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AQUACULTURE ASIA

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Breeding snakehead

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AQUACULTURE ASIA

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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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What's it going to take?

I never really needed to be convinced of climate change. I was fortunate as an undergraduate studying geology and paleontology in the early 90's, to be taught by Professor Patrick De Deckker, who used microfossils and their chemical composition, among other things, to reconstruct historical climatic records and environmental changes. Professor Ken Campbell taught us invertebrate paleontology, and later vertebrates from the first fish on up, stepping through the evolutionary transitions and laying out extraordinary fossil specimens before us ("if you drop this, don't come back!"), with attendant climatic and environmental implications.

And we dug up plenty of evidence ourselves. On a field trip to the arid zone a fellow student whacked a rock open with their hammer, exposing a surface that hadn't seen the light of day for millions of years. We looked around us at the stunning, burning desolation of the desert as we marveled at the unmistakable leaves of a *Eucalyptus* tree, exquisitely preserved in the stone. There were many such moments.

At that time, the possibility of human-induced climate change was only just starting to enter the public awareness, although historical climate change was of course a long established fact amongst the scientific community. Not the "2 degrees" kind of climate change, but rather the wholesale *transformation of landscapes*, and of the biological communities that were part of them.

Thirty years later, now that we know so much more about the more near-term perils of climate change, it is extraordinarily frustrating that the issue still isn't being taken as seriously as it should be, including I am sad to say, by the aquaculture community. Yes it receives lip service now, but little more than that. Strategic consultations on aquaculture development are still being held that don't even have climate change on the agenda! When the issue is raised, it tends to be mentioned in passing, and almost always in the context of adaptation, as opposed to mitigation, as if any and all consequences that arise are going to be manageable.

Well let me tell you: They won't be. A study of the history of the Australian continent provides boundless examples of the impacts of climate change, and increasingly, so do present day observations. Who would have thought that it could get to 50 degrees in *Sydney*? Or that hail the size of *golf balls* could fall on Canberra? Or that the bushfires could be so intense that coastal communities would be driven onto the beaches because they had *nowhere else to go.* All within the last month.

Somewhat incredulously, the potential "benefits" of climate change to aquaculture production are also occasionally raised. The argument is that in some regions human-induced climate change will actually improve pond productivity or other local farming conditions. Perhaps there will be some such transitory "winners" (not my word), but I don't think people entertaining such thoughts have fully thought this through: What is the value of improved local aquaculture conditions in a world suffering from disruption of key crops (think feed supply), supply chains (think transport) and markets (think economic impact on consumers). And so on. Is the net global impact really going to be a positive one?

The effects of climate change, economic and otherwise, are going to impact every sector, directly or indirectly, and the combined effect will almost certainly be profound. Mitigation is the only viable adaptation strategy we have.

Simon Wilkinson

AQUACULTURE ASIA

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Mahseer sanctuaries of Meghalaya: A conservation and recreational perspective

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An adult red finned mahseer, Tor tor.

Meghalaya is one of the eight states of Northeast India encompassing an area of approximately 22,430 km^2. The state is considered as the wettest place on earth, experiencing an average annual rainfall as high as 12,000 mm, and therefore leading to the name Meghalaya, which means "the abode of clouds" in Sanskrit language. The state is bounded by Bangladesh on the south and west side and by the state of Assam in the north and east part. The state has a rich biodiversity in terms of flora and fauna due to varying climatic conditions and 70% of the state is covered by forest featuring high plateaus, gorgeous waterfalls, crystal clear river basins and their meandering rivulets and streams. These pristine water bodies provide ample scope for commercial fisheries in the state.

The indigenous tribes of Meghalaya viz., the Khasis, Garos and Jaintias, are skilled in fishing by various means for their consumption and recreation. But these also create the risk of over exploitation of natural resources and decline of entire fish populations. Therefore, to conserve the fish species in their natural conditions, the concept of establishing fish sanctuaries in the state was raised.

A sanctuary is a place of safety, a nature reserve where endangered and threatened species are cared for and fishing is prohibited. These sanctuaries have been established with an objective to preserve and enhance aquatic biodiversity, protect the fish species, preserve breeding and feeding grounds, restore declining stocks by artificial propagation and serve as a tourist attractions to benefit the local rural people and improve their livelihoods (MASM, Govt. of Meghalaya). In order to fulfil these objectives an array of initiatives has been taken in the form of awareness raising programs to encourage local people to conserve the local wari, now affirmed as fish sanctuaries, to protect the decreasing population of indigenous species. A total of 54 sanctuaries have been established since 2012 in Garo, Khasi and Jaintia hills of Meghalaya (Table 1) under the Meghalaya State Aquaculture Mission (MASM) project propagated by the Fish Farmers Development Agency. Funding is provided under the project to construct a view point for the sanctuary under the jurisdiction of the District Administration and Department of Fisheries.

Table 1: Distribution of mahseer sanctuaries in Meghalaya (data to July 2018).

Districts of Meghalaya	No. of sanctuaries
East Khasi hills	13
West Khasi hills	5
Jaintia hills	7
Ri-Bhoi	4
South Garo hills	12
East Garo hills	8
West Garo hills	5


Mahseer population in Nengmandalgre santuary.

Moreover, conservation measures are being undertaken by the Government of Meghalaya and NGOs to rekindle the mahseer stock in many of the river systems such as the Simsang and Ganol river routes. The mahseer stock of these sanctuaries are dominated by chocolate mahseer (*Neolissochilus hexagonolepis*), but some others such as golden mahseer (*Tor putitora*), red finned mahseer (*Tor tor*) are prevalent.

In this context, it will be worth mentioning herewith that the chocolate mahseer of family Cyprinidae is the pride species of Meghalaya and is widely recognised as a sport fish, apart from its food value. This fish is also rated as an ornamental fish in its juvenile stage. The flesh of chocolate mahseer is highly relished by the people of Meghalaya and Northeastern region of India due to its well flavored and nutritious nature. With a high n-3 poly unsaturated fatty acid (21%) and essential amino acid content (Sarma et al., 2013) chocolate mahseer is considered as a nutritive fish for human health. The species has gained the urgent attention of researchers and conservationist during the past 20 years due to its rapidly declining population. There are concerns about its reduced population due to anthropogenic pressures, pollution, unregulated and destructive fishing methods. As a result, chocolate mahseer was been declared as a “Near Threatened” species by IUCN in 2010.

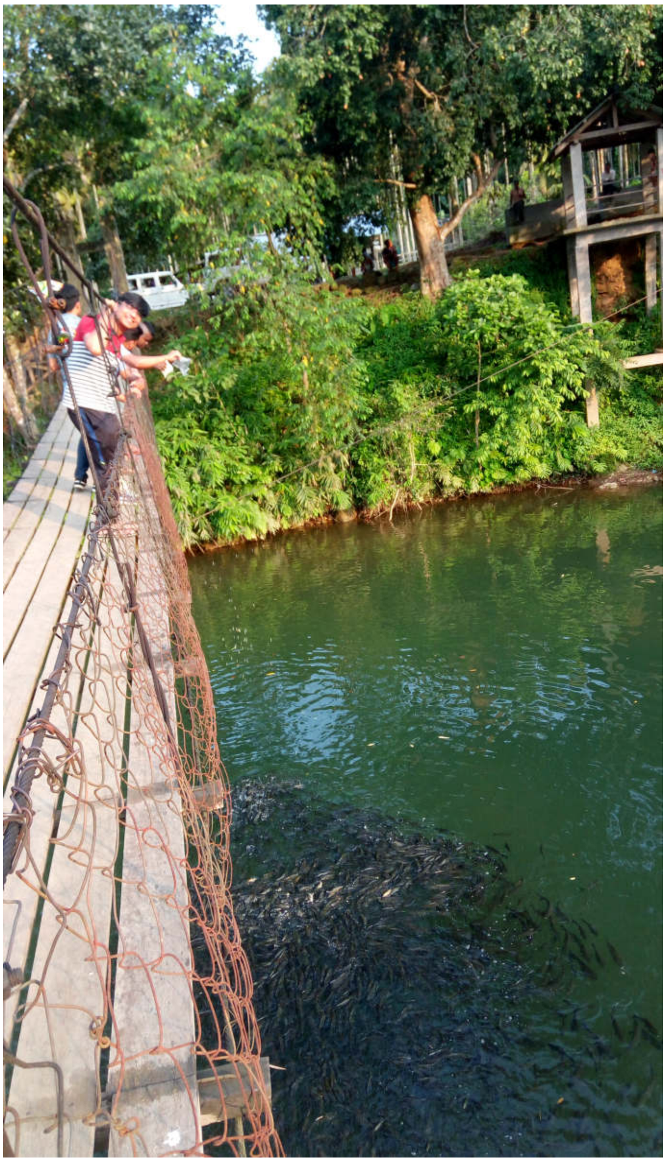
This article seeks to gather the available information regarding the present status of chocolate mahseer and the conservation measures been undertaken in the East Garo Hills of Meghalaya up until 2018. The information was collected by a team of scientists from ICAR-DCFR, Bhimtal by conducting field surveys of four fish sanctuaries in the East and West Garo Hills, namely Nengmandalgre, Rongsakgre, Bansamgre and Songkalwari-Rombagre with the co-operation and logistical support from the Deputy Commissioner and State Fisheries Officers of Willimnagar.

