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Indigenous wisdom on conservation of fisheries and fish preservation by *Khasi* tribes of Meghalaya

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Indigenous Technical Knowledge (ITKs) preserves ancient wisdom and beliefs to ensure efficient utilization and conservation of fish resources in hill farming. Northeast India has documented ITKs on several agricultural practices, but they are mostly ignored in the livestock sector, particularly in fisheries. This study collected, compiled, and documented 34 ITKs on community fishing (12), fishing gears (7), piscicidal plants (5), fish attractants (6), and fish preservation and value addition (4). Repeated field visits, semi-structured personal interviews, focus group discussions, and observation methods were used to gather primary data from 75 villages covering 278 respondents in northeastern hill states of Meghalaya (Ri-Bhoi). Community fishing mostly uses piscicidal plants such as *Milletia pachycarpa* and *Zanthozylum alatum*. The plant parts, including roots, contain toxins like saponins and rotenone, which either kill the fish or burn their eyes to come to the water surface. To catch *Channa gachua* and *Channa lipor* fish, they use active fishing gear where earthworms are pierced by a needle grass and attached to a bamboo fishing rod, locally known as *'Khwai-kynjlom'*. To catch fish, they use attractants like leaves and fruits of *Prunus nepalensis* and *Viburnum foetidum*, larvae of sour ants, wasps, honey bees, caterpillars, etc. A rectangular wooden structure, known locally as Tympan, is used to preserve the smoke drying of salted fish, which has a shelf life of 6 months or more. To increase the value of small fish, they are sun-dried, crushed, and mixed with vegetables (e.g., pumpkin, papaya, yam stems, or banana plantains), and then added white ash and bamboo vinegar to extend the shelf life for 2 months. Refinement of these ITKs through research and development can enable their cost-effective large-scale adoption in climate-resilient sustainable farming systems.

Keywords: Fish attractants, Fish preservation, Hill farming, Indigenous fishing, Piscicidal plants, Value addition

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The fisheries sector is a major contributor to the livelihood and nutritional security of the resource-poor farming population in Northeast India. Due to its rich and unique ecological diversity and ethno-fisheries knowledge, the region has the potential to become a fresh water aquaculture hotspot. The region has over 300 species, and approximately 33% of the total 2,163 freshwater fish species in India are found in this region[1]. A rich diversity of fish found in the rivers, springs, streams, ponds, and beels provides a healthy source of protein for the local people and thus, fishery has become an important economic activity in this region[2]. Traditional knowledge is utilized by various tribes in the region to manage aquaculture activities, including the rearing and harvesting of fish from natural water bodies. Despite more than 90% of the population consumes fish, there is a significant shortage in the local supply. The region's current annual per capita fish availability is estimated to be around 6.0 kg while consumption is 18.0 kg and the highest in the country[1]. Annual fish production in the region is ~0.518 million tons in contrast to the demand of 0.938 million tons, resulting in a deficit of over 45% of the required amount[1,2]. To meet its local consumption, hence, the region relies heavily on other states in the country, as well as neighboring countries like Bangladesh and Myanmar.

The Northeastern hilly states of Meghalaya, despite being rich in biodiversity and fisheries resources, only produce 45% of their annual fish requirement of 11.0 million tons[3]. As a result, the state relies heavily on the import of fish from far-end states of India like Andhra

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Pradesh and Uttar Pradesh. The long duration and high transportation costs result in the availability of stale fish with high prices, making it difficult for resource-poor tribal populations to include fish in their diet. The state's water resources are abundant and diverse, with rivers, reservoirs, streams, perennial springs, lakes, swamps, ponds, mini barrages, and low-lying paddy fields. With an average annual rainfall of >2000 mm[4], the fisheries sector has tremendous scope for development, but it lags behind in harnessing the potential of these natural resources. Despite the abundance of natural water bodies, there is still a lack of scientific exploration to enhance fish production and advance the fisheries sector. The need of the hour is to combine advanced technologies with traditional, age-old practices for horizontal and vertical expansion in unused water bodies. The tribal farmers of the region are generally reluctant to adopt modern fisheries' production technologies. Therefore, the inclusion of age-old traditional practices in the blending technology will greatly boost adoption levels.

