International Journal of Entomology Research
www.entomologyjournals.com
ISSN: 2455-4758
Received: 08-05-2026, Accepted: 08-06-2026, Published: 23-06-2026
Volume 11, Issue 2, 2026, Page No. 512-527

Insects in the life of the Bodo community of Assam: Food, medicine, culture and sustainability - An ethnoentomological review

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DOI: https://doi.org/10.66856/ijer.2026.11.2.11214

Abstract
The Bodo community of Assam possesses a rich tradition of indigenous knowledge associated with the use of insects for food, medicine, livelihood, and cultural practices. This review synthesizes existing literature on the role of insects in Bodo society, focusing on entomophagy, entomotherapy, ecological importance, socio-cultural relevance, and sustainability perspectives. Ethnoentomological studies conducted across different regions of Assam have documented nearly 23–32 species of edible and medicinal insects traditionally utilized by the Bodos. Commonly consumed species include *Lethocerus indicus*, *Samia ricini*, *Oecophylla smaragdina*, *Apis indica*, termites, crickets, grasshoppers, beetle larvae, and wasp larvae. These insects are important sources of proteins, essential amino acids, healthy fats, vitamins, and minerals, thereby contributing significantly to household nutrition and food security in rural communities.

Insects also hold an important place in Bodo ethnomedicine. Honey, ants, silkworm pupae, termites, and wasp larvae are traditionally used in the treatment of cough, asthma, fever, wounds, digestive disorders, arthritis, and physical weakness. Scientific investigations increasingly support the medicinal value of insect-derived products because of their antimicrobial, antioxidant, and anti-inflammatory properties.

Beyond their nutritional and medicinal importance, insects contribute significantly to pollination, sericulture, apiculture, nutrient cycling, sustainable livelihoods, and biodiversity conservation. They are also closely associated with Bodo cultural traditions, folk beliefs, oral knowledge systems, and ecological practices. However, rapid urbanization, modernization, pesticide use, habitat degradation, climate change, and declining interest among younger generations are gradually threatening both insect diversity and traditional entomological knowledge. The review therefore highlights the urgent need for scientific documentation, biodiversity conservation, and preservation of indigenous knowledge systems related to insects.

Keywords: Bodo community, entomophagy, entomotherapy, edible insects, indigenous knowledge, Assam, sustainability

Introduction

Insects are the most diverse and abundant group of organisms on Earth and occupy nearly every terrestrial and freshwater habitat. Their ecological importance is immense, as they contribute significantly to the functioning and stability of natural ecosystems. Insects perform essential ecosystem services such as pollination, decomposition of organic matter, nutrient recycling, soil formation, biological pest regulation, and maintenance of food chains. The survival of many plant and animal species, including humans, is directly or indirectly dependent on insect activities. Besides their ecological role, insects have maintained a close association with human societies since ancient times and have been utilized as sources of food, medicine, textiles, dyes, and several industrial products.

In recent decades, insects have attracted increasing global attention as sustainable and nutrient-rich food resources. Edible insects are considered highly nutritious because they contain substantial amounts of proteins, essential amino acids, healthy fats, vitamins, and minerals. Compared to conventional livestock farming, insect production requires less land, water, and feed while generating fewer greenhouse gas emissions. Consequently, insects are increasingly recognized as promising alternatives for ensuring food security, nutritional sustainability, and environmental conservation in the future.

North-East India, forming part of the Indo-Burma biodiversity hotspot, is well known for its exceptional biological and cultural diversity. The region is inhabited by numerous indigenous communities that possess rich traditional ecological knowledge developed through long-term interaction with nature. Forests, wetlands, rivers, and agricultural landscapes form the basis of traditional livelihood systems in the region, where wild edible plants, fishes, insects, and other natural resources are commonly utilized. Among many tribal communities of North-East India, entomophagy, or the practice of consuming insects as food, has been an integral component of traditional food culture for generations. The use of insects as food and medicine is closely linked with seasonal cycles, cultural beliefs, local biodiversity, and indigenous knowledge systems.

The Bodos are one of the oldest and largest indigenous communities of Assam and are mainly concentrated in the Bodoland Territorial Region (BTR), particularly in the districts of Kokrajhar, Chirang, Baksa, and Udalguri. Traditionally, the Bodo community has depended extensively on forests, wetlands, and agricultural ecosystems for food, medicine, and livelihood. Their close association with nature has led to the development of rich ethnozoological and ethnoentomological knowledge that has been transmitted orally from one generation to another.

Among the Bodos, insects are not merely regarded as occasional food items but are deeply embedded in their socio-cultural life, traditional healthcare practices, and ecological understanding. Various insects such as grasshoppers, crickets, termites, silkworms, water bugs, ants, beetles, and caterpillars are traditionally consumed

either as delicacies or as supplementary protein sources. These insects are collected from paddy fields, forests, freshwater bodies, and surrounding natural habitats using indigenous harvesting methods. Preparation techniques such as roasting, boiling, frying, smoking, and cooking with local spices are commonly practiced within the community.

Apart from their dietary importance, several insect species are also traditionally used for therapeutic purposes among the Bodos. Indigenous medicinal practices involving insects are associated with the treatment of ailments such as cough, fever, stomach disorders, wounds, and general weakness. Such traditional knowledge systems represent an important aspect of Bodo cultural heritage and reflect centuries of empirical observations and ecological adaptation. However, rapid modernization, urbanization, habitat destruction, indiscriminate pesticide use, and changing food preferences among younger generations are gradually threatening the continuity of these traditional practices and knowledge systems.

Several studies conducted in different parts of Assam have highlighted the rich diversity of edible and medicinal insects utilized by the Bodo community. Narzari and Sarmah (2015) [19] documented 25 species of edible insects belonging to different taxonomic groups and emphasized their nutritional and medicinal importance in Bodo society. Similarly, Hazarika and Goyari (2017) [9] recorded 23 species of edible insects consumed by the Bodos of Udalguri district and noted their significance in traditional food systems and nutritional security. More recent studies have further emphasized the ecological, nutritional, therapeutic, and socio-cultural relevance of insects among the Bodo people and stressed the urgent need for systematic scientific documentation and conservation of this indigenous knowledge.

In the present era of increasing concern over food insecurity, biodiversity loss, and sustainable resource utilization, the traditional insect-related knowledge of indigenous communities offers valuable insights for future nutritional and ecological sustainability. Therefore, the present review aims to comprehensively synthesize available literature on the role of insects in the life of the Bodo community of Assam, with special emphasis on entomophagy, entomotherapy, socio-cultural significance, ecological importance, and future sustainability prospects.

Insects as Food Resources in Bodo Society

1. Diversity of edible insects

The consumption of insects as food has long been an integral part of the traditional food culture of the Bodo community of Assam. For generations, the Bodos have depended closely on forests, wetlands, agricultural fields, and surrounding natural ecosystems for sustenance, which has enabled them to develop extensive knowledge regarding edible insect species, their seasonal availability, harvesting methods, and modes of preparation. Among the Bodos, insects are not viewed merely as emergency food resources but are regarded as culturally accepted delicacies, nutritious dietary supplements, and valuable components of indigenous food heritage. The practice of entomophagy is deeply connected with their traditional ecological knowledge, livelihood systems, and close relationship with nature (Narzari & Sarmah, 2015) [19].

Ethnoentomological studies conducted in different parts of Assam have revealed remarkable diversity in the edible insects consumed by the Bodo community. Narzari and Sarmah (2015) [19] documented 25 species of edible insects belonging to eight orders and fourteen families, whereas Hazarika and Goyari (2017) [9] reported 23 edible insect species from the Udalguri district of the Bodoland Territorial Area Districts (BTAD) (Narzari & Sarmah, 2015; Hazarika & Goyari, 2017) [9, 19]. More recent studies by Kalita *et al*. (2022) and Muchahary *et al*. (2023) [11, 18] further emphasized the nutritional, medicinal, ecological, and socio-cultural importance of edible insects among the Bodos. Together, these studies indicate that the diversity of edible insects consumed by the community ranges from approximately 23 to 32 species depending on geographical location, habitat availability, and seasonal occurrence.

The edible insects utilized by the Bodos belong mainly to the orders Orthoptera, Hemiptera, Coleoptera, Hymenoptera, Lepidoptera, Isoptera, Odonata, and Dictyoptera. Grasshoppers, crickets, water bugs, silkworms, termites, ants, beetles, bees, and wasp larvae are among the most preferred edible groups. Different developmental stages such as eggs, larvae, pupae, nymphs, and adults are consumed depending upon the species and local preference. The selection of edible insects is influenced by taste, texture, nutritional value, abundance, body size, and cultural familiarity (Hazarika & Goyari, 2017) [9].

Among the various edible insects, the giant water bug *Lethocerus indicus* is considered one of the most preferred species because of its large size, distinctive flavor, and comparatively high nutritional value. It is commonly collected from wetlands, ponds, irrigation channels, and paddy fields during the monsoon season. The insects are usually fried or roasted before consumption and are regarded as delicacies in many Bodo households. Hazarika and Goyari (2017) [9] observed that the popularity of *Lethocerus indicus* among the Bodos is closely associated with its easy availability and taste preference (Hazarika & Goyari, 2017) [9].

The eri silkworm, *Samia ricini*, also occupies an important place in the traditional food system of the Bodos. The larvae and pupae are widely consumed and are considered highly nutritious because of their rich protein and fat content. The consumption of silkworms is closely associated with the traditional sericulture practices of Assam, where rearing eri silkworms is both a cultural and economic activity. Silkworm pupae are generally boiled, fried, or cooked with local spices and herbs, and they are especially popular during community feasts and family gatherings (Narzari & Sarmah, 2015) [19].