The sanctuaries attract tourists with their beautiful location, crystal clear water and the presence of thousands of chocolate mahseer. The fee for visiting a sanctuary is INR 5.00 per person in certain regions or is free. Each of these sanctuaries is maintained by the local villagers by electing a working President, Secretary and members for its care and management. The management practices inside a sanctuary include the feeding of fishes with puffed rice, ripe jack fruit and cleaning of the premises. Moreover, the management authority is also responsible for constituting strict rules for the conservation of the sanctuary which include a ban on fishing of any kind and heavy penalties and imprisonment for anyone found in violation of the rules. The penalty criteria differs from one sanctuary to another, for example in Nengmandalgre sanctuary the fine is levied to a poacher is INR 15,000, one cow and a bag of rice, whereas in Rombagre it is INR 10,000, a cow, a pig, a bag of rice and sugar. The villagers also catch the fish once in a year from areas nearby, but not in, the sanctuary sites. It was observed that the fish are not found or sold in the local markets. In certain places of the East Garo Hills namely Bangsangre, Somagre, Rongsogre and Samunda, the local people sell the fishes at a very high price of INR 1,000 per kg in their villages.

An adult chocolate mahseer.

Above: Nengmandalgre santaury, Williamnagar, Meghalaya. Below: Chocolate mahseer farm pond of of Mr Semburtush Momin at Rombagre.

The culture of chocolate mahseer is at a low level in the Garo Hills. People generally prefer to culture other carps such as rohu, common carp and catla, for which seeds are readily available round in the year in the neighbouring state of Assam. A very few farmers were seen to have adopted the farming of chocolate mahseer in the Garo Hills by collecting mahseer seed from the wild. The lack of seeds and of an established fish hatchery in the region is the major constraint for uptake of the culture of chocolate mahseer. Therefore, the culture practices of chocolate mahseer are not much popularised in the Garo Hills and thus the fishes are largely restricted to sanctuaries. However, modifications have been seen with the culture fisheries of mahseer in the rearing systems of Mr Semburtush Momin at Rombagre. This farmer has been cultivating the fish since 1973 in ponds near to the Simsang River in a flow through system. The ponds are supplied with a continuous flow of water over a gravelly bottom in order to simulate a natural river environment. The mahseer seed are either collected from the wild or self-recruit through natural spawning in the pond. The mahseer seeds are being cultivated with carp seeds in the same pond and the discharged water is drained to an integrated unit of rice culture with fishes. This shows a perfect example of water management as practiced by the farmers of Meghalaya.


View point of Nengmandalgre santuary.

Conclusion

Chocolate mahseer is a very popular, preferred and highly priced fish in the entire Northeast region of India. The major limitations for its successful commercialisation in the Himalayan region are the lack of seed availability, infrastructure facilities with adequate water flow and the availability of low cost feed. Investigations on developing protocols for the captive propagation of this species have been carried out over the past years to obtain better knowledge on spawning biology, ecological aspects and behavior in its natural habitat. This resulted in the development of seed production and hatchery technology of the species using gravid brooders from the wild. The initiative of ICAR-Directorate of Coldwater Fisheries Research, Bhimtal has opened avenues for the possibility of culture of chocolate mahseer in pond systems, offering a potential opportunity to strengthen the aquaculture production. A hatchery has been established at Tura, West Garo Hills District, Meghalaya, for continuous seed production and ready supply to the fish farmers of the state.

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Impacts of climate change on aquaculture in Vietnam: A review of local knowledge

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Traditional sea cage.

The aquaculture industry in Vietnam plays an important role in both food production and employment. Vietnam is the 4th largest aquaculture producer in the world after China, India, and Indonesia and in 2016 contributed 4.5% of the world's total production[1]. The majority of Vietnam's aquaculture production occurs at the small, or familial scale. Of the 2.4 million households that are involved in aquaculture, 75% of them have farms that are less than 2 ha in area and 90% are less than 3 ha[2]. The small-scale nature of Vietnam's aquaculture sector makes it particularly vulnerable to the unpredictable and changing weather patterns brought on by climate change.

According to Germanwatch's Global Climate Risk Index, Vietnam is in the top ten countries most affected by climate change. In 2017 they were ranked 6th in the world[3]. This ranking is based on combined socio-economic and extreme weather event data spanning over a 20-year period. The index value indicates a country's level of vulnerability and exposure to extreme events[3,4]. A combination of geographic and social factors makes Vietnam especially vulnerable to climate change. Vietnam has a vast coastline which exposes it to typhoons and flooding. Additionally, 20% of Vietnam's total area falls within a low elevation coastal zone, a coastal area with an elevation of 10m or less. 55% of the country's population live within these areas[5]. As sea levels rise, low lying areas will become increasingly affected by flooding and saltwater intrusion. Vietnam's socio-economic situation also make it particularly vulnerable to climate change impacts. Vietnam is a quickly developing country, but there are still many low-income areas. Low-income earners will be most impacted by climate change as they do not have the monetary resources available to adapt.

Farmers are at the frontlines of experiencing climate change as their livelihoods are intrinsically linked with the natural environment. Weather patterns and external natural inputs are all important factors in the success of their crops. Therefore, they observe and monitor environmental trends closely so that they can adjust their practices when necessary.

Aquaculture farmers in Vietnam are especially vulnerable to change. Sea cage farms are located offshore where they are exposed to storms, while shrimp farms are often located in low lying areas that are impacted by rising sea levels.

Aquaculture farmers are experiencing the impacts of climate change firsthand. Therefore, our study aims to collect and summarise local knowledge of aquaculture farmers living in South Central Vietnam. We visited sea cage, hatchery, and shrimp farms throughout Khanh Hoa and surrounding provinces to interview farmers and aquaculture experts. We also had the opportunity to meet with several shrimp farmers from the Mekong delta. The purpose of the interviews was to gather firsthand knowledge on current climate change impacts experienced by farmers, as well as which climate change threats they are most concerned about, and how they are adapting to these threats. We hope that the experiences and knowledge of aquaculture farmers presented in this paper can be used by other farmers who are seeking strategies to similar climate impacts, and for aquaculture researchers to better understand the current threats facing farmers.

Major climate change threats

The biggest climate change threats identified by interviewed farmers are an increased intensity of storms, warming temperatures, and reduced weather predictability. These threats are already impacting farmers and their effects are only expected to worsen.

Storms

An increasing intensity of storms was a concern shared by all interviewed farmers. Farmers have noticed that in recent years storms are causing more and more damage to their facilities resulting in higher repair costs. Storms are damaging farm infrastructure such as roofs, pond walls, and cages. They also cause power outages which impact a farmer's ability to oxygenate the water and can lead to fish/shrimp mortality. Typhoons are a particularly frightening threat for farmers as they are unpredictable, result in major damages, and there is very little that can be done to protect against them.

In 2017, Vietnam was affected by the typhoon Damrey which hit the Khanh Hoa province the hardest resulting in hundreds of millions of dollars in damage. Khanh Hoa is the province where most interviewed farmers live. Every shrimp and hatchery farmer interviewed reported extensive damage to their farms while all sea cage farms in the area were entirely wiped out by this typhoon. Prior to 2017, the area had not experienced a typhoon in over a decade. Farmers had grown accustomed to not having to check the weather or worry about major storms. Since 2017, farmers watch the weather carefully and most have some form of a plan in place for future typhoons and major storms.

Sea cage farms are the most vulnerable to typhoons since their offshore location leaves them unprotected from storms. A typhoon will destroy a sea cage farm's infrastructure. Therefore, the typhoon plans put in place by farmers are focused on salvaging stock rather than protecting infrastructure. Several interviewed farmers said that they have in land aquaculture

Feeding cobia.