ITK can complement knowledge of modern science of fisheries resource management by providing long-term baselines for stock assessments, local knowledge of species' ecology and behavior, habitat conditions, value addition, and customary management systems. The sustainability of the fisheries sector could be greatly improved by using these ITKs as a panacea. In the region, 114 plant species have been used as piscicides for fish harvesting for a long time[5]. Significant work on ITKs from the region has been documented recently on low-cost pathways for accessing healthy foods[6], medicinally important orchids[7], traditional salt producing springs[8], rice-husking technology[9], and traditional crop and soil conservation practices[10]. The livestock sector, including fisheries, has not received enough attention. Only few ITKs on fisheries, such as edible freshwater molluscs[11] and the preparation of an ethnic fermented fish product of the Garo tribes of Meghalaya[12] were documented. In another study from the region (Tripura), Saha and Nath[13] documented traditional knowledge about integrating animal and plant components in a fish-based farming system, while sparingly covered bamboo based traditional fish trapping methods. In many tribal communities of Meghalaya, indigenous methods such as sun drying, salting, and smoking fish have been integral in ensuring year-round protein access, especially during lean seasons. One of the few ITKs that are documented in fish preservation is locally known as Tungtap. In this recipe, a fish paste or chutney is prepared from dried fish (*Puntius* sp) and stored in an earthen pot (*Khiew Khyndew*) to preserve it for over 3 months[14]. There has been an inadequate attempt to document, characterize, raise awareness, adopt, and assess the perceived effectiveness of traditional fishing techniques, fishing gears, indigenous fish attractants, and preservation knowledge. Traditional fishermen are concerned that ITKs may disappear due to the increasing capital intensity and improved technologies in fish aggregation. The fisheries sector's sustainability can only be ensured by documenting and validating these treasure troves of traditional knowledge in the region. The aim of this study is to identify, collect, compile, and document ITKs on fisheries and fish preservation in Northeast India, particularly the hill states of Meghalaya.

Methodology

Study site

The study area lies in the Ri-Bhoi district (between latitude of 25°15’ and 26°15’ N and a longitude between 91°45’ and 92°15’ E) of Meghalaya (Fig. 1). The district covers a total area of 2,448 sq. km and has a population of 2, 58,840 spread across 635 villages. The majority (90%) of the population is

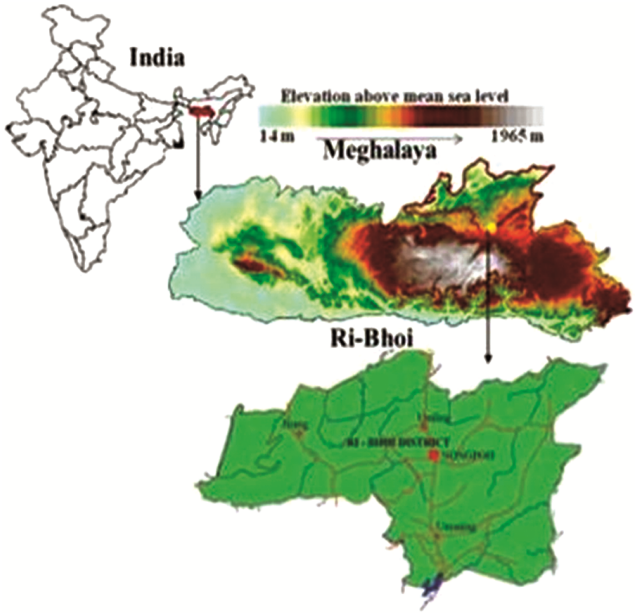

Fig. 1 — Study area (Ri-Bhoi district) in the hilly Northeastern states of Meghalaya, India (Source: Adopted from National Remote Sensing Centre (NRSC, 2019)[29]. https://bhuvan-app1.nrsc.gov.in/thematic/index.php.

made up of tribal hill farmers with marginal resources. The district is categorized into two agro-climatic zones: (i) Sub-tropical hill zone and (ii) Mild tropical hill zone[1]. The district is blessed with vast and varied resources of natural water bodies in the form of river (511 km), reservoirs (650 hectares), beels, lakes, swamps, canals, ponds, tanks, and lowland paddy fields occupy another approximately 500 hectares[3,4]. The temperature varies from 4°C in winter to 28°C in summer. The district experiences an average annual rainfall of around 2450 mm, 65% of the rainfall, is received during the monsoon months (June to October) every year[1,15].

Data collection

Our study was conducted from April 2019 to March 2020 to identify, collect, compile, and document ITKs on fisheries and fish preservation. The primary data was gathered from the local fishermen, experienced individuals, and village elders of 75 villages in three administrative blocks of Ri-Bhoi district. Significant areas under natural water bodies were present in these selected villages. The information was collected through extensive field visits, personal interviews using semi-structured interview schedules, focus group discussion, and observation methods. A total of 278 respondents were interviewed, comprising elderly community members (84), experienced fishermen (112), women fish vendors (46), and youth anglers (36). The information on community fishing for most ITKs was given by elders, while men and women explained fishing gear practices. Elders and experienced fishermen shared their knowledge on piscicidal plants, while active anglers provided information on fish attractants. Indigenous knowledge on fish preservation and value addition practices was primarily shared by women.

