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AQUACULTURE ASIA

Integrating conservation and development

Aquaculture field schools & climate change adaptation

Red tilapia breeding

Aquaculture & livelihoods

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Aquaculture Asia

is an autonomous publication that gives people in developing countries a voice. The views and opinions expressed herein are those of the contributors and do not represent the policies or position of NACA.

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NACA

An intergovernmental organisation that promotes rural development through sustainable aquaculture. NACA seeks to improve rural income, increase food production and foreign exchange earnings and to diversify farm production. The ultimate beneficiaries of NACA activities are farmers and rural communities.

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COVID-19 and extreme poverty trends

The World Bank's most recent estimates are that the COVID-19 pandemic drove 97 million people into extreme poverty in 2020. You may be surprised to learn that the bank estimates that global poverty will *decrease* by 21 million people in 2021.

According to the bank, its previous estimates were based on data collected through high-frequency phone surveys as detailed household surveys have, understandably, been put on hold. To generate the most recent estimates, the bank has extrapolated the income and consumption data from past household surveys using national accounts growth forecasts. The bank says that this method generally outperforms more complicated methods in 'nowcasting' poverty.

I can't claim to have any data in hand to dispute this finding, so feel free to take my observations with a large helping of salt. But I admit to being a sceptic.

Last year's lockdowns saved many lives at the expense of a large economic impact (your mileage may have varied depending on where you live and on how strict the lockdowns were). But clearly, the economic impact was not evenly distributed. Some sectors, such as tourism, were completely devastated, while for many others were less affected and able to keep operating.

Another trend was that large businesses were better able to weather the storm while smaller owner-operator and family businesses with fewer resources to draw on quickly went bust. Later in the year, as we began to learn how to live with the virus (with varying levels of success), it was evident that the surviving larger businesses were able to corner much of the demand that previously would have gone to their smaller competitors. Whether their businesses actually 'improved' or not I cannot say, but the distribution of income clearly become more concentrated, going into fewer hands.

Then recently, the alpha and delta strains took hold in the region. Measures that successfully contained the original strain of the virus are now failing to contain these more infectious strains. As I write, most countries now find themselves battling renewed outbreaks, and with them, harsher control measures and in many cases, renewed lockdowns.

The difference is that this time there is far less systemic capacity to withstand the impact. Unemployment is surging. Both public and private debt have significantly grown over the past year. Consumer confidence is, to put it mildly, low.

2021 has a long way to run yet, and I find it difficult to accept the assertion that extreme poverty is going to fall until significant progress is made in national vaccination programmes. While we have good news on that front - effective vaccines exist and vaccination now underway everywhere - there are wide discrepancies in the state of implementation between countries. Supplies are limited and developing countries are not first on the list of recipents.

Perhaps by the end of the year there will be a little more economic sunshine. But not for everyone, and we need to be mindful of that.

Simon Wilkinson

AQUACULTURE ASIA

CONTENTS

Integrated taxonomy, conservation and sustainable development: Multiple facets of biodiversity

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Promotion of the sustainable use of biodiversity is of greater importance for maintaining biodiversity in the present decade. Justifiably, the CBD (Convention on Biological Diversity) focuses on an "ecosystem approach to the conservation and sustainable use of biodiversity" as a framework for action, in which all the goods and services provided by biodiversity are considered. Consequently, as a signatory to the United Nations Convention on Biological Diversity, India enacted the *Biological Diversity Act, 2002* to regulate access to and use of its biological resources and mandate approval from the National Biodiversity Authority and to inform the State Biodiversity authorities towards access and judicious utilisation of biological resources. That way, the United Nations declared 2011-2020 as 'Decade on Biodiversity' to support and promote the implementation of the objectives of the Strategic Plan for Biodiversity and the Aichi Biodiversity Targets for significantly reducing biodiversity loss. Sustainable Development Goals (SDG) such as SDG 12 (Sustainable consumption and production) and SDG 14 (Life below water) established by the United Nations, during 2015 have also adopted the global path towards sustainable development for the next 15 years. To achieving the targets of CBD and SDG, cataloguing faunal diversity is essential so as to promote and enhance the ecosystem function for the sustainable development of mankind.

Exploratory surveys to document faunal and floral diversity are the foundation of biodiversity science, which have led to the inventorisation of new species / distributional records, thus supplementing the existing knowledge on total species richness of the region. Taxonomy, which deals with the discovery, description, naming and classification of biodiversity on the Earth along with their phylogenetic relationships, is the basis of biodiversity science (Dar et al. 2012). The advent of molecular methods for species differentiation and delimitation, have revolutionised conventional taxonomy in which it is complemented with information generated from these methods. Thus, integrative taxonomy involving molecular and conventional approaches have led to the unravelling of many cryptic and overlooked species. Taxonomy bestows distribution and biological information, which is crucial for the comprehensive policy making, effective planning and decision making in environmental management. Such work is essential for the fundamental understanding of biodiversity, its documentation, conservation and sustainable use. The integration of the science of taxonomy, ecology and conservation is required to meet the current challenges on global biodiversity.

Realising the existing impediments to taxonomy such as shortage of trained manpower, taxonomic gaps in several biota, lack of monographic and revisionary studies, the Global Taxonomic Initiative has been initiated under the aegis of the CBD for making a global inventory of biodiversity on Earth to assist conservation and management of biodiversity (Convention on Biological Diversity, 2006; Narendran 2008; Dar et al. 2012). Furthermore, capacity building, integrative taxonomic approaches, trans-disciplinary research, assessment of conservation status of species, allocation of adequate funds, easier access to literature and specimens, collaborative online databases and international linkages with researchers are also required for improving the prospects of biodiversity inventory in India. At this significant juncture, the Government of India has initiated mission mode programs such as the Deep Sea and Biodiversity Missions for exploration, mapping and conservation of biodiversity.

Fishes constitute more than half of all vertebrates, with well over 35,768 valid species (Fricke et al. 2021). Fishes known from the fresh and marine waters of India comprises

Figure 1. Number of fish species described worldwide during 2001 - 2020 (Source: Fricke et al 2020).

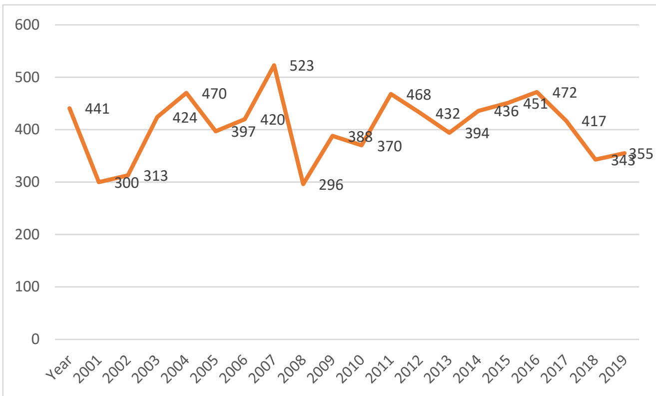


Figure 2. New species and new distributional records of fishes described in India during 2010 - 2019 (Source: Chandra et al. 2020).

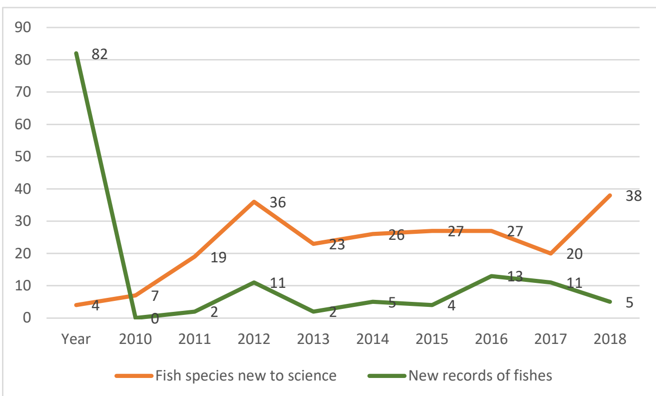


Table 1. Details about the new species and new records of fin and shell fishes described by ICAR-NBFGR during 2015-2020.

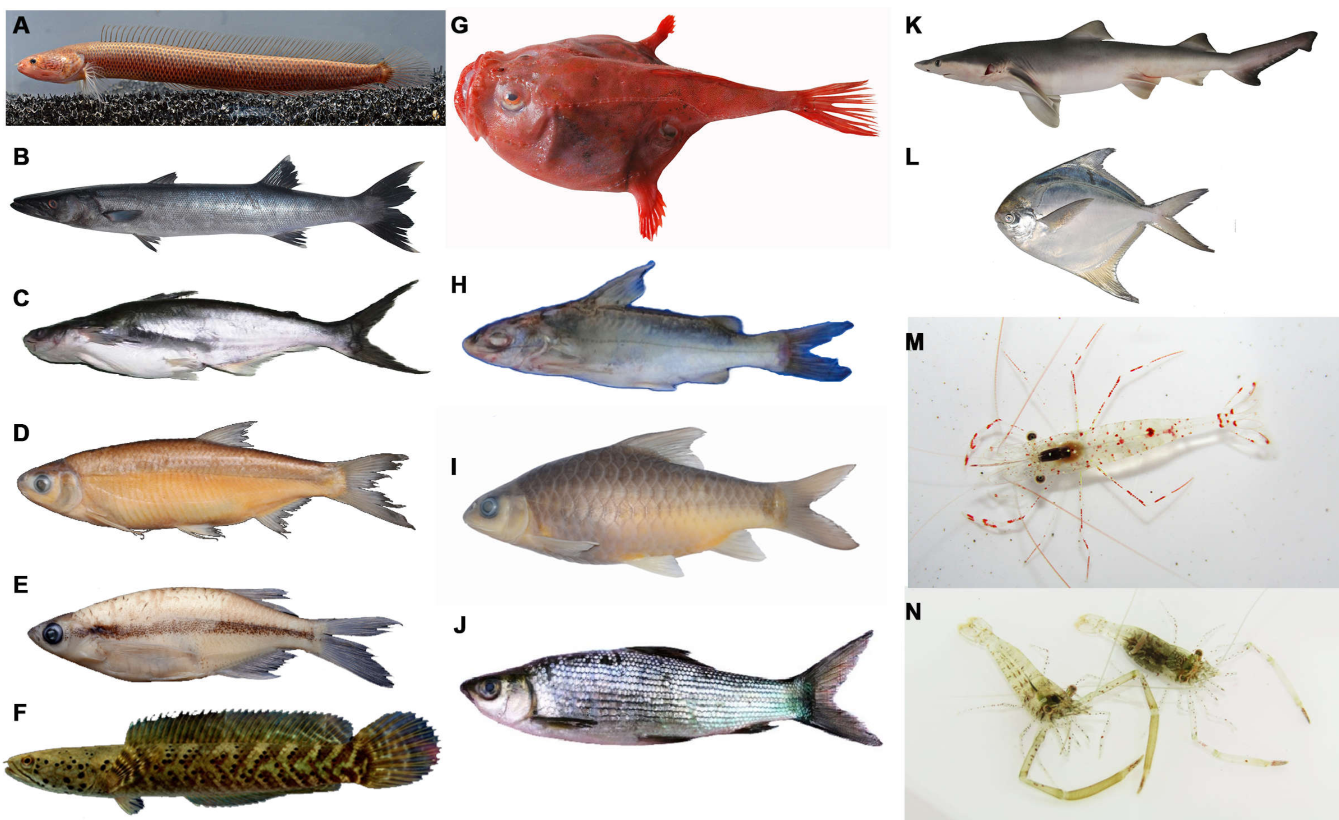
New species	Family	Place of collection	Habitat	Publication
Finfishes				
Aenigmachanna mahabali Kumar, et.al., 2019 (Fig 3.a)	Channidae	Thiruvalla, Kottayam, Kerala	Freshwater	Zootaxa, 2019
Sphyraena arabiansis Abdussamad & Retheesh, 2015 (Fig 3.b)	Sphyraenidae	Cochin Fisheries Harbour, Kerala	Marine water	Indian J. Fisheries, 2015
Pangasius silasi Dwivedi, et. al, 2017 (Fig 3.c)	Pangasiidae	Krishna River at Nagarjuna-Sagar Dam, Guntur District, Andhra Pradesh	Freshwater	Hydrobiologia, 2017
Cabdio crassus Lalramliana, Samuel Lalronuga and Mahender Singh, 2019 (Fig 3.d)	Cyprinidae	Kaladan River of Mizoram	Freshwater	Zootaxa, 2019
Laubuka parafasciata Lalramliana, Vanlalhlimpuia and Singh, 2017 (Fig 3.e)	Cyprinidae	Sala River, a tributary of Kaladan River, in the vicinity of Lungpuk, Siaha District, Mizoram	Freshwater	Zootaxa, 2017
Channa stiktos Lalramliana, Lalronunga, S. and Singh, M. 2018 (Fig 3.f)	Channidae	Tiau River, Kaladan River drainage, Mizoram	Freshwater	Vertebrate zoology, 2018
Chaunax multilepis Ho, Meleppura & Bineesh 2016 (Fig 3.g)	Chaunacidae	Kollam, Kerala, Arabian Sea	Marine water	Zootaxa 2016
Rita bakalu Lal, Dwivedi and Singh 2017 (Fig 3.h)	Bagridae	Pranhita River, Bejjur, Godavari river system, Telangana, India	Freshwater	Hydrobiologia 2017
Neolissochilus kaladanensis Lalramliana, Lalronunga, Kumar and Singh, 2019 (Fig 3.i)	Cyprinidae	Kaladan River in the vicinity of Kawlchaw Village, Mizoram	Freshwater	Mitochondrial DNA, 2019
Shellfishes				
Periclimenella agattii Bharathi et al 2019 (Fig 3.m)	Palaemonidae	Agatti Island, Lakshadweep	Marine water	Zootaxa, 2019
Urocaridella arabianensis S. Akash et. al., 2020 (Fig 3.n)	Palaemonidae	Agatti Island, Lakshadweep	Marine water	Zootaxa, 2020
Re-description/ re-discovery				
Labeo rajasthanicus Lal, Datta and Majumdar, 1970 (Fig 3.j)	Cyprinidae	Jaismund Lake in western Rajasthan region.	Freshwater	Indian J. Fisheries, 2015
Lamiopsis temminckii (Muller and Henle, 1839) (Fig 3.k)	Carcharhinidae	Newferry wharf, Sasson dock and Satpati fisheries harbour Maharashtra coast	Marine water	Zootaxa, 2016
Pampus candidus (Cuvier, 1833) (Fig 3.l)	Stromateidae	Bay of Bengal and Arabian Sea	Marine water	Zoological studies, 2019
New distributional records				
Finfishes				
Bathymyrus simus Smith, 1965	Congridae	Nagapattinam (Tamil Nadu) and Digha (West Bengal) landing centres	Marine water	Thalassas, 2019
Cypselurus opisthopus (Bleeker, 1865)	Exocoetidae	Vizhinjam, Kerala	Marine water	Journal of Ichthyology, 2019
Leptojulis lambdastigma Randall and Ferraris, 1981	Labridae	ChidiyaTapu, Andaman	Marine water	JMBAI, 2020
Shellfishes				
Thor hainanensis Xu and Li 2014	Thoridae	Agatti Island, Lakshadweep	Marine water	Zootaxa, 2019
Lysmata hochi Baeza and Anker, 2008	Lysmatidae	Agatti Island, Lakshadweep	Marine water	Zootaxa, 2020
Association				
Argeiopsis inhacae Kensley, 1974 with *Stenophus hispidus* (Olivier, 1811)	Bopyridae	Agatti Island, Lakshadweep	Marine water	Current Science, 2019

of 3,439 valid species constituting around 10 percent of the total number of fish species of the world (Chandra et al. 2020). During 2020, 355 new species of fishes have been discovered worldwide (Fricke et al. 2021) (Figure 1) and 38 new species of fishes in India during 2019 (Chandra et al. 2020) (Figure 2). Nevertheless, it is expected that thousands of species await discovery both in Indian and internationals contexts. The global taxonomy initiative of the CBD, is an important milestone, as through this the convention of parties recognised that taxonomy is important for management of genetic resources for alleviating hunger. Nations advocated that there is an urgent need to build capacity and repositories to strengthen the documentation of genetic diversity. Unless there are strong initiatives in this direction, many species might undergo unrecognised extinction. Examples are provided by the focussed explorations from the ICAR-National Bureau of Fish Genetic Resources (NBFGR), an organisation from India, mandated for cataloguing of genetic resources of the country and which carries out research on systematic accounts, distributional records and reports with surveys and inventories of fresh and marine water fin and shell fishes, providing fundamental knowledge on the distribution and abundance of ichthyodiversity. These cover exploratory surveys of various ecosystems ranging from fauna of deep sea to the high-altitude regions of the Himalaya, falling under diverse biogeographic zones and unexplored regions of the country, including North-eastern India, Western Ghats, Lakshadweep and Andaman and Nicobar Islands towards cataloguing faunal and floral diversity. These efforts by a single institute, ICAR-NBFGR, have resulted in reports and publication of 14 new fish species and 6 new distribution records during the small period of 2015 to 2020 (Table 1). Of these 14 species, 11 are new to science and first discoveries and descriptions; three species are rediscoveries, which were reported elsewhere but not considered as valid by science due to lack of evidence or specimens (Figure 3). These species were rediscovered, re-described, validated and their original names are resurrected (Table 1) and thus such rediscoveries are equivalent to new species discoveries. New distributional records for six species previously unknown from Indian waters constituting of previously known species but discovered in a new distributional range have been documented. The research used integrated taxonomy in most of cases to reach the conclusion, complementing morphology with molecular tools.