Shrimp nursery.

ponds where they can move their brood stock to in the case of major storms. Others opt to harvest their stocks early. Some farmers have decided to transition from the traditional wood/bamboo sea cage structure to the Scandinavian style plastic cages that can better withstand storms. The cost differential however is massive with the traditional cage set up costing around US$50,000 and a plastic cage costing around a million. One sea cage farmer, Mr. Hung, pointed out that a plastic sea cage is still likely to be severely damaged in a storm by the debris from neighbouring wooden cages.

Warming temperatures

For farmers, the biggest impact of warming temperatures on aquaculture production is the increased prevalence of disease. The interviewed farmers all expressed concern over the increasing disease rates in their stocks and they contributed it to the warming and changing environment. Every living species has a tolerance range for abiotic environmental conditions. This means that there is a maximum and a minimum temperature that each fish or shrimp species can tolerate. With warming temperatures, many aquaculture species are living at, or near the maximum end of their range. This creates stress and makes them more susceptible to disease. Mr. Vinh, a hatchery owner, said that he has noticed a significant reduction in cobia (*Rachycentron canadum*) survival. 5 years ago, if cobia reached 2 kg their survival was almost 100%. Now he is finding mortality in cobia that are larger than 2 kg. He has also found that pompanos have become harder to cultivate as they are becoming increasingly sensitive to disease.

Living in stressful environmental conditions can also reduce an organism's ability to reproduce successfully. Farmers are worried that in the future they may no longer be able to farm some staple native species. For example, Mr Hung said that some species can only breed in the winter when the water temperature drops below 23 degrees. With the cold season becoming shorter, the water may eventually be too warm for these species to fertilise successfully.

Reduced predictability of weather

Climate change is resulting not only in warmer temperatures in Vietnam but is also causing shifts in weather patterns. Farmers are observing the impacts of reduced weather stability in many ways. Droughts and heavy rain periods have become harder to predict. They are occurring during abnormal times of the year and with greater intensity. Shrimp farmers are finding that this is making it more difficult to maintain good water quality. Large rainfalls reduce their ponds salinity while drought increases it. Mr Hung, a farmer with sea cages said that large rain events are also impacting his operations. His cages are located in a closed bay, so the inland run off into the bay reduces salinity levels and delivers inland pollutants to the sea.

Many farmers have also noticed a shift in the seasons. They say that over the past few years the divide between the wet and dry season is becoming less distinct. Weather patterns that used to only occur during the dry season are now happening during the wet season and vice versa. Farmers have observed that the wet season is becoming shorter. This

Table 1. Summary of impacts to aquaculture farmers resulting from climate change threats.

System	Increased storm intensities	Increased temperatures and temperature anomalies	Rainfall anomalies and droughts	Rising water levels
Hatcheries	Damage to infrastructure Electricity outages. Reduced demand from customers.	Increased disease occurrence.	Flooding.	Flooding.
Sea cages	Damaged infrastructure, especially vulnerable to typhoons. Lost fish stocks from ripped nets.	Increased fish mortality Reduced spawning and fertilisation success. Increased prevalence and reduced predictability of disease.	Increased rainfall resulting in inland pollutant transfer and reduced salinity.	Increased inland pollutant transfer.
Shrimp farms	Damage to infrastructure. Electricity outages stopping pumps and water oxygenation equipment. Increased rainfall reducing the salinity of ponds.	Increased prevalence and reduced predictability of disease. Reduced ability to maintain consistent pond temp and salinity levels.	Large rainfalls reduce the salinity of shrimp ponds. Droughts reduce ability to maintain consistent salinity levels.	Flooding results in damaged infrastruc-ture and escaped stock. Increased soil salinisation from infiltration.

Table 2. Summary of climate change adaptation strategies applied by aquaculture farmers.

System	Increased typhoon frequency and severity	Inconsistent and rising temperatures	Unpredictable weather patterns / seasons	Increased disease and mortality
Hatcheries	Stronger roofs / sandbagging roofs. Backup generator stored up high.	Reduce stocking densities.	Monitor weather and water quality. Reduce stocking densities.	Reduce stocking densities. Manage feeding to reduce feed pollution. Apply permitted antibiotics.
Sea cages	Monitor weather. Move brood stock to an inland pond facility.	Move cages to open ocean. Increase depth of cages.	Monitor weather closely. Change to more tolerant species. Shift farming season.	Wash nets with fresh water often. Reduce stocking densities. Harvest early. Change to more tolerant or faster growing species. Apply permitted antibiotics.
Shrimp farms	Monitor weather. Sand bag roofs. Cover ponds. Harvest early.	Rear juvenile shrimp in covered ponds. Shift to indoor ponds.	Closely monitor water quality. Shift farming season.	Apply Biofloc systems. Transition to a multi-trophic polyculture system. Apply natural prophylactic remedies. Use high quality seed. Apply permitted antibiotics.

is particularly problematic for farmers practicing integrated rice-shrimp farming as the wet season is becoming too short for many rice varieties.

Another major impact of unpredictable weather is that diseases are becoming less predictable. A common trend between interviews was that farmers are finding it increasingly difficult to manage for disease. Farmers are finding that diseases that used to only occur during specific seasons or at certain points in an organism's lifecycle are now occurring year-round and during all life cycle stages. Mr Vo, a Mekong shrimp farmer, has noticed that early mortality syndrome (EMS) has become much less predictable. Within the last three years he has found EMS to occur year-round and during all shrimp life stages, before EMS had specific and expected periods where it was a problem.

Adaptation strategies

Farmers are already implementing adaptation strategies for current climate change impacts as well as devising future strategies. These strategies are based on government recommendations, information acquired at local training sessions, knowledge from university educations, and personal experience.

Infrastructural adaptations

Farmers are making structural changes to adapt to climate change impacts. They are finding that building deeper ponds and sea cages is an effective way to protect against warmer temperatures and to mediate temperature swings. Farmers with more monetary resources are considering shifting their farming practices indoors to protect against unpredictable weather. This however is not a feasible option for smaller scale farmers. Most of the shrimp farmers interviewed said that they have started using covered nurseries to help shrimp adapt to the warmer temperatures. Juvenile shrimp spend their first 25 days in a covered pond where they are protected from the heat. This gives them a chance to gain strength before they are moved to the exposed ponds. One problem that farmers are finding with this method is that the shrimp juveniles reared in these covered nurseries have softer shells then those reared in uncovered ponds.

Mixed farming methods

A transition to mixed farming methods could help farmers adapt to climate change impacts by reducing their reliance on external water inputs and diversifying their income. Systems such as biofloc and integrated rice-shrimp farming are already widely applied by farmers in Vietnam while multi-trophic polycultures such as algae-shrimp or tilapia-shrimp polycultures are still uncommon[6]. These systems rely on natural nutrient cycling to recycle aquaculture waste products. They allow farmers to recycle the water in their systems, reducing the risk of bringing in disease and pollutants from external sources. Farming multiple species provides a backup source of income to farmers. If one crop fails, they still have another crop to sell.

Mr Dung, an engineering specialist at a medium scale shrimp farm, explained to us the biofloc system his farm implemented in 2010. They combine the biofloc mixture with water and molasses to grow the bacteria. This mixture is then added to the shrimp ponds where the bacteria consume the waste produced by the shrimp. Along with the biofloc bacteria mixture, Mr Dung adds natural prophylactic ingredients to help prevent gastrointestinal diseases. He adds a combination of fermented green banana, garlic, and ha chau plant (*Phyllanthus urinaria*) to the ponds. He estimates that since the farm implemented the biofloc system, shrimp survival rates have increased from 50% to between 70-90%.

Multitrophic aquaculture systems are mixed farming methods based on natural nutrient and waste cycling between trophic levels. In an algae-shrimp polyculture, wastewater from the shrimp ponds is cycled through ponds containing algae. The algae consume the waste produced by the shrimp which purifies the water. This water can then be cycled back into the shrimp ponds. Species from additional trophic levels can be added to create a more complex polyculture. For example, tilapia can be added to filter feed organic waste materials and will provide an alternate income source for the farmer[6].