From 75 villages, 34 ITK practices were documented and categorized into five thematic areas. Five thematic areas were used to group the 34 ITK practices. They are namely (i) Community fishing (05), (ii) Traditional fishing gears (10), (iii) Piscicidal plants (07), (iv) Fish attractants (06), and (v) Fish preservation and value addition (06). Some examples of community fishing documented include *Buh Kroh, Riam Kyllong*, and others. The documented fishing gear includes *Khwai-kynjoh, Jakhoi, Khoh-nam, Paron, Dan*, and others. Similarly, piscicidal plants like *Millettia pachycarpa, Zanthoxylum alatum*, and others, while fish attractants like earthworms, termite larvae, sohiong, dieng-sohlang, etc., were covered. The documentation includes techniques for fish preservation and value addition, such as sun-drying, smoking, *Tung Dung, Tympan* storage, and more. Three extension expert specialists were employed as team members in the study to conduct and format the interviews of the villagers. On-field validation by the fisheries scientists as team members was also conducted, and only the refined validated ITKs were documented and photographic evidence was collected and preserved.

Results and Discussion

Traditional fishing involves catching fish in a community or individually from their natural environment, either by hand or using fishing gear. Active and passive fishing gears are two types of traditional fishing gear. To catch fish, active fishing gears must be operated, while passive fishing gears are set up as a trap[16]. Traditional fishing gears and techniques in Meghalaya vary from place to place and season to season. Fishing in the Ri-Bhoi district is commonly done for both food and recreational purposes, such as community fishing. The *War Khasi* community of the state has evolved several traditional fish-harvesting practices, locally known *as Buh Kroh, Riam Kriah, Riam Khohka, Riam Kyllong, Ring Khashiar, Buh Ruh and Bia Dohpieh*[7]. The most targeted fishes in traditional fishing methods are the *Neolisochilus hexgonalepis* (locally known as kha saw), *Tor putitora* (Kha lad), *Clarias magur* (Kha makur), *Channa* sp (dohthli), *Heteroneupteus fosilis* (Kha snah), and others.

ITKs on community fishing

The villagers in a village or a group of villages hold a fishing festival once a year called community fishing (Fig. 2). Piscicidal plants like *Milletia pachycarpa* and *Zanthozylum alatum* are used to catch the fishby various traditional active and passive fishing gears on the occasion. To participate in fishing, the participants are required to bring some piscicidal plants. The running water bodies are redirected and piscicidal plants are crushed to be added as piscicides to kill fish. Follow-up fishing is done using either hand gathering or any type of fishing gear.

ITKs on traditional fishing gears

Fish species differ in their habitat, feeding habits, including surface or bottom feeders, and feed quality. To catch these fish, various fishing techniques and

gears are necessary. The term '*Kem kite'*, also known as hand gathering, is a traditional fishing technique that doesn't require fishing gear and the villagers frequently use it during January to February when the water level is shallow. In few villages (Umthangiong and Umkaduh) of Ri-Bhoi, villagers catch fish by hand during the heavy rain on the onset of monsoon as the fish, especially genus *Glyptothorax*, crawl over the rocks to reach the stream bank. The hand gathering fishing technique is most commonly used to catch *Channa* sp, *Lepidocephalus guntea*, and crabs. The streams are often diverted to temporary dams during the dry months when the water level drops. The diverted part is drained and fish are caught by hand or using active gathering. This technique is known locally as *'Pynsngat um'*. Fishes caught by fishing gear from natural water bodies and paddy fields are kept in a homemade unique basket which is locally known as '*Lanap'* (Fig. 3a).

Active fishing gears

Manpower is necessary for active fishing gears to catch the fish, and is used in both community and individual fishing. The active fishing gears used in Ri-

Fig. 2 — Community fishing at Liarkhla Village, Ri-Bhoi district of Meghalaya

Fig. 3 — Different types of traditional fishing gears such as (a) *Lanap* with different designs, (b) *Khwai-kynjlom*, (c-d) *Khoh-nam* placed against water current, (e) *Jakhoi*, (f) laying of *Khoh kha*, (g) *Paron*, (h) *Kroh*, and (i) *Fog 15 Kroh*

Bhoi include the *'Khwai-kynjlom'* or *'Khwai-kynjoh'*, the '*Jakhoi*', and the *'Krih-shut-dohkha'*. The *Khasi* word '*Khwai-kynjoh*' (Fig. 3b) is a rephrasing of '*Khwai*', which means to fish and '*kynjoh*' means to wiggle. Children aged between 7 to 16 use this traditional fishing technique most frequently. This technique requires needle grass, thread, a fishing rod made of bamboo, earthworms, and a basket, which are carried in an umbrella to catch the fish during August to October. The needle grass is only used for piercing and stitching the earthworm (Fig. 3b) together, then it can be cut off. In this technique, earthworms are wiggled in the targeted fish habitat and as soon as the bait is taken, the fish is pulled out as quickly as possible. To pull the fish into the basket (known as *Lanap*), skill is necessary because the worm does not have a fishing hook inside to hold it for a longer time. This technique mostly catches *Channa gachua, Channa lipor, Channa punctatus, and Channa Stewart* as these fish are aggressive and directly swallow the bait. A total of 40-50 *Channa gachua* and *Channa lipor* can be caught by stitching together 10 worms (jumping earthworms).

