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Indigenous technical knowledge in aquaculture sector: A literature review

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Abstract
A review of literature was conducted to bring together information available on the indigenous practices followed by aqua farmers in various parts of the world. The information was grouped under the different steps of aquaculture starting from site selection for pond construction to fish health management. In addition, aquaculture practices based on indigenous knowledge like the periphyton-based aquaculture and various integrations of aquaculture are discussed.

Keywords: Aquaculture, Traditional practice, Fish breeding, Fish feeding, Integrated aquaculture

1. Introduction
Aquaculture remained as the fastest-growing food production sector in the last decade. Asia has been the center of aquaculture production for decades and currently, more than 90 percent of the total aquaculture production comes from Asian countries, China being the biggest producer in the world [1]. Interestingly, more than 70 percent of the total aquaculture production comes from small-scale farmers, who are also the major contributors of small-scale innovations and adaptations of aquaculture technologies. In many countries of the world, the adaptation of indigenous technologies has resulted in the development of sustainable and environmentally friendly aquaculture practices and hence helped the farmers to increase aquaculture production during the past decade [2, 3]. In this paper, we have attempted to enlist some of the indigenous knowledge practiced by fish farmers.

2. Methodology
The topic of the review was searched in Google database with different key words related to the subject and with the literature available with us. Personal contacts were also made with experts to collect information. The experiences gained by the first author during interaction with farming community as a part of extension service were also included. The information thus received was utilized for writing this article.

3. Results and discussion
3.1. ITKs in aquaculture practice
Aquaculture is the controlled production, propagation and rearing of aquatic organisms of highly economic value in a controlled environment such as ponds, channels and enclosures, using a higher density of cultured aquatic organisms than normally found in nature. Many rural farmers have applied indigenous knowledge in various stages of aquaculture in order to meet their livelihood necessities.

3.1.1. Pond construction and maintenance
i. ***Site selection*****:** The fish farmers of Assam hill district are reported to have selected low-lying areas near the home for fish pond. These ponds can be used as multipurpose ponds for bathing, cloth and utensil washing in addition to fish culture [4]. They preferred to construct embankment ponds to the dugout ponds considering economy.
ii. ***Soil quality*****:** In order to test the suitability of soil in terms of water retention, a mud ball is prepared from the soil where the pond is to be constructed. If the ball does not break, the soil is considered to have enough water holding capacity, hence suitable for pond construction (Saha and De, unpublished).

iii. ***Outlet*:** Farmers of Assam hill district used hollow bamboo fitted at a certain height from the bottom as outlet pipes. The end of the bamboo facing the ponds is blocked with stone and clay soil [4].

iv. ***Protection of pond dyke*:** During pond construction, the top of the pond is made wider than the bottom as it can better withstand the force of water (Saha and De, unpublished). In places experiencing heavy rainfall, most dykes are prone to erosion and damage. Farmers plant plantation crops like coconut, papaya or vegetable crops with creeping vine like cucumber, gherkin etc. or turf with fodder grass. In Manipur, farmers use pond dykes for *Colocasia* plantation at 3000 nos. ha^{-1}, which is used as a vegetable in many parts of India [5].

3.1.2. Fish breeding and seed transportation

i. ***Breeding*:** Knowledge on dry and wet bundh systems of fish breeding and spawn production has been recorded from farmers (Saha and De, unpublished). Breeding in bundh including Bangla bundh with hormonal injection is a very cheap and effective method practiced by the farmers in many parts of West Bengal. These bundhs are most economical and very much tuned to the environment.

Farmers in West Bengal were reported to use proper doses of the extract of water-immersed catechu (*Acacia catechu*) and myrobalan (*Myrobolus indica*) nut in hatching pool, to make the eggshell hard [6]. This is known to help in shell hardening and prevent immature release of hatchlings, enabling higher hatching rates.

In Tamil Nadu, the practice of covering the rostrum of brood stock of freshwater prawn with plastic tube has been reported (TNAU). This is done to avoid damage of packing material during transport.