Integrated rice-shrimp systems are common in the Mekong region. Shrimp are farmed during the dry season and rice is grown during the wet season. This method of mixed farming provides a year-round source of income. Mr Vo, a shrimp farmer in the Mekong delta, has been practicing integrated rice shrimp farming for twelve years. He believes that maintaining an integrated system is crucial for farm health especially with climate change. In his experience, a successful rice crop will mean a healthy shrimp crop. Recently however, maintaining this system has become more difficult for him. There has been an increased intrusion of saltwater from sea level rise and flooding that is causing the soil to become more saline. He has also noticed that the wet season is becoming shorter. This has forced him to change his practices to farm

Above, below: Growing biofloc.

short season rice species. He is concerned that as weather patterns continue to change, he may run out of ways to adapt to climate change.

Collaboration

As climate change threats worsen, collaboration and collective action between farmers in Vietnam's aquaculture industry will become increasingly important. Many of the threats facing farmers extend past the farm and sectoral level and are impacting aquaculture farmers in multiple regions and across sectors. Working as a collective to share information and devise strategies for managing common threats will be key in protecting livelihoods. Collaboration gives farmers the opportunity to learn which techniques are working well or are not working well for fellow farmers and how they can apply successful techniques to their own farms. Current collaboration efforts are organised formally through government

Hatchery produced pompano seed.

created farmer's associations, while our interviews tell us that farmers are also choosing to collaborate informally with their neighbours and colleagues.

Our interviews show polarisation between the willingness of farmers to collaborate. Some farmers were entirely opposed to collaboration because they consider other farmers to be their competitors while others said that they are already sharing ideas and techniques between farms. All farmers interviewed however agreed that government organised information sessions are a useful way for them to learn about new technology and adaptation strategies.

Conclusions and recommendations

The information gathered during the interview process demonstrates that across multiple areas of aquaculture, farmers are aware of the changes occurring, contribute them to climate change, and are applying adaptation strategies. This was true for farmers from all educational backgrounds. We also found a high level of consensus between farmers as to what the biggest threats they face are and which adaptation strategies they are applying. Farmers agreed that the increasing intensity of storms along with the increasingly unpredictable weather are having the biggest impacts on their farming practices. Farmers across various sectors said that they are monitoring the weather much more closely, reducing their stocking densities, and building deeper ponds or cages to adapt to changing temperatures.

As a result of climate change, farmers are faced with higher management costs and increased risk. When making adaptation decisions they must consider the trade off between money and risk. For example, some farmers are choosing to harvest their crops early to reduce the risk of losing their crops to disease or storms. By doing this they are accepting a lower income as the fish or shrimp will be smaller, but they are eliminating the chance that they lose everything. A similar trade off situation exists with hatchery production. Rising temperatures are resulting in increased disease occurrence. In order to prevent disease outbreaks, hatchery farmers are reducing their stocking densities. Lower stocking densities means less profit, but also a reduced chance of losing a stock to disease.

Vietnam's aquaculture industry, especially small-scale producers, relies heavily on external environmental inputs and weather patterns. This forces farmers to be aware of environmental changes as they can have major impacts on their livelihoods. Farmers are at the forefront of experiencing and reacting to change. Therefore, gathering the experiential knowledge of farmers is important when developing new climate change adaptation strategies. Successful plans will require open communication between government, farmers, and researchers in order to develop plans that are both feasible and meet the current needs of farmers. We also recommend that future adaptation plans focus on the needs of small-scale aquaculture producers since they are the majority and the most vulnerable to climate change impacts.

This study demonstrates that aquaculture farmers in Vietnam have a breadth of valuable climate change knowledge. They have first-hand experience with current climate change threats impacting their industry and insight into successful adaptation strategies. As one of the top ten countries most impacted by climate change, the threats facing Vietnam's aquaculture industry will likely worsen. This will severely impact the industries ability to produce enough fish and seafood to feed demands and impact farmer's abilities to make a living. The experiential knowledge of farmers is an important tool that should not be undervalued when making decision about how the industry can adapt to climate change.

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Water quality monitoring test kits.

Simple means of water aeration adopted by progressive fish breeders in West Bengal, India

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Importance of aeration of hatchery water

In India, West Bengal is the leading state in hatchery-based seed production (spawn, fry, advanced fry) of major carps and other economically important freshwater fishes. Dissolved oxygen is the most critical parameter of water quality and basic necessity in fish hatcheries, nursery and grow-out ponds. Hatchery fish seed production can be limited by the dissolved oxygen content of circulating water. Progressive fish breeders in villages of West Bengal have overcome and eliminated this problem by designing simple but effective means of water aeration to improve dissolved oxygen in hatchery water supplies, maximising survival of fertilised eggs, hatchlings and spawn.

Often water supply to overhead storage tanks are arranged by pumping water from an open well or deep tube-well first into a small pond and subsequently lifting it up into the tank. Underground water drawn up via bore wells or submersible pump contains little or no dissolved oxygen, so fish breeders have adopted conventional aeration systems to add dissolved oxygen. Fertilised eggs require dissolved oxygen for embryonic development and the concentration plays an important role on the percentage hatching, incubation time and survival of spawn[1]. Dissolved oxygen levels in hatchery ponds is normally lower in summer months, thus its aeration becomes much more necessary.

Involvement of indigenous technical knowledge

The simple but effective means of water aerating devices described in this article may be attributed to indigenous technological knowledge and skill possessed by elderly, experienced and progressive fish breeders in rural West Bengal and is a glaring instance of farmers' innovation. Traditional knowledge of farmers is applied in the development of both fish seed and table-sized fish production using low-cost inputs. Such practices are low-cost, more profitable and sustainable. An indigenous method of oxygenisation of shallow tube well water with condemned pipes for use in hatchery pond has been adopted by ManikHira Fish Production Group at North 24 Parganas District, West Bengal; a simple mechanical process adopted with efficiency. In the context of rural aquaculture, I have attempted to make indigenous technical knowledge of important aspect of fish seed production such as hatchery water aeration widely known and evident. Genuine information has been gathered through personal on-site conversation with ten fish breeders in West Bengal.

Dissolved oxygen management in Indian major carp hatchery

Overhead tank water

In West Bengal, depletion or deficiency of dissolved oxygen in carp hatcheries is arrested by fish farmers through indigenous and traditional methods and adaptations using local materials. State awardee fish breeder-cum-farmer Sri Bijoy Roy at Kalna-I Block, Purba Bardhaman District positioned four large rectangular perforated tray-like structures of approximate dimension 1.60 m x 0.80 m in a stack separated by 0.45 m gaps, around 1 m above the upper rim of the concrete overhead tank. Groundwater for supply to the hatchery is drawn out and lifted up to the topmost rectangular tray; passing down through holes in each, and in the process acquiring oxygen from the air. The water is finally poured down into the tank, enriching the contents with dissolved oxygen. Such water is considerably improved for the hatched and growing larvae (till spawn stage) of Indian major carps in each of circular concrete egg incubation-cum-hatching chambers.

In ponds from where water is pumped and stored in overhead tanks, a system similar to the above-mentioned device may be constructed in shallow areas. Three circular baskets made from halved-bamboo, some 1.5 m in diameter and 0.6 m high may be positioned one above another, keeping 1.2 m height in between bottom-most basket and pond water level. Groundwater is supplied over topmost basket with a 10 cm diameter hose pipe.

Cascade aerator above overhead tank.

Aeration of broodstock ponds

In earthen broodstock ponds, and in ponds (800-3,200 m^2) from where water is to be supplied to overhead tanks, fish breeders like Sri Tapan Maity at Kakdwip Block, South 24 Parganas District; Sri Jibananda Singha at Kushmandi Block, Dakshin Dinajpur District; and Sri Jiban Ch. Ghosh at Madarihat Block, Alipurduar District and others use simple splashing-type surface aerators that are kept operative continuously for sufficient duration in phases. Water is drawn up from pond and a hose pipe or nozzle of a portable pump machine shoots out water with high velocity over the surface from the pond embankment, facilitating the entry of atmospheric oxygen into the water column. It is done twice a week in the brooder pond.

Water pump machine flushing water in IMC broodstock pond.

National awardee fish breeder Sri Babul Majumdar at Barrackpore-I Block, North 24 Parganas District, makes use of long pieces of thermoplastic pipe having 7.6-10.2 mm inner diameter or rubber hose pipe to pour water over the pond surface from a height of 5.5-6.0 m at points 4.5-5.0 m from pond periphery towards the centre. Horizontally-positioned bamboo poles high above the pond act as supporting structures for the pipes to carry water, underneath which the pipes run. Two stout bamboo poles support the open end of the horizontally-placed bamboo as well as that of pipe. These upright poles are buried in the pond bottom at one end, secured together, crossed over each other and fastened near the upper end. It is at this junction where the open end of the horizontally-positioned bamboo pole rests. The mouth of the water supply pipe over such a structure takes the form of a 'T', thus water flow is divided and poured down from openings facing opposite directions.