Asia is rich in biodiversity. There is an opportunity for many countries to join hands in capacity building and documenting the unknown treasure of genetic resources. This is also important from the viewpoint of the Nagoya protocol, as nations have sovereign rights over their genetic resources, however, to stake claim the precise data and knowledge of genetic resources under their respective national jurisdictions is very important.

Considering various threats to biodiversity, new knowledge of existing species and discovery of new species and their ensuing study is strongly warranted for conservation and sustaining biodiversity for the future, since degradation of habitat and unsustainable fishing practices as well as their illegal collection are contributory factors for dwindling populations in natural habitats. Conservation of diversity is contingent on the number of taxa in an area, distribution and their taxonomic relationship, and uses biodiversity inventory provided by taxonomy for deciding and planning conservation strategies (Giangrande, 2003). Systematic taxonomic surveys

Figure 3. New fin and shellfish species described by ICAR-NBFGR during 2015 - 2020.



along with well-maintained collections and catalogues are also a prerequisite for the conservation. Besides, identification, categorisation of endangered, threatened and vulnerable fish species and studies on their biology also aids in conservation. Therefore, conservation of biodiversity is central as other than providing goods and services, which are necessary for human survival, it is also concomitant with providing livelihoods and improving the socio-economic conditions of local people, contributing to sustainable development and poverty alleviation. Many of the new discoveries could aid in future as value-added biological/biotechnological resource-materials besides providing new species for aquaculture diversification and utilisation for ornamental trade.

Description of new species and at the same time their evaluation and mainstreaming so that the pathway of harmonising conservation and livelihoods through aquaculture and ornamental trade is established. This is carried out though implementing the concept of Live Fish Germplasm Resource Centres for prioritised species (NBFGR, 2016). For example, Pangasius silasi, a new species, reveals a healthy nutritional profile, with good PUFA contents and broodstock development of the species is under progress at Nagarjuna Sagar dam, Telengana, to promote the species for inland aquaculture in the near future (NBFGR, 2019). Likewise, captive propagation technologies are also underway to develop ornamental shrimps described from Lakshadweep islands recently for sustainable aquarium trade and conservation, besides promotion of livelihood to the islanders (Anonymous, 2020). Thus, holistic, and sustainable development of coastal communities without compromising the biodiversity is the need of the hour.

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A note on 100th birth anniversary of the late Dr Hiralal Chaudhuri

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Dr Chaudhuri injecting a brooder IMC. Courtesy ICAR-CIFE Kolkata Centre.

The year 2021 is the one-hundredth anniversary of the birth of the 'Father of Induced Fish Breeding in India', the late Dr Hiralal Chaudhuri, DSc, former Senior Fishery Scientist at the ICAR-Central Inland Fisheries Research Institute, Barrackpore, India and Ex-Chief Technical Advisor in Aquaculture, FAO/UNDP at Lao PDR. In his honour, National Fish Farmers' Day is celebrated annually on 10 July, to acknowledge the contribution made by professional fish farmers and breeders to India's economy, food supply and production of table-sized major carps and other important inland food fishes. As the architect of first induced breeding and spawn production of the economically important carp *Cirrhinus reba* in captivity on 10th July 1957, Dr Chaudhuri's unique success generated unprecedented fish culture activity in sub-urban and rural India leading to prosperity among fish farmers. West Bengal moved ahead and produced 22891 million healthy carp fry (22-26mm) in 2018-2019 with first position in India; having 454 private carp hatcheries and another seven operated by the state government. Such production and prospects owe much to Dr Chaudhuri. It was mentioned in the 1959-1960 ICAR-CIFRI Annual Report 'During 1959 fish breeding season (May to August), work on induced breeding by injection of pituitary hormones was taken up at Cuttack in Orissa and Joysagar in Assam under CIFRI's Pond Culture Division. Breeding was successfully induced in *Catla catla*, *Labeo rohita*, *Cirrhinus mrigala*, *Puntius sarana* and *Labeo calbasu* and commercial production of large number of spawn and fry achieved for the first time by this method'.

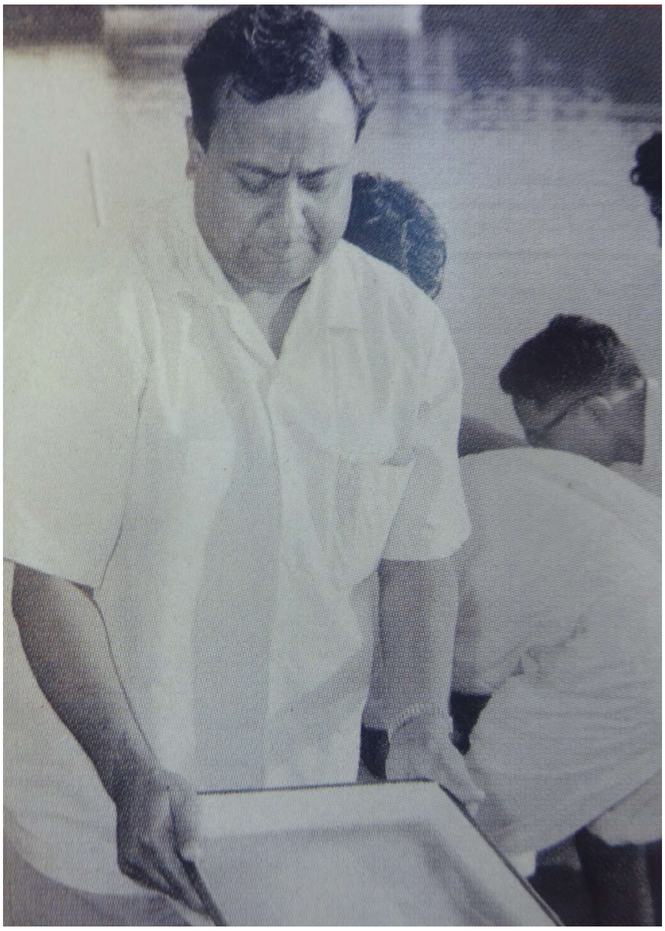
Dr Chaudhuri was born in Sylhet Town in the then Colonial Assam (now in Bangladesh) on 21/11/1921. He died on 12/9/2014 and his obituary was published in Current Science Vol. 108 No. 2 on 25/1/2015 authored by Dr A. P. Sharma and Dr B. P. Mohanty; in Fishing Chimes Vol. 34 No. 7 in October

2014 by Dr B. K. Mahapatra; in the CIFRI Newsletter Vol. 19 No. 2 in July-December 2014; in Aqua International Vol. 22 No. 9 in January 2015 by the author and in other places. The backdrop, time and site of Dr Chaudhuri's discovery; significance and widespread application of induced breeding technology; his life sketch, career and pivotal scientific contributions have been discussed in many programmes and published in books, magazines and documents (Fishing Chimes Vol. 24 No. 10 in January 2005; SEAFDEC Asian Aquaculture Vol. XX No. 2 in April 1998 and others). In a brochure published by the Kolkata Centre of the ICAR-Central Institute of Fisheries Education entitled 'Celebration of Fish Farmers' Day at CIFE Kolkata Centre', two rare black and white photos captured the attention of the author where Dr Chaudhuri in his early days is wearing a half-sleeve white shirt, preparing fish pituitary extract and carefully injecting it into a brooder Indian major carp, helped by his colleagues.

The 31-page article 'History of induced breeding in fishes and its application to aquaculture' authored by him and published in the Proceedings of the Zoological Society Vol. 47 No. 1, 1994, provides a clear understanding of successful experimental works on induced breeding of Indian inland fishes. His article 'Modern aquaculture - its contribution to human nutrition' published in the Souvenir of the National Symposium on Finfish and Shellfish Farming organised by the Deptartment of Zoology, University of Calcutta during 17-18 July 1998 is comprehensively written for students. During this time, the author, studying in his second year of a BSc in Fisheries, read and heard about Dr Chaudhuri and in this programme had opportunity to see him during his address as Chief Guest. In Current Science, the most high-valued science journal in India, his works on induced breeding and intensive composite carp culture were published in Vol. 26 No. 12 in December 1957 (co-authored by Dr K. H. Alikunhi) and Vol. 43 No. 10 in May 1974 (with five co-authors) respectively.

In the Book 'Reminiscence CIFRI 1947-2007' published on 10 July 2007 by ICAR-CIFRI, Dr Chaudhuri is seen in two black and white photos, standing in knee-depth water holding a white rectangular enamel tray and observing carp larvae obtained from controlled breeding in hapa enclosures in the pond, and examining the developing embryos inside fertilised eggs with a simple microscope wearing white shirt, khaki pants and gumboots. Such noteworthy moments of the past of distinguished persons greatly inspired the author as an extension worker, who understands that Dr Chaudhuri

Garlanded photo of Dr Hiralal Chaudhuri. Courtesy ICAR-CIFRI Barrackpore.



Dr Chaudhuri observing fertilised carp eggs in enamel tray. Courtesy ICAR-CIFRI Barrackpore.

Cirrhinus reba brought success to Dr Chaudhuri on 10 July 1957.

did laboratory and field work painstakingly and with great dedication, perseverance and sincerity in the late 1950s, 1960s and 1970s, in less-favourable conditions as compared of today. In this book, the first chapter was contributed by Dr Chaudhuri, entitled 'My journey from breeding a mud goby to global aquaculture through CIFRI', where he writes: 'CIFRI during 1948 had primitive facility, without electricity, instruments; even drinking water was difficult to get. Throughout the night under light of hurricane lantern, I sat watching the developing fertilized eggs of small fish Gobioptures chuno in petridish under microscope and drew sketches of developing embryonic stages. My excitement had no bounds when I saw some eggs hatched out in about two days and live goby hatchlings wriggle out'.

Nowadays commercial products are available to kill aquatic insects and undesirable organisms in fishponds but Dr Chaudhuri during 1951-1954 formulated safe soap-oil emulsion method to eradicate such predatory insects from

Dr Hiralal Chaudhuri. Courtesy ICAR-CIFA Bhubaneswar.

nursery ponds before stocking carp spawn to increase its survivability. This is still practiced in many nurseries associated with hatcheries and fish seed farms in West Bengal. He devised pond zooplankton culture methods to increase availability of natural live food for growing spawn. According to Dr R. D. Chakraborty, Retired Head, PCD of ICAR-CIFRI and his co-worker: ‘Dr Chaudhuri was a teacher of outstanding ability. I feel his extension work of demonstrating and teaching aquaculture has contributed largely to its spread and he remains the Guru par excellence’. Dr J. H. Primavera, Aquaculture expert from SEAFDEC, Philippines mentioned: ‘At his home at Tigbauan, Dr Chaudhuri would painstakingly gather the freshly fallen fruits of popular tree Muntingua calabura and offer these to local children who lined up in morning for the delicious red berries. He was as generous with the fruits of his garden as those of his research’. Dr D.R. Bhatia, the then Deputy Fisheries Advisor to Government of India once said: ‘Chaudhuri, if you succeed in induced breeding of major carps, it will be comparable to getting the Nobel Prize’. Dr V. R. Pantalu has mentioned: ‘Dr Chaudhuri is a very unassuming, amiable gentleman and a good songster with sonorous voice’. At International Festival of Films on Aquaculture organized at Kyoto, Japan during May-June 1976, the Indian film on induced breeding won the 1st prize, which was shot under technical guidance of Dr Chaudhuri.

Dr Chaudhuri giving a talk at CIFRI. Courtesy ICAR-CIFRI Barrackpore.

In ‘Aquaculture Beyond 2000: New Horizons’, Dr Chaudhuri writes: ‘I have always been averse to name, fame and public appreciation for whatever I have achieved little in my scientific endeavours’. In the early 1970s, Dr Chaudhuri used to tell his colleagues: ‘If you want to know how to distinguish between matured male and female of *P. sarana* before administering injection, you have to meet the semi-literate elderly fish farmers who will make you understand it clearly. Perhaps they know more than us’. His large wood-bound photo can be seen as one enters into Dr Hiralal Chaudhuri Library on the 3rd floor of the ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar, India. After revisiting at some of lesser-known facts and moments, finally, without boasting, the author brings into remembrance the happy feelings upon receiving a hand-written affectionate Bengali inland letter from ‘Sir’ Dr Hiralal Chaudhuri on 30/8/2000 with words of inspiration and blessings and expresses homage humbly to this great person with reverence in his birth Centenary year, to whom Indian pisciculture sector will remain ever grateful.

Aquaculture field schools supporting mangroves for climate change adaptation of Indonesian milkfish-shrimp farmers

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Mourning the loss of land and mangrove

The 1960s were years of prosperity in Demak regency, Java, Indonesia. Farmers cropped rice, vegetables and fruits. From their produce, they were able to build good houses and send their children to secondary schools. Back then, the sea was more than a mile away from the fields of villages, like Timbulsoko in Sayung near Semarang, Java's fourth largest city. Until 1972, layers of mangroves, with highly specialised root systems, protected the farmed areas from erosion and flooding. The delta was still a navigable estuary about 1,300 years ago, but sediments were captured and mangrove forests expanded. Halfway through the 20th century, the forests which were sited further from the sea were transformed into paddy fields, but a wide mangrove greenbelt still remained.

However, after farmers began cutting and converting mangrove forests into fish-shrimp ponds, the coastlines became more vulnerable to erosion, particularly during strong storms, waves and winds. Further worsening the toll to the environment, industries from Semarang city began relocating their operations to Sayung, a sub-district in Demak. These industries heavily extracted groundwater which resulted in sinking of the land (subsidence) that is more than a ten-fold of sea-level rise (Chaussard et al, 2013). The sinking greatly changed the village setting, and daily flooding changed the life of farmers. After 2000, with a few patches of mangrove forests left, the abrasion started eating away the coastline

Photo 1: Bedono, near Semarang, protects some of its remaining infrastructure with a series of permeable dams.

of Demak. Gradually, many farmers abandoned their ponds (Figure 1). In 2012, the first communities were evacuated, and after 2015 a tidal lake was formed (Photo 2).