The '*Jakhoi*' (Fig. 3e) is made from split bamboo using the proper handicraft technique. It has a conical shape and a triangular mouth. The '*Jakhoi*' isused by dragging it towards the fish with the right hand and then lifting it with the left hand or vice versa. This fishing gear can only be used in small and shallow water bodies. This fishing gear is mostly used by women for catching small fishes (e.g. *Danio rerrio, D. aquipinatus, Lepidocephalus guntea, Puntius sophore, Channa gachua*, etc.) in the outlet of a paddy field, narrow and shallow streams. In the winter or spring season, small streams are frequently diverted or dammed, and then fishing is performed by dragging the *Krih-shut-dohkha*.

Passive fishing gears

Passive fishing gears are those that are kept as a trap for fish. Some of these gears need bait to lure fish, while others do not need any bait as they depend on the water current and fish migration. Most commonly used traditional passive fishing gears are *Khoh-Nam, Khoh-kha, Paron, Kroh or Dan and Frog 15 Kroh* (Fig. 3).

'Khoh-nam' is a *Khasi* word where *'khoh'* means basket and *'nam'* means to receive. Depending on the season, *Khoh-nam* can be set up against or for the water current to catch the fish. The fishing gear is cylindrical and tapered towards the posterior end. The entrance of '*Khoh-nam'* (Fig. 3c) is opening up for the water current as the fish migrate from the lower region to the upper region during the monsoon season. In order to ensure that entry is against the water current, it is reversed after monsoons as the temperature becomes cooler and the water level drops. The '*Khoh-nam'*is used only in small channels in paddy fields or any small streams (Fig. 3d). The fish will be attracted to it if it is properly covered with grasses. Usually, *Khoh-nam* catches small fish (e.g., *Puntius sophore, Channa gachua, Channa puntatus, Clarias magur, Heteroneupteus fosilis,* etc.). Bigger fish can be expected if the gear size is larger.

Khoh-kha is a traditional fishing gear is cylindrical and tapered towards the posterior end (Fig. 3f). It is made of split bamboo and is used during October and November as the fish tend to migrate from the higher altitude to the lower altitude region. The fish can enter by setting it up against the water current in the paddy field outlet and other narrow streams or channels (Fig. 3f). *Khoh-kha* is fully covered with grass and mud to enter more fishes. Mostly fish species belonging to genus *Channa* (e.g., *Gachua, Lipor, Punctatus, Striatus, and Stewarti*) are caught. The '*Paron*' is the traditional fishing gear (Fig. 3g) is used in Umtasor village of the district and commonly used in all rural areas of the region. In swamps or small caves where fish are present, this passive fishing gear is used. *Channa* sp, such as *Gachua, Stewarti, Pardalis, Lipor, and Punctatus*, are the most targeted fish species of this fishing gear. It is important to keep bait like rubella or mature termite inside the *Paron* before setting it up to lure the fish inside and as soon as the fish enters, there is no escape. *Kroh or Dan* is the biggest traditional fishing gear, known as '*Kroh*' or '*Dan'* and is used by damming the stream or small river (Fig. 3h) of Ri-Bhoi district. The set-up occurs in the last week of September as the fish begin their downward migration from a higher altitude to lower altitude. Solid bamboo, split bamboo, bamboo-wire, *Khoh-kha*, and grasses are used to construct the '*Fog 15 Kro'* (Fig. 3i) by damming the stream or river.

Preservation of fishing gears

The people of the RI Bhoi District had developed exceptional skills and wisdom over the ages in their traditional knowledge of fishing gears and techniques. Bamboo and bamboo-wire are the materials used in making traditional fishing gear, and they are preserved either by sun drying or smoking after use. At present, due to the availability and accessibility of modern

fishing gears on the market, the use of traditional fishing gears is starting to decline even in rural areas. The traditional preservation of fishing gear is very simple and only a few steps are needed to be followed:

1. Proper washing and removing all the impurities stuck in the gears.
2. Properly dry the fishing gear with either sundry or smoking.
3. Make sure to keep them in dry areas and away from children.