Ants, particularly the red weaver ant *Oecophylla smaragdina*, are extensively used both as food and traditional medicine. Their larvae, pupae, and adults are consumed either raw, roasted, or prepared as chutney mixed with local spices. The sour taste of these ants, mainly due to the presence of formic acid, is highly appreciated by many members of the community. In addition to their culinary importance, they are traditionally believed to possess medicinal properties and are often consumed for relief from cough, fever, and digestive ailments (Muchahary *et al*., 2023) [18].

Honey bees (*Apis indica*) and their brood are also consumed traditionally among the Bodos. Honey collected from wild and domesticated bee colonies is valued not only as food but also as an important medicinal substance. Bee larvae and

pupae are sometimes roasted or fried and consumed as protein-rich food items. Similarly, termites, particularly the winged reproductive forms emerging during the rainy season, are collected near termite mounds and consumed after frying or roasting. These termites are considered highly nutritious due to their rich fat and protein content (Narzari & Sarmah, 2015) [19].

Orthopteran insects such as grasshoppers, locusts, and crickets are among the most commonly consumed edible insects among the Bodos. Grasshoppers belonging to the genus *Oxya* are abundant in paddy fields and agricultural landscapes and are generally collected manually during the early morning or evening hours. Crickets are commonly fried and consumed as snacks or side dishes. Beetle larvae and palm weevil larvae are also consumed in several areas and are preferred for their soft texture and rich fat content. Dragonflies and their aquatic nymphs are occasionally consumed in some localities, particularly in wetland-dominated regions. Wasp larvae and pupae are considered delicacies and are carefully harvested from forest nests using traditional techniques (Narzari & Sarmah, 2015; Hazarika & Goyari, 2017) [9, 19].

Table 1: Diversity of edible insects consumed by the Bodo community of Assam

Order	Species	Local Use	Life Stage Consumed	Habitat	Preparation Method
Hemiptera	*Lethocerus indicus*	Delicacy and protein source	Adult	Wetlands, paddy fields	Fried, roasted
Lepidoptera	*Samia ricini*	Nutritious traditional food	Larva, pupa	Sericulture farms	Boiled, fried
Hymenoptera	*Oecophylla smaragdina*	Food and medicinal use	Larva, pupa, adult	Trees and forests	Chutney, roasted
Hymenoptera	*Apis indica*	Honey and brood consumption	Larva, pupa	Forests, homesteads	Raw, roasted
Isoptera	*Macrotermes* sp.	Seasonal protein source	Winged adults	Termite mounds	Fried, roasted
Orthoptera	*Oxya* sp.	Common traditional food	Adult	Paddy fields	Fried, roasted
Orthoptera	*Gryllus* sp.	Protein-rich snack	Adult	Agricultural fields	Fried
Coleoptera	Beetle larvae	Fat-rich delicacy	Larva	Decaying wood	Roasted
Coleoptera	*Oryctes* sp.	Traditional food item	Larva	Palm trunks	Roasted
Odonata	Dragonflies	Seasonal food	Nymph, adult	Wetlands	Fried
Hymenoptera	*Vespa* sp.	Delicacy	Larva, pupa	Forest nests	Roasted
Lepidoptera	Silkworms	Traditional nutritious food	Larva, pupa	Sericulture habitats	Fried, boiled
Hemiptera	Water bugs	Protein-rich delicacy	Adult	Aquatic habitats	Fried
Orthoptera	Katydids	Seasonal snack	Adult	Grasslands	Roasted
Dictyoptera	Praying mantis	Occasionally consumed	Adult	Vegetation	Fried

The methods used for collecting edible insects among the Bodos reflect a deep understanding of local ecology and insect behavior. Aquatic insects are harvested using hand nets, bamboo traps, and traditional fishing devices, whereas terrestrial insects are collected manually from crop fields, grasses, shrubs, and tree trunks. Seasonal emergence patterns, breeding periods, and habitat preferences of different insect species are well understood within the community and guide harvesting practices. In many villages, insect collection is not merely an individual activity but often involves collective participation by family members, including children and elderly people, thereby facilitating the intergenerational transfer of indigenous knowledge (Narzari & Sarmah, 2015) [19].

Preparation methods of edible insects are equally diverse and culturally significant. Frying and roasting are the most commonly practiced methods because they improve flavor, texture, and shelf life. Some insects are boiled with local herbs and spices, while others are smoked for preservation and future use. Chutneys prepared from red weaver ants are especially popular because of their distinctive sour taste. In many rural households, insect-based dishes are prepared during festivals, seasonal celebrations, and social gatherings, indicating that edible insects continue to occupy an important place in Bodo culinary traditions and cultural identity (Muchahary *et al*., 2023) [18].

The nutritional significance of edible insects among the Bodos is considerable. Many of the consumed insect species contain high levels of proteins, essential amino acids, healthy fats, vitamins, and minerals, thereby serving as valuable dietary supplements in rural communities where access to conventional animal protein may sometimes be limited. Researchers have suggested that traditional entomophagy can contribute significantly to nutritional security and sustainable food systems, particularly in ecologically sensitive and economically marginalized regions of North-East India (Kalita *et al*., 2022; Hazarika & Goyari, 2017) [9, 11].

Apart from their dietary importance, edible insects also possess economic value in local markets. Seasonal sale of edible insects in rural markets provides supplementary income to many households and demonstrates the continued socio-economic relevance of entomophagy within the community. However, rapid urbanization, changing food preferences among younger generations, habitat degradation, and indiscriminate pesticide use are increasingly threatening both edible insect diversity and the traditional knowledge associated with their utilization. Therefore, systematic documentation, conservation, and sustainable management of edible insect resources are urgently required to preserve this important component of Bodo cultural and biological heritage.

2. Traditional Collection and Harvesting Practices

The collection and harvesting of edible insects among the Bodo community reflect a deep understanding of local ecology, seasonal rhythms, and insect behavior developed through generations of close interaction with nature. The Bodos have traditionally relied on forests, wetlands, paddy fields, riversides, and surrounding vegetation not only for agriculture and livelihood but also for gathering a wide variety of edible insects. These harvesting practices are closely linked with seasonal cycles, agricultural activities, and indigenous ecological knowledge that has been transmitted orally within families and communities over centuries (Narzari & Sarmah, 2015) [19].

Paddy field collection

Paddy fields represent one of the most important sites for the collection of edible insects among the Bodos. Rice agroecosystems provide ideal habitats for several edible species such as grasshoppers, crickets, katydids, water bugs, dragonflies, and aquatic beetles. During the monsoon and post-monsoon seasons, the abundance of vegetation and standing water creates favorable conditions for insect breeding and growth, resulting in increased availability of edible insects. Grasshoppers belonging to the genus *Oxya* are particularly common in paddy fields and are generally collected manually during the early morning or evening when insect activity is relatively low (Narzari & Sarmah, 2015) [19].

Aquatic insects such as *Lethocerus indicus* are harvested from flooded paddy fields, irrigation channels, and nearby ponds using hand nets, bamboo traps, or simple manual collection methods. In some areas, light sources are used during night hours to attract water bugs and other flying insects for easier collection. The harvesting of insects from paddy fields illustrates the close relationship between traditional agriculture and indigenous food systems within Bodo society (Hazarika & Goyari, 2017) [9].

Forest collection

Forests and surrounding vegetation are another major source of edible insects. Several insects such as ants, bees, wasps, caterpillars, beetle larvae, and silkworms are collected from forest ecosystems and trees. The red weaver ant, *Oecophylla smaragdina*, is commonly gathered from nests built on tree branches. Harvesting is usually carried out carefully using bamboo poles, leaves, and traditional containers to minimize injury from ant bites (Muchahary *et al*., 2023) [18].

Wasp larvae and pupae are also collected from forest nests, often during early morning or evening hours when the insects are less active. Beetle larvae and palm weevil larvae are extracted from decaying logs, rotten wood, and dead palm trunks. The eri silkworm, *Samia ricini*, is associated with traditional sericulture practices and is harvested from host plants cultivated near villages and agricultural fields. Forest-based insect harvesting reflects the extensive ecological knowledge possessed by the Bodos regarding insect habitats, breeding cycles, and seasonal occurrence (Narzari & Sarmah, 2015) [19].

Water body harvesting

Wetlands, ponds, marshes, streams, and seasonal water bodies serve as important harvesting grounds for several edible aquatic insects. Large water bugs, dragonfly nymphs, aquatic beetles, and other freshwater insects are collected from aquatic habitats using traditional methods such as hand nets, bamboo baskets, and locally designed traps. Among these, *Lethocerus indicus* is one of the most preferred edible aquatic insects because of its large body size, rich flavor, and nutritional value (Hazarika & Goyari, 2017) [9].

The collection of aquatic insects is especially common during the rainy season when wetlands become highly productive and insect populations increase significantly. Traditional ecological knowledge enables local people to identify productive harvesting areas and suitable periods for collection.

Seasonal abundance and availability

Seasonal variation strongly influences the availability and consumption of edible insects among the Bodos. Most edible species are abundant during the monsoon and post-monsoon seasons when climatic conditions support rapid insect growth and reproduction. Termites emerge in large numbers during rainy evenings, grasshoppers proliferate in paddy fields during crop growth periods, while ants and wasp larvae become available during specific reproductive seasons (Narzari & Sarmah, 2015) [19].