Narrated by one farmer. "…the flooding began, the high tides came and wiped out all those rice fields, we had no choice but to transform our land into fish ponds… Our parents warned us that we should protect the mangroves [because] these mangroves provided many benefits like securing a place for the oysters, crabs and fish in their roots; and protecting the coastline from being swept away. But our people wanted to make more money to feed their families. So, the mangroves also became ponds for milkfish and shrimp." One farmer lamented over the loss of his 10 hectares of pond which he bought in 2004, but which were swept away three years later (Photo 1).

Although the state forbids cutting of mangroves, investors and farmers tended to disregard the law by clearing the mangrove forests almost up to the coastline to farm shrimp. Efforts to plant mangroves on the bunds of the ponds, a type of silvo-aquaculture that is practiced by farmers in Demak (Figure 1), did not prevent land loss (Photo 2).

Training farmers

In the last five decades, over 30 million people along Java's north coast have experienced subsidence and subsequent soil erosion. Consequently, the agri-and aquaculture sectors have incurred a multibillion-dollar loss. Practices such as heavy groundwater extraction by nearby industries and cities and clearance of mangrove forests are the key factors that have degraded the environment. Another contributing factor to this environmental decline is the lack of training among farmers. In their lifetime, most Indonesian shrimp farmers have never received a proper training on good aquaculture practices (Elfitasari and Albert, 2015). Thus, their benefits from shrimp farming were only short-lived.

Figure 1: The land use of the close to 5,400 ha in seven coastal villages of Demak regency in 2015. Only 3 ha of aquaculture was intensive.

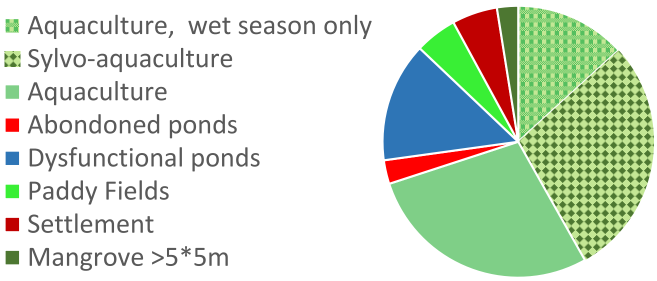


Photo 2: Section of the new tidal lake with mangrove rows lining along destroyed silvo-aquaculture ponds.

Looking at this these flooding episodes, farmers have realised that they could not continue with their past practices, one of which was cutting mangrove. "Since 2003, I have elevated our house three times. I told my son that he will be doing it next, as I have neither enough energy nor money to do it again. But thanks to the support of the Building with Nature project, we were able to increase the quality of our shrimp."

Building with Nature: an integrated approach

In 2015, Building with Nature Indonesia (BwNI) started a coastal protection project in 10 communities of nine coastal villages of Demak regency. The households in the seven sampled villages owned an average of two hectares of ponds, but only about one-third of them still stocked shrimp. Farmers earned an average income of 600 USD ha^{-1} yr^{-1} from milkfish-shrimp ponds; those who stocked shrimp made 30 USD ha^{-1} yr^{-1} more.

To reduce coastal erosion and make the livelihood system sustainable, BwNI-Demak introduced four approaches in the pilot sites:

1. Protect the remaining coastal mangrove and capture sediments to create an ecology for natural mangrove regrowth.

2. Rehabilitate mangrove by giving up ponds along sea and rivers.

3. Improve aquaculture practices.

4. Reduce groundwater use.

Together with Indonesian institutions and villages, BwNI-Demak, funded by the governments of Indonesia and the Netherlands and the partners of the Ecoshape consortium, implemented the first three of these interventions, while starting advocacy for the last. These interventions were embedded in a community approach by a team of field-workers in collaboration with the government agents, among whom were the village authorities.

BwNI-Demak introduced protection measures in villages such as Bedono by using permeable structures (dams) that successfully capture sediment. In most locations these permeable structures support the natural recovery of mangroves within 4-5 years (Photo 3a, b). In the absence of land subsidence, this recovery could effectively counteract climate change that is induced by sea-level-rise; that is if the villages were to maintain these permeable dams for at least 5 years. In the 4th year of the project, most coastal villages integrated the cost for this maintenance in their village budgets. As for aquaculture, the project expected that improving yields and income of this activity were needed to motivate farmers to restore mangrove greenbelts and to contribute to the maintenance of the permeable dams and other measures.

Aquaculture Field School (AFS)

AFS is a learning process adapted from the Farmer Field School, an approach initiated by the FAO for Integrated Pest Management in the 1980s (Brown, 2015). To build the capacity of the local small-scale farmers, AFS trains them on good aquaculture practices. Here, during one production cycle, farmers learn, among others, the ecology of coastal waters and ponds, the low external input sustainable aquaculture (LEISA) and pond management.

AFS is field-based and lasts for a full cropping season. Its educational methods are experiential, participatory and learner-centered. Before developing a learning contract, AFS meets participants, determines their needs, recruits them and prepares a learning contract. Locally recruited AFS facilitators undergo an intensive season-long residential training to prepare them for organising and conducting field schools (Box 1). Between 25 and 30 coastal villagers, women and men, participate in an AFS. In this project, the number of women to men participating in the AFS was not always balanced; thus, BwNI had to organise some female field schools. In addition to gender representation, AFS also aims that at least 75% of the participants come from poor or vulnerable households.

An AFS meets once a week or fortnight for a half-day to one-day session, or a total of 12-16 sessions. To maximise their learning, participants learn together in small groups of 5 to 12. Each AFS meeting includes at least three activities: 1) agroecosystems analysis, 2) special topic and 3) group dynamics activity. The primary learning material is the pond, and the meeting place is close to the demonstration ponds, often in a farmer's home (Photo 4) and sometimes beneath a convenient tree (Photo 5). Participants usually compare treatment and control plots. Depending on local problems, AFS

Photo 3: Permeable dams in in Timbulsloko (left) and Purworedjo (right), end 2019, 3-4 years after building and maintenance.

participants often conduct additional field studies. Resource persons (practitioners, academicians and government extension staff) may supplement the curriculum (Photo 6). All AFS curriculum includes a Field Day in which farmers present and discuss the results of their studies. The curriculum ends with a final meeting, among others, to plan for follow-up activities. To diagnose problems and identify follow-up activities, the AFS implementing program conducts a pre- and post-test.

While being enrolled at AFS, farmers study the agro-ecosystem, design aquaculture production systems, observe demonstration ponds, synthesise their data, and debate with their colleagues. Finally, they make informed decisions on the next steps of the pond management. By going through the process, the participants could already determine which new practice(s) would be practical for them to apply straight away. Moreover, in the farmer-centered learning environment, they acquire soft-skills such as having more confidence in decision making and in public speaking (Box 1). In this project, after finishing the curricula, AFS alumni continued to engage in post-field-school activities which included discussing their innovations practices, such as transforming their ponds into an associated mangrove aquaculture (AMA) and practicing forms of multitrophic shrimp aquaculture (MTA).

Photo 4: During each AFS session, farmers engage in participatory learning activities in classrooms and in the pond areas (see photo 5 below).

Photo 5: AFS participants assess the water colour of a demonstration pond.

Low external inputs sustainable aquaculture (LEISA)

Low yields in traditional Indonesian milkfish-shrimp ponds stem from poor soil and water management. For example, some farmers may use excessive or inappropriate chemicals such as pesticides. To correct these practices, farmers are introduced to LEISA by the AFS. LEISA as an ecological farming principle was first developed for agriculture, and aimed to reduce the excessive use of external inputs, particularly from synthetic chemicals harming the environment. Later, LEISA implementers adapted it for aquaculture; it advocates the use of locally available natural resources (soil, water, plants) and inputs (e.g., animal and organic wastes). With LEISA, farmers would be able to:

Maintain and enhance soil fertility by using solid compost or manure and liquid compost.

- Stimulate recycling of organic matters in the pond with liquid compost.
- Conduct pest and disease management through prevention and safe treatment.
- Produce good yields of healthy food for consumers.

At the AFS, farmers learn to use monitoring kits and prepare liquid compost from fermented vegetables and/or fruits. This liquid compost improves the soil and maintains water quality (Photo 7 and 8). It also enhances the chemical, biological, physical and structural properties of the soil, and complements the effect of manure as fertiliser. Moreover, the liquid compost adds energy, minerals and micro-organisms to the pond water; it facilitates recycling of both deposited and suspended organic matter; thus stimulating the growth of natural feed for shrimp and fish (Figure 2).

Photo 6: A university professor lectures at an AFS session.

Photo 7: AFS participants chop the waste of fruits and vegetables for the liquid compost.

Photo 8: The mixture of wasted vegetables and fruits fermenting into liquid compost.

Box 1: From farmer-learner to farmer-expert

Abdul (52) farms brackish water ponds near Tambakbulusan village. When he first joined in the AFS Training of Trainers in 2016, the master trainer told them that they were expected to be an agent of change for aquaculture practices in their village. At that time, he responded the expectation with skepticism. He did not think that he could be of such influence, because he was convinced that farmers would not be willing to listen to him.

Nothing could be further from the truth. As he proceeded in the training, he became confident in speaking in front of other participants and in facilitating the discussion session during the AFS class. In his milkfish-shrimp ponds, he tested the LEISA system and other innovations. Just to mention a few, his experiments included rearing green mussels and saline tilapia, and mud crab fattening. All along, he gathered knowledge of his pond production system.

Considering his potential, scientists from Diponegoro University recruited him as their partner in doing research since 2017. This collaboration has furthered his capacity as an aquaculture farmer with the eye of a scientist. His experience in discovering an effective production system immediately spread beyond the neighboring villages. Other farmers have called on him frequently for technical advice. The government fisheries agency has invited him to co-facilitate extension sessions or to speak in workshops. Abdul Ghofur, an AFS alumnus, is currently an active change agent for good aquaculture practices in Demak.

LEISA adopters

After training, 80% of the 177 AFS participants adopted LEISA and made gainful changes (Box 2). After having followed an AFS for one milkfish-shrimp culture season, the farmers who used liquid compost were able to harvest higher yields than those who didn't (Figure 3). From 125 LEISA adopters, we found that they didn't harvest more milkfish in 2017-18 than in 2015, the baseline yield. Nevertheless, they increased their margins because they could culture shrimp again; they also reduced cost for milkfish farming.

In the sample which we monitored financially, the non-LEISA farmers, who did not stock shrimp, continued using chemicals in their milkfish production. Although they harvested more, about 700 kg milkfish ha^{-1} yr^{-1}, they earned less compared to the sampled LEISA farmers who harvested thrice more milkfish than the baseline yield. The adopters also had six times more shrimp yield over the baseline data. In general, farmers with smaller ponds had 13-21% higher yields per hectare than those with larger ponds.

Return of aquaculture field schools

In a sample, the estimated gross margin of the AFS alumni-farmers who adopted LEISA was more than 900 USD ha^{-1} year^{-1} higher than that of the AFS alumni who did not adopt LEISA. Likewise, the gross margin of the LEISA adopters was also more than 700 USD ha^{-1} year^{-1} higher than that of the baseline (Figure 3). This higher gross margin could be attributed to lower cost but higher yields among the LEISA adopters over the non-adopters. Owning an average of about 2 hectares of ponds, AFS farm households gained about 1,400 USD yr^{-1} complementary gross margin.

The internal rate-of-return (IRR) of this AFS program is more than 130%, which means that the project's investment is recovered within one year. This IRR is in the highest ten percentile among the 1,066 agricultural research and development innovations in developing countries with a median of 41% (Rao, et al., 2019 cited by Widowati et al., 2021). Thus, incorporating LEISA technology training in the AFS is very cost-effective; this same trend was also documented by Brown and Fadillah in South Sulawasi (2015; Aquaculture Asia 18 (2): 12-19).

Figure 2. The mean specific growth and survival rate of *P. monodon* in ponds with liquid composts from vegetables, fruits or a mix, with or without mangrove leaves (*Avicennia marina*) versus those in a control (Adapted from: Ariyati, Rejeki, Widowati, Elfitasari, Bosma. 2019. DOI: 10.1007/s40071-019-00239-x/).

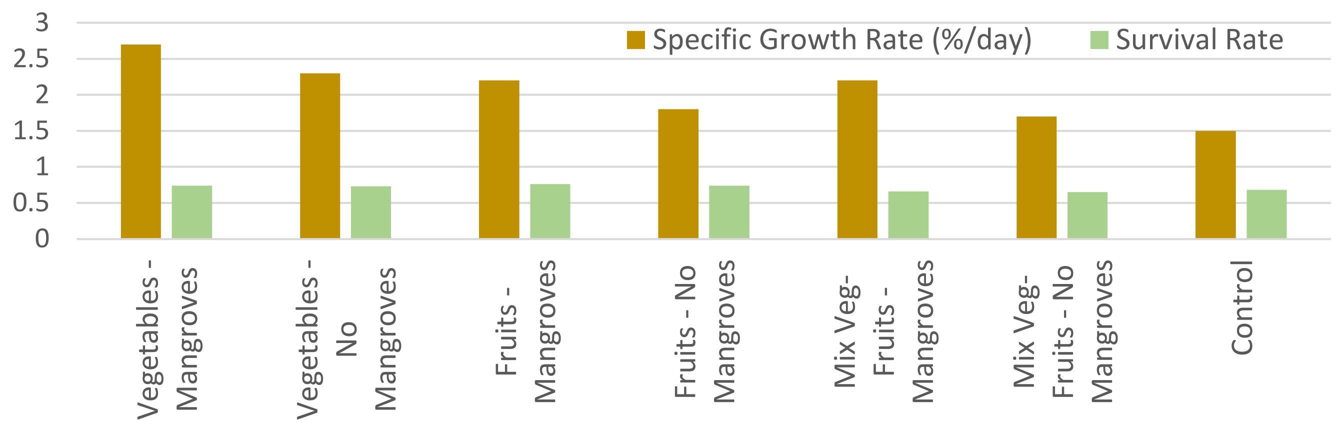
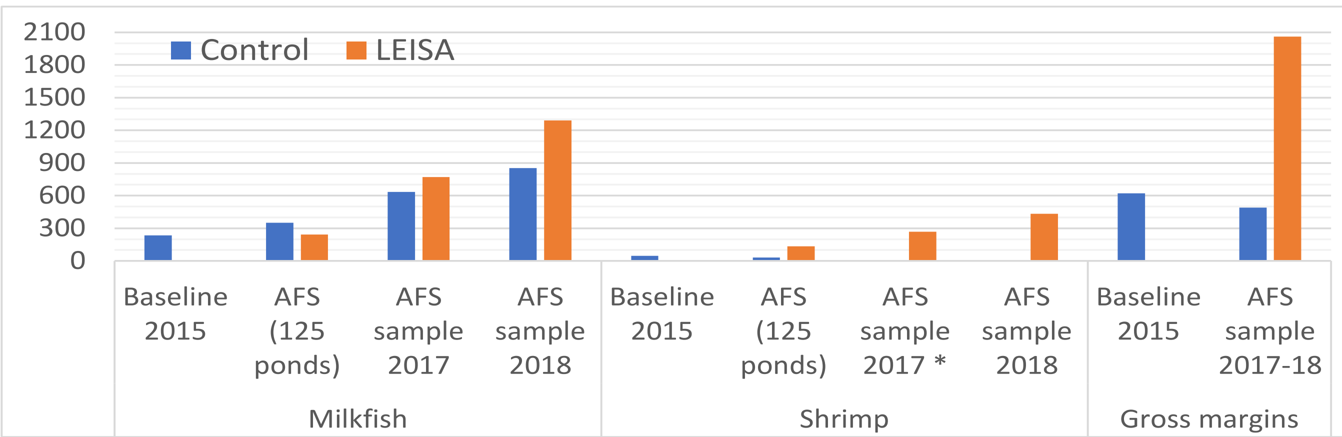


Figure 3. The yields of milkfish and shrimp and the gross margins of farmers applying LEISA and those who did not adopt this innovation (Adapted from: Widowati et al, 2021).



