fishery can contribute to food and nutrition security in hills and remote regions. Therefore, in planning process, the fishery in hills, needs to be provided due importance in terms of financial, infrastructure and modern institutional back-up facilities. In hills, the fishery development through aquaculture, sport and conservation should be promoted and supported to introduce crop-animal-fish integration and diversification, so that natural resource management becomes economically sustainable activity. This will result in sustainable and profitable utilization of small resource base available in hills for any farming activity.

Table: Important Coldwater Fish Species of Northeast Himalaya

Important Coldwater Fish Species of Northeast India		
Snow trout:	**Exotic carp:**	**Barils/Minnows/ Catfishes/Loaches:**
Schizothorax richardsonni	Cyprinus carpio var. specularis	Barilius bendelisis
S. esocinus	C. carpio var. communis	B. vagra
S. plagiostomus	C. Carpio Var. nudus	Raimas bola
S. progastus	Ctenopharyngodon idella	Danio devario
Mahseer:	Hyphthalmichthy smolitrix	Botia birdi
Tor putitora	Carrasius carrasius	Glyptothorax pectinopterus
T. tor	**Minor carp:**	G. brevipinnis
Neolissochilus hexagonolepis	Labeo dyocheilus	N. multifasciatus,
Neolissochilus hexasticus	Labeo dero	
Exotic trout:	Crossocheilus latiuslatius	
Onchorhynchus mykiss	Garagotyla,	
Salmo trutta fario	G. lamta,	
	Puntius conchonius,	
	Semiplotus	

Enclosure culture technologies for openwaters of Northeast

S. Yengkokpam[1]
D. Debnath[1]
P. Das[1]
B.K. Das[2]...✍

[1]ICAR-CIFRI RC, Guwahati
[2]ICAR-CIFRI, Barrackpore

Fish species selected for pen culture should be based on the availability of seed, market demand and the environmental conditions required by the species.

Introduction

Reservoir and wetland ecosystems of the country, despite having high fish production potential (1000-1500 kg ha-1 y-1) are producing sub-optimal fish yields. In order to realize potential from these resources, enclosure culture (pen and cage) technologies and adoption of fisheries enhancement options are important. Pen aquaculture is one of the low-cost with high economic return aquaculture practices that can be practiced at various management levels. The technology is suitable for open waterbodies such as floodplain wetlands, reservoirs, lakes and even in riverine pool zones having mild water currents. This technology is suitable for production of seed and table fish of Indian major carps, exotic carps, minor carps (Labeo bata, L. gonius, Osteobrama belangeri) and also small indigenous fishes (SIFs) such as Amblypharyngodon mola, Puntius spp. and Gudusia chapra. In Northeast India, cage aquaculture of major carps (Labeo rohita, Cirrhinus mrigala mainly for seed raising), minor carps (L. bata, L. gonius), exotic carps (Ctenopharyngodon idella, Cyprinus carpio) is being carried out on experimental basis with moderate success in certain floodplain wetlands (beels) of Assam and Arunachal

Pradesh, Loktak lake of Manipur, reservoirs of Manipur, Mizoram, Nagaland, Tripura and Meghalaya. Enclosure culture technologies were also proven to be climate resilient in wetlands of Assam and Manipur. Cages, pens with increased height before onset of monsoon and floating pens (using macrophyte mass called phumdi) were able to withstand flood condition. It is necessary to standardize package-of-practice for locally-preferred fish species and popularize the technology in NE India. Large-scale demonstration and adoption of the technology are required for the realization of optimal fish yield from inland waterbodies of the Northeast, thereby contributing to making this region self-sufficient in fish production.

Open waters of Northeast India

The Northeast India has about 8% of the country's geographical area and 4% of country's population, but possesses 44.85% of derelict water, 31.53% of wetlands, 10.36% of rivers and canals and 0.80% of reservoirs of the country. Northeast India is having a total of 3.84 lakh ha water resources in terms of reservoirs, tanks and ponds, beels, oxbow lakes and other derelict waters, except the rivers and canals which are extending to a length of 20,875 km in all the NE states of India taken together. Among capture fisheries resources, the floodplain wetlands reservoirs have high potential for fisheries development in NE India.

Pen aquaculture

A pen is defined as a fixed enclosure in which the bottom is the bed of the waterbody and the sides are enclosed with the bamboo screen or nylon net. Pens can be completely enclosed on all four sides in the middle of the waterbody with no foreshore, a shore enclosure with a foreshore extending to deep water surrounding by a net structure or a bay enclosure with an embankment or net structure only at the entrance. Pen culture is a low-cost and simple culture technology for enhancement of fish production from inland openwaters, especially wetlands. In the past, pens were used for purposes like short-term rearing of fin and shellfish, holding of fish temporarily for a short-period before transferring to the other places, but raising of fish in pens constructed in large waterbodies is gaining importance day-by-day, because survival and growth of carp fingerlings in pens is encouraging.

Pen aquaculture technology has been developed by CIFRI as an avenue for additional fish production in beels parallel to the enhancement of their capture fisheries/ stock enhancement, where a manageable part of marginal areas of the beel is encircled with net-lined split-bamboo screens (bana) for rearing of carp fingerlings/table fish. The technology is a good management option for macrophyte-choked shallow waterbodies where netting and catching fish is very difficult. Studies in Assam and Manipur showed that in situ raising of fingerlings as well as table fish production in pens is technologically and economically feasible in the floodplain wetlands.

The Northeast India has about 8% of the country's geographical area and 4% of country's population, but possesses 44.85% of derelict water, 31.53% of wetlands, 10.36% of rivers and canals and 0.80% of reservoirs of the country.

Pen culture trials for production of table fish in NE Region showed benefit cost ratio ranging from 1.3 to 3.2 and net production of 4125 to 6312 kg ha-1 y-1.

Advantages of pen aquaculture

Pen aquaculture is one of the most economical land-based culture systems offering many advantages. Pen culture technology (a) is a high-density culture practice with very high productivity potential, (b) is suitable for rearing compatible species together to fully utilize different ecological niches, (c) saves reared fish from predators, (d) is most useful for weed-choked unproductive water areas, where netting and catching of fish are highly difficult, (e) does not disturb the capture fisheries in a large waterbody, because pens are normally constructed in the marginal areas of the waterbody, (f) offers easy, rapid and complete harvesting of fish with lesser efforts, (g) offers exchange of water encouraging growth of natural fish food organisms inside the pens reducing cost of feeding fish to a certain extent, (h) offers easy monitoring of growth and health condition of stocked fish. However, pen aquaculturists should be aware of the fact that the site with strong water current, turbulence, wind and wave action is not suitable for pen culture because they may damage the pen structure. Entry of non-target small fishes is almost unavoidable inside the pens; these fishes will compete for food and space with the target species. One of the most important constraints in pen culture systems is the risk of theft, because fishes in the pens may be easily poached.

Fish species for pen aquaculture

Fish species selected for pen culture should be based on the availability of seed, market demand and the environmental conditions required by the species. The desirable characteristics in the candidate species for pen culture are fast growth rate, high survival rate, adaptability

to overcrowding, easy acceptance of supplemental feed, high feed conversion ratio and disease resistance. The Indians and Chinese carps (Catla catla, Labeo rohita, L. calbasu, L. bata, Cirrhinus mrigala, Cyprinus carpio, Hypophthalmichthys molitrix and Ctenopharyngodon idella), air breathing fish (Clarias magur, Heteropneutes fossilis), climbing perch (Anabas testudineus), snakeheads (Channa striatus, C. marulius) and freshwater prawn (Macrobrachium rosenbergii) satisfy most of the above characteristics for pen culture in India. Polyculture of carps in pens with 40% surface feeders (catla Catla catla & silver carp Hypophthalmichthys molitrix), 20% column feeder (rohu Labeo rohita), 30% bottom feeders (mrigal Cirrhinus mrigala & common carp Cyprinus carpio) and 10% macrophyte feeder (grass carp Ctenopharyngodon idella) is normally practiced. Fish species of local importance such as Osteobrama belangeri (pengba) and Labeo gonius (kuri) performed well when stocked in net pens in Takmu pat of Manipur. Labeo bata, Barbonymus gonionotus and other small indigenous fishes like Puntius sarana, Amblypharyngodon mola and Gudusia chapra can also be stocked along with carps for additional income from the pens.