ITKs on piscicidal plants

Piscicidal plants are those plants which are used to poison the fish in the river or stream to be able to catch them since time immemorial. During the dry season, piscicidal plants are used to poison the water body, especially in March and April. There are 112 plants in India that have piscicidal action on fish, out of which 40 are found in the Northeast[1]. The tribal community of Northeast India has an age-old tradition of harvesting fish using poisonous plants[17]. The active ingredients in piscicidal plants include alkaloids, resins, tannins, saponins, and nicotine. These compounds affect the fish when they pass through the gills or when they are ingested. Saponins and Rotenone are two toxins that are widely known to be present in piscicidal plants. Saponins go directly into the bloodstream of fish through the gills and cause the breakdown of the red blood cells. Rotenone is a toxic alkaloid that impairs the respiratory function of fish and is derived from *Mellettia pachycarpa* roots. There are certain plants that only damage the eyes and have no effect on the health of the fish.

The traditional use of 45 species of ichthyotoxic plants and their mode of application in Manipur has been reported by local people[18]. The Mizo tribe uses a community herbal fishing method that involves using leaf, bark, root, fruit, and other plant materials[19]. About 500 medicinal plants have pharmacological significance in Arunachal Pradesh, with 30% of them being used as fish poison[20]. Plants like *Acacia pennata, Aesculus pavia, Ageratum conyzoides, Athyrium filix-femina, Zenthoxylum rhesta* DC., etc., are reported to be used by the Adi, Galo, Miri, and Tagin tribes of Arunachal Pradesh[21]. Similarly, a rich ethno-fisheries technique of harvesting fish is reported from Assam[22]. *Polygonum hydropiper* is commonly used as a fish toxicant by the *Karbi* tribes of Assam[23]. There are 6 piscicidal plants found in Sikkim[24] and the *Khasi* community in Meghalaya uses a similar method of harvesting fish[16].

Traditional indigenous fish catchers in the Ri-Bhoi district of Meghalaya classified piscicidal plant species into two categories. The first category is those plant species which can kill fish, while the second category plants won't kill fish, but burn the eyes and force the fishes to come up to the water surface. Some of the piscicidal plants commonly used include *Millettia pachycarpa* (*Khariew*), *Zanthoxylem alatum* (*Jaiur*), and *Meyna species* (*Sohmynthiang*)[15,25]. *Millettia pachycarpa* is a piscicidal plant and in *Khasi* is commonly known as '*Khariew'* or '*Kharu'* (Fig. 4a-b). Fish that are killed by this plant are safe to consume. The fish are poisoned, only by the root of this plant; the dried roots are more effective than the fresh ones. Villagers tie the roots of *M. apachycarpa* in a bundle and then they crush them with a stick on the rock in the upper catchment of the selected river or stream site. The water at the selected site is mixed with crushed roots. The fish that is affected will either come to the surface of the water or die, and can be caught using either hand or any appropriate active fishing gear.

Catunaregam uliginosa is locally known as either '*Sohmynthiang*' or '*Sohkyrbi*' (Fig. 4c-d). The district is rich in that species and has been used throughout it for centuries. The fish are poisoned, only with the fruit of this species. To produce juice that acts as a piscicide, the fruits are crushed, dipped in water, and beat again. The poisonous nature of this plant is quite

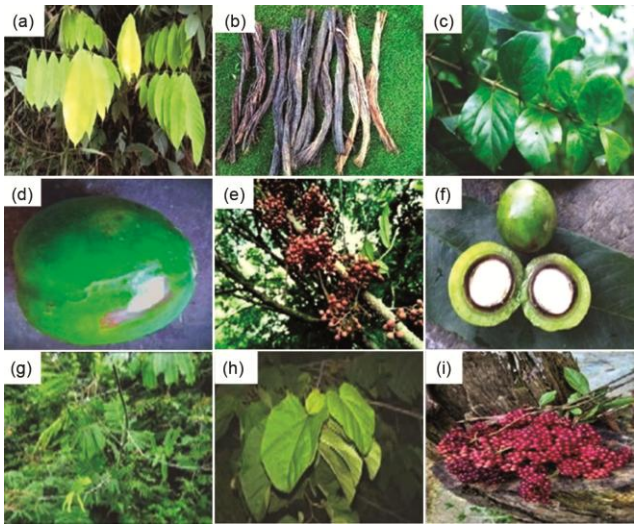

Fig. 4 — Different types piscicidal plant such as leaves (a) and bark (b) of *Millettia pachycarpa* (*Kharu*), leaves (c) and fruits (d) of *Catunaregam uliginosa*, fruits of *Zanthoxylum alatum* (f), leaves and fruits *of Sapindus mukorrosi* (g), leaf of *Acacia pennata* (h), and leaves and fruits of *Viburnum foetidum* (sohlang) (i) as fish attractant

low in comparison with *Millettia pachycarpa*. *Zanthoxylum alatum* is locally known as '*Jaiur*' in the Ri-Bhoi District and fish can be poisoned with both fruits and leaves. As reported by the people, *Zanthoxylum alatum* (Fig. 4e) burns only the eyes of the fish, which makes it easy to catch them as they come up to the surface.