Box 2: Business booms after applying LEISA

I am Indah Purwanti, and I live in Purworejo village. My husband and I have a 1.5 ha pond. Until 2015, I was full-time housewife, but then I became a member of the Kartini Bahari womens group that organises skills training. To manage our milkfish pond, we used chemical fertiliser and pesticides. In March 2018, I joined the Aquaculture Field School (AFS) so I could help my husband in managing our milkfish production.

Through this AFS, I learned about managing the pond in an environmental-friendly way; I learned how to make home-made liquid compost, compost and other local feed additives. When we applied what we learned from AFS, we succeeded to double our milkfish harvest; in 2020 we harvested as much as two tons. Moreover, the milkfish gets fewer diseases and grows faster, thus the cultivation cycle is shorter.

We invested part of the income that we gained from our milkfish in buying a good cracker cutter and packaging tools for my business in making seafood crackers from shrimp, milkfish and squid since we live near the coastal area. The cutter shapes the crackers better, and the good packaging makes them more hygienic and more attractive to the buyers. Using these tools has tripled my production and sales of seafood crackers.

Given that most milkfish is cultured traditionally, the milkfish output of coastal districts like Demak can at least double. At present, 80% Indonesian traditional shrimp farmers occupy about 22% of the production area, but produce only 10% of its shrimp (Halim and Juanri 2016, cited by Widowati et al., 2021). After all these farmers go through AFS training, the Indonesian shrimp production is expected to increase by 25 to 50%, with low cost and low risk of disease outbreaks (Shinn et al. 2018, cited by Widowati et al., 2021).

In general, the yields and incomes of the farmers applying LEISA were higher in the second year than those in the first year (Figure 3). This can be explained by: i) farmers stocking shrimp more often, ii) more farmers using (more) industrial feed, and/or iii) other factors such as better application of their learning after discussions organised by the AFS alumni (Photo 6). After an AFS, any farmer can earn at least three times more than their usual income which they had from traditional practices; thus, giving them a first step out of the poverty trap; simultaneously, the country recovers its investment within one year. Moreover, we have observed that farmers, after finishing one season of the AFS training, became more confident in adopting innovations towards more sustainable and resilient aquaculture systems such as AMA, MTA and marketing (Box 3).

Associated mangrove aquaculture (AMA)

BwNI piloted the associated mangrove aquaculture (AMA) system proposed by Bosma et al. (2014). While traditional silvo-aquaculture could not stop the land loss (Photo 2), the practice of AMA could prevent land loss through a riverine greenbelt that is created by growing mangroves along the waterways in a separated section of the aquaculture farm (Photo 9). Thus, AMA hydrologically connects the farm's mangroves with the natural waterways outside the pond and enlarges the nursery and feeding ground for the marine species. AMA is different from the usual silvo-aquaculture where mangroves are planted in the pond or on its dykes, shed their leaves onto the pond and adversely affect the pond water quality. Because the mangroves are grown in a separate section, with AMA i) water quality is improved; ii) the power of the waves is reduced, iii) sedimentation is increased, iv) pond dykes are protected and v) marine and coastal fisheries and other related livelihood opportunities are improved.

Figure 4. The average harvested volume (kg ha^{-1}) and gross margin (*10,000 IDR ha^{-1}) from 18 AMA ponds in 2019 vis-à-vis those in 2018 from the ponds (total average area 2.4 ha). In both years 17 farmers stocked milkfish and one cockle; in 2018, eight farmers cultured tiger shrimp and in 2019, twelve did.

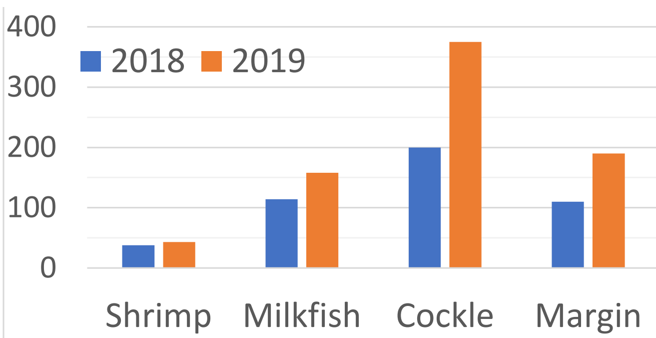


Photo 9: In the centre, the mangrove component of the AMA pond of pak Zaeni in Timbusloko, six months after building the separation dyke.

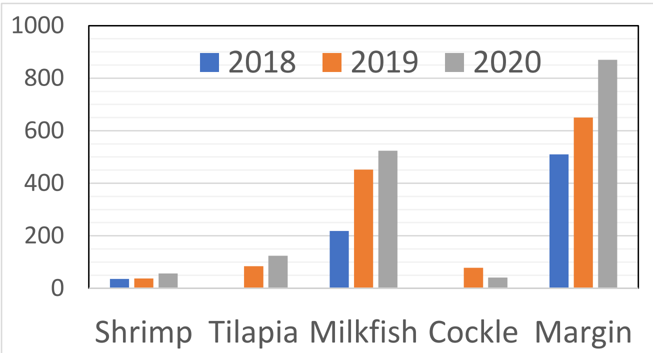
In 2018, about 120 farmers implemented AMA in Demak. Of these, 45 AMA ponds were monitored for inputs and yields, and from 18 other ponds, data on finances and water quality were also collected. In their smaller ponds, the AMA farmers were able to maintain, on average, the yields of milkfish and shrimp. This was in contrast to the yields that were obtained by the non-adopting farmers, who since 2015, didn't even stock shrimp (Figure 4). The soil subsidence continued since 2015, and floods were more severe in 2019 and 2020 than all those in the previous years; this may explain the lower average yields obtained from those obtained in 2017 and 2018 as reported above. Nevertheless, the AMA farmers were convinced of the advantages: Now they can harvest shrimp, trap more shrimp and fish in the main gates and catch more from cane-fishing (Photo 10).

Multitrophic shrimp aquaculture (Shrimp MTA)

A research project on multitrophic aquaculture (MTA) was introduced alongside AMA. MTA consists of simultaneously stocking milkfish ponds with shrimp, tilapia, seaweed and mussel or cockles (Photo 11). During the preliminary studies, even before a pilot was started, some farmers had already adopted stocking seaweed, mussels or cockles; and some had succeeded (Box 3).

Because of frequent floods and losses of aquaculture stock, 2019 and 2020 were difficult years for the farmers. Despite experiencing these deficient years, the efforts of twelve farmers venturing on shrimp MTA in a one-hectare-pond area paid off (Box 4). Unlike most farmers who lost their investments due to flooding, these twelve were able to maintain their margins during these bad years (Figure 5).

Figure 5. The average yields (kg ha^{-1}) and gross margin (*10,000 IDR ha^{-1}) of 12 MTA farmers in 2019 and 2020 from ponds of 0.5 or 1 ha, compared to their results in 2018 from their other ponds (average area 2.4 ha). In 2018 seven farmers stocked tiger shrimp and 11 milkfish, in 2019 10 stocked tiger shrimp, 12 milkfish, 12 tilapia and 5 cockles; in 2020 all 12 also stocked cockles.



Discussion

Our narrative here for the farmers' yields and gross margins does not include their shrimp/fish catch in the main gate(s), although they all said that this catch was an important source of food and income for them (Box 4). Some estimated the shrimp/fish catch value at the gate to be as high as that from the pond, especially when these were near mangrove areas, or the nearby AMA-transformed areas. Because of the importance of the catch in the gates, the farmers might neglect the original AMA advice to open the dyke to the river (Bosma et al., 2020); and thus, not remove the water-gates. Keeping the dyke is also a way to protect their land property rights and this reduces a barrier to broad-scale adoption of AMA. Studies

Box 3: After AFS, he by-passes the middlemen

In 2016, Kasmudi from Tambak Bulusan participated in the AFS. Like most other farmers in the village, he stocked milkfish, killed and prevented pests with chemicals and applied urea and phosphate fertiliser in his ponds. But his yields were still low. He had stopped stocking shrimps long ago. At the AFS, he learned the LEISA practices and also learned about the effect of seaweed on water quality.

At the end of the dry season in 2017, he bought 1,000 kg of seaweed - these all died during the heavy rains of January-February. But, after he had prepared the pond and stocked shrimp when salinity increased, the seaweed grew again. Yearly, the seaweed apparently disappears, but regrows and keeps the pond water clear. To manage salinity, he reduces the water exchange frequency and keeps the quality good by adding liquid compost weekly.

He stocks shrimp post-larvae in three small nursery ponds and transfers the good sizes to his grow-out pond. There, from April to December, every 4 to 6 weeks, he can harvest more than 150 kg shrimp of the size of about 20 pieces/kg. This volume he can sell directly to a fishmonger in Semarang, where he fetches 50-100% more than what the village collectors would pay him.

on optimising mesh sizes of nets, as well as the schedules for opening the gates, are needed to reach the goals of the farmers as well as those of the AMA to increase breeding and nursing grounds for estuarine and marine species.

The MTA with seaweed and mussels was tested because in most of Demak's ponds as incoming riverine waters contain high amounts of organic matter and thus nutrients. In our experience, combining 100 g m^{-2} seaweed and 60 g m^{-2} green mussel works best for both the reduction of organic matter and the growth of the cultured organisms. In our pilot ponds, the practice of feeding 50 saline-tolerant red tilapia in a cage of 25 m^{-2} ha^{-1} would sufficiently prevent noxious microbes from developing in the pond water, and thus reduce the risk of shrimp diseases.

In Demak, we have observed that several investments in shrimp monoculture using high technology sometimes lasted only for a year and left behind a destroyed landscape and a lot of plastic lining and feed bags littering the waters. Plastics are already found in most seafoods, and at the medium term, they may put human health at risk. Policies relevant to reducing plastic wastes, in general, and in aquaculture in particular, are thus urgently needed.

Policymakers may argue that for a sustainable food security, one must strive for much higher yields. In contrast, we view that to achieve a sustainable food security base, knowing and practicing LEISA, improving income and accumulating capital, are the first steps to sustainably increase yield. After complementary learning, in e.g., innovation platforms, reducing pond sizes and using limited amounts of manufactured pelleted feed for the last stages of the grow-out, farmers harvested up to 400 kg ha^{-1} yr^{-1}. However, in aquaculture only 20-40% of feed is retained by the animals; the rest is metabolised, excreted or wasted and pollutes ponds and the surrounding waters, because most pelleted feeds are formulated to optimise growth of shrimp and fish. Feeds can also be formulated considering both the culture species and the requirements of the pond ecosystem (Joffre and Verdegem 2019). Such nutritious pond feeds contain less

Photo 10: Catch of some hours of cane-fishing after the construction of AMAs; and enlarged greenbelts.

Box 4: AMA and IMTA changed family livelihood

Since 2000, pak Abdul Kohar did not stock shrimp or milkfish in his 2 hectare pond. In the second month after stocking shrimp, most of these died; while some he lost during spring tides. So, he just harvested the wild seafood that got trapped in his pond and in the gate traps at full moon. In 2017, BwNI proposed to the village group to apply AMA in ponds adjacent to rivers. The location of his pond matched the criteria, and he built the extra dyke and gates. In 2018, he started emptying his gate traps daily. The results made him very happy, next to fish, such as mullet and white snapper, he caught tiger prawns (*Penaeus monodon*) and white shrimp (*P. merguensis*); the last two he hardly ever caught in the last years. This made Kohar think that his pond could be used again for cultivation.

Also, in 2017, UNDIP-FPIK-Aquaculture looked for farmers who would pilot IMTA. In this IMTA, shrimp, milkfish, seaweed, cockle and a cage with tilapia are combined to take advantage of all nutrients in the water. Pak Kohar tried to grow all together the tiger prawns, milkfish, blood clams and seaweed. In the first cycle, the shrimp did not die; in the third month, he harvested 50 kg of tiger prawns and 500 kg of blood clams of which he initially stocked 200 kg. In addition, the milkfish harvest, which used to be only 200 kg before 2000, reached 600 kg. Pak Kohar also succeeded in cultivating seaweed, and in producing enough volume to interested factory buyers. Later, he proposed to several other farmers to add seaweed in their shrimp pond. This first success encouraged Kohar to manage his pond more seriously. After preparing the pond, he added tilapia to his other crops. His second year was even more successful: His yields doubled for shrimp and milkfish, and tripled for blood clams. In addition, the daily catches in his traps increased both in volume and variation: he caught also blue swimming crabs which have a high selling price.

This success gave Kohar the capital to improve his other pond; there he also applies AMA, IMTA, and his other learnings from the AFS. From the remaining money, he bought a new motorbike for the daily transport of his small family.

protein and more carbohydrates, are 10 to 15 % cheaper, reduce feed waste and improve pond water quality. Moreover, similar studies in Bangladesh recorded a 21% increase in yields of tilapia. In Vietnam, although the shrimp did not grow significantly faster, the resulting better water quality reduced disease and led to a longer growth period with 10-15% lower cost for additives. Together with the lower cost of the feeding, the financial returns from the shrimp ponds improved, as well as other aspects of sustainability. The nutritious pond concept opens opportunities for further increase of the yields and benefits of the MTA for shrimp.

Conclusions

Based on our experience, aquaculture field schools are an effective channel to train farmers in adopting environment-friendly approaches such as LEISA, AMA and MTA systems. We found in our pilot areas that farmers, who learned and adopted these approaches at AFS, significantly increased their gross margin, with three-to-five times more yield for milkfish and shrimp compared to that of the baseline. The high rate-of-return guarantees the project donors a payback time of less than one year for an AFS program. Moreover, enriching the farmers' skills with AFS can potentially double Indonesian milkfish production and increase its shrimp production by 25 to 50%, without human and environmental health being put at risk because of the polluting effect brought about by the more capital-intensive high-tech innovations.

Using multitrophic systems, that is, simultaneously raising of shrimp, tilapia, seaweed and cockles or mussels in appropriate ratios, has been shown to reduce shrimp diseases and the high nutrient loads of the incoming waters in Demak. Moreover, the MTA increased the resilience of the aquaculture production, and thus improved farmers capacity to adapt to rising sea-level and sinking land.

The practice of dedicating an area to create a mangrove fringe along the waterway, as in the AMA systems, does not in any way reduce the margins, because smaller ponds give better yields. One of the impacts in using AMA is that more shrimp and fish are trapped in their water-gates and more fish are caught through cane-fishing -- resulting in more food and more income for the farmers. Because of this effect, villagers, in general, have a positive attitude towards AMA. In the long-term, farmers are assured that their catch of estuary and marine fisheries will be more, and floods will be less because of increased sedimentation and water storage capacity. These make the AMAs an effective tool to mitigate the impacts of climate change and land subsidence.

Photo 11: Farmers checking the growth of red saline tilapia in hapa in an MTA with milkfish, shrimp, seaweed and cockles.

Associated mangrove aquaculture, Suhadi Tambakbulusan.