Elderly fish breeder Sri Bimal Biswas at Barrackpore-I Block uses metallic window wire mesh rolled into cylindrical structure to aerate his broodstock pond, nursery and rearing ponds. It is positioned hanging down at one side of the pond 0.8 m over water surface and water from a flexible PVC hose pipe of 7.5-10.0 cm diameter is poured over the structure forcibly. As the water collides with the wire mesh and disperses, oxygenation is enhanced.

Aeration of pond water by Sri B. Majumdar.

Cylindrical metallic wire mesh used by Sri B. Biswas.

Sprinkler system in Indian major carp egg incubation pool

In Chinese type egg incubation-cum-hatching pools, fertilised eggs of major carps and subsequently developing hatchlings are kept in incessant circular motion in the outer chamber. In such conditions, white PVC pipes of 18-24 mm inner diameter and 0.6-0.8 m in length are used with small drilled holes to act as a sprinkler system to enhance oxygenation of the water. For the convenience of developing embryos and hatchlings, water is sprayed out from several holes and poured over the surface of the outer chamber as small drops. Two such sprinklers are positioned over each egg incubation-cum-hatching chamber at diametrically opposite ends. Water is sprayed continuously for 72 hours until the spawn are ready for stocking in ponds.

As an alternative to PVC pipes, fish breeders use showerheads as sprinklers to maintain optimum dissolved oxygen content in water where the fertilised eggs of carps and subsequently hatchlings are maintained. The preferred position is the top of the curved outer wall of egg incubation pools. A richly oxygenated environment in egg incubation chambers accelerates development of fish embryos[2]. Here, if

Showerheads in operation in egg incubation cum hatching pool.

PVC pipes as aeration device, used by Sri L. Barman.

particles like liberated egg shells are kept moving in water in the presence of oxygen, their decomposition will be aerobic and by-products will not be harmful for the growing hatchlings.

Shower system in Indian major carp breeding pool

Reputed fish breeder Sri Shyamacharan Chatterjee at Chinsurah-Mogra Block, Hooghly District has installed overhead circular perforated metallic water supply pipeline 2 m above the top level of a circular breeding pool; having a diameter smaller than that of the breeding pool. It is used for aerating water during conditioning of male and female brood fishes separately inside hapa net enclosures prior to injection and also during the latency period of injected brooders till mating and release of gametes. Water is gravity fed from several deliberately-made leak points on the pipeline. Dissolved oxygen in the breeding pool can be increased by providing such a shower or artificial water dispersal device.

In north Bengal, state awardee fish breeder Sri Lakshmikanta Barman of Mathabhanga-I Block, Coochbehar District, uses an 8 m long PVC pipe of 7.6 cm diameter in a Chinese-style breeding pool, which connects two opposite ends of the pool. Tiny perforations are made over it at intervals of 25-30 cm. Water when supplied ejects through the perforations and enriches the dissolved oxygen content of pool water.

Overhead circular metallic pipeline used by Sri S.C. Chatterjee.

Dissolved oxygen management in *Clarius batrachus* hatchery

In order to maintain fertilised eggs of the indigenous catfish *C. batrachus* under well-aerated conditions in dug-out, rectangular, tarpaulin sheet-lined earthen enclosures with 12-15 cm depth, experienced catfish breeder Sri Sayer Mohammad Sarkar at Gazole Block, Malda District uses a PVC pipe 2.50-3.25 cm in diameter and 1.5 m in length, having 10-12 drilled holes fixed at one end of the enclosure along its width, 30 cm above the bottom. This functions as a water sprinkler in egg incubation-cum-hatching chambers. Through a perforated pipe, water is sprayed evenly over the surface of the chamber. It is kept operative for 24-26 hours during the incubation period and even after hatching. The sprinkling of water over evenly-spread fertilised eggs through the perforated PVC pipe is essential for oxygenation and to maintain the water temperature in enclosures between 27-30°C. It also prevents fungal attacks on *C. batrachus* eggs.

Perforated thin PVC pipe aerating water in C. batrachus egg incubation chamber.

National awardee fish breeder Sri Dipak Roy at Habibpur Block, Malda District uses empty transparent mineral water bottles of 1-2 litre capacity with 22-24 syringe needle-made

Perforated mineral water bottle used in C. batrachus brooder tank.

linear perforations made on one side of plastic body. One such device is used in each of his ten rectangular concrete catfish broodstock rearing cisterns separately holding *C. batrachus, Ompak pabda*, *Mystus vittatus* and *Mystus cavasius.* Such sprinkler aerators are also used in rectangular larvae and fry rearing cisterns/tanks. Water enters into the bottles from metallic water pipelines permanently fitted on outer wall of cisterns via flexible rubber tubes or pipes, whose diameter corresponds with the mouth of bottle.

At the *C. batrachus* hatchery of Joygopalpur Gram Vikash Kendra at Basanti Block, South 24 Parganas District, discarded plastic 250-300 ml coconut hair oil bottles with several perforations made on the base surface are used as water sprinklers to aerate water of *C. batrachus* fry (18-24 mm) rearing trays. A PVC hose suction pipe connected to main metallic pipeline is used to supply water into bottle forcibly, whose diameter (24-36 mm) corresponds to the mouth diameter of bottle.

Coconut oil bottle used as sprinkler in C. batrachus fry rearing trays.

Pump machine flushing out water in C. batrachus broodstock pond.

Epilogue

In both major carp and *C. batrachus* earthen broodstock ponds, progressive and elderly fish breeders in West Bengal make adequate arrangements to sprinkle or splash water on the surface to increase dissolved oxygen level and at the same time lower the temperature. In both broodstock and nursery ponds, dissolved oxygen is not allowed to go down below 3 ppm. The methods adopted and in practice have low operational and maintenance cost. As discussed, such simple water aerating devices, an established component of ‘village science’, are a product of indigenous technical knowledge and local pathways to success. These fish breeders are experienced and progressive but not resource rich and mostly live in distant villages; their contribution to healthy fish seed production and progress of freshwater fish culture in West Bengal has been well and truly significant.

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Breeding striped snakehead (*Channa striata*) using the concrete tank method in the Cangkringan Area, Special Region of Yogyakarta

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The striped snakehead (*Channa striata*) is a species of swamp fish that has a high economic value. To fulfill the increasing demand for striped snakeheads, the intensity of the capture of this fish in the wild has also increased. Intensive fishing has reduced the wild populations of striped snakehead.

In Indonesia, especially in Sumatra, Kalimantan, and Java, the striped snakehead has many uses, both economically and for health purposes. Initially, the striped snakehead was known as a pest or predator that feeds on small fish living in freshwater and brackish water such as in swamps or channels. Today, the striped snakehead is known as a food fish and an ornamental fish.

The striped snakehead is a nutritious species that can be utilised as a source of antioxidants and contains around 25.2 g of protein per 100 g of flesh.

Efforts to domesticate the striped snakehead from the wild in a controlled environment (aquaculture) have been conducted. The striped snakehead can live in waters poor in oxygen. This is advantageous in the culture of striped snakeheads.

In China, the striped snakehead has been cultured in large numbers using styrofoam boxes for spawning with a male to female ratio of 1:1. The fertilised eggs are then transferred to concrete ponds filled with zooplankton. After the hatchlings are 3-5 cm long, they are fed pellets.

Having biological and economic advantages, the striped snakehead is suitable for breeding and producing seed that are ready to be released to the wild as an effort to conserve fish resources and increase the natural population. In addition, striped snakehead seed from hatcheries can be used in controlled aquaculture businesses.

Below we describe a protocol we used for controlled spawning and hatchery operations for striped snakehead.

Fish fecundity is determined using the gravimetric method with the following equation:

$$F = \frac{Bg}{Bs} \times Fs$$

Where:

F = Total number of eggs
Bg = Weight of the entire gonad (g)
Bs = Weight of a small part of the gonad (g)
Fs = The number of eggs in part of the gonad

Fecundity is related to the fish's body length and weight using regression analysis.