Cage aquaculture

Cage aquaculture can be defined as rearing of aquatic organisms in a volume of water enclosed on all sides with cage netting materials including bottom, while permitting free circulation of water through the mesh of cages. The technology is suitable for almost all kinds of waterbodies provided there is sufficient water depth so that the bottom cage net is at least 2 m above the bottom of the waterbody. In India, cage culture was attempted for the first time in case of air-breathing fishes like Heteropneustes fossilis and Anabas testudineus in swamps during the 80s. Trials on cage culture carried out at Darbhanga (Bihar) and Guwahati (Assam) under Coordinated Research Project on Air-

Cage aquaculture can be defined as rearing of aquatic organisms in a volume of water enclosed on all sides with cage netting materials including bottom, while permitting free circulation of water through the mesh of cages.

breathing fish culture demonstrated production level of 0.3, 0.7, 1.0, 1.7, 1.5 and 1.3 kg/m3/month in Anabas testudineus, Heteropneustes fossilis, Clarias magur, Channa striatus, C. punctatus, respectively. The optimum stocking density of Cirrhinus mrigala fry and Labeo rohita fry in net cages for stock enhancement purpose was standardized at 300 and 200 fry/ m3, respectively in beels of Assam.

Experiments were carried out in floodplain wetlands (beels) of Assam to optimize stocking density of commercially important minor carps. Considering the fish yield and economics of cage aquaculture system, a stocking density of 75 fingerlings m-3 was recommended as optimum for rearing L. bata up to advanced fingerlings during winter months and a stocking density of 30 fingerlings m-3 for producing table sized fish of L. bata. In case of L. gonius, a stocking density of 40 fingerlings m-3 was recommended as optimum for table fish production. Cage culture of the endemic minor carp Osteobrama belangeri was tried for the first time in Takmu pat of Manipur. A stocking density of 20 fingerlings m-3 was found to give economic production considering the high cost of seed. In spite of small and large-scale demonstrations and experiments conducted in wetlands of Assam, Manipur and Arunachal Pradesh and some reservoirs of the region, cage culture is yet to make an impact, mostly because of limited adoption and low-level of management. However, it has been recommended to expand cage aquaculture only up to 1% of the total water area of beels so that there is no problem of eutrophication in years to come.

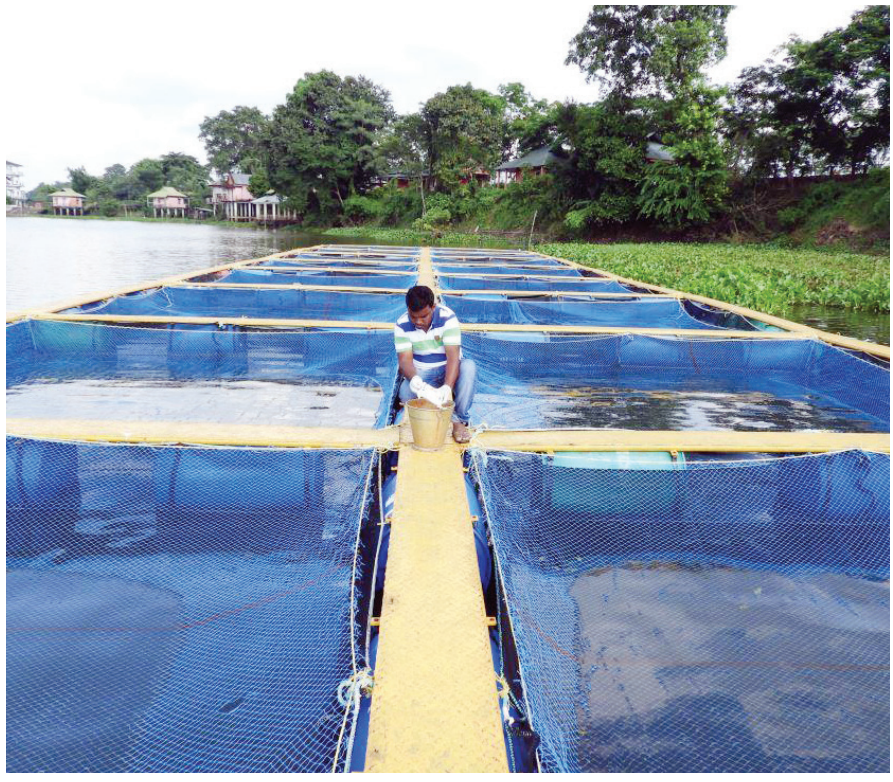
Advantages of cage aquaculture

Rearing and raising of fishes in cages is gaining importance all over the world because of its increasing technical, ecological, social and economic advantages over capture fisheries and conventional aquaculture. Cage culture technology is (a) compatible and not competitive with other fish production systems and complementary to some, (b) applicable to almost all aquaculture species, (c) ideally applicable in openwaters where low fish yield and other fishery development is impractical, such as inland reservoirs and large rivers, (d) basically developed and ready for practical application in freshwater environments, (e) technologically simple, (f) not capital intensive, (g) economically and technologically available to all sectors of society including uneducated and poor, small-holder farmers, (h) more adaptable than conventional aquaculture to matching production to market demand. It also has social advantages in that landless people can find habitation and employment in cage aquaculture. Small-scale cage aquaculture is a flexible technology adaptable to the needs of poor people by placing only the cages under the ownership of the landless.

Stock enhancement through enclosure culture

Fish stock enhancement (i.e., augmenting the stock of desirable fish species) is one of the most common and effective management

measures followed in the beels of Assam, which can also be practiced in many of the reservoirs. However, the major constraints of practicing stock enhancement in open waterbodies at large-scale are (i) non-availability of carp fingerlings of desired size i.e., about 10 mm or above in required quantities at the beel site, (ii) high cost of carp fingerlings and (iii) associated high mortality during transportation. All these constraints can be overcome by in-situ rearing of fingerlings in pens/ cage within the beels. Enclosure culture, especially for raising stocking material offers a great scope for the effective utilization of available floodplain wetland resources for fisheries enhancement that will lead to significant improvement in the socio-economic status of fishers. Cage aquaculture is especially effective in raising carp seeds in seasonally open beels of the region where practicing pen aquaculture is a difficult proposition during the south-west monsoon season (June-September). Moreover, floating nature of cage enclosures makes them most suitable for waterbodies which are affected by occasional flood and drought-like situations.



Enclosure culture as a climate resilient technology

Main threat of climate change on the numerous floodplain wetlands of river systems are floods due to irregular and excessive precipitation during the southwest monsoon (June-September) and drought during pre-monsoon seasons (Jan to April). Experiments and demonstrations conducted in the region showed that enclosures installed in inland waters are resilient to climate change impact. In dry seasons when the water level reduces, temporary pens erected around the deepest part of a wetland can be used to culture fish. On the other hand, height of the pen enclosures are increased using netting before the onset of monsoon to prevent escapement of cultured fish due to flood. If cage enclosures are considered, floating nature of the cages makes it resilient to flood. However, in dry seasons, cages can be moved to deeper areas provided there is at least minimum permissible water depth prevailing in the waterbody.

Conclusion

Inland openwater resources like floodplain wetlands and reservoirs are the vital resources and must be utilized sustainably for fish production. Enclosure culture technologies create an avenue for additional fish production from such waterbodies. Pen culture also serves as a good management option for macrophyte-choked shallow and unproductive wetlands that solves the problems created by gear restrictions and catchability. Pens can be used for raising fingerlings or table fish. Fish species with local importance such as O. belangeri (pengba) and L. gonius (kuri) performed well when stocked in net pens. Economically important small indigenous fishes can be stocked in pens, which would reproduce in them and become a self-recruiting population providing nutritional securities to the fishers. Cage culture technology has been successfully field tested in several beels/ wetlands of Northeastern India with special emphasis on Assam. The technology is also being demonstrated and tested (using CIFRI GI Cage as well as Modular cages) in Umiam lake of Meghalaya, Loktak lake, Khuga and Mapithel reservoirs of Manipur, Serlui reservoir of Mizoram, Borbeel of Arunachal Pradesh, Dumbur reservoir of Tripura and Doyong reservoir of Nagaland. Research and development in enclosure culture are needed to standardize package-of-practice including the size of stocking and harvesting, stocking density, species ratio of compatible species, feeding rate and culture duration of new candidate species. Large-scale demonstration and adoption of the technology is essential for realization of optimal fish production from the beels/ pats, reservoirs and natural lakes of the Northeast thereby contributing substantially to making this region self-sufficient in fish production. By adopting enclosure culture technology in large openwater resources of the Northeast, the region can produce significant quantities of fish reducing the demand-supply gap.