TNAU also recorded that some fish breeders use banana leaves for deposition of eggs and teak leaves to maintain acidic pH in the ornamental fish tanks during breeding egg layers and place carrot/ potato slices and banana peels in ornamental fish larval rearing tanks to enhance the formation of live feed Infusorians.

ii. ***Seed collection*:** Collection of spawn of murrells like *Channa punctatus,* which moves in shoals and periodically comes to the surface for breathing in natural waters using bamboo sieve/mosquito net/ cloths is reported to be a practice during monsoon in Assam [4].

iii. ***Seed transportation*:** Saha and Chowdhary [7] have described the traditional method of transporting fry and fingerlings in *hundi*s, practiced in Bengal. A traditional *hundi* is an earthen vessel, but later aluminum *hundi*s were introduced. Though the *hundi*s are of variable sizes, they are generally of two types, the smaller one has 22 cm mouth diameter and 23 l capacity carried as a head load and the other larger one has 23 cm diameter and 32 l capacity used for transport by rail or bicycle or as slings. The *hundi*s are filled with water from the same source as the fry and are stocked at 50 000 in the smaller and 75 000 in the larger ones. About 58 g of fine silt is sprinkled over the water surface in the *hundi*. During transport, the *hundi*s are shaken periodically. Basu [8] had reported that addition of silt coagulates the suspended organic pollutants. Saha and Chowdhury [7] have observed that management practices like addition of silt, removal of sediments by mopping them up with a rough cloth rope and partial exchange of water permitted transport up to a duration of 30 hrs. Saha *et al*. [9] demonstrated that pulverized earth and activated charcoal tend to absorb carbon dioxide and ammonia from the medium, consequently increasing the survival of fry.

Use of around 50 ml of rice beer for every 10 l of water in aluminum *hundi*s, which probably acts as an anesthetizer has been reported in Assam during seed transport [4]. However, traditional methods of transporting fish seed in hundies (earthen or aluminum pots) resulted in heavy mortality of fish seed [10].

3.1.3. Seed stocking

i. ***Weed fish eradication*:** Mahua oil cake is used for killing unwanted fish. This later gets converted into organic manure enhancing pond fertility, reducing the quantity of cow dung to be applied subsequently.

ii. ***Bird scaring*:** The first author of this article has recorded the use of audio/video tapes/coloured plastics for bird scaring in several fish farms of Karnataka.

iii. ***Testing the seed quality and species identification*:** To test the quality of seeds, farmers keep a few of them in the water taken in a plate and rotate the water with finger. Those seeds which swim in the opposite direction are considered as healthy seeds (Saha and De, unpublished). Kalitha *et al*. [4] have recorded that farmers distinguishing fry of catla from rohu and mrigal by its bigger head and their preference of fingerlings to fry since they grow quickly.

iv. ***Stunted seeds*:** Andhra Pradesh farmers have developed the technique of using stunted seed that are aged but have not attained a weight proportionate to their age, and stimulating their rapid growth in a limited period of time by compensatory growth effect [11].

3.1.4. Fish feeding

i. ***Fish feeding using gunny bags*:** Andhra Pradesh farmers have developed a simple feeding method called “the bag feeding technique” whereby the feed is kept in feed bags with small perforations that may be arranged in two to three rows. Indian major carps have the habit of browsing, sucking the feed through perforations [11].

ii. ***Supplementing common salt with feed:*** Another indigenous practice followed by Andhra farmers is the use of common salt in feed [11]. Studies conducted at College of Fisheries, Mangalore with carps have revealed the growth promoting potential of NaCl [12-14].

iii. ***Use of agriculture by-products as fish feed*:** Some farmers are reported to feed partially fermented maize, poultry offal and chopped dead poultry birds to the African catfish for high growth (Saha and De, unpublished). Many farmers in Bangladesh were found to use *kura*, the red powdery coating of rice under the husk as feed. Other food sources include cow dung, poultry waste, *choker* (the remains of wheat grains) obtained after the extraction of *aata* and oil cake [15]. Chowdhury [16] had observed that farmers in Lalmonirhat, north-west Bangladesh, frequently grind up the intestines of livestock and feed it to fish. In Joydebpur, termites are a frequently cited problem by farmers. It is reported that the local women and children collect up the mounds which are then thrown into fish ponds. Carp, particularly rohu, catla and Thai saputi appear particularly fond of termite eggs. Feeding fish with other on-farm resources like grass, azolla have been observed by the first author in some parts of Karnataka. The addition of banana leaves to ponds stocked with grass carp was recorded by Islam [15]. Grass-

fed fishponds are reported mainly from China and Thailand [17, 18]. In a polyculture pond, the poorly-digested excreta from grass carp serve as fertilization for the pond ecosystem and also as direct feed for other fish species. The inclusion of grass carp as 'grass bio-processor' enables the use of near-pond grass sources and leads to marked increases in overall fish production.