To determine the fertilisation rate of the fish eggs, the following equation is used:

$$FR\ (\%) = \frac{Po}{P} \times 100\%$$

Where:

FR = Egg fertilisation rate (%)
P = Number of egg samples
Po = Number of fertilised eggs

The hatching rate (HR) is affected by the egg movement, temperature change, light intensity, and dissolved oxygen. The equation used to calculate the hatching rate is:

$$HR = \frac{\text{The number of eggs hatched}}{\text{The number of eggs fertilised}} \times 100\%$$

Growth rate can be calculated using the following equation:

$$GR = \frac{Wt - Wo}{t}$$

Where:

GR = Growth rate (g/day)
Wt = Final average weight (g)
Wo = Initial average weight (g)
t = Maintenance duration (days)

The specific growth rate can be calculated using the following equation:

$$SGR = \frac{(\ln Wt - \ln Wo)}{t} \times 100\%$$

Where:

SGR = Percentage of average weight (% g/day)
Wt = Final average weight (g)
Wo = Initial average weight (g)
t = Maintenance duration (days)

The survival rate can be calculated using the following equation:

$$SR = \frac{Nt}{No} x100\%$$

SR = The fish's survival rate (%)
Nt = The number of fish at the end of the study (individuals)
No = The number of fish at the beginning of the study (individuals)

The breeding technique of striped snakehead included a few processes. Broodfish were maintained in a permanent pond of 3 x 3 x 1 m. Pond preparation prior to stocking included draining, cleaning, rinsing, and filling it with water. The pond was cleaned by brushing the walls and floor to dislodge dirt, algae, and feed debris on the pond walls.

The pond was filled with aquatic plants such as water hyacinths to emulate the fish's natural habitat. The broodfish released in the ponds were at least 8-12 months old and weighed 150-200 g/individual.

The process of producing high-quality striped snakehead seed begins with high-quality broodfish. One of the factors that affect broodfish quality is feed. The type of feed given to the striped snakehead broodfish was artificial feed in the shape of 4 mm pellets. The nutritional content of the feed for striped snakehead broodfish can be seen in Table 1.

The striped snakehead broodfish were fed twice a day, once in the morning at 8 AM and once in the afternoon at 3 PM. However, the feeding frequency in the semi-intensive and intensive culture systems is 4 - 6 times a day. This is done to provide a greater opportunity for the fish to feed at any time of the day, and thus ensure that their nutritional needs are always fulfilled.

Because maintaining feed quality is very important, feed must be stored properly. Properly stored feed will not easily get moldy. In Cangkringan, the fish feed was stored in a

feed warehouse. The feed sacks were neatly stacked using wooden boards as the base. This was done to prevent mold from growing on the feed, especially during the rainy season when the floor was damp. Feed must be stored in a dry condition with low moisture content (10-12%) to prevent the growth of mold. In the storage area, the feed sacks must be placed on a base to prevent direct contact with the floor. As a base, wooden girders of 10 x 10 cm size can be used at an interval of 10 – 20 cm. Wooden boards are then placed on the base to provide a space between the stack of feed sacks and the floor. If there are any damaged feed sacks, they must be placed on the outer part of the stack so that they are used first.

Another factor that influences fish survival is water quality. The water quality does not need to be checked daily; once a month is sufficient. However, the water needs to be monitored daily. The water quality parameters that need to be checked include the pH, temperature, salinity, and dissolved oxygen.

The results of the water quality parameter measurements in the broodfish striped snakehead raising ponds can be seen in Table 2.

Spawning ponds were prepared by draining and drying. The ponds need to be completely dried to minimise the presence of pests and diseases in the pond. After the ponds had been dried out, they were filled with water to the depth of 40 cm, planted with water hyacinth to provide a place for the striped snakehead eggs to attach and to emulate the fish's natural habitat, and had pieces of pipe were placed in them to provide a place for the fish to hide.

Selection of male and female broodfish is the determining factor of the spawning success because high-quality seed are produced by high-quality broodfish. The broodfish to be spawned were at least 10-12 months old and weighed at least 150-200 g/individual. The broodfish selected to be spawned were also healthy, with no wounds or defects, exhibited lively movements, and were gonad-mature.

In the wild, striped snakehead spawning occurs at the beginning of the rainy season. After the water level slowly rises, striped snakehead will spawn by building a nest near water hyacinths in the perimeter of shallow waters with a weak current. Striped snakehead spawning can occur 2-3 times in a single spawning season and even occurs at the end of the rainy season. Out of several reproductive parameters observed, it was found that the change in water depth had a strong correlation with the egg diameter.

Natural spawning was conducted in concrete ponds of 3 x 3 x 1 m^3 size. Before being placed in the pond, the male and female broodfish were weighed to determine the initial weight before spawning and final weight after spawning. The data for male and female broodfish weight before and after spawning can be seen in Table 3.

The natural striped snakehead spawning was done at a ratio of 1:1 based on the number of fish in each pond. After they were placed in the pond, the fish were left to spawn on their own. Once the eggs were laid, the broodfish were not immediately moved to the broodfish maintenance pond because striped snakeheads will look after their eggs until they hatch. Striped snakehead eggs float on the surface of the water, so to determine whether the fish have spawned, the ponds were monitored daily. Spawning occurs at night and begins with chasing between the male broodfish and the female broodfish. This is followed by the female broodfish turning around while releasing the eggs and at the same time the male releases its sperm. The process will be repeated several times until all the eggs are released. The following morning, the fertilised eggs will be translucent and the unfertilised eggs colored. The fertilised eggs will hatch in 48 hours with aeration.

Fecundity is the broodfish's ability to produce eggs based on the fish's weight. The method for determining the striped snakehead broodfish fecundity was by weighing the broodfish before and after the spawning and calculating the difference. After that, 100 eggs were collected as a sample, weighed, and the average calculated. The equation for calculating the fecundity of striped snakeheads can be seen below. Before spawning, the weight of the female fish was 640 g, after spawning it was 620 g, while the male's weight remained 500 g.

The female gonad weight : 20 g

$$F= \frac{\text{Gonad weight}}{\text{Average egg weight}}$$

$$F= \frac{20}{0.002}$$

= 10,000 eggs

So the fecundity of the striped snakehead was around 10,000 eggs.

Table 1. The nutritional content of broodfish feed.

Nutrient	Percentage(%)
Protein	44-46
Fat	Min 12.0
Crude fibre	Max 3.0
Ash	Max 15.0
Moisture	Max 11.0

Table 2. Water quality parameter measurements in the broodfish raising ponds.

Parameter	Result	Optimum range
Dissolved oxygen	2.8 ppm	>3 ppm
Temperature	29.9°C	26-28°C
pH	8.3	4-9

Table 3. Weight of male and female broodfish before and after spawning.

Broodfish	Before spawning (g)	After spawning (g)	Gonad weight (g)
Male	500	-	-
Female	660	640	20

Table 4. The characteristics of fertilised and unfertilised eggs.

Fertilised egg	Unfertilised egg
The egg cell begins to divide into two cells	The egg remains a single cell
The egg is bright yellow, and then the egg cell will divide	The egg is opaque white and dead
Two cells divide into four and so forth until the egg hatches	
The egg is translucent	

Table 5. The nutritional content of powdered feed.

Nutrient	Amount (%)
Protein (min)	43
Calcium (min-max)	1.5-2.5
Phosphorous (min-max)	1.5-2.0
Amino acids (min)	2.6
Total fat (min-max)	5-10

Source: feed packaging.

Table 6. The results of water quality measurements in the first stage nursery.

Parameter	Amount	Optimum range
Dissolved oxygen	2.4 ppm	2.0-3.7 ppm
Temperature (C)	30.50C	25.50 - 32.70
pH	8.3	4-9

The fecundity of each female individual depends on the age, size, species, and environmental condition (availability of feed, water temperature, and season). Fecundity is influenced by feed, fish size, and environmental condition, and could also be affected by egg diameter. Striped snakehead broodfish weighed 60-640 g and had a fecundity of around 1,100-16,500 eggs and had a gonad weight range of 1.15-21.4 g.

After the fecundity was calculated, the egg fertilisation rate was calculated. For this, a sample of 100 striped snakehead eggs was collected randomly. From the sample collected, the number of fertilised eggs was 92 and the unfertilised eggs 8. Therefore, the number of fertilised eggs was estimated to be 9,200. The characteristics of fertilised and unfertilised eggs can be seen in Table 4.

Striped snakehead eggs were hatched in the 3 x 3 x 1 m spawning pond. The percentage of hatched eggs was 94%; therefore, the number of hatchlings was around 8,600. The fecundity of striped snakehead usually ranges between 1,000 and 57,000 eggs.