Sustainable management of Reservoir fisheries in Northeast India

S. Borah
P. Das
A.K. Yadav
S.C.S. Das...✍

ICAR-CIFRI Regional Centre, Guwahati

In India, the area under reservoir fisheries was estimated at about 4.03 million ha with over 14,000 reservoirs. The area of small reservoirs (<1000 ha) is around 1.78 million ha and that under medium (1000-5000 ha) and large reservoirs (> 5000 ha) in India is estimated to be 2.25 million ha.

Reservoir Resources

In India, the area under reservoir fisheries was estimated at about 4.03 million ha with over 14,000 reservoirs. The area of small reservoirs (<1000 ha) is around 1.78 million ha and that under medium (1000-5000 ha) and large reservoirs (> 5000 ha) in India is estimated to be 2.25 million ha. The reservoirs are predominantly located in the peninsular and central states viz. Tamil Nadu, Karnataka, Andhra Pradesh, Kerala, Odisha, Maharashtra, Uttar Pradesh and Madhya Pradesh. Maharashtra has the maximum number and area under reservoirs. The state also has the highest area and number of small reservoirs. Small reservoirs (No.: 13691; Area: 17,77,708 ha) and medium & large reservoirs((No.: 829; Area: 22,54,810 ha) are important water resources of the country with fish production potential besides its other uses.

Fish Diversity

Indian reservoirs exhibit rich fish diversity with approximately 117 fish

species reported, of which 96.5% species are food fishes, providing protein rich diet to the people living in the vicinity of reservoirs. Fish production from the reservoirs of the Indo-Gangetic basin is dominated by about 30 species. Reservoirs located in upper part of Ganga-Brahmaputra basin (Uttarakhand, HP, J&K, NE states) is dominated by mahseers (Tor spp.), snow trouts (Schizothorax spp.) and other cyprinids. Reservoirs along northern, central and eastern India (UP, Bihar, MP, Chhattisgarh, Jharkhand, WB) is predominated by major carps. Large reservoirs on an average, harbour 60 species of fishes, of which 40 contribute to commercial fisheries. Fish diversity in reservoirs is basically formed on the biodiversity of the original rivers, particularly the principal river system. Gangetic carps occupy a prominent place among the commercially important fishes. Contribution of exotic species to total fish catch is increasing in a number of reservoirs. Reservoir ecosystems are subjected to both natural and anthropogenic changes (e.g., introduction of exotic species) that can adversely affect the ecosystem functions. More than 300 exotic fishes have been introduced to India for different purposes; the most common exotic fishes reported from Indian reservoirs are Oreochromis mossambicus, Hypophthalmichthys molitrix, Cyprinus carpio specularis, C. carpio communis, Gambusia affinis and C. idella. A total of 10 exotic fish species has already been reported from the Ganga basin which is likely to enter the reservoirs ecosystems and may affect their community structure and ecology.

Reservoirs in Northeast India

There are a total of 20 small reservoirs in 8 states of NE India with an area of 3390.53 ha. The state has 6 medium reservoirs covering an area of 15585.34 ha. The region does not have any large reservoirs. Details of reservoir fisheries of the region are given below:

Table 1. List of some reservoirs in NE India

State	Reservoir	Remarks
Arunachal Pradesh	Ranganadi	Small reservoir
	Bichom	Small reservoir (recently commissioned)
Assam	Umrangso	Small reservoir
	Khandong	Medium reservoir (A part of this reservoir falls in Meghalaya)
Manipur	Khoupum	Small reservoir
	Khuga	Small reservoir
	Singda	Small reservoir
	Thoubal	Small reservoir
	Dolaithabi	Small reservoir
	Mapithel	Medium reservoir
Mizoram	Serlui B	Medium reservoir
	Tuirial	Medium reservoir
Meghalaya	Umiam	Small reservoir
	Nongmahir	Small reservoir
	Kyrdemkulai	Small reservoir
	Narbong	Small reservoir
	Stage III	Small reservoir
	Leshka	Small reservoir
Nagaland	Doyang	Medium reservoir
Sikkim	Rangit	Small reservoir
	Teesta-V	Small reservoir
Tripura	Dumbur	Medium reservoir

Table 2. Reservoir Fisheries Resources by States of Northeast India (2019-20)

States	Small Reservoir		Medium & Large Reservoir	
	Number	Area(ha)	Number	Area (ha)
Arunachal Pradesh	1	136	0	0
Assam	1	717	1	1,096
Manipur	5	960	1	1,182
Meghalaya	7	717.53	0	0
Mizoram	3	10	2	8,000
Nagaland	0	0	1	2,258
Sikkim	3	850	0	0
Tripura	0	0	1	3,049.34

Studies carried out by ICAR-CIFRI in reservoirs across the country have ultimately led to development of management modules for reservoir fisheries development in the country.

Fisheries Management

Studies carried out by ICAR-CIFRI in reservoirs across the country have ultimately led to development of management modules for reservoir fisheries development in the country. Among the series of management measures suggested, culture-based fisheries in small reservoirs and stock enhancement in medium and large reservoirs are by far the most successful ones. Cage and pen culture are also viable options towards augmenting fish production in reservoirs. Cage and pen culture operation in reservoirs has taken a quantum leap over the last decade with states of Chhattisgarh and Jharkhand at the forefront. Management modules and technologies of ICAR-CIFRI are being recently implemented in few reservoirs of NE India with good success rate. One notable example is that of Doyang reservoir, Nagaland, where fish production has increased considerably (358 tonnes per annum at present) following supplementary stocking. Growth rate of these stocked fishes was also found to be on the higher side. Field studies conducted by ICAR-CIFRI have also revealed that culture-based fisheries respectively in Bichom reservoir (recently commissioned), Arunachal Pradesh has been instrumental in improving fish production from the water body. ICAR-CIFRI is also instrumental in popularizing cage culture in Doyang reservoir, Nagaland and Umiam reservoir, Meghalaya.

Challenges

All of the reservoirs in the region are developed for hydropower generation, with fisheries as a secondary activity. They are located in interior and poorly connected regions, lack proper scientific fisheries management and are resources with multiple stakeholders. Poor connectivity and remote location is a major hurdle in timely supply of inputs (seed, feed etc.). There is a lack of awareness among fishers on scientific management of reservoir fisheries and they are totally dependent on government machinery for any activity whatsoever. Pollution particularly plastic and sewage are burgeoning threats to reservoir ecosystem. Reservoirs located downstream of major towns of the region receive sewage leading to eutrophication in addition to huge quantities of plastic waste. Low pH (<4) in Umrangso reservoir, Assam, caused by coal mining in bordering region of Meghalaya led to collapse of whole reservoir ecosystem. Stocking of exotic species in reservoirs, particularly due to ignorance on the part of the fishers' and subsequent colonization (as in the case of common carp) is another major issue facing reservoir fisheries of the region.

Way forward

Reservoirs are a highly potential fishery resource, which are under-utilized till date. We have not been able to harness them in the right way. Scientific research and management involving all stakeholders can help us to utilize these resources and it can occupy its rightful place in the food basket.

Ornamental fisheries in Northeast India
State of the art and future directions

N. Sharma,
S.Yengkokpam
P. Das
D. Bordoloi ...

ICAR-CIFRI Regional Centre, Guwahati

Ornamental fish keeping is a growing sector in aquaculture and still the 2nd most popular hobby comprising of 100 million of hobbyist in the world.

Introduction

Ornamental fish keeping is a growing sector in aquaculture and still the 2nd most popular hobby comprising of 100 million of hobbyist in the world. The global ornamental fish market has been expanding in its trade in more than 125 countries and valued at USD 5.88 billion in 2022 with an average annual growth rate of over 10%. The ornamental fisheries industry also includes plants, accessories, aquarium, feed, and drugs is estimated to be worth more than US$18-20 billion. The top global importers of ornamental fishes are the United States of America (USA) and European Union (EU), followed by UK and Singapore. Globally, USA, Europe, and Japan are the largest markets for ornamental fishes, but more than 65% of the exports come from Asia encouraging economic development. India's share to global ornamental fish export 0.4% (US$ 1.4 million) of the total world. More than 100 million ornamental fish are kept as pets in aquariums and ponds in the United Kingdom. Around 4 million families own a pet fish in UK, which is 14% of their population. An aquarium can be

found in approximately 7.2 million homes in the United States and 3.2 million homes in the European Union, a number that is steadily rising worldwide. Ornamental fisheries are gaining rapid importance in earning foreign exchange and as a source of employment.

More than 2500 fish species are involved in the global ornamental fish industry, where over 60% are of freshwater origin and 40% of marine origin. Over thirty freshwater fish species dominate the global market, such as gold fish, angel fish, live bearers, neon tetra, zebra danio and discus. The guppy and neon tetra species alone represent more than 25% and 14% of the market by volume and value. Most (85-90%) of the ornamental fish trade is in freshwater species which are farm-bred and rest constitute of marine species are predominantly wild-caught.