The Bodos possess detailed traditional knowledge regarding the seasonal appearance, habitat preference, and breeding behavior of edible insects. Such knowledge guides collection activities throughout the year and ensures efficient harvesting practices. Seasonal abundance also influences dietary patterns and community food traditions, with some insects being associated with specific festivals, agricultural seasons, and cultural celebrations.

Market availability and local trade

In many rural areas of the Bodoland Territorial Region, edible insects are sold in local weekly markets and roadside stalls. Species such as silkworm pupae, termites, water bugs, crickets, and ant larvae are commonly available during peak harvesting seasons. Women and elderly villagers often participate actively in the collection and sale of edible insects, thereby contributing to household income and local food economies. The continued market demand for edible insects demonstrates that entomophagy remains socially accepted and economically relevant within Bodo society despite increasing modernization and changing food preferences (Hazarika & Goyari, 2017) [9].

Indigenous collection techniques

The collection of edible insects among the Bodos involves several simple yet efficient indigenous techniques developed through long-term interaction with natural ecosystems. Bamboo traps, hand nets, earthen containers, leaf baskets, light-based attraction methods, and manual collection are commonly employed depending on the habitat and insect species. These techniques are environmentally sustainable and require detailed knowledge of insect ecology and behavior. In many villages, insect collection is often a collective family activity, enabling the transmission of traditional ecological knowledge from older to younger generations (Narzari & Sarmah, 2015) [19].

3. Preparation and Consumption Methods

The preparation and consumption of edible insects among the Bodo community exhibit remarkable diversity and reflect the richness of indigenous culinary traditions. Different insect species are prepared using various traditional methods depending on their size, texture, flavor, and cultural preference. Common preparation techniques include frying, roasting, smoking, boiling, preparing curries, consuming raw, and making insect-based pastes or chutneys (Kalita *et al*., 2022) [11].

Frying is one of the most common methods of preparation. Grasshoppers, crickets, termites, silkworm pupae, beetle larvae, and aquatic insects are frequently fried with oil, garlic, onions, chilies, and indigenous spices. Fried insects are often consumed as snacks or side dishes and are appreciated for their crispy texture and savory flavor. Roasting over open fire or charcoal is another widely practiced method, especially for termites, crickets, wasp larvae, and water bugs. Roasted insects are considered highly flavorful and are commonly consumed during social gatherings and festivals (Narzari & Sarmah, 2015) [19].

Smoking is traditionally used both for flavor enhancement and preservation. Certain insects are lightly smoked after collection to reduce moisture content and extend storage life. Smoked insects may later be consumed directly or cooked with vegetables and local herbs. In some villages, smoked silkworm pupae and grasshoppers are regarded as delicacies during community feasts and ceremonial occasions.

Preparation of insect curries is also common among the Bodos. Silkworm pupae, crickets, beetle larvae, and water bugs are cooked with vegetables, bamboo shoots, herbs, and local spices to prepare flavorful curries that are generally eaten with rice. These dishes form an important part of traditional rural cuisine (Kalita *et al*., 2022) [11].

Some edible insects are consumed raw or prepared as chutneys and pastes. The red weaver ant, *Oecophylla smaragdina*, is particularly popular for preparing sour chutneys and pastes because of the formic acid naturally present in the ants. Ant larvae and adults are crushed with chilies, salt, garlic, ginger, and local herbs to prepare traditional condiments with a distinctive taste. These preparations are valued not only for their flavor but also for their perceived medicinal properties (Muchahary *et al*., 2023) [18].

The diversity of cooking methods indicates that edible insects occupy an important place within Bodo food traditions and are consumed as culturally valued foods rather than merely survival resources. Their preparation methods also demonstrate the adaptability and creativity of indigenous culinary knowledge systems.

4. Nutritional Significance of Edible Insects

Edible insects consumed by the Bodo community possess high nutritional value and serve as important dietary supplements, particularly in rural areas where access to conventional animal protein may be limited. Recent scientific studies have increasingly recognized edible insects as sustainable and nutrient-rich food resources because of their substantial content of proteins, lipids, amino acids, minerals, vitamins, and bioactive compounds (Kalita *et al*., 2022) [11].

Protein and amino acids

Most edible insects consumed by the Bodos are rich in high-quality proteins and essential amino acids necessary for human growth, tissue repair, and metabolic functioning. Silkworm pupae, termites, grasshoppers, and crickets contain significant levels of digestible protein comparable to or even exceeding several conventional livestock products. These insects therefore play an important role in improving nutritional security in rural communities (Kalita *et al*., 2022) [11].

Edible insects also provide essential amino acids such as lysine, methionine, leucine, and valine, which are often deficient in cereal-based diets. The inclusion of insects in traditional food systems helps diversify nutrient intake and contributes to balanced nutrition among indigenous communities.

Lipids and fatty acids

Several edible insects such as termites, beetle larvae, and silkworm pupae are rich sources of lipids and essential fatty acids. These lipids provide concentrated energy and support various physiological functions within the human body. The fat content of edible insects also contributes to their characteristic flavor, texture, and culinary appeal. In many rural communities, fat-rich insects are particularly valued as nutritious seasonal foods (Muchahary *et al*., 2023) [18].

Minerals and vitamins

Edible insects are recognized as important sources of micronutrients including iron, zinc, calcium, magnesium, phosphorus, and potassium. These minerals are essential for blood formation, bone development, immune function, and metabolic regulation. Insects also contain vitamins such as riboflavin, niacin, thiamine, and vitamin B-complex, which contribute to improved nutritional balance and overall health (Kalita *et al*., 2022) [11].

Antioxidants and bioactive compounds

Recent studies suggest that several edible insects possess antioxidant and bioactive compounds with potential therapeutic significance. Ants, bees, silkworms, and other edible insects are traditionally believed to improve immunity, physical strength, and general health. Muchahary *et al*. (2023) [18] observed that many insects consumed among the Bodos are also used in folk medicine because of their perceived medicinal benefits and therapeutic properties.

The nutritional richness of edible insects highlights their importance not only as traditional food resources but also as promising components of sustainable future food systems. Their high nutrient content, comparatively low environmental footprint, and cultural acceptance among indigenous communities indicate their potential contribution toward addressing global challenges related to malnutrition, food insecurity, and sustainable resource management.

Insects in Bodo Ethnomedicine and Entomotherapy

The traditional healthcare practices of the Bodo community of Assam are deeply connected with nature and rely extensively on locally available biological resources, including insects and other arthropods. Besides their role as food resources, many insects are traditionally regarded as therapeutic agents capable of treating various human ailments and improving overall health. The use of insects and insect-derived products in indigenous healing practices, commonly known as entomotherapy, has been practiced among the Bodos for generations and continues to survive in many rural areas despite the growing influence of modern medicine (Basumatary & Choudhury, 2023) [2].

Traditional medicinal knowledge associated with insects is largely transmitted orally through elderly family members, village healers, and traditional practitioners. Such practices reflect centuries of empirical observations and close interaction with local ecosystems. Basumatary and Choudhury (2023) [2] documented 23 medicinally important arthropod species belonging to 17 families and 11 orders that are traditionally used by the Bodo community of Kokrajhar district for treating at least twelve different ailments, including cough, asthma, fever, stomach disorders, wounds, rheumatoid arthritis, weakness, allergies, epilepsy, digestive problems, blood pressure irregularities, and urinary disorders. The study further revealed that all respondents interviewed during the survey had used at least

one medicinal insect or arthropod species during their lifetime, indicating the continuing relevance of entomotherapy within Bodo society.

The medicinal insects utilized by the Bodos are collected from diverse habitats such as forests, wetlands, agricultural fields, tree canopies, freshwater ecosystems, and underground burrows. Different developmental stages including larvae, pupae, nymphs, and adults are used either directly or after simple preparation methods. In many cases, freshly collected specimens are preferred because they are believed to possess greater medicinal efficacy (Basumatary & Choudhury, 2023) [2].

1. Traditional Therapeutic Uses of Insects

Traditional entomotherapeutic practices among the Bodos are closely associated with nutritional supplementation, respiratory care, wound healing, digestive health, and restoration of physical strength. Several medicinal insects are also edible species, indicating a strong relationship between entomophagy and ethnomedicine in the community. Honey, ants, silkworms, termites, beetles, crickets, wasp larvae, spiders, and other arthropods are commonly used in indigenous therapeutic preparations (Basumatary & Choudhury, 2023; Muchahary *et al*., 2023) [2, 18].