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An insight to red tilapia breeding and culture: A farmer advisory

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Fish, being a highly traded agricultural commodity, is an important source of nutrition as well as a livelihood for many rural people in developing nations (FAO, 2020). This affordable high quality protein food is either harvested from natural resources via capture fisheries or cultured using available natural resources via culture-based fisheries. However, the over exploitation of natural resources has led to declining returns from capture fisheries. To compensate, commercial aquaculture has emerged as an important food production sector at the global level. Initially, the availability of seed was the major limiting factor for growth of the industry. However, the success of induced breeding in the 1980's revolutionised aquaculture by making plenty of quality seed available for grow-out. In subsequent years, the heavy dependency on hatchery-produced seed and poor management of broodstock has resulted in a deterioration in seed quality, which has led to severe disease outbreaks and economic losses. Experts suggested diversification, through introduction new species or new varieties of strains in aquaculture to overcome this issue.

Tilapia, the most diversified cultivable fish species in the world, has reached new heights of production in recent times. The estimated production of tilapia in 2020 was around 6.8 mmt. At present, the tilapia industry is growing at a rate of 4% (Tveteras et al., 2019). However, disease outbreaks, especially *Streptococcus* infection, significantly threaten the tilapia industry. The industry has introduced various new strains, genetic improvements and better management practices to combat these emerging problems. Among the new strains, red tilapia – an alternative to Nile tilapia – is showing an impressive rate of success in due to its attractive colour, faster growth rate and good market demand. Supply of quality seed will play a major role in achieving the anticipated growth of this industry. Effective broodstock management and proper seed production is required to produce quality seed. To achieve this it is necessary to disseminate knowledge about red tilapia breeding and seed production to farmers.

Status of red tilapia

Tilapia is projected to overtake carp production by 2025. Among the different strains of tilapia developed, red tilapia was first developed in Taiwan, Province of China, during the late 1960's. Originally, red tilapia was a genetic mutant, which was produced by crossing female reddish-orange Mozambique tilapia with normal male Nile tilapia. Later, many countries such as USA and Israel developed their own red varieties using different strains, which changed the genetic makeup of original red strain. Subsequently, scientists have discovered that red tilapia has greater growth potential in salt water and produces fish with slightly higher EPA and DHA content.

After the introduction of red strains in farming, the production of red tilapia significantly increased from the 1980's onwards. In Malaysia, within three decades, red tilapia production exceeded the mossambicus tilapia production. In countries such as Colombia and Jamaica red tilapia replaced the culture of Nile tilapia. In India, states including Kerala, Andhra Pradesh, Tamil Nadu and Odisha have cultured red tilapia for the past 30 years for domestic consumption. Other countries including Thailand and Bangladesh also promoted red tilapia farming. Increased domestic consumption of red tilapia convinced Chinese farmers to popularise red tilapia farming. Presently, four red tilapia strains from Taiwan Province of China, Thailand, Malaysia and the Stirling strain, dominate the red tilapia industry.

Male (top) and female (bottom) red tilapia brooders.

Female (left) and male (right).

Breeding of red tilapia

Tilapia is a prolific breeder and breeds throughout the year. However, comparatively, small sized eggs and low fecundity occur in red tilapia during the summer months (April – May). In general, tilapia breeding is carried out using three methods:

- **Pond-based breeding:** In this method either earthen or lined ponds are used to breed the fish. Since the pond ecosystem provides a natural environment for pit construction – tek – frequency of breeding is high in pond-based systems. However, the collection of broodstock for egg or seed collection is a difficult task in pond-based breeding of tilapia.

- **Tank-based breeding:** In this method concrete cement tanks are used to breed the fish. Similar to pond systems, collection of brooders is a difficult task. However, tank systems are highly suitable for early larval rearing.

- **Hapa-based breeding:** In this method hapa are installed in the earthen ponds to keep the brooders separated for breeding and seed production purposes. Easy handling of brooders, egg and fry collection making this method a more suitable one for tilapia breeding (Bhujel, 1999).

Red tilapia breeding using hapa system

The most common and widely practiced successful method of tilapia breeding. In hapa breeding, a set of predetermined numbers of male and female brooders of red tilapia are released and allowed to mate and produce fertilised eggs. However, successful breeding needs technical as well as field level knowledge about red tilapia breeding patterns.

Red tilapia brooders

In any captive breeding activity, the status of the broodstock plays a major role in deciding the success and quality of seeds produced. In hatcheries, healthy brooders are separately maintained using high quality diets. In general, males and females are stocked and reared in the same pond and segregated for breeding after attaining maturity.

Male	Female
Genital papilla is tapered (pointed) in shape	Genital papilla is round (button) in shape
Genital papilla has one opening (urinary pore)	Genital papilla has two openings (oviduct and urinary pore)
Smaller in size with flat belly	Bigger in size with bulging belly

Brooder hapa installation.

Breeding hapa with red tilapia brooders.

Hapa installation

Hapa are rectangular or square net cages or impoundments, placed inside a pond to contain broodstock during breeding operations. There are different sized hapas available on the market. However, hapa made of polyethylene with total area of 30 m^2 (10 m × 3 m × 1 m) are mostly preferred for easy handling of tilapia broodstock. Hapa are installed and anchored using bamboo poles and ropes. To install one brooder hapa, four bamboo poles of 3.6 m height are required. Each bamboo is cut into two pieces (1.8 m height each, for a total of eight poles) and driven into the pond bottom approximately 30 cm deep. The first two poles are placed parallel to each other at a distance of 3 m. Then, from those two poles, at a 90° angle, two more poles are placed 10 metres apart to make a rectangular shape 10 m long and 3 m wide. After installing four poles, the hapa is tied 30cm above the bottom and 30 cm below the top of the bamboo. Then at approximately 3 m intervals, on both sides, place the remaining four poles. The water level inside the hapa is maintained at 90 cm depth.

Breeding

Once the hapa is installed, broodstock are released inside. Healthy brooders of >200 g size should be selected for breeding purpose. The fecundity of tilapia used to be high at younger age (smaller size), therefore, while selecting the brooders, fish that have crossed the reproductive age (>500 g) should be avoided. Handling difficulty during egg collection and lower breeding frequency are additional problems associated with the selection of older brooder fish.

The sex ratio maintained for red tilapia broodstock is 2:1 (female : male) and stocking density is 2 brooders/m^2. Therefore, a brooder hapa is stocked with 20 well matured males and 40 female red tilapia. However, one or two pairs may be additionally stocked to compensate for the loss of brooders due to natural mortality. Red tilapia, being a prolific variety, breeds once in a month, however, removal of eggs from the mouth reduces the inter-spawning interval and increase the spawning frequency. After the release of brooders in the hapa, they should not be disturbed for 10-15 days and the first egg collection can commence after this period. In breeding hapa, brooders are fed twice in a day (3% of body weight) with a high-quality diet. The fecundity of red tilapia is about 4,500-5,500 eggs/kg body weight.

Egg collection

Eggs can be collected from breeding hapa once in 7-10 days. Egg collection is comparatively easier in hapa breeding than the pond- or tank-based systems. To gather the brooders in one corner, a 3 m long bamboo pole is used. The pole is first placed below the bottom of the breeding hapa, which is then lifted above the water column from one corner. In the same

Female red tilapia incubating eggs in mouth.

position, the pole is dragged from one corner to the other which helps to congregate all the brooders. The pole is then placed over the breeding hapa in such a way that it should temporarily hold the brooders in the corner.

Female fish incubate the fertilised eggs in their mouth. Therefore, while hand picking the brooders during egg collection, their mouth should be closed, otherwise they may spit the eggs into the water. Females with eggs in their mouth should be transferred to an egg collection trough, where their mouth and opercula are opened to collect the eggs. After collection the female fish are released back into the hapa. The egg collection trough is maintained with minimum water (2-3 litres) to maintain the collected eggs in good condition. An average female yields about 1,500 of eggs per cycle. Collected eggs are moved to a jar hatchery. Brooder health condition is also checked during the egg collection process.

Colour of the eggs	Condition of the eggs
Slightly brownish	Good condition and ready to hatch
Yellow	Mostly immature eggs and takes more time for hatching
White	Unfertilised eggs

Tilapia glass jar hatchery

In the hatchery, collected eggs are first measured (by volume, in ml) and counted and loaded in the hatching jar. The jar is a vertical container made of glass or transparent FRP or PE. The jar should be transparent material to allow egg condition to be observed. Capacity of the jar is 5 litres (14.5 cm diameter) and it can be loaded with 250 ml of eggs (approximately 6,250 eggs). With the help of a vertical PVC pipe, water is released in the bottom of the jar to keep the eggs in suspension. Water flow is maintained at 3-5 l/min. The larvae is float to the surface once they hatch, due to the presence of an oil globule, and are collected in the hatchling collection tray. Water overflowing from the hatching jar is passed through a simple biofilter unit, a 200 litre FRP tank filled with charcoal and sand, and collected in a sump. A submersible pump (2 hp) placed in the sump, with a help of sensor, automatically pumps the water to the overhead tank. The treated water stored in the overhead tank is circulated again to the jar hatchery. In this way water flow is maintained in the hatchery to minimise the entry of pathogens and other foreign substances.

Generally, each hatching jar is operated for 48-72 hours after loading the eggs. After this period the unhatched and white coloured eggs are discarded. The fry are collected and kept in a separate tray for 24-48 hours with mild water flow, to complete absorption of the egg yolk. Once, the yolk sac is completely absorbed, the fry are shifted to an all male production nursery rearing unit.


Egg collection from brooders.

Red tilapia glass jar hatchery.

All male production

In general, all male tilapia seed are produced to avoid stunted growth due to prolific breeding behaviour and to obtain better production by the faster growing males in grow-out conditions. Androgenic hormone, 17α methyl testosterone (17α MT), is commonly mixed with the feed and fed to the early fries to convert them to males. Producing all male seed using hormone is the cheapest and easiest method, however, it has various environmental as well as potential human health issues. 1 kg of hormone incorporated feed is prepared by dissolving 70 mg of 17α MT in 125 ml ethanol. The dissolved content is sprayed over fry feed having a protein content of >34% and mixed well. Then the feed is dried for overnight and stored in good condition. Gloves should be worn while preparing the feed to avoid direct contact with 17α MT.

Yolk sac absorption tray.

The hormone-treated feed is fed to fry for 21-28 days. In general, either indoor or outdoor based cement tanks are used for all male production rather than the hapa-based system. The availability of natural feed in the hapa-based system leads to poor sex conversion. Generally, square cement tanks (2 m × 2 m × 1 m; 4,000 l capacity) or rectangular tanks are preferred for all male red tilapia production. Stocking density is maintained at 2 individuals/l. Fry are fed four times in a day at 10-12% body weight. Once in three days, 30% of the water needs to be exchanged to get better production. The development of algae along the walls of cement tanks should be avoided, because behavioural domination has been noticed among the red tilapia fries. The domination of shooter fry during feeding leads the weaker fry to graze the algae developed along the walls which again affects the effectiveness of sex conversion.

Fry rearing in nursery hapa

25-30 day old all male seed (approx. 1.5-2.0 cm) are stocked in hapa, installed at ponds. Generally, nursery hapa (8 m × 3 m × 1 m) with a closed top are used for nursery rearing to avoid the entry of fish eating birds. At one corner, a zip-like opening is provided to open the hapa for feeding. Each hapa can be stocked with around 10,000 fry (400-425 fry/m^2). Fry are fed four times daily. Rearing is continued for 30-45 days, as per the size requirement. Once they reach 3-5 g the seeds are transferred to grow-out ponds.

Grow-out culture

Fingerlings (4-6 cm) are directly stocked in fertilised pond for grow out culture. Generally, rectangular ponds of 1,000 m^2 are preferable. Fingerlings are stocked at the rate 5 individuals/m^2 and fed twice a day. Water depth should be kept above 1 m and care taken to ensure the availability of natural food in the culture pond to maintain the colouration. Culture duration is 4-6 months and it varies based on the growth performance and market demand. Harvesting at a size of >300 g size fetches a good market rate (Rs. 120/Kg) in the local market. Mostly fish are supplied to the local market and very few commercial farmers are involved in exports.

Water quality

In any aquaculture activity water quality is one of the major factors that decide the successful production of fish. Therefore, knowledge about the physical, chemical and biological parameters of water are more important. However, red tilapia, being hardy varieties, tolerate a wide range of environmental variations. Red tilapia can tolerate and be grown in the following water quality conditions:

Water quality parameter	Range
Dissolved oxygen (mg/l)	3-5
Temperature (°C)	24-32
Salinity (ppt)	0-35
pH	6-9
Alkalinity (mg/l)	20-400
Hardness (mg/l)	20-500
Ammonia (mg/l)	0.01 – 0.1
Nitrite (mg/l)	0.01 – 0.1

Feed management

Feed plays a major in broodstock development because the quality of seed produced is directly proportional to the quality of broodstock. In the case of grow-out culture, most of the farmers are using locally available low cost ingredients such as rice bran, groundnut oil cake, and broken rice to feed the fish. Since, red tilapia is a voracious feeder, it is recommended to feed them three to four times a day. On the other hand, all male production unit must use pellets with >32% crude protein to avoid morphological deformities in the developing fry. The following feeding schedule can be practiced for red tilapia to obtain better production:

Stage of fish	Crude protein (%)	Feedings	Ration (% bw)
Brooder	28-32	2 / day	2-3 %
Fingerling	24-28	2 / day	3-5 %
Fry (nursery)	28-30	4 / day	8-10 %
Fry (all male production)	>32	4 / day	10-15 %

Challenges in red tilapia farming

- The non-availability of a sufficient quantity of quality seed limits commercial level farming of red tilapia in many parts of the world.
- The improper management of broodstock may lead to inbreeding which results in low quality seed production.
- Red tilapia is a hybrid variety, therefore, strict biosecurity measures must be implemented in farms to prevent the escapement of culture stocks to the wild which may lead to genetic pool contamination of wild or native stocks.
- Sex conversion and all male seed production using hormone incorporated feed may have impacts on natural ecosystems due to residual effects.

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Aquaculture for livelihoods and food security in North-western India

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Above, below: Pangas catfish brood stock and seed produced under agro-climatic conditions of Punjab by GADVASU in 2018.

As per the Department of Economics and Social Affairs (DESA) of the United Nations, the fisheries sector (capture and culture fisheries) has an imperative role to play in feeding the world population, which is estimated will grow to 9.8 billion by 2050 and 11.2 billion by 2100. Aquaculture is one of the fastest growing food production industries, with a striking contribution to livelihoods, employment generation and food/ nutritional security across the world. Fish and other aquatic organisms provide at least 15% of average per capita intake of animal protein to more than 4.5 billion people worldwide[1]. However, as per the Food and Agriculture Organization (FAO) of the United Nations, fish provides about 3.0 billion people with almost 20% of their average per capita animal protein intake, while it contributes 15% to animal protein consumed by 4.3 billion people globally. Fish accounts for 30% of animal protein intake in Asia, 20% in Africa and 10% in Latin America[2], while it constitutes more than 50% in coastal regions, especially in small islands like Andaman and Nicobar.

In 2018, global fish production was 178.5 million metric tons (mmt), including 96.4 mmt from capture and 82.1 mmt from aquaculture sector and about 59.5 million people were engaged in the primary sector of capture fisheries (38.97 million) and aquaculture (20.53 million). With an annual growth rate of 5.3% during the period 2001–2018, aquaculture continues to grow faster than other major food production sectors in the world[3]. Further, the employment opportunities have increased more in aquaculture sector as compared to capture fisheries. Employment in capture fisheries decreased from 83% in 1990 to 65.5% in 2018, while it increased from 17 to 34.5% in the aquaculture sector. According to the employment database of 2018, about 84.66% and 95.54% of the global population employed in the fisheries and aquaculture sectors are in Asia. Over the last two decades, significant employment growth has been witnessed in fisheries and aquaculture in Asia and Africa, with a more pronounced increase in aquaculture sector in special reference to Asia.