Criteria for selection of ornamental fish

Ornamental fishes are also known as living jewels, where in a confined aquatic system, attractive and colourful fishes of various characteristics are reared. The criteria for selection of fish species for keeping as an ornamental are:

- attractive look with beautiful coloration
- adaptability to live in small confined areas
- peaceful nature and compatibility to live with other fish
- ready acceptability of artificial feed
- peculiar nature (colour change in chameleon fish, Badis badis).
- unique/ unusual appearance (e.g., the Devil catfish, Chaca chaca)
- rare species (e.g., the coloring snakeheads, C. barca, C. stewartii, C. bleheri)

In recent years, ornamental hobbyists are liking for unique or unusual fishes. These fishes are fetching high demands in the ornamental market such as the indigenous snakeheads (C. aurantimaculata, C. stewartii and C. bleheri) from Northeast India. Figure 1 showing some of the potential native ornamental fishes of Northeast India caught from the wild.

More than 2500 fish species are involved in the global ornamental fish industry, where over 60% are of freshwater origin and 40% of marine origin.

Ornamental fisheries in Northeast India: State of the art

Ornamental fishes of India are contributing about 1% of the total ornamental fish trade. Due to its unique geographical and hydro-biological circumstances, and rich biodiversity, India has enormous potential for producing ornamental fish. The abundance of native species has made it possible for the country's ornamental fish sector to grow dramatically. North-eastern region are blessed with potential indigenous and endemic fish species, as a bliss for a variety of ornamental fish species. About 90% of native species (85% are from northeast India) are collected and reared to meet export demand. Presently, about 100 native species are reared as aquarium fish. 90% of India's exports comes from Kolkata, where Northeast India accounts for the lion's share, followed by 8% from Mumbai and 2% from Chennai. Almost 80% of the fish species present in Northeast region considered as of ornamental valued, among them are Loaches, Eels, Barbs, Catfish, snakeheads, Goby etc.

Out of the 422 fish species that have been reported for the Northeast region, 250 have the potential to be ornamental, with Assam having the largest number of ornamental fish species (187 species) recorded. Several species of fish can be considered as potential ornamental fish, at least during their early juvenile phase or during their breeding season. Wetlands/lakes of Assam and other Northeast states contribute a major portion in Ornamental fish diversity of Northeast India. Along with beel fishes, various small hill stream fishes of other northeast states possess interesting morphological characters. Some of these fishes like Devario spp., Garra spp., Barilius spp., Pangio pangia, Balitora brucei, B. tileo, Batasio tengana, Erethistes pussilus which augment the species diversity of north eastern region. However, the maintenance of hill stream ornamental fishes in aquarium needs special care and relatively high cost due to the sensitivity of these fishes to low oxygen level and different temperature factors. In terms of comfortable maintenance, several fishes such as eels, tank goby, rasboras, barbs, chameleon fish, small catfishes, nemachelids, etc. can be considered as potential fishes for aquarium. A variety of microhabitats are found in the hill streams of Arunachal Pradesh, Meghalaya and Nagaland, these unique habitats harbour qualitatively rich fauna. The small size, strange shape, body colouration and peculiar patterns make the hill stream fishes as decent ornamental species. There are many such fishes

Ornamental fisheries occupied an important position in commercial trade mainly in earning foreign exchange. Ornamental fish farming is one of the most favourite hobby in the world and the number of ornamental fish-keeping enthusiasts is increasing day by day.

from this region with very high value in the global ornamental fish trade, mostly dominated by the attractive snakeheads (Figure 2). Snakeheads are most valued but rare ornamental fish species from this region which made its mark globally. There are around 17 snakehead species till discovered and a lot to explore, yet few are in danger of disappearing (Channa barca) due to uncontrolled exploitation.

Importance of Ornamental fisheries

Ornamental fisheries occupied an important position in commercial trade mainly in earning foreign exchange. Ornamental fish farming is one of the most favourite hobby in the world and the number of ornamental fish-keeping enthusiasts is increasing day by day. Ornamental fisheries not only plays important role in global trade but also have importance in communicating science. Ornamental fisheries as a hobby gives pleasure to young and old people, provides relaxation to the mind, keeps blood pressure under control and helps in prevention of other diseases. During Covid-19 pandemic, the number of aquarium keeping has increases in many countries. It was reported that over 80% of the respondents, irrespective of age, gender, employment status confirmed that aquariums have produced stress-relieving benefits during the COVID-19 pandemic. Children could acquire new knowledge and skills, by observing the fish's behaviour, colour and fin shape. They could develop sense of attachment with nature. Ornamental

fish keeping is easy over other pets as they don't make noise and tank cleaning once in a while is enough. Ornamental fishes like Goldfish, Arowana are believed to bring good luck, wealth and prosperity.

The ornamental fisheries business has been recognized as an avenue of employment, especially for women in various countries, contributing to women empowerment. Because it provides a great opportunity for entrepreneurship development and income generation for livelihood secure for future. It has enormous opportunities, low investment, less time and water requirement. The Ornamental fish farming can be realized at every stages of activities, namely at production, marketing and export. In the north east India, Ornamental fish production was observed to be financially as well as economically viable and investment friendly. With the initiatives by the Govt. as the key institutions, ornamental fisheries can be developed substantially in the region, which in turn can gradually gain a larger share in the world market. To make the ornamental fishery sector more vibrant and lucrative, public-private partnerships can be encouraged by establishing ornamental fish production facilities in different locations throughout the region.

Future directions

The ornamental fish have recently taken on a larger role in the commercial world especially in terms of foreign exchange. Indian domestic trade in this area is growing @ 20% annually and demand at domestic level is higher than supply. The ornamental fish market is expected to gain market growth in coming years. The primary reason of ornamental market expansion is the customer choice for a high-end lifestyle, rise in disposable money and due to rising knowledge of the psychological benefits of keeping ornamental fish in homes, as doing so can lower stress levels and increase comfort, which in turn encourages many people to buy these kinds of ornamental fish. To basically match the interior decors and improve the aesthetics, a number of businesses are providing ornamental species with aquariums in a variety of shapes, including rimless, half land, half water, pentagon, square, and hexagon. Popularization of aquarium accessories and development in packing techniques will uplift the existing market.

As the demand of the native ornamental fishes are increasing in domestic as well as global ornamental fish trade, to meet the high demand, few native fish species are getting endangered because of unregulated and illegal ways of fishing from nature. Some of the key threats are identified as overexploitation (destructive fishing methods/ wild catch/ over fishing), water pollution (deforestation/ industrial release/ chemical contamination), flow modification (hydropower generation/ diversion and withdrawal of water for irrigation or urban or industrial use), destruction or degradation of habitat, exotic species invasion and Climate change etc. There are various conservation measures and management strategies to be adopt for development and improvement of ornamental fisheries in the region, such as conservation of spawning ground, regulation of illegal fishing or wild catch, captive breeding, ranching of fish seed in their natural habitat, strengthening the indigenous fish population, prohibition of bio piracy (illegal export of high valued fish to foreign market), development of proper database on indigenous ornamental species and creating awareness among people etc.

Prospects of Fish Processing Technologies in Northeast India

A. U. Muzaddadi ...✍

ICAR-CIPHET, Ludhiana

In the domestic markets people prefer live fresh water fishes such as the carps, cat fishes and murrels. Traditionally three methods major method have been reported for live carp transportation for food purpose.

Introduction

In Northeast India over 95% population are non-vegetarians. It is widely accepted fact that non-vegetarian foods have immense potential to provide food and nutritional security to a large section of the world population and fish is the source of cheap and good quality protein. The health benefits associated with fish consumption have been attracting the consumers towards fish and fish products. As the nation charges into a high state of development with high aspirations under "Make in India" slogan, Prime Minister's Matsya Sampada Yojona (PMMSY) and The Blue Revolution concept, new requirements and needs in life, especially in the food style are emerging not only for domestic consumption and to export more and more meat and fish products. In such perspectives, there occurs a high demand in quality and nutrition and obviously people look forward to freshness, quality and hygiene components in fresh and processed foods.

Fish Processing and the Northeast states

The indigenous population of all the NE states of India (Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland and Tripura) are fish eaters by default.

The numerous natural water bodies including rivers, rivulets, streams, lakes, oxbow lakes etc. are the haven of a huge fish biodiversity and people naturally have a way of life finely stitched with these water systems, thus they, by default, become fish eaters. In fact, they prefer freshly cooked fish rather than the processed products of fish. Nevertheless, processing plays key roles for providing a hefty profit margin to the fishers, ensuring freshness and quality of fish for the consumers, establishing hygiene for environmental safety, reducing post-harvest losses and finally providing food safety to the consumers, even if the fish is consumed as freshly cooked form.