Table 2: Medicinal insects and arthropods used in Bodo ethnomedicine

Scientific Name	Common Name	Ailment Treated	Method of Use	Traditional Practice
Apis indica	Honey bee	Cough, cold, weakness, wounds, BP regulation	Honey consumed orally or applied externally	Household medicinal remedy
Oecophylla smaragdina	Red weaver ant	Asthma, cough, fever, stomach disorders	Ant chutney or paste consumed orally	Common folk therapeutic practice
Samia ricini	Eri silkworm	Weakness, malnutrition	Larvae and pupae consumed	Nutritional recovery food
Vespa sp.	Wasp	Arthritis, body pain, fatigue	Roasted larvae consumed	Traditional strengthening food
Gryllus sp.	Cricket	Weakness and fatigue	Fried insects consumed	Protein-rich therapeutic food
Macrotermes sp.	Termite	Weakness and exhaustion	Roasted winged adults consumed	Seasonal medicinal supplement
Dytiscus marginalis	Diving beetle	Nutritional deficiency and weakness	Cooked and consumed	Traditional strengthening diet
Beetle larvae	Beetle grub	Joint pain and weakness	Roasted larvae consumed	Folk restorative food
Pholcus phalangioides	Daddy long-legs spider	Asthma and breathing difficulty	Spider tied inside eri cocoon around chest	Indigenous respiratory treatment
Periplaneta americana	Cockroach	Respiratory disorders	Burnt extract traditionally used	Folk medicinal preparation
Dragonflies	Dragonfly	Fever and weakness	Fried adults or nymphs consumed	Seasonal medicinal food
Honey bee products	Honey and bee products	Wound healing	Applied externally	Indigenous wound care
Ant larvae	Ant brood	Digestive disorders	Chutney preparation	Traditional digestive remedy
Scorpio sp.	Scorpion	Joint pain and paralysis-related conditions	Oil or extract used traditionally	Ethnomedicinal practice
Neuropteran insects	Lacewing insects	Skin allergy and irritation	Paste preparation	Indigenous topical remedy

Among all insect-derived medicinal resources, honey obtained from *Apis indica* occupies a particularly significant position in Bodo ethnomedicine. Honey is widely used for the treatment of cough, throat irritation, fever, digestive disorders, wounds, and physical weakness. It is either consumed directly or mixed with herbal preparations and warm water. In several rural households, regular consumption of honey is also believed to help regulate blood pressure and improve general health (Basumatary & Choudhury, 2023) [2]. Similar therapeutic uses of honey have been documented globally because of its antimicrobial, antioxidant, and wound-healing properties (Takov *et al*., 2025) [24].

The red weaver ant, *Oecophylla smaragdina*, is another highly valued medicinal insect among the Bodos. The ants, larvae, and pupae are commonly prepared as chutney and consumed for treating cough, asthma, stomach disorders, and fever. The characteristic sour taste of the ants, resulting mainly from formic acid, is culturally associated with medicinal potency. Muchahary *et al*. (2023) [18] reported that ant-based preparations are commonly consumed during seasonal illnesses and are believed to improve respiratory health and digestion.

The eri silkworm, *Samia ricini*, is regarded not only as a nutritious food source but also as a restorative medicinal resource. Its larvae and pupae are rich in proteins and lipids and are commonly consumed to restore body strength after illness or physical exhaustion. The therapeutic importance of silkworm pupae is closely associated with traditional sericulture practices among the rural communities of Assam (Basumatary & Choudhury, 2023) [2].

Similarly, wasp larvae (*Vespa* sp.), termites, beetle larvae, and crickets are considered strengthening foods capable of reducing fatigue and improving physical stamina. Roasted wasp larvae are traditionally consumed for relieving arthritis, body pain, and weakness, whereas crickets are regarded as protein-rich foods useful for improving energy and vitality (Muchahary *et al*., 2023) [18]. Termites and beetle larvae are also valued because of their high nutritional content and are often consumed during periods of weakness or nutritional deficiency (Basumatary & Choudhury, 2023) [2].

An interesting example of traditional Bodo entomotherapy involves the use of the spider *Pholcus phalangioides* for treating breathing difficulties and asthma. In this practice, the live spider is placed inside an eri silkworm cocoon and

tied around the chest or neck region of the patient. Although such practices may appear symbolic from a modern scientific perspective, they represent deeply rooted indigenous beliefs and healing traditions developed through generations of cultural experience (Basumatary & Choudhury, 2023) [2].

2. Medicinally Important Insect Species

Apis indica

Honey bees and their products are among the most extensively utilized medicinal resources in Bodo ethnomedicine. Honey possesses nutritional, antimicrobial, antioxidant, anti-inflammatory, and wound-healing properties and is widely used both internally and externally. Takov *et al*. (2025) [24] emphasized that honey contains flavonoids, enzymes, amino acids, vitamins, phenolic compounds, and antimicrobial substances that contribute to its therapeutic value in both traditional and modern healthcare systems.

Oecophylla smaragdina

The medicinal importance of the red weaver ant is strongly associated with its acidic secretions and bioactive compounds. Traditional ant-based preparations are widely used among the Bodos for respiratory and digestive ailments. Scientific studies have shown that ants contain antimicrobial compounds and antioxidant substances capable of inhibiting microbial growth and stimulating immune responses, thereby supporting some traditional medicinal claims (Muchahary *et al*., 2023) [18].

Samia ricini

The eri silkworm is considered an important medicinal nutritional resource because of its high protein, fatty acid, and amino acid content. Silkworm pupae are rich in bioactive peptides and micronutrients that may support nutritional recovery, immune function, and body strength. Their medicinal use among the Bodos reflects the close relationship between traditional nutrition and healthcare practices (Basumatary & Choudhury, 2023) [2].

Vespa sp.

Wasp larvae and pupae are traditionally consumed to relieve body pain, arthritis, fatigue, and weakness. Their therapeutic significance is mainly associated with their high nutritional value, particularly proteins and minerals. In several Bodo villages, roasted wasp larvae are considered restorative foods capable of improving stamina and immunity (Muchahary *et al*., 2023) [18].

Crickets and Other Orthopterans

Crickets and related orthopteran insects are consumed both as food and medicinal supplements. Their high protein and mineral content make them valuable restorative foods in rural communities. Fried crickets are commonly consumed during periods of weakness or nutritional stress and are traditionally believed to improve body strength and vitality (Basumatary & Choudhury, 2023) [2].

3. Scientific Basis of Entomotherapy

Several traditional medicinal uses of insects among the Bodos are increasingly supported by modern scientific investigations. Many insects and insect-derived products contain biologically active compounds with antimicrobial, antioxidant, anti-inflammatory, immunomodulatory, and wound-healing properties. Takov *et al*. (2025) [24] highlighted that insect-derived substances such as honey, propolis, royal jelly, and insect extracts possess significant medicinal potential and are increasingly being explored in modern pharmacology and biomedical research.

Honey contains sugars, enzymes, amino acids, flavonoids, vitamins, and phenolic compounds that contribute to its antibacterial and antioxidant activities. These compounds help inhibit microbial growth, accelerate wound healing, reduce inflammation, and protect cells against oxidative stress. Similarly, ants such as *Oecophylla smaragdina* contain formic acid and other bioactive substances that may possess antimicrobial and anti-inflammatory properties.

Silkworm pupae, termites, crickets, and wasp larvae are rich in proteins, essential fatty acids, minerals, and bioactive peptides that contribute to improved nutrition, immune function, and tissue repair. The growing scientific interest in insect-derived compounds has opened new opportunities in the development of nutraceuticals, pharmaceuticals, and functional foods. Therefore, the traditional entomotherapeutic knowledge of the Bodo community represents not only a valuable cultural heritage but also an important resource for future biomedical and nutritional research. At the same time, rapid modernization, habitat degradation, and declining transmission of indigenous knowledge threaten the continuity of these traditional practices, emphasizing the urgent need for systematic documentation and conservation of Bodo ethnomedicinal knowledge systems.

Insects in Bodo Culture and Tradition

Among the Bodo community of Assam, insects occupy a significant place not only in food and medicine but also in cultural traditions, social practices, folk beliefs, and indigenous ecological knowledge. The relationship between the Bodos and insects has evolved through centuries of close interaction with forests, wetlands, agricultural landscapes, and surrounding natural ecosystems. As a result, insects have become deeply embedded in the socio-cultural life of the community and continue to influence traditional food habits, seasonal activities, healing practices, and environmental understanding (Narzari & Sarmah, 2015) [19].

Traditional insect-related knowledge among the Bodos is primarily transmitted orally from one generation to another through family practices, agricultural activities, community participation, storytelling, and observation of nature. Elderly members of the community play an important role in teaching younger generations about edible and medicinal insects, their habitats, seasonal availability, collection techniques, and preparation methods. This intergenerational transfer of knowledge has helped preserve indigenous ecological wisdom and cultural continuity for generations despite increasing social and technological changes (Muchahary *et al*., 2023) [18].

1. Insects in Festivals and Traditional Food Practices

Insects form an important component of the traditional food culture of the Bodos and are often associated with seasonal celebrations, agricultural activities, and communal gatherings. The availability of edible insects usually coincides with specific agricultural seasons, particularly the monsoon and post-harvest periods, when many insect species become abundant in paddy fields, forests, wetlands,

and grasslands. During these periods, insect collection and preparation often become collective social activities involving family members and neighboring households (Hazarika & Goyari, 2017) [9].

Traditional dishes prepared from silkworm pupae, termites, crickets, grasshoppers, beetle larvae, and red weaver ants are frequently consumed during family feasts, village gatherings, and seasonal celebrations. Such foods are regarded not only as delicacies but also as symbols of traditional lifestyle and indigenous culinary heritage. In several rural Bodo households, the preparation of insect-based dishes during communal events reflects cultural identity, hospitality, and social bonding within the community (Narzari & Sarmah, 2015) [19].

The eri silkworm, *Samia ricini*, occupies a particularly important cultural position because of its close association with traditional sericulture practices in Assam. Besides contributing to silk production and household economy, eri silkworm larvae and pupae are consumed as nutritious traditional foods during social gatherings and special occasions. Likewise, honey collected from *Apis indica* is commonly used during festivals and ceremonial activities and is often associated with purity, health, and prosperity (Muchahary *et al*., 2023) [18].

2. Ritual Consumption and Folk Beliefs

Several insects consumed by the Bodos are also associated with traditional beliefs, ritual practices, and symbolic meanings. Certain edible insects are believed to possess protective or strengthening properties and are consumed during particular seasons or periods of illness. For example, the red weaver ant, *Oecophylla smaragdina*, is traditionally believed to improve immunity and protect against seasonal diseases because of its medicinal value. Chutneys prepared from these ants are commonly consumed during seasonal transitions and periods when respiratory illnesses are prevalent (Muchahary *et al*., 2023) [18].