For over two decades, Asia has contributed about 89% to world's total aquaculture production[3]. Over the same period, Africa, America, Europe and Oceania also lifted their share. However, the contribution of China, the top fish producing country, to global aquaculture production decreased gradually from 65% in 1995 to 58% in 2018. Among other top producers, India, the second highest aquaculture producer in the world, has strengthened its share in global production from 4.2% in 1997 to about 8.6% in 2018[3,4].

Indian fisheries

India's diverse inland aquatic resources, in the form of 195,000 km of rivers and canals, 2.92 million hectares (mha) of reservoirs, 0.79 mha of flood plain lakes and derelict water bodies, 2.43 mha of ponds and tanks, 1.15 mha of brackish water resources[5] and 6.74 mha of inland saline water resources[6], offer great opportunities for livelihood and employment generation through fisheries, besides steering the national economic prosperity.

Over the last six decades, marine production dominated Indian fisheries sector has transformed and inland fisheries (with 8% compound annual growth rate from 1950-51 to 2016-17) emerged as major contributor to overall fish production. During 2015-16, India produced 10.76 mmt of fish/shellfish, with 7.16 mmt (66.55%) from inland sources and export earnings of ₹ 30,420 crores (Cr.) or USD 4.68 billion[7], while during 2016-17 total fish/shellfish production increased to 11.41 mmt, with inland sector share of 68.10% (7.77 mmt) and export earnings of ₹ 37871Cr. (USD 5.80 billion). During 2017-18, the total fish/shellfish production of India further

Pangas catfsh culture and overwintering in polyhouse at College of Fisheries, GADVASU, Ludhiana (Punjab).

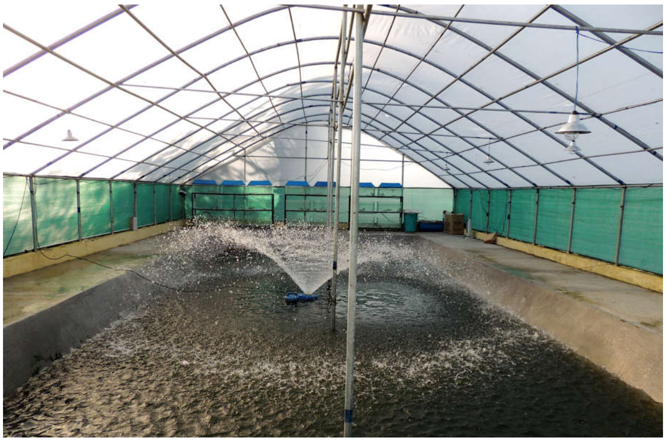

Table 1. World employment of fishers and fish farmers (thousands).[3]

Year	Asia	Americas	Europe	Africa	Oceania	Total
Fisheries						
2000	28,079	1,982	679	3,247	451	34,439
2018	30,768	2,455	272	5,021	460	38,976
Aquaculture						
2000	12,355	257	104	100	8	12,825
2018	19,617	388	129	386	12	20,533
Total						
2000	40,434	2,239	783	3,348	459	47,263
2018	50,385	2,843	402	5,407	473	59,509

increased to 12.61 mmt[8], with the inland sector share of about 8.92 mmt (70.73%) and export earnings of over ₹ 45,000 Cr. (USD 7.08 billion). As per the latest estimates, India's total fisheries production increased to 13.75 mmt[9] during 2018-19, with the inland sector share of 9.58 mmt (69.67%) and export earnings of about ₹ 46,589 Cr.

Further, within inland fisheries, a major shift from capture fisheries to aquaculture has been witnessed over the last three decades and the contribution of freshwater aquaculture has increased from 34% in the mid 1980s to 78% in recent years. During 2018-19, fisheries contributed 1.24 % to National Gross Value Added (GVA) and 7.28% to the Agricultural GVA[3,5,10,11].

So far, about 0.895 million ha (mha) water area has been brought under aquaculture. About 15 million people in India depend on fisheries and aquaculture for their livelihood at the primary level and almost double that number are engaged along the value chain[9]. About 75% of the fishers are engaged in various inland fisheries activities (including aquaculture) and 25% in marine fisheries activities[12]. For every person employed in capture fisheries and aquaculture about three jobs are created in the allied activities, including post-harvest processing.

Under the national 'Blue Revolution' scheme, the total fish production of India was aimed to increase to 15 mmt by 2020, while the Fisheries and Aquaculture Infrastructure Development Fund (FIDF), Department of Fisheries (DOF), Ministry of Agriculture and Farmers Welfare (Now under Ministry of Fisheries, Animal Husbandry and Dairying), Government of India (GOI) targets to augment national fish production further to 20 mmt by 2022-23. With an estimated marine and inland fisheries potential of 5.31 and 17.0 mmt, respectively; the total fish production potential of India has been estimated to be 22.31 mmt[9]. Since, marine resources are already overexploited worldwide and are witnessing ecological imbalances due to pollution and climate change, there is little scope of any remarkable increase in production from the marine sector. Hence, inland resources are anticipated to fill the gap, with the major share coming from aquaculture. The future potential of this sector towards livelihood and employment generation and food/nutritional security depends on its sustainability in ecological, social, and economic contexts.

Realising the socio-economic potential of inland fisheries, a centrally sponsored scheme on 'Development of Inland Fisheries and Aquaculture' was initiated by the Indian Government during the early 70s (1970-74) with following objectives:

- Enhancement of inland fish production and productivity.
- Popularisation of modern fish farming.
- Creation of employment opportunities through fisheries.
- Diversifying aquaculture practices.
- Providing assistance to fish farmers engaged in aquaculture.
- Providing training to fish farmers by 422 (now 429) Fish Farmers Development Agencies (FFDAs) and 39 Brackish Water Fish Farmers Development Agencies (BFDAs).

The major components of the scheme identified following thrust areas for overall development of inland fisheries, with special reference to aquaculture:

- Development of freshwater aquaculture.
- Development of brackish water aquaculture.
- Development of coldwater fisheries and aquaculture.
- Development of waterlogged areas.
- Productive utilisation of inland saline/alkaline soils for aquaculture.
- Integrated development of inland capture resources (reservoirs, rivers, wetlands etc.).
- Innovative projects.

Later on, the Ministry of Agriculture and Farmer's Welfare, Department of Animal Husbandry, Dairying and Fisheries (DAHDF) restructured the scheme to "Development of Inland Fisheries and Aquaculture" by merging all its components under one umbrella called "Blue Revolution", taking care of both culture (freshwater aquaculture, brackish water aquaculture and mari-culture) and capture (inland and marine) fisheries under the National Fisheries Development Board (NFDB), Hyderabad, with a total central outlay of ₹ 3000 Cr. for 5 years (2015-016 to 2019-20). The scheme is described below.

Blue revolution

Main objectives

- To increase overall fish production in a sustainable manner for economic prosperity from the available water resources.
- To introduce new technologies in the sector for responsible and sustainable utilisation of resources in an eco-friendly manner.
- To ensure food and nutritional security.
- To generate employment and export earnings.
- To ensure inclusive development and empower fishers (capture sector) and aquaculture farmers (culture sector).

Thrust areas

- Freshwater aquaculture.
- Brackish water aquaculture.
- Coldwater fisheries/aquaculture.
- Saline/alkaline soil aquaculture.
- Wetland aquaculture.
- Inland capture resources (reservoirs, rivers etc).
- Innovative projects.

The COVID-19 pandemic has affected aquaculture activities from seed production to stocking, feeding, harvesting and marketing during 2020, but being a prime food production sector it will continue to feed the human population across the globe. For optimised utilisation of resources to achieve the production targets, there is need to develop a holistic strategic plan involving an ecosystem approach, to meet food and livelihood security requirements at state, regional and national levels.

Aquaculture development in North-western India

In the north-western states of India, there is great scope for generating substantial livelihood/employment opportunities through following aquaculture activities, which can improve the socio-economic status of the farming community, furnish additional food and nutritional security and boost the national economy as well.

Freshwater aquaculture

Among different aquaculture sectors (freshwater aquaculture, brackish water aquaculture and mari-culture), freshwater aquaculture is contributing the major share, which is traditionally dominated by extensive/semi-intensive poly culture of carps, including three species of Indian major carps, popularly called Indian major carps (IMCs), *Catla catla*, *Labeo rohita* and *Cirrhinus mrigala* and three species of exotic carps *Cyprinus carpio*, *Ctenopharyngodon idella* and *Hypophthalmicthys molitrix*. In North-western India, Punjab and Haryana are two progressive states with highest average annual aquaculture productivity of over 6 t/ha and net profit ranging from ₹ 1.25- 2.50 lakh/ha, depending on the management practices followed by the farmer. The IMCs contribute between 70% and 75% to the total freshwater aquaculture production, while exotic carps, catfish and freshwater prawn (‘scampi’) make up 25% to 30% of the production[13], while fresh water aquaculture contributes over 90% to national total aquaculture production. Cold water fisheries are presently contributing a very small share of about 3% to inland fish production, but commercial farming of high value cold water species like rainbow trout (*Oncorhynchus mykiss*) is expanding in medium to high altitudes of Himalayan corridor, including Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, West Bengal and all the northeastern states.

The carp culture industry is well developed across the country, with an effective hatchery network in every state (public/private) to supply seed of all cultivable species; 429 FFDAs and NFDB to provide start up financial impetus (loans/ subsidies) to aspiring candidates to take up aquaculture; and well connected technology cum extension backup from ICAR fisheries institutes/directorates/bureaus (7) at national level; and fisheries universities (2)/deemed university (1) and fisheries colleges/institutes (29) in state/central agricultural (SAU/ CAU), state veterinary universities (SVUs) or state fisheries universities (SFUs) at regional levels[14,15]. So far, aquaculture has benefitted 1.1 million people across the country and inclusion of aquaculture as an agriculture diversifying component also possesses great scope towards enhancing farmer’s income. During 2015-16 and 2016-17, about 14,212 ha area was developed for aquaculture, benefitting 63,372 fish farmers and 799 new fish markets were constructed including retail/wholesale outlets and kiosks, which reflects employment generating potential of the sector[5]. Rapid growth of freshwater aquaculture sector has generated diverse employment opportunities for professional, skilled, and semi-skilled workers for different support activities (construction and management of farms, hatchery management, seed production/supply, feed mills, netting gears, pharmaceuticals, marketing/trading, processing etc).

Diversification of carp culture

During the last decade, attempts have been made to diversify low value carp culture with high value species for dual benefit of higher productivity (vertical expansion) and higher income per unit area, making aquaculture even more lucrative as compared to other agricultural/livestock farming systems. Moreover, unlike many coastal states where people relish pond reared freshwater carps having intramuscular spines, the north-western population of India prefers to consume spineless fish (murrels, catfishes etc.). In this context, *Pangasianodon hypophthalmus* (pangas), an exotic catfish without intramuscular spines, has a winning edge towards diversification. Pangas culture is well developed in southern states of the country. The top producer Andhra Pradesh is supplying pangas to almost all parts of India, especially the northern states (covering >2,000 km of distance). About 56,000 mt pangas was produced in India during 2015-16 from 5,743 ha in 7 states (Andhra Pradesh, Maharashtra, West Bengal, Tamil Nadu, Kerala, Karnataka and Odisha), while 4,500 mt was imported from Vietnam during 1st half of 2017 to meet the national demand. Internationally, Vietnam exported 3.30 mmt pangas (92% fillets and 08% frozen) to 40 countries[16]. China alone imported 19,500 mt of pangas during the first half of 2017. Both national and international demand makes pangas a hot candidate for diversification in India, offering additional food/nutritional security and income, without expansion in area under aquaculture (reduced pressure on multiple use land and water resources to meet the production targets). About 400-500 t of additional fish can be produced from every 40 ha of area diversified or used for pangas culture (enhanced food security) supporting about 500 livelihoods including farmers family, farm labour and the linked backward/forward industry; being a potential candidate species for processing, especially filleting.

Unlike carps, pangas catfish is a cold sensitive species, which restricts its culture to 6-7 months in northern states, where temperature drops below 20°C during winters. Guru Angad Dev Veterinary and Animal Sciences university (GADVASU), Ludhiana in Punjab tested, validated, and demonstrated pangas culture under agro-climatic conditions of the State[17]; with an average productivity of 17.5 tons (t)/ha (three times higher than carps) in six months and corresponding net profit of ₹ 6.25 Lakh (2.5 times higher than carps); clearly indicating its potential in doubling farmers income.

After harvesting pangas (before the onset of winter) in northern states, the emptied pangas ponds can be utilised for rearing carp fingerlings from November to March for additional income. It will support the ‘Mission Fingerling’ of Blue Revolution, which was envisaged to achieve the target of enhancing national fisheries production to 15 mt by 2020. As per an estimate, total national fish seed requirement for stocking of existing ponds, new ponds and reservoirs (‘ranching’) is about 60,000 million fry, while 50,252 million fry were produced during 2016-17, leaving a gap of 9,748 million fry[5], which decreased to 39,261 million fry in 2017-18, leaving a gap of 20,739 million fry[18]. Hence, innovative initiatives are required to produce surplus quality seed of cultivable species to achieve the projected production targets. In the last two years, pangas culture has been adopted successfully in Haryana state and now fish farmers of Punjab state are also equally motivated to take up pangas fish culture on a larger scale.

Major concerns

- Presently there is no pangas hatchery in the north-western region of the country. Hence, seed needs to be airlifted from far off coastal states, adding to the seed cost, besides procurement hassles, mortality and delayed stocking.

- Fish mature after four years. Hence, brood stock development is the major bottle neck due to overwintering challenge in the northern states, which causes mortality, besides adding to brood stock and seed production cost.

- Harvesting must before the onset of winter. Hence, farmers are forced to sell the stock at compromised price, reducing farmers profit margin.

- No cold chain facility and processing industry in the region for preservation, processing/value addition (extend shelf life/availability), leading to post-harvest losses, food safety issues and consequentially economic loss.

Action plan

- **Cluster pangas farming:** Cluster farming approaches with small scale processing units (filleting) can serve as an effective 'entrepreneurial module' offering ample employment opportunities for rural youth and women folk.

- **National policy:** Since the seed of pangas is to be airlifted from far off hatcheries in southern states; a national policy is required to link non-coastal and coastal states of the country for ensured input (seed and feed) supply and marketing/processing support to non-coastal states.

Pangas fish from Andhra Pradesh sold in Ludhiana Fish Market of Punjab.

- **Cold chain facilities** and subsidised refrigerated transport vans are required to minimise post-harvest losses and facilitate direct marketing by the pangas farmers for higher economic returns

- **Research and development programs:** Pangas hatcheries need to be established in the northern states through a strategic R&D program involving brood stock development and breeding of fish under climatic conditions of the region. Most recently for the first time in north-western region, GADVASU achieved the breakthrough of breeding 4 year+ brood stock of pangas catfish (developed in Punjab by overwintering under poly-house conditions from 2015-2018) through induced breeding technology. Hence, there is scope of developing pangas hatcheries (with overwintering facilities) in north-western region to overcome seed availability issues.

Relative economic benefits, in terms of productivity enhancement (additional food/nutritional security) and doubling of farmer income per unit land holding, outcast climatic challenges restricting commercial adoption of pangas culture in northern region. It also offers a potential solution for achieving production targets, in harmony with climate change and depleting multiple use land and water resources. Hence, 'pangas culture cum processing model' can serve as a promising entrepreneurial enterprise for north-western states of the country, where a large quantity of iced pangas fish from coastal states, mainly Andhra Pradesh, is sold throughout the year. Further, Vietnamese pangas fillets are also popular in the supermarkets of the region.