Fish needs processing immediately after harvest, may it be a primary processing unit operation or a secondary processing unit operation. Fish needs processing considerations even if they are transported or marketed alive, because processing or post-harvest technology encompasses all the unit operations to keep fish in its best quality from farm to fork.

Some important aspects on post-harvest management of fish in context of Northeast states of India have been discussed here.

Handling

Handling of raw material plays an important role in shelf-life extension and end product quality of the product. Especially fish is either transported live or iced/frozen state and finally processed to various products and it should be ensured that it reaches the consumer or the processor in the freshest possible condition. The primary quality will depend on how it is handled onboard, preserved, packaged etc. Handling practices adopted should ensure that the fish is washed well, sorted species-wise and size-wise and cooled to near 0°C employing hygienic methods, and store them appropriately. Icing is, perhaps, the most ideal method of cooling fish.

In India majority of the fishing craft are small and devoid of modern facilities for handling and chill storage. However, there are extensive uses of boxes made of high-density polythene insulated with polyurethane foam and insulated plastic containers for storing iced fish onboard such vessels and short distance transportation.

Fish needs processing immediately after harvest, may it be a primary processing unit operation or a secondary processing unit operation.

Bigger fish should be considered for bleeding, gutting, washing, grading and transferring to stacking systems integrated with icing.

There are modern sophisticated processing equipment and machineries lashed with Artificial Intelligence, Sensors and IoT based operations and the entire process operations can be monitored using computers. These machineries provide a seamless operation for fish handling, grading, cleaning, icing, packing etc.

Live fish handling

In the domestic markets people prefer live fresh water fishes such as the carps, cat fishes and murrels. Traditionally three methods major method have been reported for live carp transportation for food purpose.

1. The whole backside of truck is converted into a small pool of water with plastic (LDPE/HDPE sheets) linings.
2. Bamboo barrel method- polythene lined bamboo baskets
3. Aluminium hundi / plastic (PVC) drums for small scale transportation

First method is extensively used all over North India, East India and Northeast India. Fishers transport live fish, mostly table carps, production sites to auction markets involving around 3-6 hours travel time. In this method about 50-60% mortality is encountered.

The second method is observed in Northeast India. It is local innovation by the fishers making use of locally available materials such as bamboo. The outer rigid barrels are made from split bamboo strips. This method is inexpensive and handy but prone to leakage and puncture of polythene bags by the sharp edges of bamboo during handling.

The third method is mostly used for table fish and fry and fingerlings in the village areas of Northeast states of India. This method is handy and appropriate for small scale use, however due to improper aeration mass mortality of fish may arise.

ICAR-CIPET Live fish carrier system (LFCS)

Live fish carrier system (LFCS) is useful system for live ornamental fish transportation. It is a electric tri-cycle based live fish transportation system for

short and medium distance (about 80 km) transportation of fish. It is devised with water filtration, aeration and cooling system providing good quality water to reduce fish mortality while transportation (Fig. 1).

It is eco-friendly, low-cost, easy to handle and keep fish alive for more than 4 hours while transportation.

It has all facilities including aeration, filtration and ammonia removing to keep fish alive during transportation with less than 1% fish mortality per trip of 40 km with carps of 0.5-2.0 kg individual weight. The vehicle is useful for both freshwater and saltwater fishes to transport fish in live condition. The capacity of the present system is 100 kg live fish per trip, however this capacity can be increased by enhancing the carrying capacity of the vehicle.

The LFCS has automatic aeration, filtration and evaporative cooling system ensuring continuous availability of good quality water and less fish mortality (<1%). Other features of this system are

1. Its water requirement is less than 50% as compared to the traditional systems.
2. LFCS requires only 1 (one) worker which is otherwise 4-5 workers in case of traditional system, thus reducing cost of labour.
3. It ensures supply of freshest quality of fish to the consumers.
4. It zero polluting system with less running cost for marginal farmers/ entrepreneurs.
5. The system is woman-friendly and can be operated by one or two women.

Primary processing

Fish flavour and texture change rapidly during storage after death. It is thus advisable to keep the fish alive as long as possible. Primary processing aims to assure best possible market quality, to provide a proper form of semi-processed of final product, to assure health safety of products, to - apply the most rational raw processing method, and to reduce waste to the extent possible.

Fresh fish cutting and dressing is considered to be a laborious and dirty work, while the manual dressing requires skill and extra time. Many fish-eaters often want to eat freshly cooked fish, but they cannot because they don't have time or skill to do it.

Immediately on death fish should be iced as whole or deheaded, gutted, washed and chilled in order to inhibit unfavourable enzymatic and microbiological processes. If not sold fresh, preservations methods such as freezing, smoking, thermal preservation (canning, pasteurization, etc.) should be used. As a step of minimal processing the product may also be given an attractive form e.g., skinless fillet or deheaded fish with fins removed which have advantages of added value and extended shelf life.

Fish processing must ensure full health safety of fish products and proper sanitary conditions as well as selection of a process.

Appropriate processing should enable maximal use of raw material and thus contribute to increased economic profitability which is a basic approach in modern industry. For example a filleting operation offers the fillets and side by side minced meat can be produced from the waste material and the remainder sold as animal feed. Thus the process results in practically no unused waste material.

These operations essentially require mechanization and at the same time the profitability can be a decisive factor for the survival of many fish processing plants, especially the small ones.

Fishing, processing, transportation and sale of fish products are links in a complete processing chain. Each has its own importance but only together can they form an inseparable process to provide the customer with a top quality product (Bykowski, P. and Dutkiewicz, 1996)

Secondary Processing / Preparation of Ready-to-Cook (RTC) Products

Fresh fish cutting and dressing is considered to be a laborious and dirty work, while the manual dressing requires skill and extra time. Many fish-eaters often want to eat freshly cooked fish, but they cannot because they don't have time or skill to do it. There is a big market for such fish consumers. Fish are neatly cleaned, dressed into pieces in the form of steaks or fillets and then iced or frozen in packaged form to sell. Before cooking fish is just thawed. Different equipment and machinery can be used such as steaking machine, filleting machine etc. ICAR-CIPHET Ludhiana developed a Fish Dressing cum Waste Collection System for this purpose.

Fish Dressing and Waste Collection System (FDACS)

It is a machine for steak cutting of fish with channelized system of collection of solid and liquid wastes separately. The machine has provision of continuous washing of blade (cutter) and complete fly protection and protected storage of

collected wastes until they are deposed off. The machine has a system for continuous cleaning of cut pieces of fish, the blade and the table-top during dressing operation through a controlled spray of clean water. Solid wastes (intestine, gill, scales and fins) are instantly collected in a covered bin through an opening on the table-top with swing closure. Liquid waste is channelized through a slit at the bottom of the blade through which all the washed water, blood, slime etc. are collected in a separate bin placed under the table (Fig. 2).

Freezing methods

Extensively used freezers are plate freezers and air blast freezers. Radical changes have taken place in the freezing set up over the years and several modifications have been brought about in the total infrastructure.

Yet another improvement in the freezing process is the application of cryogenic techniques such as liquid nitrogen and liquid/ solid carbon dioxide (dry ice). These rapid methods are useful for processing value added products like individually quick-frozen prawns. This method may be useful for giant freshwater prawns which are naturally available in the Brahmaputra and its tributaries.

Heat processed products

The canning industry especially in the design and development of containers, canning equipment and nature and type of the products has been growing steadily. The containers like retortable pouches, rigid plastic containers, aluminium cans, drawn and wall ironed (DWI) as well as drawn and redrawn (DRD) cans made of tinplate, easy-open cans with ring or pull tabs are of recent origin. Heat processing of retortable pouches, heat sealed plastic containers as well as easy-open cans with pull/ring tabs is carried out in over-pressure autoclaves of which many models are now available.

The product mix up in the heat-processed category includes several 'convenience' ready-to-serve products such as fish curry, fish-in-rice etc. These products can conveniently be processed in retort pouches using an over-pressure autoclave. Because of the smaller cross sectional profile of retort pouches such products need to be maintained only for a shorter time in the retort and hence temperature induced changes on the quality parameters of the product are minimum.

Modified atmospheric packaging

The shelf life of fish can be increased by enclosing

it in an atmosphere so modified that it slows down the activity of microorganisms and minimizes the development of oxidative rancidity.