Sapindus mukorrosi is locally known as '*Sohpieng-rah*' (Fig. 4f) in *Khasi* (Bhoi) language. Only the peel of the dried fruit is employed as a piscicides. The peels are kept in a gunny bag and then crushed with a wooden club until they are crushed properly. The fish poisoning was caused by mixing with the water and splashing in the selected site. *Acacia pennata* is locally known as *'Dieng-Lachih'* (Fig. 4g) in *Khasi* (Bhoi) language and only the bark of the plant is used as a piscicide. After peeling the bark, it is crushed with a stick and then dipped in the water of the chosen site.

ITKs on fish attractants

Fish attractants are those substances used by fishermen to lure or attract fish, including worms, larvae, pulses, and yams that can be used as bait for the fish. In fish traps, fish attractants are commonly used[15]. Fish poisoning caused by piscicidal plants is harmless and there are no reports of adverse effects on consumers[15,24,25]. Fish poisoning can result in over-exploitation of the fish population, regardless of their age. To maintain the fish population and its diversity, it should be discouraged by all means. In the past, fish were only attracted to passive fishing gear like the *Paron* by the use of earthworms and termites. Angling has become a common hobby for the locals over the years, and many fish attractants, such as fruits, insect larvae, and so on, are used. With the coming up of the fishing competition, anglers searched for the most attractive fish attractant to use as bait to attract more fish. Below are the baits that the villagers have been using for centuries.

Fishes are traditionally attracted to certain leaves (Fig. 4h) and fruits (Fig. 4i) as bait, which include Sohiong (*Prunus nepalensis*) and Dieng-Sohlang (*Viburnum foetidum*). Larvae are used by anglers for fishing and the larvae used include those from sour ants, wasps, honey bees, and caterpillars. Sour ant larvae are scientifically known as *Oecophylla smaragdina*, which is locally known as *'Dkhiew-jew'*, which means sour ants (Fig. 5b). During the months of April to June, only the larvae are used for fishing, as their size increases compared to the rest of the year. Anglers use these larvae, as one of their preferred fish, baits, especially in fishing competitions or in ponds or rivers where fish often reject other baits. The larvae are collected by cutting the branch of the tree to where the nest of *smaragdina* is located, and then the nest is thrown away in the banana leaves. After that, the larvae are kept in the bamboo tube. To preserve it, this bamboo tube is kept in a bucket half filled with water in a cold place.

Wasp larvae are locally known as '*Khun ngap'*. The larvae are captured by either killing or chasing their parents, or by either smoking or burning their nest. Fully grown wasps like *Dolichovespula media* (locally known as *Ngapryiang*) (Fig. 5c) and *Dolichovespula sylvestris* (*Ngap-sla*) (Fig. 5d) are also used as fish attractants. Honey bee larvae (*Apis mellifera*) are locally known as '*Khun ngap-ri'* (Fig. 5e), is obtained from either the wild or a farm. Maggots like wood boring beetles (*Chalcophora virginiensis*) locally known as *Niangkseh*, (Fig. 5f) and May beetles (*Phyllophaga* sp), locally known as *Niangbyrnei* are used as fish attractants. Earth worm is locally known as *"wieh*" in *Khasi* (Bhoi) language. In the RI Bhoi District, two types of worms, *Lumbricus rubellus* and *Amynthas* sp, are commonly used as fish attractants. *Lumbricus rubellus* is locally known as *"wieh saw*" (Fig. 5g-h) in the *Khasi* language, which means red worm and have soft tissue. On interaction with the farmers, they said that *rubellus* is the preferred bait for common carp, chital, and grass carp. The *rubellus* worm can be found in cow dung, banana tree, and wet