Aquaculture in village/community ponds

Village/community ponds, an important and integral part of rural India, represent an underutilised aquatic resource with prodigious potential for developing aquaculture. India has more than 600,000 villages, hosting a massive aquatic resource in the form of village or community ponds that could be used for aquaculture development, which holds more relevance in reference to depleting aquatic resources and hence, need to be utilised through an ecosystem approach for human as well as environmental wellbeing. The role of village ponds in aquaculture development can be estimated from the database available in respect to some states of the country. In Punjab, out of total 11,268 aquaculture ponds (16,226 ha)[19], about 78% are village ponds (8,794), while private ponds are 2,474 constituting only 22%. However, only 60% of the existing village ponds in Punjab have been brought under aquaculture so far. In Haryana, 10,000 farmers are engaged in aquaculture covering 18,975 ha area (18,000 units), where more than 80% (15,550) of existing village ponds has been utilised[20], while number of private ponds is only 2,500. However, aquaculture development in village or community ponds has not been promoted to its actual potential due to various social and political issues.

Major concerns

- Food safety concerns due to the presence of potential contaminants (pollutants) in village ponds such as domestic sewage discharge, visiting cattle and pesticide entry with runoff from catchment areas, including agriculture fields.

- Low aquaculture productivity due to poor water quality, with special reference to organic pollution/load, biological oxygen demand, pH, dissolved oxygen and ammonia levels.

- Culture of hardy banned exotic fish, Thai magur (*Clarias gariepinus*) in polluted village ponds, owing to non-suitability for carp culture practices.

- Thai magur has not only spread its tentacles in the village ponds, but it has also escaped into the rivers, posing serious ecological threats to the indigenous aquatic biodiversity. In Uttar Pradesh and Uttrakhand, C. gariepinus has been reported to have invaded into the Ganga, Yamuna, Ramgamaga, Gomti, Sai, Tamsa, Sone, Baigul, Nakatia, Hindon, Kali, Gerua, Sharda and Dewa rivers by National Bureau of Fish Genetic Resources, Lucknow[21,22]. It is also seen as a big ecological threat for the native fish species inhabiting natural waters of Punjab and Haryana. Most recently, about 700 kg of Thai magur seed consignment to Punjab State from Kolkata (West Bengal) was seized and destroyed in the month of March, 2019 by the State Fisheries Department in district Patiala. As per various scientific reports, Thai magur has been reported in rivers of Punjab as well[23,24,25]. It indicates that the problem is already deep rooted and hence, need to be addressed in a 'mission mode'.

Action plan

- **Database generation:** Documentation of village ponds in each state, including number, area, utility status, water quality in respect to potential contaminants (physical, chemical and biological) and biosafety for designing village pond development plans.

- **Rural aquaculture development program:** To promote aquaculture in village/community ponds, with a 'triple mission':

  - **Resource conservation and optimised utilisation:** For economic gains through aquaculture (pollution control and reuse).

  - **Employment:** Generation of livelihoods.

  - **Food security and safety**.

- **Utility Services:** Water testing, bioremediation model development, consultancy/ technical guidance and capacity building (training/skill development) programs for farmers/youth/entrepreneurs/officials/scientists/gram panchayats for promoting healthy aquaculture practices in village ponds.

- **National surveillance program:** For monitoring pollution levels and aquaculture activities in village ponds.

Aquaculture in village ponds through scientific management will also help in expansion of the sector without exerting any additional pressure on depleting multiple use land and water resources. The said mission will not only improve water quality of village ponds (enhanced aquaculture productivity and food safety), but also make them suitable for carp/pangas catfish culture and check proliferation of Thai magur, besides generating livelihood/employment opportunities for the

Polluted village ponds in Punjab, India.

Thai magur, Clarias gariepinus.

rural youth and communities. An energy saving eco-friendly 'bio-remediation technology' can enhance productivity of village ponds by 2-3 t/ha/yr. A duckweed based bioremediation ("phytoremediation") model is available, which has been tested successfully by GADVASU with dual benefit of wastewater remediation for 'reuse' or 'recycling' and nutrient rich 'duckweed biomass' production (feed resource) for feeding animals, including fish, duck, chicken, pigs, goats etc. For this purpose, the village ponds need to be transformed from a waste dumping site to a potential aquaculture resource.

Inland saline water aquaculture

Inland saline water aquaculture in non-coastal northern states holds gigantic potential towards reclamation of salt affected, poor/zero earning waste lands, besides creating livelihood/employment opportunities and revenue generation through export earnings. Over 1,300 million hectare (mha) area across the world has been documented to be salt affected[26], which has hit agricultural output and consequentially the rural economy of many developing countries, including India. Out of total 6.74 mha salt affected areas (including coastal saline soils) in India distributed in 15 states and 13 agro-climatic regions[27,28,29], about 1.20 mha is present in non-coastal Indo-Gangetic plains (northern India) covering seven states, including Punjab (151,000 ha), Haryana (232,000 ha), Rajasthan (375,000 ha), Bihar (153,000 ha), Uttar Pradesh (137,000 ha), Madhya Pradesh (139,000 ha) and Jammu and Kashmir (17,000 ha). As per an estimate by ICAR-Central Soil Saline Research Institute, Karnal (Haryana), the salt affected area in India is expected to expand from 6.74 mha to 16.25 mha by 2050, which need to be managed scientifically for its optimised utilisation for food production and livelihood security.

Owing to R&D initiatives by GADVASU in Punjab and Regional Center of Central Institute of Fisheries Education (CIFE), ICAR in Haryana, inland saline water aquaculture technologies have been tested, validated, demonstrated, and adopted successfully in both the states[30,31,32, 33,34,35], under the Blue Revolution promotional schemes implemented by the state governments/state fisheries departments. In 2014, three farmers in Haryana started farming vannamei shrimp (*Litopenaeus vannamei*) successfully in 5 ha of salt affected area[19], which increased to 30 ha in 2015, 128 ha in 2017 and crossed 160 ha mark in 2018. About 250 ha salt affected waterlogged lands in southwest Punjab have also been converted into aquaculture farms in last five years, including fresh water carp culture in low saline areas (≤ 5 parts per thousand or ppt or g/l) and vannamei shrimp culture in medium to high saline areas (10-25 ppt). In Punjab, after the first pilot project on vannamei shrimp culture (0.4 ha) in 2014, area under shrimp farming increased to 15 ha in 2017, 92 ha in 2018, 140 ha in 2019[36]. Further, inspired by the success stories of Punjab and Haryana states, Rajasthan state is also following the footsteps, where area under shrimp farming increased from 3.5 ha in 2017 to 6 ha in 2018 and over 20 ha in 2019 (survey data, unpublished). During 2020, the COVID pandemic affected shrimp farming across the country due to its major dependence on USA and China for import of brood stock and marketing (export) of shrimp.

Owing to aquaculture development in inland salt affected areas, resource deficient farmers are now earning net profits of ₹ 1.0-1.25 lakh/ha/year through freshwater carp polyculture (catla, rohu, mrigal and common carp) and ₹ 800,000-1,000,000 /ha/crop of just four months through vannamei shrimp farming in their erstwhile zero earning waste lands. It has not only opened the much-needed window for self-employment/employment but has also increased the value of salt affected lands due to increased demand among progressive entrepreneurs/agencies for developing commercial shrimp industry in these states.

Shrimp farming is a well-developed industry in southern coastal states, where frozen shrimp accounts for 68.46% and 41.10% of total exports from India, in terms of value and quantity, respectively[37]. In the last five years, shrimp farming has also converted inland salt affected degraded lands of non-coastal states into an economic resource beyond imagination. Although, the winter period (November/December to February/March) restricts the shrimp culture period in northern region to 7-8 months, but still two crops of shrimp can be harvested between April to November (before the onset of winters), making it highly remunerative as compared to any other agriculture and livestock enterprise. However, for long term sustainable development of shrimp farming in inland saline areas, it is recommended to adopt a single crop concept (100-140 days) to facilitate complete drying of pond for its preparation for the next crop, without/minimised effluent/sludge disposal issues. As compared to carp farming, a low cost low risk crop, shrimp farming as a high cost high risk crop needs a very high capital investment, which limits its adoption to only big farmers possessing higher investment and risk-taking capacity. However, small farmers can also establish shrimp farms with one time start up financial assistance from state/central government. Income from the first crop will be sufficient to generate a revolving fund for the subsequent crop, ultimately transforming the small farmers into bigger progressive farmers with every crop they harvest.

Shrimp, being an export commodity, can play a significant role in revenue and employment generation. Shrimp farming in 40 ha of salt affected areas in northern India will produce about 400 t of shrimp (1 crop/yr, with average productivity of 10 t/ha) worth ₹ 10-16 Cr., depending on the market value (₹250-400/kg). In shrimp farming, backward (consultants, hatcheries, feed mills, pharmaceuticals etc.) and forward (processors, traders, exporters etc.) linkages have been estimated to create 4 jobs/t of shrimp produced[4], which means every 40 ha (400 t) of shrimp farms can support over 1,600 livelihoods. Presently, approximately 60,000 shrimp farmers are producing about 500,000 t of shrimp (tiger and vannamei shrimp) from 120,000 ha brackish water ponds in coastal states, where each farm employs 2-3 labourers during crop period, supporting the livelihood of 120,000-180,000 skilled/unskilled worksers directly and holding a potential of providing jobs to at least 2,200,000 workers in the shrimp industry, through backward and forward linkages. Likewise, utilisation of only 1% of existing salt affected lands in Punjab (1,510 ha), Haryana (2,320 ha) and Rajasthan (3,750 ha) for shrimp farming can produce about 75,000 t of shrimp (average productivity 10t/ha) and support about 300,000 livelihoods.

Major concerns

- Vannamei shrimp culture is a high-cost high risk intensive technology, hence, highly skilled manpower, stringent monitoring and high level bio-security is required.

- SPF (specific pathogen free) shrimp seed is to be air lifted from registered hatcheries located in far off coastal states, adding to seed cost, besides transportation hassles, mortality and delayed stocking.

- No shrimp feed industry in northern region; transportation adds extra cost to an already high feed cost.

- No cold chain facility and processing industry in the northern region, contributing to post-harvest losses and quality issues.

- International dependence for marketing (export) and no backup domestic market, leading to a marketing crisis, as recently witnessed in the case of COVID-19 international lock down and restrictions.

Conversion of inland salt affected waterlogged lands into aquaculture ponds by GADVASU Team.

- Unlike sea water, the salinity and composition of inland saline water varies with location, even within the same district. A requisite database is lacking for development of region-specific aquaculture practices in respect to species selection and water quality management.

- Effluent/sludge disposal issues causes social conflicts and environmental impact.

- Salinisation of soil/ underground water resources. In special reference to those areas where underground saline water available below the freshwater aquifer is extracted for shrimp farming activities.

Action plan

Recommendations

- **Cluster shrimp farming:** Cluster farming approaches under self help groups (SHGs), fish farmers producers originations (FFPOs), co-operatives or contractual farming are required to address the listed concerns.

- **Biosecurity and disease surveillance:** Shrimp farming needs to be promoted under strict biosecurity and surveillance (monitoring and reporting) to prevent any unforeseen loss due to disease outbreak.

- **Single crop concept:** For maintaining healthy pond conditions and optimised shrimp production levels, the concept of a single crop (100-140 days) per year is desired be adopted to facilitate complete drying of pond till cracking of bottom soil (oxidation) and preparation of pond (ploughing, levelling and dyke strengthening) for the next crop, so that environmental issues in respect to effluent/sludge disposal could also be addressed.

- **Food safety and quality assurance:** Farmer-level awareness and abidance to guidelines/best management practices (BMPs) is required for export quality shrimp production and sustained profitability.

- **Introduction of alternate species:** Some potential low-cost low-risk brackish water species need to be introduced in the region for sustainable development of inland saline water aquaculture, in special reference to small and marginal farmers.

Policies

- **Regional research cum training centers (RRTCs):** State level RRTCs are required for sustainable development of inland saline water aquaculture in each non-coastal/ northern state, after complete ecological mapping of salt affected areas (salinity and composition), through:

    - **R&D:** Development and dissemination of region-specific aquaculture technologies for marginal. small, medium and large farmers/entrepreneurs.

    - **Capacity building:** Training/skill development/experiential learning.

    - **Utility services:** Consultancy, technical hand holding, water testing, seed testing, disease diagnosis/health management, processing etc.

Freshwater carps harvested from low salinity (<5 ppt) ponds in Shajrana Village, Fazilka District, Punjab.

- **Regulatory governance:** Like coastal states, inland saline water aquaculture also needs to be regulated on the lines of the Coastal Aquaculture Authority of India, including registration and insurance of shrimp/aquaculture farms; biosecurity standards; BMPs; effluent/sludge disposal standards; impact assessment etc.

Shrimp farming in Punjab.

- **National aquaculture policy:** Public-private-community partnerships (PPCPs) involving shrimp farmers producers organisations are required to develop effective working linkages between coastal and non-coastal states under a national aquaculture policy, for ensured input supply (seed and feed) and marketing/processing/export support to northern states, subsequently leading to optimised utilisation of resources across regional borders.

- **Cold chain facilities and subsidised refrigerated transport vans:** Self-marketing support for domestic marketing, necessitates provision of cold chain facilities and refrigerated transport vehicles to shrimp farmers, to help them preserve and sell their produce at competitive rates for higher returns.

- **Processing cum export hub:** A regional 'processing cum export hub' is required to promote export industry for enhanced marketing/trading efficiency within the north-western region.

Development Initiatives

Recognising the socio-economic impacts of fisheries and its contribution in national economy, the Department of Animal Husbandry, Dairying and Fisheries under the Ministry of Agriculture and Farmers Welfare, was bifurcated to create a separate Department of Fisheries in 2019, as an impetus measure to drive the nation towards a sustainable 'Blue Revolution' plateau.

To evolve an integrated and comprehensive approach towards sustainable development of inland fisheries and aquaculture, that caters the needs of the states and national priorities, the Department of Fisheries proposed the National Inland Fisheries and Aquaculture Policy with the following vision and mission:

Vision

"Ecologically healthy, economically viable and socially inclusive, inland fisheries and aquaculture that generates gainful employment and economic prosperity."

Mission

"Inland fisheries and aquaculture resources are developed, managed, conserved and sustainably utilised for improving livelihoods, generating gainful employment, food and nutritional security, economic prosperity and wellbeing through appropriate strategies, and legislations, stakeholder's participation, public private and community partnership, market support, and strengthening research, extension and their linkages"

Further, a separate Fisheries and Aquaculture Infrastructure Development Fund (FIDF) was created, with an aim to boost fish production from both inland and marine fisheries sectors in India, so as to achieve the production target of 20 mt by 2022-23, at a sustainable growth rate of 8-9%, besides generating 950,000 lakh employment opportunities as per FIDF guidelines[8].

Most recently in May 2020, the Indian Government approved the scheme "Pradhan Mantri Matsya Sampada Yojana" under DOF to accelerate Blue Revolution through sustainable and responsible development of the fisheries sector in India, with an estimated investment of over ₹ 20,000 Cr. for a period of 5 year (2020-21 to 2024-25) in all states /union territories of the country, with following vision and objectives:

Vision

"Ecologically healthy, economically viable and socially inclusive fisheries sector that contributes towards economic prosperity and well-being of fishers and fish farmers and other stakeholders, food and nutritional security of the country in a sustainable and responsible manner."