Different combinations of gases have been studied for extension of shelf life of fish in a modified atmosphere. For lean fish gas mixture containing 40% carbon dioxide, 30% nitrogen and 30% oxygen has been found the most suitable combination. For fatty fish, a combination of 60% carbon dioxide and 40% nitrogen is ideal. The temperature of the storage also has been found to significantly affect the shelf life, for example the shelf-life extension possible with the above combination of gases is up to 9 days for lean fish at 0 °C. At temperature 2 °C storage, the shelf-life of MAP fish can be extended up to 5 days. The method may useful for long distance transportation of farmed carps, catfishes and prawns.

Irradiation for dried fish preservation

All states of Northeast are fond of dried fish and more than 90% of dry fishes produced in India are transported to Jagiroad Dry Fish Market, (located 55 km east to Guwahati) for further distribution to all these states. Insect infestation and huge quantities of storage loss in dry fish is a common phenomenon. Irradiation is the solution for this persistent problem, as Irradiation of fish helps controlling insect infestations of stored dried fish. Irradiation damages the eggs of the pests/ flies which are normally deposited on the skins of fish while open sun-drying. Many of the pathogenic bacteria like Salmonella and Listeria can be destroyed at relatively lower radiation doses. At lower doses, irradiation will only pasteurise the food and hence it is necessary to hold the food at lower temperature to prevent the remaining micro-organisms from multiplying and spoiling the food.

Fish mince can be used in formulation and production of several value added products that are already popular in the export market and are becoming popular in the domestic market.

Drying

Different types of dryers can be used for the production of dry fish under protected condition. Solar tent dryer, drying kiln, mechanical dryers, fluidized-bed dryers, continuous dryers, microwave dryers can be potentially used for fish drying.

Eco-Friendly Hybrid Solar Drier of ICAR-CIFT

The technology introduces a hybrid solar drying system for hygienic production of dry fish by using environment friendly abundantly and freely available renewable solar energy. Continuous drying of fish is possible in this system with the help of LPG back up, where the fish can be dried in unfavourable weather conditions without spoilage and maintaining its nutritional values.

Collapsible Solar Tent Type Dryer of ICAR-CIPHET

This solar tent is handy to operate without any major electrical power supply requirement. Made with durable materials for increase longevity, its black-body surface area is increased by keeping all but one internal sides black. Its 4 raised platforms increases capacity to about 10-20 kg fish per batch. Its internal hot air circulation is forced by fans supported by a small PV plate to increase drying rate and the lockable Caster wheels provided for easy maneuvering for receiving better sunlight. It can be folded so as to reduce storage space while not in use and transportation.

Fermented fish products

There are a plethora of fermented fish products which are traditional prepared from different fish and vegetables by the indigenous people in all the NE states. These products including shidal, ngari, tungtap, numsing etc. have ample scope of process improvement, scaling up and popularization. Advanced techniques in process mechanization, nutrition profiling and attractive package development can certainly be the ways to bring these products to the global markets.

Extruded products

Extrusion is a process which combines shear, pressure and temperature leading to molecular transformations in the constituents and involves denaturation of the proteins, fragmentation of the starch molecules and changes in the non-covalent bonds between proteins, lipids and carbohydrate. Extruded products like noodles, wafers, flakes, etc. can be produced by formulation of appropriate types of products using fish mince, starches etc. Such products can

command very high market potential particularly among the urban elites. The technology can be employed for profitable utilization of by catch and low value fish besides providing ample generation of employment opportunities.

Battered and breaded products

The battered and breaded products processed out of a variety of fish are highly potential value-added products. These products offer a convenience food valued widely by the consumer. The process of coating with batter and breadcrumbs increases the bulk of the product thereby reducing the cost element. The pick-up of coating on any product can be increased either by adjusting the viscosity of batter or by repeating the process of battering and breading. As a convention 50% fish portion is expected in any coated product. Fish fingers, fish portions, fish cakes etc. are the staple breaded products. The production of battered and breaded fish products involves several stages. The method varies with the type of products and pickup desired. In most cases it involves seven steps viz., portioning forming, pre-dusting, battering, breading, pre-frying, freezing, packaging and cold storage.

Fish Mince and Mince Based Products

Fish mince can be used in formulation and production of several value added products that are already popular in the export market and are becoming popular in the domestic market. It is an important breakthrough in the utilization of low value and by catch fish.

Fish mince is the flesh separated in a comminuted form free from scales, skin, bones and fins of fish. In principle meat can be separated from any species of fish in this style; but it becomes significant when applied to low value fish which otherwise find difficulty in marketing and utilization. Significant value addition will occur to such fish by the application of this technology because of the use of mince in processing a variety of high value products.

Surimi and surimi-based products

'Surimi' is mechanically deboned fish mince from white fleshed fish that has been washed, and mixed with cryoprotectants for good frozen shelf life. Washing removes fat, blood, pigments, soluble proteins and odoriferous materials and increases the concentration of myofibrillar proteins, which improves the gel strength and elasticity of the product. Because of its gel strength, surimi is used as an intermediate product in the processing of several fabricated products with simulated texture, flavour and appearance such as shrimp, lobster tail, scallop meat and crab legs.

By-product Utilization

Fish waste which is either high in oil or has excessive bones or is unsuitable for edible purposes can be converted to valuable feed and industrial products. Researchers have shown that a number of useful compounds can be isolated from seafood waste including enzymes, gelatin and proteins that have antimicrobial and antitumor capabilities.

The development of absorbable surgical sutures from fish guts has been found quite useful in ophthalmic and other microsurgeries.

Cost effective technologies can be used for preparing concentrates of n-3 PUFA from fish oil. Fish processing wastes can be profitably used as one of the essential raw materials for compounding fish feeds.

Packaging

Packaging is one of the neglected areas in fish processing. Even if, adequate attention is paid for the packaging of fish and fishery products meant for export, the packaging of fish and dry fish for domestic market is yet to be explored for quality assurance and price enhancement. Functional and cost effective packaging can meet the varied needs of different types of fish and fish products intended for domestic market. Packaging also provides an attractive look to the product which directly affect the price. With hilly terrains almost all NE states (except Assam) have very limited areas for big aquaculture farms to meet their high demand of fish. Consequently, these states always depend on the fish import from other states of mainland in packaged form. These packages are mostly the polystyrene (thermocoal) or plastic containers of cubical shape. However, the dry fish packaging is in jute sacks or polythene bags are in poorest forms. Development suitable packaging material, container, pouch, bags etc. for fish, dry fish and other fish based products including indigenous fermented fish products such as shidal, ngari, tungtap, nemsing etc.

Conclusion

In bringing The Blue Revolution in India, processing alone can be a game changer, because this field have huge potential for capture the domestic market and give a hefty profit margin to the fishers. Skill development in primary and secondary processing of fish amongst the fishers is, perhaps, the important key to generate awareness about fish processing and also to eradicate misconception which has already become a belief even in the minds of the policy makers that 'fish processing means just product development'. Not only in the NE states, but this is also the high time to develop proper value chain, cold chain and supply chain for fish and fish products for the whole nation as well. Development of infrastructure facilities such as scientifically designed landing centers, cold storages, fish markets, ice plants, fish processing plants, refrigerated transportation systems and packaging systems may be the immediate course of action in a mission mode.

Role of entrepreneurship for sustainable development of the fisheries sector in northeast India

D. Kashyap ...

Assam Agricultural University
Jorhat, Assam

Fisheries and aquaculture sector is one of the most crucial potential sectors of the national economy. Fish has been a staple food, and its demand is increasing due to the growing population and awareness on health benefits.

Introduction

Fisheries and aquaculture sector is one of the most crucial potential sectors of the national economy. Fish has been a staple food, and its demand is increasing due to the growing population and awareness on health benefits. The fisheries sector is emerging as an important solution, and the challenge is to make this growth more inclusive. Given the growing pressure on natural resources and the mounting threat posed by climate change, it is vital to make it more sustainable. The sector contributes to poverty alleviation as it employs millions of people, both in the sector itself as well as in support services. This sector provides employment to more than 28 million fishers and fish farmers, contributing 1.12 percent of the national GDP and 7.28 percent of the Gross Value Added (GVA) from agriculture. The sector is now gaining importance as an attractive investment destination and a lucrative business activity. With the changing consumption pattern, emerging market forces, and recent technological developments, the sector has assumed increased importance with farmers and other stakeholders in the country.

Northeast India is blessed with

aquatic recourses due to its unique climatic condition. Unexplored aquatic resources and the demand for aqua products have made this region suitable for aquapreneurship development. The presence of diverse aquatic resources ranging from warm water (25 to 32°C) to coldwater (<10 to 20°C) and the availability of different dual-purpose (food and ornamental) fin and shellfishes make this region the point of attraction for fishery scientists, environmental experts, hobbyist, and research scholars. Further, most open water bodies are pristine with high soil nutrient status and plankton productivity for technological interventions and scientific exploration at full capacity.