Traditional healing practices involving insects also reveal the spiritual and symbolic dimensions of Bodo ethnomedicine. Basumatary and Choudhury (2023) [2] documented the use of the spider *Pholcus phalangioides* in treating asthma and breathing difficulties, where the spider is placed inside an eri silkworm cocoon and tied around the patient's neck or chest. Such practices illustrate the deep connection between indigenous healing systems, cultural beliefs, and traditional concepts of health and disease.

In many villages, insects are also regarded as indicators of fortune, seasonal change, and environmental conditions. The abundance or scarcity of particular insect species is often interpreted as a sign of rainfall variation, crop productivity, or climatic changes. These beliefs reflect the close observation of natural processes and ecological patterns that characterize traditional Bodo knowledge systems.

3. Insects and Community Identity

The use of insects as food and medicine contributes significantly to the cultural identity of the Bodo community. Traditional insect-based foods are widely regarded as part of indigenous heritage and continue to symbolize ethnic identity and customary food practices. Even today, edible insects such as silkworm pupae, termites, grasshoppers, and ants are sold in village markets and weekly rural bazaars, reflecting their continued cultural and economic importance within the community (Hazarika & Goyari, 2017) [9].

Knowledge related to insect collection, preservation, medicinal use, and preparation methods also strengthens social cohesion within rural communities. Children often learn these practices while participating in farming activities, forest visits, and household food preparation. Such participation helps preserve traditional knowledge while reinforcing the relationship between people and their natural environment (Narzari & Sarmah, 2015) [19].

4. Oral Traditions and Indigenous Knowledge

Oral traditions play a central role in preserving insect-related knowledge among the Bodos. Information regarding edible species, poisonous insects, medicinal uses, seasonal occurrence, and harvesting techniques is generally communicated verbally rather than through written documentation. Folk songs, stories, sayings, and traditional conversations often contain references to insects and their ecological significance. These oral knowledge systems not only help preserve cultural traditions but also contribute to sustainable resource management and biodiversity conservation (Muchahary *et al*., 2023) [18].

The indigenous ecological knowledge of the Bodos is based on careful observation of insect behavior, life cycles, habitat preferences, and seasonal emergence patterns. Such observations have helped the community develop practical understanding regarding climatic variation, agricultural timing, and environmental change.

5. Traditional Ecological Indicators

Insects serve as important ecological indicators within traditional Bodo knowledge systems. Seasonal emergence of termites, increased dragonfly activity before rainfall, and variations in cricket sounds are commonly interpreted as signs of changing weather and seasonal transitions. Farmers traditionally observe insect abundance and behavioral patterns to predict rainfall, determine cultivation periods, and assess environmental conditions. These practices demonstrate the sophisticated ecological understanding possessed by indigenous communities and highlight the close relationship between culture, livelihood, and the natural environment (Takov *et al*., 2025) [24].

However, rapid urbanization, modernization, habitat degradation, excessive pesticide use, and changing lifestyles are gradually weakening many traditional practices associated with insects. Younger generations are increasingly detached from indigenous food systems and oral traditions, resulting in the gradual erosion of valuable ethnoentomological knowledge. Researchers have therefore emphasized the urgent need for systematic documentation and preservation of traditional insect-related knowledge among the Bodos before these cultural practices and ecological understandings disappear permanently (Muchahary *et al*., 2023) [18].

Ecological and Economic Importance of Insects

Insects play a fundamental role in maintaining ecological balance and supporting human livelihoods across the world. Besides their importance as food and medicinal resources, insects contribute significantly to ecosystem functioning, agricultural productivity, biodiversity conservation, and rural economies. Takov *et al*. (2025) [24] emphasized that insects provide essential ecosystem services such as pollination, decomposition, nutrient recycling, biological pest control, silk production, and honey production, all of

which are indispensable for the functioning of natural and human-managed ecosystems.

Among the Bodo community of Assam, insects possess considerable ecological, nutritional, and economic significance. Traditional interactions between the Bodos and their surrounding environment have enabled the community to recognize the ecological functions and practical value of various insect species. Insects contribute directly to agricultural productivity, household nutrition, traditional industries, and supplementary income generation in rural areas. Their utilization reflects a sustainable relationship between indigenous communities and local biodiversity (Narzari & Sarmah, 2015) [19].

1. Pollination and Ecological Stability

Pollination is one of the most important ecological services provided by insects. Bees, butterflies, moths, beetles, flies, and other pollinating insects play a vital role in the reproduction of flowering plants and agricultural crops. According to Takov *et al*. (2025) [24], a substantial proportion of cultivated and wild plant species depend on insect-mediated pollination for successful fruit and seed production, making pollinators essential for biodiversity conservation and global food security.

In the agricultural landscapes inhabited by the Bodos, insect pollinators contribute significantly to the productivity of vegetables, fruits, pulses, oilseeds, and forest plants. Honey bees such as *Apis indica* are particularly important because they support both agricultural production and natural vegetation regeneration. Butterflies, moths, beetles, and other insects also contribute to pollination processes in forests, grasslands, and wetland ecosystems. The ecological importance of pollinating insects is therefore closely linked with the sustainability of traditional farming systems practiced by the Bodo community (Klein *et al*., 2007) [13].

Apart from pollination, insects contribute to ecological stability through decomposition and nutrient recycling. Termites, ants, beetles, and other decomposer insects help break down dead organic matter and accelerate nutrient cycling within ecosystems. Such activities improve soil fertility and maintain ecological balance. Predatory insects also play an important role in regulating pest populations naturally, thereby reducing dependence on chemical pesticides and supporting environmentally sustainable agriculture (Takov *et al*., 2025) [24].

2. Silk Production and Traditional Sericulture

Silk production represents one of the most economically important insect-related traditional practices in Assam. Among the Bodos, the rearing of eri silkworms (*Samia ricini*) has long been associated with household economy, weaving traditions, and cultural identity. Traditional sericulture provides both silk and edible pupae, thereby serving nutritional as well as economic functions within rural communities (Hazarika & Goyari, 2017) [9].

Eri culture forms an integral part of traditional livelihood systems in many Bodo households. Women, in particular, play a major role in silkworm rearing, cocoon processing, spinning, and weaving activities. Eri silk, popularly known as “peace silk” or “Ahimsa silk,” possesses high cultural and commercial value and is widely used in traditional Bodo attire and handicrafts. The economic benefits derived from sericulture contribute significantly to household income and rural self-employment opportunities (Muchahary *et al*., 2023) [18].

Takov *et al*. (2025) [24] noted that silk-producing insects have historically contributed to textile industries, trade, and rural economies in different parts of the world. In Assam, traditional sericulture remains environmentally sustainable because it requires relatively low investment and can be integrated with small-scale agriculture and household activities without causing major ecological disturbances.

3. Honey Production and Apiculture

Honey production is another important ecological and economic contribution of insects among the Bodos. Honey bees such as *Apis indica* not only provide valuable pollination services but also produce honey and other bee products with nutritional, medicinal, and commercial importance. In several rural areas, honey collection from wild bee colonies and small-scale beekeeping practices provide supplementary income and support local livelihoods (Basumatary & Choudhury, 2023) [2].

Honey is widely valued as a nutritious food and traditional medicine used for treating cough, throat irritation, digestive disorders, wounds, and physical weakness. Bee products such as honey, wax, and propolis are also commercially important in local markets. Takov *et al*. (2025) [24] highlighted that honey contains antimicrobial, antioxidant, anti-inflammatory, and therapeutic compounds that make it valuable in both traditional and modern healthcare systems.

Apiculture also contributes to biodiversity conservation and ecological sustainability because healthy bee populations are essential for maintaining pollination networks within natural and agricultural ecosystems. Sustainable beekeeping practices therefore provide combined ecological and economic benefits for rural communities.

4. Insects and Nutritional Security

Edible insects contribute significantly to nutritional security among the Bodos, especially in rural and economically marginalized areas where access to conventional animal protein may sometimes be limited. Many edible insect species consumed by the community are rich sources of proteins, essential amino acids, healthy fats, vitamins, minerals, and micronutrients. Species such as *Samia ricini*, termites, grasshoppers, crickets, ants, and beetle larvae provide important dietary supplementation and help maintain nutritional balance within traditional food systems (Kalita *et al*., 2022; Hazarika & Goyari, 2017) [9, 11].

Takov *et al*. (2025) [24] emphasized that edible insects are increasingly recognized globally as sustainable alternative protein sources because insect farming requires comparatively less land, water, and feed resources than conventional livestock production while generating lower greenhouse gas emissions. In this context, traditional entomophagy practices among the Bodos represent valuable examples of sustainable and environmentally responsible food systems.

Seasonal availability of edible insects also helps supplement rural diets during periods when other protein sources may be scarce. In several villages, edible insects continue to reduce dependence on expensive market-based foods and contribute directly to household food security.

5. Rural Economy and Sustainable Livelihoods

Insects contribute directly to the rural economy of the Bodo community through activities such as sericulture, apiculture, edible insect trade, and traditional food preparation. Seasonal sale of edible insects in local markets provides supplementary income to collectors, vendors, and rural households. Silkworm pupae, termites, crickets, ants, and water bugs are commonly sold in village markets and are regarded as traditional delicacies with local commercial demand (Hazarika & Goyari, 2017) [9].