3.1.5. Fish health management

i. ***Dissolved oxygen deficiency*:** Depletion of dissolved oxygen especially during morning hours is managed by farmers through indigenous methods like channelizing fresh spring water, beating the water with bamboo pole/banana pseudo stem (TNAU), spraying water with open containers, making children swim in ponds (Adarsh G. Pers. Comn.) etc. Saha and De (unpublished) reported the use of ducks which swim in pond and aerate the water.

ii. ***Turbidity management*:** For controlling persistent clay turbidity farmers in Assam apply paddy straw/pieces of banana stem [4]. The application of lime to ponds to clear unclean water and addition of pieces of banana stem was also recorded by Chowdhury *et al.* [16] in Bangladesh. When these substances rot, they will be removed periodically. To control algal bloom, practices like spraying cattle urine in considerable quantities [4] or mixture or red soil and sand on pond surface (Rajesh, K.M. Pers. Comn.) have been reported to be effective. Goswami *et al*. [6] have observed the use of bamboo poles with toothed prongs or coir rope to remove aquatic weed (*Jahanesbaptistia* sp.) from water bodies where *Penaeus monodon* (*Bagda*) is cultivated.

iii. ***Argulus (fish lice) control*:** In cases of infection with the crustacean ecto-parasite *Argulus* sp., farmers plant bamboo pieces in ponds. Farmers believe that the fishes can get rid of *Argulus* by rubbing their bodies against the bamboo pieces [4, 6]. In fact, Bamboo poles are good substrates for *Argulus* to breed. They colonize on bamboo poles and lay eggs on them (Hemaprashanth, Pers. Comn.). Some farmers also keep old gunny bags submerged in pond water. Bamboo poles or gunny bags will be removed periodically and dried to kill eggs of the *Argulus* deposited over them.

iv. ***Leach control*:** Farmers in Assam are reported to throw peels of cucumber or leaves of bitter gourd made into paste form. It is believed that these bitter plant materials help in eradicating leaches [4].

v. ***Control of epizootic ulcerative syndrome (EUS):*** Application of a paste of turmeric powder and ash of hay or bamboo to control EUS has been practiced by fish farmers in Assam. Some farmers even apply branches of *Neem* plant into fish ponds [4]. Goswami *et al*. [6] have reported the use of a paste made from garlic (2 kg), salt (2 kg), $CuSO_4$ (20 g), $KMnO_4$ (20 g) mixed in 30-50 liter of water and sprayed over pond water of 0.133 ha pond by hatchery owners in West Bengal to control EUS. Saha and De (unpublished) reported the application of a solution of rotten jaggery on fish for controlling ulcers.

vi. ***pH control:*** Toddy (palm sap) is used by shrimp farmers for pH control [19]. Goswami *et al.* [6] have reported that banana pseudo stem can be used to increase pH through their alkaline secretion by cutting them into pieces and immersing in pond water. This practice of West Bengal farmers is reported to minimize protozoan diseases and *Argulus*.

vii. ***Removal of poisonous gas*:** Raking of the pond bottom by dragging tree-branches or brick suspended from a rope is practiced by some farmers for the release of obnoxious gases trapped inside the soils (Saha and De, unpublished).

viii. ***Hiding places*:** Farmers cultivating Australian freshwater crayfish *Cherax quadricarinatus* use tyres and bricks as hiding places [11]. They also use onion bag bundles to protect and harvest small juveniles from ponds. Use of bricks/tiles/ tyres as hid outs is also seen in India in prawn culture ponds.

3.2. Aquaculture practices based on indigenous knowledge

3.2.1. Sticks in the mud- the periphyton-based aquaculture

The *acadja* practice of West Africa was first described by Welcomme [20] based on the practices followed in western African countries to capture fish through trapping by establishing periphyton-based food production systems through installing bushy substrates where fish gather to breed, feed or shelter. These periphyton-based practices have been developed independently in various geographical locations all over the world, following a very similar strategy like the *katha* fishery in Bangladesh and the *samarah* fishery in Cambodia. The idea of exploiting periphyton techniques in ponds, based on traditional farmers' practices, has attracted a wide research interest [21]. Results clearly demonstrate the scope to increase fish production by using the periphyton system [22]. The practice originated from indigenous knowledge to attract fish, and fish farmers have found easy and feasible ways to understand its principle and apply it in aquaculture. The farmers in Bangladesh, where the substrate-based fish culture is more prevalent, believe that *shaola* (periphyton) can grow on substrate, and that this can not only be used as fish feed, but can protect the farmers' ponds from fish poachers, since it is difficult to use nets in ponds with substrate. The substrates used by them are available within their farming systems.