Scope of entrepreneurship development in the fisheries sector of northeast India

The northeast India is primarily hilly and about 30 percent of the area is plain, mainly on both sides of rivers Brahmaputra and Barak. Mountains and hills cover most of Arunachal Pradesh, Mizoram, Meghalaya, Nagaland, and Sikkim, along with some parts of Assam, Manipur, and Tripura. The topography of the region varies from few meters from sea level to Snowline Mountains and has different kinds of agro-climatic zones. The region receives the highest rainfall during the prolonged rainy season from mid-March to mid-September. The region has vast potential for fish production, and central and state agencies have recently shown interest in developing aquatic resources. It has been recognized that the region needs special attention because of its strategic location and fragile ecological status. In order to maintain a balance between the regional identity of the population and the pace of development, it seems appropriate to adopt the latest technologies on local inputs and skills. A few avenues of entrepreneurship development in the fisheries sector of northeast India are as follows.

Aquaculture

About 95 percent population of northeast India are fish consumers and fish production is insufficient to fulfill the local demand. Though Assam and Tripura are almost meeting the fish demand of the respective states, the region, as a whole, is still dependent on imported fish. It results in outward cash flow and creates a barrier to the economic development of the region. Currently, central government initiatives like Pradhan Mantri Matsya Sampada Yojana (PMMSY) and Mission Amrit Sarovar are underway in war footing manner, and these initiatives are helping (will help) the unemployed youths to enter into the aquaculture venture, which in turn will enhance fish productivity of the region in the coming days. The PMMSY is a scheme to bring about Blue Revolution through sustainable and responsible development of the fisheries sector in India at a total investment of Rs. 20050 crores for holistic development of the fisheries sector, including the welfare of fishers. It is implemented in all the States and Union Territories for a period of five years from FY 2020- 21 to FY 2024-25. On the other hand, Mission Amrit Sarovar aims to develop and rejuvenate 75 water bodies in each district of the country to celebrate Azadi ka Amrit Mahotsav. Every Sarovar will be a source of livelihood generation by using the water for different purposes like fisheries, irrigation, water tourism, and other activities. Diversifying the species is also necessary to efficiently utilize different niches. New area-specific technology can play a significant role in the overall development of this sector.

Cage culture

Cage culture is considered suitable to operate in a wide range of open freshwater ecosystems where fry is raised to fingerling and fingerling to table size while maintaining the free exchange of water with the surrounding water body. From an economic point of view, it is a low-impact farming practice with high return and the least carbon emission activity. It is feasible because of its simple technology and local construction materials such as bamboo can be utilized with minimal cost, which is particularly helpful in operations in remote areas. The culture of air-breathing or high-valued fish in cages is considered as the most efficient. Reservoirs constructed for hydroelectric power generation have been considered a potential area for fish production using the cage culture method. In this context, northeast India

holding many dam reservoirs, can be turned into fish production hubs by practicing cage culture.

Recirculatory Aquaculture System (RAS)

The RAS system has become popular among aquaculturists in recent years due to several advantages. It allows a high degree of environmental control, thus making it possible to get year-round fish production. Most importantly, it can be installed near the proximity to the target market. RAS also provide opportunities to improve waste management and nutrient recycling. The use of antibiotics or chemicals to combat disease can be avoided through the RAS system. Production of a few species, such as Tilapia and Pangasius, has been a massive success in the RAS system. The closed aquaculture system presents a new and expanding opportunity, and the hill states of northeast India can efficiently utilize it for their uninterrupted fish supply. As per reports, 13 numbers of RAS have already been introduced in different parts of Assam, and the culture of indigenous fish varieties like Ompok bimaculatus, Label bata, Cirrhinus reba, etc., are successfully carried out in these establishments.

Aquaponics

Aquaponics is an integrated system that links hydroponics with recirculating aquaculture. In this novel system, both crop and fish production is possible with minimized water usage and waste released to the environment. The water of fish pond, which contains fish fecal matter, unused feed, and manures, is passed through the roots of the plants, which absorb the much-needed nutrients. The water purified in this manner is redistributed to the culture ponds for fish culture. For the successful operation of the aquaponics system, selecting fish and plant species to be used becomes very important. The most commonly raised fishes in aquaponics are tilapia, ornamental fish, and catfishes.

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Rearing, breeding, and marketing of indigenous and exotic ornamental fishes

Once upon a time, ornamental fish keeping was considered a hobby, but it has gradually become a commodity of international trade. Now it has grown as a multi-million dollar industry. The economic activities of ornamental fish culture involve a complete chain of stakeholders, i.e., fish collectors from natural water bodies, local traders, exporters, aquarium manufacturers, fish breeders, ornamental fish farmers, vendors, etc. Northeast India is a hotspot of endemic ornamental fishes, and around 250 species of ornamental fishes were documented from the northeastern states, including Sikkim. The majority of the fish marketed are wild-caught, and about 85 percent export of the indigenous ornamental fish from India is from the northeast region. Entrepreneurship development through sustainable collection, breeding, and selling of native ornamental fish species as well as the rearing and breeding of exotic fish species is a feasible way of generating revenue. The ornamental fish production in the northeastern region has been seen to be financially and economically viable, and incentives provided by governmental agencies such as National Fisheries Development Board (NFDB) to establish ornamental fish production units can help interested entrepreneurs to exploit this opportunity. Apart from breeding ornamental fishes, other business options are associated with this industry, such as aquarium fabrication and selling of aquarium accessories and fish specimens. With the increase in income and urbanization, the habit of keeping ornamental fish has been increasing rapidly, and demand for personals having the art of aquarium fabrication and local accessories suppliers is also increasing considerably.

It is encouraging to mention that from a humble beginning in 2012, as many as 52 farmers of Aathgaon village, about 23 km from Nagaon town of Assam, are now involved in rearing and breeding ornamental fish. The farmers are currently producing, backed by technical support from institutions like the College of Fisheries (Raha), Dhing College, Krishi Vigyan Kendra (Nagaon), State Fisheries Department, and NFDB, around 5 lakh ornamental fishes of eighteen varieties annually and supplying them to different districts of the state. The prices of the fish are in the range of Rs. 10 to Rs. 400 per fish. The farmers are also making the fish feed by themselves. It is observed that locally produced ornamental fish is priced about 25 percent less than those from Kolkata. Besides, there are no transportation costs involved. The quality of some species bred here is better than those of Kolkata.

Aqua-based ecotourism

Ecotourism is a subset of sustainable tourism and has the prospective to become a vital segment in the overall tourism industry. The

principles of ecotourism are environmental conservation, cultural preservation, community participation, economic benefits, and the empowerment of vulnerable groups. From an economic point of view, the main advantage of ecotourism initiatives is creating employment opportunities and generating income in the regional economy. Jasingfaa Aqua Tourism Centre, situated in Nagaon district of Assam, is a leading example of fish-based tourism with blissful amenities to satisfy tourists and fish lovers. With a dozen fish ponds, Jasingfaa offers an ideal space for hosting official and family events. A restaurant, the resort's main attraction, is constructed on a small island amidst these clusters of ponds and is connected by a beautiful bridge. Similarly, few residents of Ziro valley of Arunachal Pradesh built bamboo cottages over the ponds and tanks to attract the attention of the nature-lovers. The tourists are provided rods and lines to fish in the ponds, and the harvested fish are served on their plates. Integrating homestays with fishing offers additional income to the local residents.

Recreational fishery

Northeast India offers a tremendous opportunity for recreational or sport fishery due to the immense, untapped, pristine aquatic resources in the form of rivers, streams, and lakes. The northeast being home to various game fishes like mahseer, trout, snow trout, carps, catfishes, featherbacks, and other fishes, attracts anglers from all over the country, and they are highly interested in this region. Various angling associations (Assam Bhorelli Angling & Conservation Association, Anglers Association Nagaland, etc.) are being formed to popularize sport fishing and to create awareness to conserve and preserve endemic and indigenous fishes.

Assam (Bhorelli) Angling & Conservation Association has been organizing an annual angling competition in November in collaboration with the State Forest Department of Assam since 1981. Tourists and competitors are coming for participation from all over India as well as from abroad. Although the annual angling competition is held in November, people enjoy angling here from October to April. Apart from angling, the fast currents of the rivers add excitement and adventure to river rafting. Similarly, the Arunachal Angling Festival is held in September at Pitapool, Yazali in the Lower Subansiri district, with anglers taking on a rafting expedition in Pare river. Sponsored by North East Council and organized by Arunachal Adventure Association in collaboration with the Department of Tourism, the festival aims to create awareness for conserving fish species for future generations. Inspired by such success stories, many farmers have introduced angling competitions at their farms or lease-in water bodies individually or as a group recently.