Traditional insect-based livelihood activities are generally environmentally sustainable because they rely on local biodiversity and indigenous ecological knowledge while requiring minimal external inputs. Sericulture and apiculture, in particular, provide eco-friendly livelihood opportunities that can easily coexist with agriculture and forest-based activities.

According to Takov *et al*. (2025) [24], sustainable utilization of insects can contribute significantly to future bioeconomy development, rural employment generation, and environmentally responsible production systems. Within the Bodo community, insect-related traditional practices therefore represent important examples of sustainable resource utilization that combine ecological conservation with nutritional and economic benefits.

However, rapid urbanization, habitat degradation, indiscriminate pesticide use, and changing food preferences among younger generations increasingly threaten traditional insect-based livelihoods and indigenous ecological knowledge systems. Declining insect diversity may negatively affect pollination, nutritional security, and traditional economic activities associated with sericulture, apiculture, and edible insect collection. Therefore, proper documentation, biodiversity conservation, scientific validation, and policy support are essential for preserving these traditional practices and promoting sustainable insect-based livelihoods in the future.

Entomophagy, Food Security and Sustainability

Rapid population growth, climate change, shrinking agricultural land, and increasing pressure on natural resources have created serious concerns regarding future food security and environmental sustainability. Conventional livestock production systems require large quantities of land, water, feed, and energy while also contributing substantially to greenhouse gas emissions and environmental degradation. In recent years, edible insects have received growing global attention as sustainable alternative protein sources capable of addressing nutritional demands with comparatively lower environmental impact. Takov *et al*. (2025) [24] emphasized that insects possess immense potential for supporting sustainable food systems because of their high nutritional value, efficient feed conversion, rapid reproduction, and minimal ecological footprint.

Among the Bodo community of Assam, entomophagy has long been practiced as part of traditional food culture and ecological adaptation. The consumption of edible insects among the Bodos is closely associated with indigenous ecological knowledge, seasonal resource utilization, and sustainable interaction with local biodiversity. Unlike industrialized food systems, traditional insect consumption among indigenous communities depends largely on naturally available resources and environmentally adaptive harvesting practices. These traditional systems provide valuable insights into sustainable nutrition and biodiversity-based food security (Kalita *et al*., 2022) [11].

1. Population Pressure and the Search for Alternative Protein Sources

The increasing global demand for animal protein has become one of the major challenges for sustainable food production. Conventional livestock farming requires extensive land areas, high water consumption, and large quantities of feed resources, making it increasingly difficult to sustain under conditions of growing population pressure and environmental stress. Takov *et al*. (2025) [24] reported that edible insects are emerging as promising alternatives because they contain high-quality proteins, essential amino acids, healthy fats, vitamins, and minerals while requiring comparatively fewer natural resources for production.

Several edible insect species traditionally consumed by the Bodos, including *Samia ricini*, termites, grasshoppers, crickets, ants, and beetle larvae, possess significant nutritional value. Kalita *et al*. (2022) [11] highlighted that many edible insects consumed in Assam contain protein levels comparable to or higher than conventional livestock products and can therefore contribute substantially to nutritional security in rural communities. These insects also provide important micronutrients and essential fatty acids that help supplement traditional diets.

Traditional entomophagy among the Bodos demonstrates how indigenous food systems can support sustainable nutrition while reducing dependence on resource-intensive livestock production. In many rural areas, edible insects continue to serve as affordable and locally available protein sources, especially during periods when meat or fish are less accessible (Hazarika & Goyari, 2017) [9].

2. Sustainable Insect Farming and Resource Efficiency

One of the major advantages of insect-based food systems is their high efficiency in converting feed into edible biomass. Compared to cattle, poultry, or pigs, insects require significantly less feed, water, and land resources while producing lower quantities of greenhouse gases and organic waste. Takov *et al*. (2025) [24] observed that many edible insects can be reared on agricultural residues and organic waste materials, thereby contributing to sustainable waste recycling and circular bioeconomy systems.

Traditional insect utilization practices among the Bodos already reflect several principles of sustainable resource management. Most edible insects are collected seasonally from natural habitats using indigenous harvesting techniques developed through long-term ecological observation. Harvesting practices are generally selective and are often based on knowledge of insect breeding periods, habitat preferences, and seasonal abundance, which helps prevent excessive exploitation of local insect populations (Narzari & Sarmah, 2015) [19].

The rearing of eri silkworms (*Samia ricini*) represents an important example of sustainable insect-based livelihood systems in Assam. Eri culture can easily be integrated with household agriculture and agroforestry systems and requires relatively low investment. Besides contributing to silk production, eri silkworm pupae also serve as highly nutritious food resources, thereby increasing the overall economic and nutritional value of sericulture practices (Muchahary *et al*., 2023) [18].

Similarly, traditional beekeeping practices involving *Apis indica* contribute simultaneously to pollination, honey production, biodiversity conservation, and household income generation. Such insect-based livelihood systems demonstrate how ecological sustainability and economic resilience can coexist within indigenous communities.

3. Lower Environmental Footprint of Insects

The environmental footprint associated with insect production is considerably lower than that of conventional livestock farming. Takov *et al*. (2025) [24] emphasized that insects require much smaller land areas and lower water inputs while producing fewer greenhouse gas emissions compared to cattle and poultry farming. Insects also possess shorter life cycles and faster reproductive rates, allowing rapid biomass production with relatively limited environmental impact.

Traditional insect harvesting practices among the Bodos generally involve minimal ecological disturbance because they rely on naturally available seasonal resources rather than intensive industrial production systems. Indigenous entomophagy is therefore closely linked with biodiversity conservation and sustainable ecosystem utilization. Such practices help reduce pressure on conventional livestock systems while supporting local nutritional needs and preserving traditional food cultures.

In addition to serving as food resources, insects contribute directly to ecological sustainability through pollination, decomposition, nutrient recycling, and biological pest control. Conservation of insect diversity is therefore essential not only for maintaining ecosystem stability but also for supporting sustainable agricultural production and food security (Takov *et al*., 2025) [24].

4. Climate Resilience and Adaptive Food Systems

Climate change has emerged as one of the greatest threats to global agriculture and food production. Irregular rainfall patterns, floods, droughts, increasing temperatures, and habitat degradation are affecting conventional crop and livestock systems worldwide. Insects are increasingly considered climate-resilient food resources because many species can survive under diverse environmental conditions while requiring comparatively fewer production resources.

Kalita *et al*. (2022) [11] emphasized that traditional entomophagy practices among indigenous communities of North-East India represent valuable examples of climate-resilient food systems. The seasonal collection and utilization of edible insects among the Bodos demonstrate adaptive strategies that have evolved through long-term interaction with changing environmental conditions. Indigenous communities often modify harvesting periods, collection methods, and dietary preferences according to seasonal insect abundance and climatic variability.

Traditional ecological knowledge related to insect behavior and emergence patterns also contributes to environmental adaptation. The seasonal appearance of termites, dragonflies, ants, and crickets is often associated with rainfall prediction and agricultural planning among rural communities. Such ecological observations help farmers anticipate climatic changes and manage agricultural activities more effectively, reflecting the sophisticated environmental understanding embedded within indigenous knowledge systems.

5. Indigenous Sustainable Practices and Future Prospects

The traditional insect-related practices of the Bodo community represent important examples of sustainable biodiversity-based livelihood systems. Indigenous harvesting methods are generally community-oriented, seasonally regulated, and ecologically adaptive. Insects are primarily collected for household consumption and local use rather than for intensive commercial exploitation, thereby reducing the risk of overharvesting and ecological imbalance.

Kalita *et al*. (2022) [11] emphasized that indigenous entomophagy systems possess considerable potential for supporting future food security, sustainable nutrition, and biodiversity conservation. At a time when modern food systems face increasing environmental and economic challenges, traditional insect utilization practices among communities such as the Bodos offer valuable lessons regarding ecological sustainability, resource efficiency, and responsible consumption.

Takov *et al*. (2025) [24] further noted that sustainable insect farming, insect-based food industries, and insect-derived nutraceutical products may contribute significantly to future environmentally responsible economies and global food security systems. However, modernization, excessive pesticide use, habitat destruction, urbanization, and changing food preferences among younger generations are increasingly threatening both insect diversity and the indigenous knowledge associated with traditional entomophagy.

Therefore, proper scientific documentation, biodiversity conservation, nutritional evaluation, policy support, and public awareness are essential for preserving traditional insect-related knowledge and promoting sustainable insect-based food systems in the future. The indigenous practices of the Bodo community represent valuable cultural and ecological resources that can contribute meaningfully to contemporary discussions on food security, environmental sustainability, and climate resilience.

Threats to Traditional Entomological Knowledge

Traditional entomological knowledge among the Bodo community of Assam represents an important component of indigenous cultural heritage, ecological understanding, food practices, and traditional healthcare systems. This knowledge includes identification of edible and medicinal insects, seasonal harvesting techniques, preparation methods, ecological observations, and cultural beliefs associated with insects. For generations, such knowledge has been preserved through oral traditions, practical experience, agricultural activities, and close interaction with forests, wetlands, and surrounding natural ecosystems. However, rapid socio-economic and environmental changes in recent decades have increasingly threatened the continuity and survival of this valuable indigenous knowledge system (Muchahary *et al*., 2023) [18].

The decline of traditional entomological knowledge is not merely a cultural issue; it also has ecological, nutritional, and socio-economic implications. The disappearance of indigenous insect-related practices may result in the loss of sustainable food systems, traditional medicinal knowledge, biodiversity-based livelihoods, and ecological understanding developed through centuries of human–environment interaction. Multiple interconnected factors, including

urbanization, modernization, pesticide use, habitat destruction, climate change, and declining interest among younger generations, are accelerating this process of knowledge erosion.