3.2.2. Integrated aquaculture

Integrated fish farming systems such as crop-livestock-fish culture integration were developed by Chinese farmers thousands of years ago [23], and they are still playing a major role as nutrient-recycling strategies in many developing countries of the world.

i. Paddy-cum-fish culture

Paddy-cum-fish culture is considered among the most basic type of traditional integrated fish farming system in the world [11]. Archaeological evidence has indicated the possible co-evolution of agriculture and integrated aquaculture systems since more than 8000 years ago in China [24, 25], with numerous designs and experiences in experimentation and implementation [26-29]. Usually, a small portion (5-20%) of the area of the rice field is converted into a trench, a refuge pond, or both in combination. Trench layouts vary considerably in their location in the rice fields. The integrated fish-in-paddy field system functions through the feeding of fish on organisms (particularly insects and other possible rice pests) and weeds, and the stirring of the sediment through their foraging action which leads to nutrient re-suspension [30, 31]. It has been observed frequently that rice yields increase through the inclusion of fish [26, 28].

In India, where traditional aquaculture was mainly practiced along the coastline by fisheries communities, the most ancient traditional fish farming systems include the *bheri* system in West Bengal, the *gheri* system in Orissa, the *pokkali* system in Kerala, the *khazan* system of Goa and the *khar* lands or *gazani*

(coastal khar lands) in Karnataka [11].

In West Bengal, where the salinity is either low or lowered by fresh water discharge diluting the tidal water, the cultivation of fish is undertaken in paddy fields. The *bheri* system is implemented for rice-fish culture or for fish monoculture. Most *bheries* are used for fish culture using the Kolkata city domestic sewage as the feeding source [32, 33]. This technique of sewage-fed system is considered to be unique, and it is the largest system under sewage-fed fish culture in the world.

In *pokkali* fields of Kerala, which cover an area of around 12,50,000 ha [34] summer fallow months are utilized for brackish water aquaculture. These fields are under the influence of Vembanad backwaters, which are in, turn controlled by tides. Rice is cultivated in these fields, as they are flooded during southwest monsoon (June-September). Fish and prawns are cultured during other periods. Immediately after the harvest of rice, the fields are leased out for the culture of fish and prawns. The small fishes and prawns enter the fields from near shore waters along with high tides. These fishes feed on the vegetative contents of the left over paddy plants and weeds. The production of fish and shrimp in such culture varies from 500 to 1,200 kg/ha. After the prawn harvest, the water is drained off. Subsequently, the saline nature of rice fields is nullified because of the monsoon rains and the fields are again made fit for rice culture. The traditional paddy varieties used even withstood the flooding by the 2004 tsunami. The *pokkali* paddy is a unique variety which is known to be saline, flood and acid resistant. This organically grown variety is known for its peculiar taste, high protein content and medicinal properties.

Apatani paddy-cum-fish cultivation is an indigenous farming system of North East India. 'Aptani's, a progressive agricultural community and one of the relatively advanced tribal societies in North East India practice paddy-cum-fish farming along with shifting cultivation (*Jhum*) [35]. The system uses a combination of paddy and fish together with finger millet (*Eleusine coracana*) on the bunds separating each plot. A small pit is dug in each terrace where paddy is grown, fingerlings are put. When water supply is sufficient in monsoon season, the whole paddy field is kept under shallow submergence of 5-10 cm and fishes come out of the pits and move around the terrace. During water scarcity, fishes run back to the pits and grow. Fishes get nutrition due to manuring of paddy field, wash-out from the hill slopes, house and granary sites and larger surface area for grazing. Studies have shown the possibility of getting up to 5 t of rice/ha and an average of 500 kg fish/ha.