Enhancing fish production through reservoir fisheries

There are twenty small (3390.53 ha) and six medium (15585.34 ha) reservoirs in eight states of northeast India. All the reservoirs are developed for hydropower generation, with fisheries as a secondary activity. They are located in the interior and poorly connected areas, lack proper scientific fisheries management, and are resources with multiple stakeholders. Reservoirs are highly potential fishery resources, which are under-utilized till date. There is a possibility of increasing fish production many folds in the reservoirs only by following supplementary stocking. Scientific management involving all stakeholders can help us to utilize these resources, and it can occupy its rightful place in the food basket.

Establishment of fish sanctuaries

Sanctuary is termed as a place of safety, a nature reserve where endangered and threatened species are cared for, and fishing is prohibited. Currently, fish sanctuaries are being implemented in Meghalaya under Meghalaya State Aquaculture Mission (MSAM) to conserve and enhance the aquatic bio-diversity and promote untapped and underprivileged places as tourist spots to benefit the local rural people. A few of these functional fish sanctuaries of the state are (i) Jadisil fish sanctuary (South Garo Hills) is established mainly to revive the declining population of the local fish species and is managed by the local community, (ii) Amlayee mahseer fish sanctuary at Nongbareh (West Jaintia Hills) over river Amlayee where 1.5 km of its stretch is being protected for chocolate mahseer (Neolissochilus hexagonolepis) and at the same time inviting visitors for active participation in sport fishing on the concept of 'catch and release' angling, (iii) Asim Bibra fish sanctuary over river Chibok (East Garo Hills) where community fishing event is celebrated every year with an objective to conserve the God gifted aquatic hotspots for development of livelihood ways, (iv) Deku Dobagre fish sanctuary (South Garo Hills) over river Bugai for chocolate mahseer (v) Wachi Wari fish sanctuary (West Garo Hills) over river Simsang provides an ethnic beauty for an ideal fish watching platform for chocolate mahseer by feeding them (vi) Songkal Wari fish sanctuary (West Garo Hills) on river Simsang between two main towns Tura and Williamnagar, where any visitor can view thousands of mahseers swimming in shoal. The novel concept of establishing fish sanctuary is not only helping in conserving fish species, but also helping in employment generation and upliftment of the rural economy.

Value addition of fish and fishery products

Value addition is gaining more importance due to changes in lifestyle and eating habits of people. Lack of time for cleaning the whole fish and cooking contributed to the preference for ready-to-cook or ready-to-eat products. Value addition enhances the nutrition, sensory characteristics, shelf life, and convenience of food products. Most importantly, value addition helps in increasing the profitability of fish farmers and other

associated stakeholders. The rapid development and popularization of minced fish technology could significantly contribute to the increased exploitation of low-cost and low-valued fish. The low-valued fish harvested from the wetlands and derelict water bodies of Assam and Manipur could be converted into high-valued products such as dried fish, fermented fish products, smoked fish, etc.

Fisheries entrepreneurship incubation

A country's economic development is determined by its industrial development, directly proportional to its people's entrepreneurial abilities. Therefore, the idea of cultivating entrepreneurial skills is crucial. Fisheries entrepreneurship incubation fosters entrepreneurs and start-ups in the initial stages of enterprise development, in which new business organizations are formed from ideas. It assists in integrating many partners and business development services to help the emerging enterprise in achieving sustainability. The objectives of the Fisheries Entrepreneurship Incubation are:

- To create employment opportunities for youth, wealth, and businesses aligning with national priorities.
- To promote new technology/ knowledge/innovation-based start-ups.
- To provide a platform for speedy commercialization of technologies developed by R&D institutions or individuals, or dissemination of new technology on 'Lab to land' basis.
- To build a vibrant start-up ecosystem by establishing a network between Researchers, Academicians, R & D Institutions, financial institutions, and other stakeholders.
- To provide cost-effective, value-added services to start-ups like mentoring, legal, financial, technical, and Intellectual Property Rights (IPR) related services.

> The RAS system has become popular among aquaculturists in recent years due to several advantages. It allows a high degree of environmental control, thus making it possible to get year-round fish production.

The fisheries incubator unit assists aspiring entrepreneurs by offering proactive and value-added business support through technical consulting, infrastructure, professional mentoring, and training to create technology-based business concepts and long-lasting businesses. Through a networking and interface mechanism between research institutes, companies, and financial institutions, it serves as a platform for the quick commercialization of innovative technologies. Under PMMSY, both the public and commercial sectors will be encouraged to establish Fisheries Incubation Centers (FICs). The State/Central Government, including the NDFB and/or specialized private companies/agencies, would manage them. Fisheries Incubation Centers would give incubatees opportunities to showcase their innovative ideas and commercialize them for the benefit of fishers/fish farmers, including young professionals/ entrepreneurs, fisheries institutes, fisheries researchers, cooperatives/ federations, progressive fish farmers, fisheries-based industries, and other entities. Additionally, this would aid in the growth of aquapreneurs, new business prospects, and employment opportunities in the fisheries industry.

A total of twenty-five institutions under the Indian Council of Agricultural Research (ICAR) have been successfully operating incubation facilities promoting individual entrepreneurs and Micro, Small & Medium Enterprises (MSMEs) license and scale-up technologies. The ICAR's technology-based incubation center promotes market-ready solutions that adhere to legal requirements and regulatory frameworks, making it simple for aspiring company owners to launch their ventures immediately.

Conclusion

The aquatic resources of northeast India can potentially boost its economy through entrepreneurial activity. Although there is a range of scope for developing businesses, most educated unemployed youths have not yet realized it. Immense biodiversity, rolling hills and streams, and numerous beels/wetlands make this region ideal for ecotourism and recreational fisheries development. Due to the abundance of sport fish species, this region can be developed as a paradise for sport fisheries. River rafting in the fast-flowing stream can also be considered a novel way of developing entrepreneurship. Moreover, the beels and reservoirs have the potential to generate extra revenue by cage culture of highly valued air-breathing fishes. Several options are available for improving fisheries and the aquaculture sector of northeast India. It is up to the people to develop an entrepreneurial spirit to boost their economy through the sustainable utilization of aquatic resources. The conglomeration of new technology, management practices, and creative endeavor in fisheries and aquaculture can help northeast India to climb the economic ladder.

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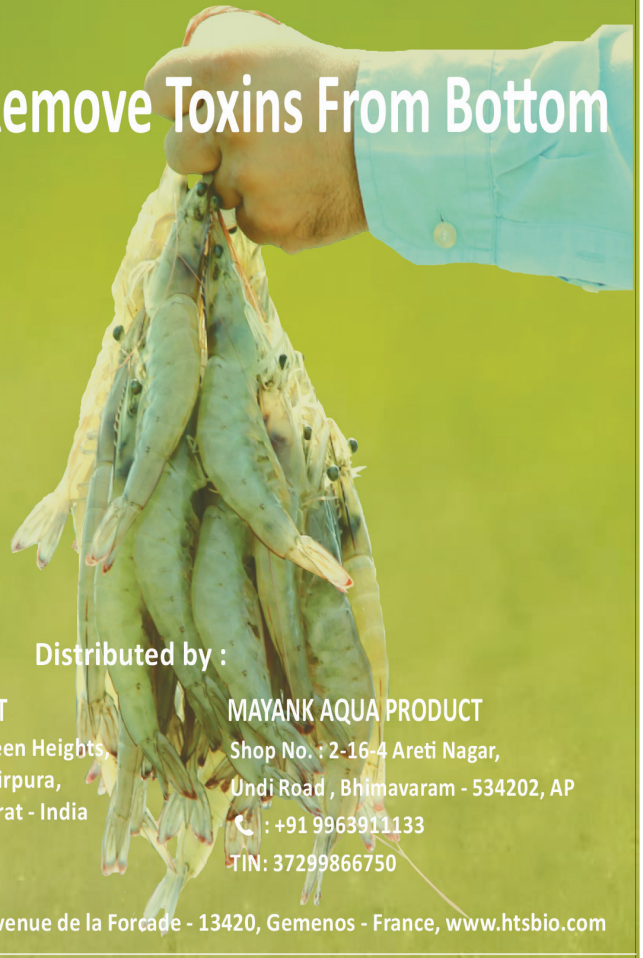

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