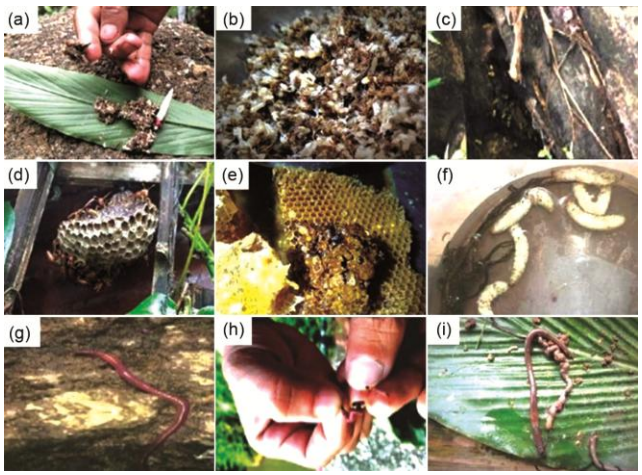

Fig. 5 — Different types of fish attractants such as larvae of (a-b) *Oecophylla smaragdina* (sour ant), (c) *Dolichovespula media*, (d) *Dolichovespula sylvestris* (*Ngap-sla*), (e) *Honey Bees* (*'Khun ngap-ri'*), (f) *Chalcophora virginiensis* (maggot), (g-h) earth worm *Lumbricus rublus* and (i) jumping earthworm *Amynthas* sp

humus soil. It can be preserved by keeping it in the bamboo tube along with some wet soil or humus. *Amynthas* sp is commonly known as a jumping earthworm and is locally known as '*wieh rang*' or '*wiehnar*' (Fig. 5i) in *Khasi* language. The *Amynthas* worm has a hardy nature and stiff body tissue. It is used to catch carnivorous and invasive species like *Clarias* sp and *Channa* sp.

ITKs on fish preservation and value addition

Fish preservation is the process by which any captured fish, whether wild caught or cultured, is preserved using different techniques to prolong its shelf life for future uses. Fish is prone to spoiling quickly after death due to their soft and perishable nature. This is caused by the action of enzymes, bacteria, fungus, etc., and the process is known as fish spoilage. The detection of fish spoilage involves noticing the decolourization of fish, particularly the eyes and gills, the firmness and softness of the body, the bad smell, and the burping of the belly. Most traditional methods of fish preservation include salting[26], smoking[27], and sun drying[28]. In today's society, there are many advanced ways to preserve and increase the value of fish, such as canning, freezing, icing, and other methods[14,16]. Drying and crushing small fish like *Puntius* sp and *Dendrobranchiata* sp is preferred by villagers (Fig. 6a-b). Traditional methods of fish preservation in the RI Bhoi District are mainly smoking (Fig. 6c-d). By crushing dry fish and making a powder, they add value to it, which is locally known as *Tung Dung* (Fig. 6c-g).

Fish preservation technique

Smoking fish using indigenous traditional methods can preserve it for up to two weeks or even longer. In this technique, live fish caught are killed and washed, followed by the following steps:

1. To prevent fish spoilage and speed up the drying process by smoking, it is necessary to completely remove the gills, gut, and scales. However, scaling is not necessary for small fish.
2. If the fish is large, it should be cut into pieces or split into two halves.
3. To increase the drying rate, the fish are salted. Villagers enhance the taste of salted fish by adding turmeric.
4. Drying salted fish is achieved by using the square or rectangular wooden structure, known locally as Tympan (Fig. 6h). It is being suspended from the roof above the kitchen stoves until the fish is completely dried.
5. The dried fish are kept inside bamboo tubes or bamboo baskets (Ruh) (Fig. 6i). To ensure the quality of dried fish and protect it from rodents or cats, the bamboo tube is kept inside the Tympan.

Value addition of dry fishes

To increase its value, prices, and market demand, it is essential to add value to dry fish[15,24]. The value addition of dry fish is achieved through an indigenous method known as Tung Dung (Fig. 6c-g). In local language, '*Tung*' means dry fish and '*Dung*' means crushing. Crushing dry fish and vegetables such as pumpkin, papaya, yam stems, or banana plantains in amortar (*Thlong*) and pestle (*Synrei*) is the usual method for making Tung Dung.

Preparation of crushed dry fish (*Tung dung*)

To make a good crushed dry fish, the villagers follow the following steps:

Step 1: Crushed dry fish is only made with small dry fish like *Puntius* sp *Chanda nama, Danio* sp or prawn, which are easy to crush and have a good taste (Fig. 6a-b).

Step 2: After washing with clean water, the fish is sun-dried to a level that makes crushing it easy (Fig. 6c-d). Crushing is done outdoors on non-windy days to minimize losses (Fig. 6e).