The *khazan* system of paddy-cum--fish culture is practiced along the coast of Goa and is an example of a community-managed agriculture-aquaculture integrated ecosystem. The history of the system dates back to the sixth century [36]. This system was developed by local farmers who used their traditional knowledge on climate, tidal cycles, geomorphology, monsoon precipitation, runoff, sediment dynamics, soil properties and drainage characteristics of estuarine lands, in order to develop a suitable practice [37]. The production system is located in the mangroves, which have been reclaimed using a system of dykes, canals and gates. The traditional and highly adapted *khazan* technology is based on the principle of salinity regulation and tidal clock. The system is currently under threat due to urban growth; thus, efforts are being made to preserve this traditional fish farming technology.

A traditional paddy-cum-fish culture system has been practiced in mangrove areas of Guinea Bissau (a country in West Africa) from ancient times and is based on the integration of the culture of *Tilapia* spp. and *Clarias* spp. (both can tolerate high salinity rates) with rice production [11]. The system is based on the construction of a main dam and secondary dykes to regulate the entrance of seawater and to facilitate the storage of rain water into the rice field, in order to create a brackish environment appropriate for rice and fish culture. This "artificial" ecosystem created by rainfall water mixed with sea water decreases the number of predatory species less tolerant to low salinity.

The integration of paddy cultivation with fish culture has also been an indigenous practice followed in other Asian countries. In Bangladesh, a recent achievement is the control of the golden apple snail, a rice pest, by the common carp [38]. A beneficial technology for smallholders has been the use of rice fields as nurseries for rearing fish fry to fingerlings during the 3-month rice-cropping period [39]. In Indonesia, traditional systems combined rice and fish culture and the wastes from this system often flowed downstream into brackish water aquaculture systems (*tambak*). The *tambak*s themselves were poly culture ponds, often combining fish, vegetables and tree crops [40].

ii. Integration of Makhana cultivation with fish culture

Integration of Makhana (*Euryale ferox*) cultivation with fish culture is reported from Manipur [5]. Indian major carps and exotic carps, air-breathing fishes like *Channa* sp. and *Anabas testudineus* have been used for culture. Makhana fruits are tasty, have herbal value, mature and immature fruits serve as vegetables and the tender leaves and petioles also serve as vegetables after removing the spiny part. The rhizome of the plant is used as diuretic and in the treatment of dropsy, jaundice, scabies and gonorrhoea. Ripe seeds are used in the treatment of chronic diarrhea. The plants are propagated from mature seeds. Soaked mature seeds are sown up to the end of January in a separate pond. Seedlings are transplanted in culture ponds with a plant to plant gap of 5-6 ft, accommodating around 700-800 plants/ha. The integration is reported to give farmer a net profit of around Rs. 1,78.525/ha/yr.

iii. Other integrations

Trenches in fruit orchards: In the Mekong Delta in southern Vietnam, farmers implement a system of trenches within their fruit orchards, usually surrounded by a lateral trench and a connection to the adjacent rice field [41]. Fish and freshwater prawns can move between the sub-systems and benefit from the decomposing rice straw, the fallen fruit and from insects dropping into the water.

Mangroves and brackish water shrimps: The term 'forestry-fish' co-culture is used for the cultivation of brackish water fish and shrimps in fenced-off mangrove forests in Malaysia, the Philippines and Vietnam [42].

Bamboo-fish culture is conducted in China, in which the mud from fish ponds is used to fertilize bamboo plantations grown around the ponds. The waste from the processing of the bamboo shoots is fed into fishponds [17].

Another system previously utilised widely in China is the combination of aquaculture and mulberry trees growing adjacent to ponds, in which silkworm droppings and waste pupae are fed into fishponds along with the washings from silkworm trays [43, 17, 44].

4. Conclusion

In the coming years, small scale aquaculture (sometime referred to as 'rural aquaculture') is poised to play significant

role in increasing freshwater fish production in the country. This low-input aquaculture system is closely associated with Indigenous Technical Knowledge (ITKs). Though efforts are made to identify, validate and recommend ITK by some Governments, much indigenous knowledge remains undocumented. There is a need to recognize ITK, compile, value and appreciate their interaction with local communities. The enhancement of the quality of life of the people who depend on aquaculture production would be almost impossible if this rich tradition of ITK is kept to a few people. Therefore, ITK needs to be incorporated into the zonal research and development agenda. However, before reliable recommendations can be made, there is an urgent need to understand, critically validate and document the different ITKs so as to integrate the best ones into the farming system.

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