The survival rate of the larvae reared for one week was calculated by comparing the number of live fish larvae at the end of the rearing period to the number of the fish larvae that hatched. The calculation was done when the larvae were about to be released into the first stage nursery pond. The larvae harvesting was conducted in the morning by collecting the larvae using a fine scoop net and placing them in a bucket then counting the harvest results manually. The number of larvae harvested was 8,129 with an SR of 93.9%.

The purpose of the nursery is to raise the newly hatched striped snakehead larvae that have used up all their yolk in the yolk sac in ponds to obtain striped snakeheads that are ready to become prospective broodfish. The nursery phase is usually divided into two sub-phases: first stage nursery and second stage nursery.

The first stage nursery of the striped snakehead was conducted in a semi-permanent pond sized 10 x 5 m with a depth of 1.5 m. The first stage nursery medium preparation began with pond draining, application of lime, fertilisation, and refilling.

Feed management in the nursery phase is very important because it is needed to guarantee that the striped snakeheads receive adequate nutrients for their growth. On the first day, the larvae were not fed because they still have food stored as egg yolk. After two days, the larvae were given additional feed in the form of tubifex worms for two weeks, providing feed around the clock. The worms were first weighed and then observation was conducted to determine how many days it took to finish the worms to determine how many worms were needed by the striped snakehead larvae during the rearing period. After the larvae entered the color-change phase from yellow to black, they were fed powdered artificial feed and after 3 weeks, when the larvae became seed, they were fed pellets. Feeding additional artificial feed is difficult because striped snakeheads are predominantly carnivorous and require special treatment during feeding. The nutritional content of the powdered feed can be seen in Table 5.

The larvae were fed twice a day manually by sprinkling the feed around the periphery of the pond so that the feed was evenly distributed. The feed was given using the ad libitum method. Before the feed was given, it was first weighed to determine the amount of feed consumed daily and to reduce the possibility of wastage. The remaining feed was weighed afterward.

In the first nursery phase, the water quality was not checked daily but instead it was done once a month because striped snakehead can survive in less than optimum water conditions. The water quality parameters measured included dissolved oxygen, salinity, temperature, and pH. The results of the water quality measurements in the first stage nursery phase can be seen in Table 6.

Sampling was conducted to determine the average growth in terms of length and weight. Sampling was done once a week to determine the striped snakehead seed's growth. Samples were collected using a wooden lift net because this species is easily stressed, necessitating careful and gentle handling. The number of fish observed at each sampling was 10 individuals. The measurements taken were the weight using a digital scale and the total length using a ruler.

The larval growth rate in this study was 0.019 g/day. This was higher than the results in the study by Astria et al. (2013) which was 0.0063-0.0072 g/day

The specific growth rate (SGR) or specific daily growth rate is defined as the change in the fish's weight, size, and volume. The SGR during this study was 15%.

In the cultured of striped snakeheads in ponds, the main source of pests in the nursery ponds is the water source which may bring in wild fish, freshwater mussels and crabs, whereas pests that come from land are snakes and frogs. To prevent the entry of fish and crabs when filling the ponds with water, a filter was fastened to the pond inlet. There were no special treatments for pests; they were removed manually during harvest.

The first stage nursery activity lasted 45 days with an initial stock of 8,129 hatchlings. After the seed were 45 days old, they were harvested and moved to the second stage nursery to grow into fingerlings. The harvest was conducted in the morning by draining the water in the pond. The striped snakehead seed were then herded toward the pond outlet. The seed in the outlet were quickly collected using a fine-meshed scoop net and placed in a bucket.

The total harvest of the striped snakeheads from first nursery was 3,112, which means the survival rate of the seed was 38%, which was suspected to reflect a degree of cannibalism.

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Join us for the aquaculture event of the decade!

2020 GLOBAL CONFERENCE ON AQUACULTURE
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Farmed fish and plants have been contributing for a long time to healthy diets, poverty alleviation and rural development, but it is only recently that aquaculture has grown to be the leading source of aquatic food and is expected to meet the expanding dietary demands of all people, while also meeting the food security needs of the poorest. As such, aquaculture's role in the global food system becomes increasingly relevant as the world community strives to achieve the Sustainable Development Goals.

In order to accelerate the growth and ensure the sustainability of future aquaculture, FAO and NACA with the Chinese Ministry of Agriculture and Rural Affairs invite governments, business, academia and civil society to discuss the theme "Aquaculture for Food and Sustainable Development".

Specifically, the Conference will:

- Review status, trends and emerging issues in aquaculture development;
- Identify opportunities and challenges in aquaculture and its contributions to sustainable development;
- Evaluate the progress of aquaculture development in light of previously recommended strategies and policies at regional and global level; and
- Build consensus on priorities and actions needed for advancing aquaculture as a global, sustainable and competitive food production sector.

The conference features a forward-looking agenda that addresses emerging issues and opportunities, ranging from traditional family farming to cutting-edge enterprises. Themes will cover issues such as:

- Climate and environment: Climate smart aquaculture and improved environmental performance.
- Science, innovation and investment: Research and resources for new technology, training and upscaling.
- Gender and social equity: Towards equity, inclusiveness and empowerment of rural communities.
- Health and risk management: Better management practices, contingency planning and alternatives to antimicrobials.
- Education and training: Improving skills, empowering youth and building capacity for industry.
- Partnerships, policy and governance: Working together to create an enabling environment for sustainable aquaculture.

The full programme will be available shortly from the conference website.

https://aquaculture2020.org

18th Meeting of the Asia Regional Advisory Group on Aquatic Animal Health

The Advisory Group (AG) is a body of technical experts that meets annually to provide advice to NACA member governments on aquatic animal health management. The group is drawn from academia, the private sector and government.

The role of the AG is to review disease trends in the region, identify emerging threats and developments in global aquatic disease issues and standards, evaluate the Quarterly Aquatic Animal Disease Reporting Programme operated by NACA/FAO/OIE and regional governments, and to provide guidance on strategies to improve aquatic animal health management.

This year's meeting took place from 18-19 November at the Amari Don Muang Airport Hotel in Bangkok. Opening remarks were delivered by Dr Huang Jie, Director General of NACA, and with a progress report given by Dr Eduardo Leano, Coordinator of NACA's Aquatic Animal Health Programme. The meeting discussion included:

- Outcomes of recommendations from OIE General Session and the Aquatic Animal Health Standards Commission (Dr Ingo Ernst, AAHSC, OIE).
- Updates on FAO initiatives in Asia-Pacific in support of aquatic animal health management (Mr Weimin Miao, FAO-RAP).
- Biosecurity in Aquaculture: Progressive Management Pathway for Aquaculture Biosecurity (PMP/AB) (Dr Jie Huang, NACA).
- Updates and emerging threats on finfishes: Diagnosis, management and prevention (Dr Siow Foong Chang, SFA, Singapore).
- Updates and emerging threats on crustaceans: Diagnosis, management and prevention (Prof. Tim Flegel, Centex Shrimp, Thailand).
- Updates on other diseases (molluscs and amphibians): diagnosis, management and prevention (Dr Andy Shinn, Fish Vet Group, Thailand).
- Activities of the Fish Health Section, SEAFDEC Aquaculture Department, Philippines (Dr Eleonor Tendencia, SEAFDEC AQD).
- Update from OIE-Regional Representation in Asia and the Pacific (Dr Jing Wang, OIE-Tokyo).
- Activities of the Aquatic Animal Health Research and Development Division, Thailand (Dr Thitiporn Laoprasert, AAHRDD).
- Activities of the Australian Department of Agriculture and Water Resources (Dr Ingo Ernst, DAWR-Australia).
- Aquatic animal health activities of China (Dr Chenxu Cai, MoA-PR China).
- Activities of the Norwegian Veterinary Institute, Norway (Dr Saraya Tavornpanich, NVI).
- A Special Session on Regional Aquatic Animal Health Management Activities of the Private Sector was held, featuring presentations by PHARMAQ (Zoetis)-Asia (Dr Kjetil Fyrand), and Fish Vet Group Asia (Dr Andy Shinn).

With regards to disease reporting, discussions were held on:

- SHIV: Status and updates including change of name to DIV1 (Dr Liu Hong, GAC, China).
- QAAD Reporting: Status and updates (Dr Eduardo Leaño, NACA).
- New OIE Disease List and revisions to the QAAD List for 2018 (Dr Ingo Ernst, AAHSC, OIE).

Participating experts in the 18th Advisory Group meeting.