1. Urbanization and Changing Rural Lifestyles

Urbanization has significantly transformed traditional lifestyles and ecological relationships within many indigenous communities of Assam. Expansion of urban settlements, road networks, markets, and infrastructure has reduced dependence on forests, wetlands, and agricultural ecosystems that once supported traditional insect collection and utilization practices. As increasing numbers of people migrate toward urban centers or adopt urban lifestyles, daily interaction with natural ecosystems has gradually declined.

Traditional food habits are also changing rapidly under urban influence. Processed foods, commercially available meat products, and modern dietary preferences are increasingly replacing indigenous food systems, including entomophagy. In many cases, traditional insect-based foods that once symbolized cultural identity are now perceived by some sections of society as outdated or less desirable. Such changing perceptions contribute to declining acceptance of traditional insect consumption practices, particularly among educated urban youth (Narzari & Sarmah, 2015) [19].

Urbanization additionally reduces opportunities for younger generations to learn practical ecological skills associated with insect collection, habitat identification, seasonal observation, and traditional food preparation. As a result, many aspects of indigenous ecological knowledge are gradually disappearing from everyday community life.

2. Modernization and Cultural Transformation

Modernization has introduced significant socio-economic changes within indigenous communities through formal education, modern healthcare systems, technological development, market integration, and mass media exposure. While these developments have improved access to healthcare, communication, and economic opportunities, they have also contributed to weakening many traditional knowledge systems.

Traditional entomophagy practices are increasingly being replaced by market-based food consumption patterns and commercially processed dietary products. Younger generations often prefer modern foods over traditional insect-based diets because of changing social values and lifestyle aspirations. In certain contexts, consumption of insects is incorrectly associated with poverty or social backwardness, resulting in declining cultural prestige of traditional food practices.

Muchahary *et al*. (2023) [18] observed that modernization and changing socio-cultural attitudes are gradually distancing younger members of the Bodo community from indigenous food traditions and ecological practices. This transformation not only threatens traditional dietary systems but also weakens cultural identity and collective ecological memory.

3. Erosion of Oral Traditions and Knowledge Transmission

Traditional entomological knowledge among the Bodos is transmitted primarily through oral communication rather than written documentation. Knowledge regarding edible and medicinal insects, ecological indicators, harvesting techniques, and seasonal patterns is generally learned through observation, participation, storytelling, and interaction with elders.

However, rapid social change and weakening intergenerational communication are increasingly disrupting this traditional process of knowledge transmission. Elderly community members who possess extensive ecological and cultural knowledge are gradually disappearing, while younger individuals often show limited interest in learning traditional practices. Consequently, valuable information regarding insect diversity, medicinal applications, and ecological observations is at risk of being permanently lost.

The absence of systematic scientific documentation further increases the vulnerability of indigenous knowledge systems. Many traditional practices associated with medicinal insects, seasonal ecological indicators, and insect-based therapies continue to exist only within oral memory and remain largely undocumented in formal literature (Basumatary & Choudhury, 2023) [2]. Once such knowledge disappears, it becomes extremely difficult to recover.

4. Pesticide Use and Decline of Insect Populations

The increasing use of chemical pesticides in agriculture represents one of the most serious threats to insect biodiversity and traditional entomophagy practices. Agricultural intensification and modern crop protection strategies have led to widespread application of synthetic pesticides, which negatively affect both harmful and beneficial insect species.

Pollinators such as honey bees, butterflies, and beetles are particularly vulnerable to pesticide exposure. Declining insect populations directly reduce the availability of edible and medicinal insects traditionally collected from paddy fields, wetlands, forests, and agricultural landscapes. Takov *et al*. (2025) [24] emphasized that large-scale decline of insect populations due to pesticides and habitat degradation poses major ecological risks because insects are essential for pollination, nutrient cycling, decomposition, and ecosystem stability.

For the Bodo community, reduction in insect abundance also threatens nutritional security and traditional medicinal practices. Several insect species that were once commonly available are becoming increasingly scarce because of pesticide contamination and environmental degradation. Excessive pesticide use may additionally create concerns regarding contamination and safety of wild edible insects collected for human consumption.

5. Habitat Destruction and Biodiversity Loss

Habitat destruction caused by deforestation, wetland degradation, agricultural expansion, urban growth, and infrastructure development has significantly affected insect diversity in many parts of Assam. Forests, grasslands, wetlands, and agricultural ecosystems that traditionally served as habitats for edible and medicinal insects are increasingly shrinking or becoming fragmented.

Many insects utilized by the Bodos depend on specific environmental conditions for survival and reproduction. Destruction of these habitats reduces insect abundance and disrupts seasonal occurrence patterns. Wetland degradation negatively affects aquatic insects such as water bugs and dragonflies, while deforestation threatens populations of ants, bees, beetles, termites, and wasps.

Environmental degradation also weakens indigenous ecological knowledge systems because traditional observations regarding insect behavior, seasonal emergence, and habitat conditions become less reliable under rapidly changing ecological circumstances. The decline of insect biodiversity therefore affects not only ecological stability but also cultural practices and livelihood systems associated with insect utilization.

6. Climate Change and Ecological Uncertainty

Climate change is emerging as another major challenge affecting insect diversity and traditional ecological knowledge systems. Rising temperatures, irregular rainfall patterns, floods, droughts, and seasonal instability are altering insect life cycles, breeding behavior, migration patterns, and habitat suitability.

Traditional Bodo ecological knowledge is closely linked with predictable seasonal patterns of insect emergence and abundance. However, changing climatic conditions are increasingly disrupting these patterns, making traditional ecological forecasting and harvesting practices less reliable. Variations in rainfall timing, for example, may influence the seasonal appearance of termites, dragonflies, crickets, and other insects traditionally used as environmental indicators.

Takov *et al*. (2025) [24] highlighted that climate change may significantly affect global insect populations, with serious consequences for pollination, ecosystem functioning, biodiversity conservation, and food production systems. Indigenous communities such as the Bodos, whose livelihoods and cultural practices remain closely connected with natural ecosystems, are therefore particularly vulnerable to such ecological disruptions.

7. Declining Interest among Younger Generations

One of the most critical threats to traditional entomological knowledge is the declining interest among younger generations. Increasing exposure to urban lifestyles, digital media, modern education systems, and changing social aspirations has reduced youth participation in traditional agricultural and ecological activities.

Many young people are becoming less interested in insect collection, traditional food preparation, medicinal practices, and oral cultural traditions. In some cases, traditional practices are viewed as incompatible with modern lifestyles and social mobility. This cultural disconnect weakens intergenerational knowledge transfer and accelerates the erosion of indigenous ecological understanding.

Muchahary *et al*. (2023) [18] emphasized that without proper preservation efforts, valuable traditional knowledge related to edible and medicinal insects may disappear within a few generations. The loss of such knowledge would not only affect cultural identity but also reduce opportunities for sustainable food systems, biodiversity conservation, climate adaptation, and future scientific research based on indigenous ecological practices.

Therefore, preservation of traditional entomological knowledge among the Bodos requires integrated efforts involving scientific documentation, biodiversity conservation, community participation, educational awareness, and cultural revitalization. Recognizing indigenous knowledge systems as valuable ecological and cultural resources is essential for ensuring their continuity in the face of rapid environmental and social transformation.

Future Research Directions

The increasing global interest in edible insects, sustainable food systems, and insect-derived bioactive compounds has created new opportunities for scientific research and innovation. Traditional knowledge associated with insects among the Bodo community of Assam represents a valuable repository of ecological, nutritional, medicinal, and cultural information that remains insufficiently explored. Although several studies have documented the diversity of edible and medicinal insects utilized by the Bodos, many aspects related to their nutritional composition, pharmacological properties, ecological significance, conservation status, and economic potential still require systematic investigation. Future interdisciplinary research integrating entomology, ethnobiology, nutrition, pharmacology, biotechnology, and conservation science can therefore contribute significantly to sustainable development and scientific advancement (Takov *et al*., 2025) [24].

1. Nutraceutical Development

One of the most promising areas for future research is the development of nutraceutical products from edible insects traditionally consumed by the Bodos. Several insect species such as *Samia ricini*, termites, crickets, ants, grasshoppers, and beetle larvae are rich in proteins, essential amino acids, healthy fats, vitamins, minerals, and antioxidant compounds (Kalita *et al*., 2022) [11]. These nutritional properties indicate considerable potential for the development of insect-based protein supplements, fortified foods, dietary formulations, and health-supportive products.

Scientific studies focusing on nutritional profiling, digestibility, food safety, allergenic potential, and bioavailability of nutrients are essential for promoting wider acceptance of edible insects in modern food systems. Future research may also identify specific bioactive molecules responsible for antioxidant activity, immune enhancement, metabolic regulation, and disease prevention. Such investigations could help integrate indigenous food knowledge with modern nutritional science and functional food technology.

2. Pharmaceutical and Therapeutic Potential

Traditional entomotherapeutic practices among the Bodos indicate significant pharmaceutical potential of several insect species and insect-derived products. Honey, red weaver ants, silkworm pupae, wasp larvae, termites, and other medicinal insects traditionally used by the community may contain biologically active compounds with antimicrobial, antioxidant, anti-inflammatory, immunomodulatory, and wound-healing properties (Basumatary & Choudhury, 2023) [2].