Step 3: The dry fish mixture is prepared with a desired quantity of vegetables, such as pumpkin or banana-plantain, garlic leaves, salt, and turmeric powder. White ash (which acts as soda), bamboo

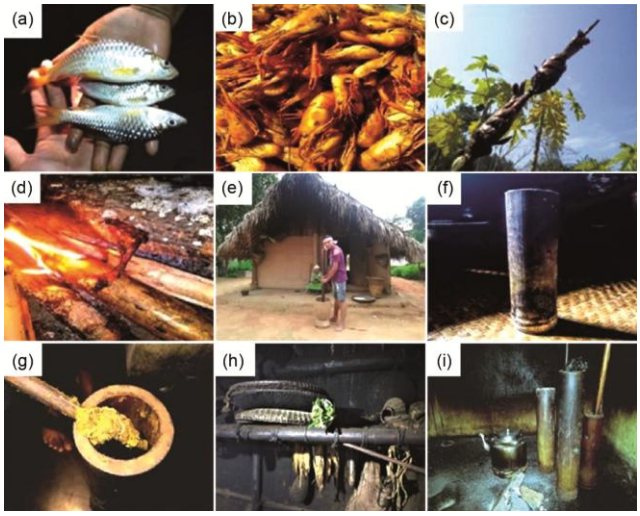

Fig. 6 — Preferred fish species such as (a) *Puntius* sp (b) *Dendrobranchiata* sp and fish preservation techniques such as (c-d) *Tung Dung*, (e) crushing of dry fishes in the mortar, (f) Bamboo tube, (g) Crushed fishes, (h) *Tympan* and (i) Bamboo tube keeping by the fireside

vinegar, local alcohol, or yeast, is then used to extend its shelf life.

Step 4: Crushed dry fish is filled into the bamboo tube (Fig. 6f) and it is tightly closed, leaving a 2-3-inch gap for sealing and covering the tube. Banana leaves and wet ash are used to seal and cover for 1-inch.

Step 5: Once everything is done, the bamboo tube is sealed (Fig. 6g-i) and held for two months before being used to preserve its pleasant smell and taste.

Preserved crushed dry fish adds flavour to traditional curry and also provides a protein supplement to the diet of the poor[15,24]. Individuals can use it all year, especially during the lean season, and it is readily available. Crushed dry fish and bamboo tubes are preserved using the following methods:

Method 1: This method involves keeping the bamboo tube upside down in the Tympan (Fig. 6h) to prevent it from getting infected by pests or diseases. Before leaving, the smoke from the stove goes through the Tympan. It also assists in preserving and maintaining the quality of crushed dry fish. Every traditional kitchen in the region has this method as a common sight.

Method 2: This method involves burying the bamboo tube in a pit made inside the house to avoid the rain. Avoiding soil contact is crucial by spreading ashes evenly over the pit. Soil and the ashes are used to cover the seal of the bamboo tubes that are left upside down in the pit. By using this method, crushed dry fish can be preserved for a long time.

Method 3: To preserve it in this method, the bamboo tube filled with crushed dry fish is kept by the fireside (Fig. 6i). The heat of the fire prevents the bamboo tube and crushed dry fish from deteriorating.

Uses of the crushed dry fish

Crushed dry fish is one of the favorite food items across the region due to its pleasant smell and exceptionally delicious taste. Therefore, it is used in different ways, such as (i) making any kind of traditional curry, (ii) it can be smoked and extract directly, and (iii) it can be used to make chutney.

Conclusion

The traditional knowledge of the native tribes of Meghalaya, about ITKs for community fishing, fish preservation, and value addition have been documented and validated as a treasured trove of knowledge. These ITKs are primarily developed using natural products and ingredients, with bamboo being a crucial component. Traditional fishermen are concerned about the future disappearance of ITKs as modern fishing gear expands. Their belief is that modern fishing gear is causing over-fishing, eroding fish diversity, and raising the cost of fishing. Modern technologies can be blended with these ITKs to develop low-cost and eco-friendly technology for specific locations, promoting sustainable fish farming to benefit the resource-poor tribal farming community in Northeast India.

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Conflict of Interest

Authors declare that there are no conflicts of interest.

Author Contributions

MI and BUC: Conceptualization, writing, original draft, editing, and revision of the manuscript; BM and AR: Field survey, interviewing, group discussion, collection, and compilation of ITKs, laboratory analysis, and validation; MI, SK and AKM: Supervision, Resources, group interaction, Scientific validation of ITKs and reviewing.

Prior Informed Consent

The knowledge holders (Tribal fish farmers) who provided information and allowed photography were informed in advance and gave their full consent for the study to use their traditional knowledge. Most farmers are collaborative partners and beneficiaries of the host Institute (ICAR RC NEH Region and its KVK, Ri-Bhoi, Meghalaya) in many outreach programs, including the Tribal Sub-Plan (TSP). The authors state this with complete sincerity and commitment to the farming community.

Data Availability

The study relies on primary or original data, which includes photographs, collected through repeated field visits and interactions with primary informants (*Khasi* Tribes of Meghalaya), to support its findings. The information, which includes raw photographs, is sensitive to the community and cannot be made

public. Upon reasonable request and appropriate permission, the corresponding author can share them.

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