New Director General of the Department of Fisheries, Thailand

Khun Mesak Pakdeekong (centre) commenced duties as the new Director General of the Department of Fisheries on 1 October 2019, accompanied here during a courtesy visit by Dr Huang Jie, Director General of NACA (left) and Dr Chumnarn Pongsri, former Deputy Director General of DOF and now Advisor, right.

Thailand holds National Sea Bass Fair

The Thailand Department of Fisheries organised a Seabass Fair from 25-26 December, in their office complex at Kasetsart University, in front of the Bangkok Aquarium. The fair was held to promote public awareness of Thai seabass products, produced according to good manufacturing practices.

Due to recent low price seabass prices against a strong Baht and trend of increasing imports from neighbouring countries, the Department of Fisheries and other agencies and stakeholder organisations such as the Ministry of Commerce departments of Internal Trade and International Trade Promotion, the Thai Frozen Food Association and Thai Union Group Public Company Limited had met to discuss solutions, of which the Seabass Fair was one, with several additional promotional events planned.

The Seabass Fair showcased high quality, domestically produced seabass and seabass products produced following Good Aquaculture Practices (GAP) standards developed by the Department of Fisheries. Products included fresh whole and large-sized fish, fillets and belly cuts, and processed products and meals. The fair also included demonstrations by celebrity chefs and cooking competitions.

Tuskfish CMS 2.0 is available

NACA is pleased to announce that the first production release of Tuskfish CMS 2 is available. Tuskfish 2 is a rewrite of Tuskfish CMS to adopt a strict model-view-viewmodel (+ controller) architecture with a front end controller and a static router to allow custom URL schemes. Tuskfish is the software that underpins the NACA website.

Additional changes since the beta release include:

- Added a GPS track content type - upload a .kml or .kmz file to automatically generate a Google Map with a route of your travel, or a polygon (requires a Google Maps API key, but could be adapted to support other mapping services with minimal effort).
- Added the ability to dynamically assign themes, templates and layout files, reducing the need to clone entire template sets (just create alternative layout or template files), to improve flexibility in presentation.
- Optional two-factor authentication via Yubikey hardware security tokens has been updated to support Yubicloud protocol V2 (V1 is officially deprecated).

PHP 7.2 or higher is required. Documentation (installation, user and developer manuals) will follow soon. Please note that Tuskfish 1 will not be developed further (forks are welcome); however, it remains a fast and reliable system, and it is somewhat easier to configure due to its simpler architecture.

Tuskfish 2 is open source software distributed under the GNU General Public License Version 2. Download it from:

https://github.com/crushdepth/tuskfish2/releases/

Regional consultations on strengthening aquaculture governance and demographic changes in fishing communities

Participants in the aquaculture governance and demographic change consultations.

Two consultations were held back to back in Thailand from 5-7 November, namely the *Consultation on Strengthening Governance of Aquaculture for Sustainable Development in Asia-Pacific* and the *Consultation on Demographic Changes in Fishing Communities in Asia*. The consultations were held at the Centara Grand Hotel at Ladprao, Bangkok. The consultations were attended by 29 participants from 15 countries in the Asia-Pacific region. The consultations were jointly organised by FAO and NACA.

Aquaculture governance

The rapid development of aquaculture in Asia is only a recent phenomenon of the past a few decades, and the industry is relatively new, with governance of the sector still evolving in many Asian countries in terms of both development of a legislative framework and enforcement of same. Good governance is fundamental and crucially important to tackle many of the issues that impair sustainable development of aquaculture, such as negative environmental impacts, low efficiency of resource utilisation, disease and food safety.

With the increasing world population and improving living standard as the result of overall economic growth, it is estimated that an additional 30 million tonnes of food fish has to be produced by 2030 to meet the increasing consumption demand. With most wild fish stocks fully or over exploited, aquaculture growth will be the major means of meeting increasing demand for food fish. However, it will be very difficult to achieve sustainable growth of aquaculture without improving the governance.

The 35th Session of Asia-Pacific Fishery Commission has identified the lack of effective governance as a major threat to sustainable aquaculture growth for greater contribution to achievement of the Sustainable Development Goals on ending poverty and hunger and achieving food security and improved nutrition. The commission recommended to FAO that it is timely needed to conduct a regional assessment on existing laws and regulations governing aquaculture and their enforcement in the region and a regional consultation on strengthening the governance of aquaculture.

The consultation and related country review studies were therefore proposed by FAO and jointly implemented by FAO and NACA in collaboration with member governments. The objectives of the consultation were to:

- Share the results of country studies on aquaculture governance in respective countries.
- Identify gaps, issues and challenges in aquaculture governance.
- Recommend strategies and actions to improve and strengthen aquaculture governance.

The consultation featured technical presentations from seven countries, namely Cambodia, China, India, Indonesia, Malaysia, Thailand and Vietnam. Audio recordings of the presentations are available for download or streaming from the NACA website at:

https://enaca.org/?id=1072

Demographic changes in fishing communities

During the recently held 7th Global Symposium on Gender in Aquaculture and Fisheries, a presentation from Japan focused on the decreasing number of fishers and fish workers in fishing communities, both men and women, as well as the ageing population in these communities. The presentation also showed that the rate of ageing in fishing communities is higher than that of the national average. This presentation brought to the fore one of the least studied subject in fisheries, ie. the demographic changes in fishing communities and the implications these may have on the future of fishing, fisheries, the fishing industry, and social development of fishing communities.

In ASEAN Member States, it is projected that by 2035, the percentage of the population over 60 years old will be 21 percent in Brunei Darussalam; 12 percent in Cambodia; 15 percent in Indonesia; 9 percent in Lao PDR; 16 percent in Malaysia; 15 percent in Myanmar; 11 percent in the Philippines; 34 percent in Singapore; 30 percent in Thailand; and 20 percent in Vietnam. Cambodia will have a young and growing population whereas Thailand will have an ageing population. A few case studies were therefore carried out to look at demographic changes in small-scale fishing communities in Cambodia and Thailand in 2019 to understand potential implications on fisheries sustainability, migration patterns, climate change adaptation, and livelihoods diversification. The studies explored the general question: How are demographic changes affecting fishing communities? Specifically the studies tried to answer the following questions:

- What are the changes in demography (ageing, migration) in fishing communities?
- How are fishers adjusting their livelihoods with the changes in fishery resources as well as labour availability? Are they diversifying to other livelihoods?
- What are the consequences of these adaptation strategies? Are there any gender differences in the impact of such adaptation strategies?
- What are challenges faced and policy and program support needed for fishing communities for sustainable small-scale fisheries?

The objectives of the meeting were to:

- Share the results from a literature review and demographic studies in Thailand and Cambodia, and demographic situations in other countries in the region.
- Identify the opportunities and threats in fishing communities under rapid demographic changes.
- Recommend strategies and actions to prepare fishing communities to adjust to the demographic changes.

The consultation featured presentations from eight countries, namely Bangladesh, Cambodia, India, Indonesia, Myanmar, Philippines, Sri Lanka and Thailand.

Network of Aquaculture Centres in Asia-Pacific

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NACA is a network composed of 19 member governments in the Asia-Pacific Region.

INFOFISH World Shrimp Conference and Exposition

Shrimp 2019 was held in Bangkok, Thailand from 12-14 November, jointly organised by INFOFISH, the Thai Department of Fisheries, NACA and the Thai Shrimp Association. The conference provided a forum for publicising shrimp farming technology, production standards, harvesting, and processing products, as well as related trade and investment. Over 200 participants attended from all regions of the world.

The theme of the conference was “Modelling for Sustainability”. A special opening address was given by His Excellency, The Hon. Semi Koroilavesau, Minister for Fisheries, Fiji, who spoke about the need to address climate change, IUU fishing, and the potential for aquaculture to offset pressure on wild fisheries, food security and import substitution. Ms Shirlene Maria Anthonysamy, Director of INFOFISH, and Mr Thaworn Jirasophonrak, Deputy DG of the Thai DOF, gave opening remarks.

Mr Robins McIntosh, Executive Vice President, Charoen Pokphand Foods Public Company Ltd gave a keynote address “Modelling the Shrimp Industry Towards Sustainability”, in which he discussed the establishment of sustainable practices that both reduced costs and improved the reliability of shrimp farming.

NACA staff Dr Yuan Derun, Coordinator of Sustainable Farming Systems and Training programmes, spoke on Ecological approaches to better sustainability of shrimp culture in China. Dr Eduardo Leano Coordinator NACA’s Aquatic Animal Health Programme spoke on Biosecurity in shrimp aquaculture.