Aim and objectives

- Harnessing of fisheries potential in a sustainable, responsible, inclusive and equitable manner.
- Enhancing fish production and productivity through expansion, intensification, diversification and productive utilisation of land and water.
- Modernisation and strengthening of value chain, post harvest management and quality improvement.
- Doubling of fisher and farmer incomes and generation of employment.
- Enhancing contribution to agricultural GVA and exports.
- Social, physical and economic security for fishers and fish farmers.
- Robust fisheries management and regulatory framework.

Shrimp farming in Rajasthan.

Shrimp farming in Haryana.

Conclusion

For overall development of aquaculture in north-western India, a holistic approach for its horizontal and vertical expansion in fresh water and inland saline resources needs to be taken up under a strategic plan. In this context, the listed issues need to be addressed at national level (beyond inter-state boundaries) under a national aquaculture network, for optimised utilisation of available resources/opportunities in every state to enhance food/nutritional security, employment/ livelihood opportunities and revenue generation, consequentially leading to national socio-economic opulence.

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Shrimp health: Online Consultation on Strategies for Hepatopancreatic Microsporidiosis caused by *Enterocytozoon hepatopenaei* (EHP)

NACA organised an Online Consultation on Strategies for Hepatopancreatic Microsporidiosis caused by *Enterocytozoon hepatopenaei* (EHP) from 9-10 February 2021 via Zoom. EHP is an important pathogen affecting shrimp health. The online consultation aimed to discuss the current status of EHP in the region, and to present recent innovations and currently recommended strategies of control, including information to give confidence that EHP cannot be spread via chilled or frozen export products prepared and packaged for human consumption.

Experiences from selected countries that have reported the presence of the disease were presented and discussed, including: monitoring, surveillance and reporting activities; recent and current research studies; problems and other issues/gaps in managing the disease especially at the farm level. Presentations included:

- History of hepatopancreatic microsporidiosis caused by *Enterocytozoon hepatopenaei* (Prof. Tim Flegel).
- Development of research tools for EHP pathogenesis and control (Dr. Kallaya Sritunyalucksana).
- Managing the hazard of *Enterocytozoon hepatopenaei* in shrimp farming through careful planning to optimize productivity (Dr. Celia Lavilla-Pitogo).
- Updates on EHP transmission route in shrimp and recommendations for its control in the farm (Dr. Diva Cano).
- Is the fungal pathogen EHP now the key health concern for Asian shrimp producers? (Dr. Andy Shinn).
- Country reports on the status of EHP, including from China, India, Indonesia, Malaysia, Myanmar, Philippines, Thailand, and Vietnam.

The consultation also discussed the possibility of forming a regional, real-time, cooperative EHP-control network.

Video recordings available on Youtube

Recordings of most presentations are available on NACA's Youtube channel. You can find the EHP playlist at:

http://bit.ly/shrimp-ehp

We would appreciate it if you would please consider liking and subscribing to the channel, which will be used to host technical presentations on aquaculture from future consultations and training courses.

Youtube is a new venture for NACA and we plan to experiment further with both audio and video format materials including lectures, interviews and educational materials over the course of the year.

NACA's Youtube channel can be found at:

http://bit.ly/enaca_org

Webinar: Pathogen Free: Non-infectious Diseases and Disorders of Aquatic Animals

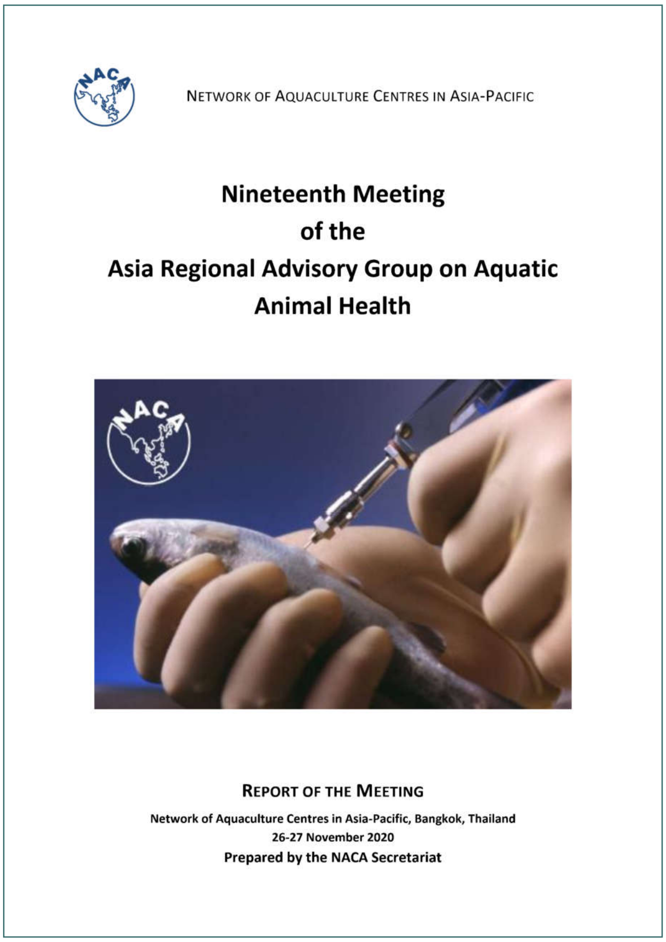
The fish Health Section of the Asian Fisheries Society will convene a webinar via Zoom on **21 April**, from 12:00 to 15:00 Bangkok time (GMT +7). Topics include:

- Stress-related non-infectious disorders in fish (Prof. George Iwama, Quest University, Canada).
- Nutritional diseases of aquatic animals Prof. Orapint Jintasataporn (Kasetsart University, Thailand)
- Harmful algal blooms and fish kills Prof. Lim Po Teen (University of Malaya)
- Aquaculture ecotoxicology Dr Roger Chong, CSIRO Australia).

Participation is free, but registration is required. To register your attendance, please scan the QR code below or visit:

http://bit.ly/pathogen-free

Report of the Nineteenth Meeting of the Asia Regional Advisory Group on Aquatic Animal Health



This report summarises the proceedings of the 19th meeting of the Advisory Group, held 26-27 November 2020 via video conference. The group's role includes reviewing disease trends and emerging threats in the region, identifying developments in global aquatic disease issues and standards, evaluating the Quarterly Aquatic Animal Disease Reporting Programme and providing guidance on regional strategies to improve aquatic animal health management. The group discussed:

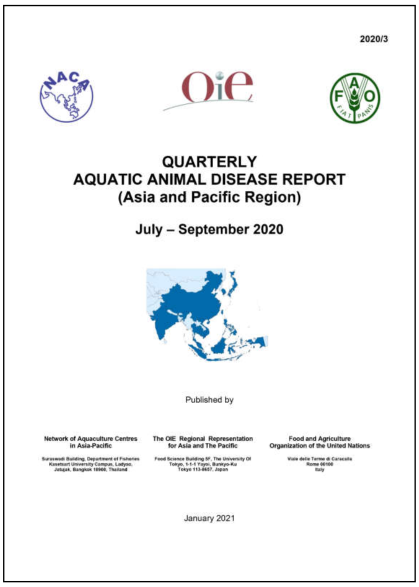
- Progress in NACA's Regional Aquatic Animal Health Programme.
- Updates from the OIE Aquatic animal Health Standards Commission.
- Updates on the Progressive Management Pathway for Improved Aquaculture Biosecurity.
- Updates on OIE Regional Collaboration Framework on Aquatic Animal Health.
- Emerging aquatic animal diseases and pathogens in the last decade in the Asia-Pacific region.

Updates on the Quarterly Aquatic Animal Disease Reporting System, including new functionality of the WAHIS system and regional disease list.

Members of the Advisory Group include invited aquatic animal disease experts in the region, representatives of the World Animal Health Organisation (OIE) and the Food and Agricultural Organization of the United Nations (FAO), collaborating regional organisations such as SEAFDEC Aquaculture Department (SEAFDEC AQD) and OIE-Regional Representation in Asia and the Pacific (OIE-RRAP), and the private sector. Download the report from:

https://enaca.org/?id=1147

Quarterly Aquatic Animal Disease Report, July-September 2020



The 87th edition of the Quarterly Aquatic Animal Disease Report contains information from fifteen governments. The foreword discusses the 19th Meeting of the Asia Regional Advisory Group on Aquatic Animal Health, held 26-27 November 2020. Download the report from:

https://enaca.org/?id=1144

2020 GLOBAL CONFERENCE ON AQUACULTURE

AQUACULTURE FOR FOOD AND SUSTAINABLE DEVELOPMENT

Registrations are open

Join us online from 22-27 September 2021. Participation in the conference is **free!** Please register your participation at the link below.

https://aquaculture2020.org/registration/

Submit a poster!

Participants are invited to submit abstracts for the poster session of the conference. Please note that a registration number is required in order to submit an abstract:

https://aquaculture2020.org/posters/

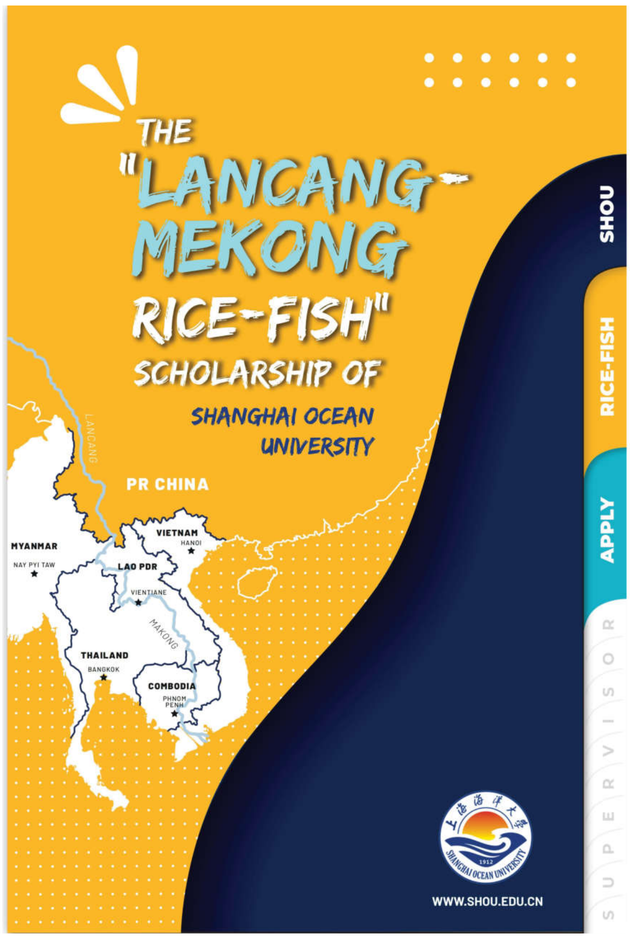
Scholarship opportunity: "Lancang-Mekong Rice-Fish" Program

Shanghai Ocean University is offering master and PhD scholarships for aquaculture and hydrobiology-related majors interested in studying rice-fish farming in the Lancang Mekong River area.

The scholarship programme is open to nationals of Myanmar, Cambodia, Lao PDR, Thailand and Vietnam who are less than 35 years old and have a bachelor degree with good academic record.

The scholarships include full tuition fee waiver, accommoda-tion, living allowance and medical insurance. Applications close **30 May 2021**. For more information, please download the brochure from:

https://enaca.org/?id=1148



International *Artemia* Aquaculture Consortium

Prof. Patrick Sorgeloos gave a presentation at FAO's FI Department Seminar Series on 27 January. A video recording of the seminar is available at:

http://bit.ly/artemia-consortium

Brine shrimp *Artemia* cysts are the critical live food source in the annual hatchery production of more than 100 billion crustacean post larvae and marine fish fry, a hatchery industry valued at more than 1 billion US$ responsible for the final production of over 10 million tonnes of high-value aquaculture species (e.g. shrimp, prawn, crab, bass, bream, grouper, flounder, milkfish).

At the first FAO Technical Conference on Aquaculture in 1976 the future use of *Artemia* as hatchery food was questioned because of its limited availability at that time from only 2 sources in the USA. Where annual world consumption of cysts was only a few 100 kgs in the 1970s it is now over 3,000 metric tons harvested from large salt lakes in North America and in Asia, and produced under controlled conditions (be it still in moderate quantities) in seasonal salt works in SE Asia.

As has happened with several lakes in the last decade, inland salt lakes are under constant threat to dry up and with climate change this situation could get worse in the future. With 90% of present *Artemia* harvested from inland salt lakes the future of the hatchery industry could be at risk and requires urgent attention.

In order to guarantee a more sustainable provision of *Artemia* for the still expanding hatchery industry several critical issues need to be addressed but also different opportunities could be better explored: e.g. conservation of *Artemia* biodiversity, use of science-based protocols (as developed for the Great Salt Lake in Utah, USA) for sustainable harvesting of wild sources (especially from salt lakes in Central Asia), socio-economic opportunities for integration of *Artemia* production as extra income in the many seasonal artisanal salt farms in Asia and Africa (locally available *Artemia* will facilitate new aquaculture developments), study of the possible impact of climate change on *Artemia* production both in inland lakes as well as coastal saltworks, development of new applications through strain selection and selective breeding (available *Artemia* genome), propagation of improved guidelines for its production and bio-secure use in aquaculture (updated *Artemia* manual, *Artemia* webinars), integration of this extractive *Artemia* farming with intensive fish/crustacean aquaculture, use of Artemia biomass as high-value protein ingredient in local human diets, among other possible improvements for the aquaculture sector.

An international interdisciplinary approach is needed to tackle these *Artemia* issues and opportunities, similar to the breakthrough in *Artemia* use in aquaculture following the FAO Kyoto conference as a result of the accomplishments of the “International Study on *Artemia*” in the period 1978-1997 by a multidisciplinary group of *Artemia* experts from Europe and the Americas. This resulted in the exploitation of several new natural resources (in Australia, Brazil, China, Ecuador, Iran, Russia and Venezuela), new techniques for the processing of *Artemia* cysts and its use in aquaculture hatcheries (*Artemia* Manual 1986, Live Food Manual 1991) and the setting up of seasonal *Artemia* production in coastal artisanal saltworks in Kenya, Mozambique, Peru, the Philippines, Sri Lanka, Thailand and Vietnam.

A recent inquiry revealed interest in establishing a new “International Artemia Aquaculture Consortium” from institutes and companies active with *Artemia* in Bangladesh, Belgium, Brazil, Cambodia, Chile, China, Ecuador, Greece, India, Indonesia, Iran, Kazakhstan, Kenya, Malaysia, Myanmar, Russia, Spain, Sri Lanka, South Africa, Sweden, Tanzania, Thailand, USA, Uganda, Uzbekistan and Vietnam. In this sense, the speaker wants to bring the issue in order to explore with FAO the best strategy to tackle these critical *Artemia* issues for the sustainable development of hatchery aquaculture as well as the new opportunities for food production and job creation.

About the speaker:

Patrick Sorgeloos has been involved in fish and shellfish larviculture R&D in Europe, Asia, Latin America and Africa ever since the mid-seventies. In 1978 he established the Artemia Reference Center and in 1986 he became the first professor of aquaculture at Ghent University in Belgium. Until his retirement as emeritus professor in October 2013 over 250 Master (from > 50 countries) and 70 PhD alumni (from > 20 countries) graduated at Ghent University in the field of aquaculture under his guidance. Patrick is a strong promoter of international networking in aquaculture and is still involved with the European Aquaculture Technology & Innovation Platform EATIP, the European Commission, FAO and the World Aquaculture Society. In 1983 he was co-founder of the spin off company Artemia Systems that is now operating under the name of INVE Aquaculture and belongs to Benchmark Holding. He received honorary awards in China, Egypt, Greece, India, Malaysia, Russia, Thailand, USA and Vietnam.

Network of Aquaculture Centres in Asia-Pacific

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