Future pharmacological investigations should therefore focus on the isolation, characterization, and evaluation of bioactive compounds from medicinal insects utilized in Bodo ethnomedicine. Detailed biochemical and molecular studies may contribute to the discovery of novel antimicrobial agents, nutraceutical compounds, immune-modulating substances, and therapeutic molecules with potential applications in modern medicine. Takov *et al*. (2025) [24] emphasized that insect-derived compounds are increasingly being explored in biomedical research because of their remarkable biological diversity and therapeutic potential.

At the same time, toxicological evaluation, dosage standardization, and clinical validation are necessary to scientifically assess the safety and effectiveness of traditional insect-based medicinal practices. Such research could create valuable links between indigenous healthcare systems and modern pharmacological science.

3. Commercial Insect Farming and Sustainable Livelihoods

Commercial insect farming represents another important area for future research and rural development. As demand for sustainable protein sources continues to rise globally, insect farming may emerge as an economically viable and environmentally sustainable livelihood option for rural and indigenous communities. Species traditionally utilized by the Bodos, including eri silkworms, crickets, honey bees, and selected edible larvae, possess significant potential for domestication and commercial-scale production.

Future studies should focus on breeding biology, life-cycle management, feed optimization, disease control, processing technologies, and market development for economically important insect species. Development of low-cost and locally adaptable insect-rearing systems could support rural entrepreneurship and livelihood diversification in Assam.

Takov *et al*. (2025) [24] highlighted that insect farming requires comparatively lower land, water, and feed resources than conventional livestock production and produces fewer greenhouse gas emissions, making it highly suitable for future sustainable bioeconomy systems. In the context of the Bodo community, scientifically managed insect farming could simultaneously contribute to nutritional security, employment generation, and biodiversity-based rural development.

4. Functional Foods and Food Innovation

Future research should also explore the use of edible insects in the development of functional foods and innovative food products. Insects contain numerous biologically active compounds that may provide health benefits beyond basic nutrition, including antioxidant activity, improved digestion, enhanced immunity, and metabolic support.

Development of insect-based snacks, protein bars, fortified flour, fermented products, and dietary supplements may create new opportunities for sustainable food industries. Research focusing on consumer acceptance, sensory evaluation, food processing, shelf life, packaging, and nutritional enhancement will be essential for promoting insect-based foods beyond traditional communities.

Kalita *et al*. (2022) [11] emphasized that indigenous entomophagy practices of North-East India offer valuable models for sustainable food innovation and environmentally responsible nutrition systems. Incorporating traditional knowledge into modern food technology could therefore support both cultural preservation and sustainable dietary diversification.

5. Conservation Biology and Insect Diversity

Conservation of insect diversity is essential for maintaining ecosystem stability, pollination services, food security, traditional healthcare systems, and biodiversity-based livelihoods. However, habitat destruction, pesticide use, climate change, and environmental degradation are increasingly threatening insect populations in many parts of Assam.

Future research should therefore focus on insect ecology, biodiversity assessment, habitat conservation, and long-term population monitoring of edible and medicinal insect species. Ecological studies examining seasonal abundance, breeding behavior, habitat preferences, and environmental sensitivity are necessary for developing sustainable harvesting guidelines and conservation strategies.

Takov *et al*. (2025) [24] emphasized that conservation of insect diversity is crucial not only for protecting ecological balance but also for sustaining future food systems and ecosystem services. Integrating indigenous ecological knowledge with modern conservation biology may therefore provide more effective approaches for biodiversity management and sustainable utilization of insect resources.

6. Documentation and Preservation of Indigenous Knowledge

Traditional knowledge related to edible and medicinal insects among the Bodos remains largely undocumented and is still transmitted primarily through oral traditions. Rapid urbanization, modernization, changing lifestyles, and declining interest among younger generations are gradually weakening these indigenous knowledge systems (Muchahary *et al*., 2023) [18].

Future ethnobiological and ethnoentomological research should prioritize systematic documentation of traditional insect-related practices, including local names, harvesting methods, preparation techniques, medicinal applications, ecological observations, and cultural beliefs. Community-based participatory research involving traditional healers, village elders, and local knowledge holders will be particularly important for preserving the authenticity and cultural context of indigenous practices.

Digital archiving, audiovisual documentation, local language publications, and integration of indigenous ecological knowledge into educational programs may further support long-term preservation and intergenerational transmission of traditional knowledge systems.

7. Insects and the Emerging Bioeconomy

The growing recognition of insects as sustainable biological resources has opened new possibilities for insect-based bioeconomy development. Insects can contribute to food production, pharmaceuticals, nutraceuticals, cosmetics, biomaterials, organic waste recycling, and environmentally sustainable industrial processes. Takov *et al*. (2025) [24] highlighted that insects are likely to become important components of future circular bioeconomy systems because of their ecological efficiency and broad industrial applications.

Traditional insect-related practices among the Bodos provide valuable examples of biodiversity-based resource utilization that can inform future sustainable development strategies. Integrating indigenous knowledge with scientific innovation may help create environmentally responsible industries while simultaneously supporting cultural preservation, biodiversity conservation, and rural livelihoods.

Overall, future research on insects in the life of the Bodo community should adopt an interdisciplinary and sustainability-oriented approach that combines ecological conservation, biotechnology, nutrition science, pharmacology, public health, and indigenous knowledge systems. Such integrated efforts will not only improve

scientific understanding of insect resources but also contribute to sustainable food security, climate resilience, biodiversity conservation, and inclusive rural development in the future.

Conclusion

Insects occupy a deeply significant position in the traditional life and knowledge systems of the Bodo community of Assam. The close relationship between the Bodos and their surrounding natural environment has, over generations, shaped a rich body of indigenous knowledge related to edible insects, medicinal practices, ecological observations, livelihood activities, and cultural traditions. The present review clearly demonstrates that insects are not merely supplementary biological resources within Bodo society; rather, they are closely interwoven with nutrition, healthcare, ecology, economy, and cultural identity (Narzari & Sarmah, 2015; Muchahary *et al*., 2023) [18, 19].

The remarkable diversity of edible insects traditionally consumed by the Bodos reflects both the rich biodiversity of Assam and the sophisticated ecological understanding possessed by indigenous communities. Species such as *Samia ricini*, *Lethocerus indicus*, *Oecophylla smaragdina*, termites, crickets, grasshoppers, beetle larvae, and honey bees provide important nutritional support through their high protein, amino acid, vitamin, and mineral content. Traditional entomophagy therefore continues to contribute significantly to food and nutritional security, particularly in rural communities where access to conventional animal protein may sometimes be limited (Hazarika & Goyari, 2017; Kalita *et al*., 2022) [9, 11].

Insects also possess substantial medicinal importance within Bodo ethnomedicine. Honey, red weaver ants, silkworm pupae, wasp larvae, termites, and other insects are traditionally utilized for treating respiratory disorders, wounds, digestive ailments, weakness, arthritis, and several other health conditions. Many of these traditional therapeutic practices are increasingly supported by modern scientific investigations that reveal the presence of antimicrobial, antioxidant, anti-inflammatory, and bioactive compounds in insect-derived products (Basumatary & Choudhury, 2023; Takov *et al*., 2025) [2, 24]. This highlights the scientific relevance of indigenous entomological knowledge and its potential contribution to future nutritional and biomedical research.

The review further demonstrates that insects play crucial ecological and economic roles within Bodo society. Insects contribute fundamentally to pollination, nutrient cycling, decomposition, soil fertility, and ecological stability, while also supporting traditional livelihood activities such as sericulture, apiculture, and edible insect trade. Sustainable utilization of insect resources among the Bodos reflects an environmentally adaptive lifestyle closely connected with biodiversity conservation and traditional ecological knowledge systems. Such indigenous practices offer important lessons for sustainable resource management and environmentally responsible food systems in the present era of ecological crisis and climate change (Takov *et al*., 2025) [24].

Equally important is the cultural significance of insects within Bodo society. Insects are deeply embedded in traditional food customs, seasonal festivals, oral traditions, folk beliefs, and indigenous ecological observations. Knowledge related to insect collection, preparation, medicinal use, and seasonal behavior continues to influence agricultural practices and community life in many rural areas. However, rapid modernization, urbanization, habitat degradation, excessive pesticide use, climate change, and declining interest among younger generations are increasingly threatening both insect diversity and the traditional knowledge associated with their utilization (Muchahary *et al*., 2023) [18].

The present review therefore highlights that traditional entomological knowledge among the Bodos possesses immense scientific, ecological, nutritional, medicinal, and socio-cultural value. Indigenous practices associated with edible and medicinal insects provide important insights into sustainable nutrition, biodiversity conservation, climate resilience, and nature-based livelihood systems. At a time when the global community is searching for sustainable alternatives to conventional food and healthcare systems, indigenous insect-related knowledge offers valuable opportunities for future scientific innovation and sustainable development.

Nevertheless, a considerable portion of this traditional knowledge remains undocumented and vulnerable to gradual disappearance. Urgent attention is therefore required for systematic documentation, scientific validation, biodiversity conservation, and preservation of indigenous knowledge systems related to insects. Collaborative efforts involving researchers, local communities, conservation organizations, and policymakers will be essential for safeguarding this important cultural and ecological heritage for future generations.

Overall, the relationship between the Bodo community and insects represents a remarkable example of harmonious coexistence between humans and biodiversity. Preserving and promoting this traditional knowledge will not only strengthen cultural heritage and ecological sustainability but also contribute meaningfully to future discussions on food security, conservation biology, public health, rural livelihoods, and sustainable development.

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