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Bear Conservation and Agricultural Sustainability: A Strategy of Strategic Fruit Planting

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BEAR CONSERVATION AND AGRICULTURAL SUSTAINABILITY: A STRATEGY OF STRATEGIC FRUIT PLANTING

Abstract: The Asiatic black bear, a key frugivorous species, crucial for conservation, faces rising conflicts with farmers due to declining fruit resources in its habitat, leading bears to agricultural lands. This results in increased fallow land and reduced food production as farmers abandon farming. We systematically reviewed literature (n=74) from 1990–2021, from key academic databases like Google Scholar, Scopus, and Web of Science, in English language, relevant to bear diet, conservation, and agricultural sustainability, excluding non-relevant studies or those lacking rigorous scientific methodology, to (i) assess Asiatic black bears' fruit diets and (ii) recommend sustainable solutions for farmer-bear conflicts, and promoting agricultural resilience. Most literature on bears' fruit diets was published in the last decade, emphasizing their heavy reliance on plant fruit families (n=40), notably Rosaceae with dominant Relative Frequency of Occurrence (RFO=0.29), and various fruit types (n=10) like berries (n=82), drupes (n=38), & nuts (n=33). To promote coexistence and conservation, we recommend planting more of these fruits in bear habitats along with implementation of conflict mitigation measures in farmland. This approach aids bear conservation, reduces conflicts, fosters ecological balance, and supports sustainable agriculture and farmers' livelihoods.

Keywords: Asiatic black bear, human-wildlife conflict, food, diet, agriculture

Introduction

Asiatic black bear (*Ursus thibetanus*), is a widely distributed, federally protected, flagship species and of a conservation concern (Sathyakumar *et al*. 2013). It is predominantly a phytophagous species (Hashimoto, 2002), pre-disposed to frugivory diet playing an essential role in forest ecosystem and maintaining the biodiversity, particularly through seed dispersal that regenerated the interiors of the forest (Tochigi *et al*. 2022). However, this species faces a critical threat with expanding agriculture, climate change and anthropogenic activities in the bear habitats. This has led to a marked decline in the fruit resources in the forest, compelling the bears to venture into the human domain for food and sustenance leading to greater interface with the human specially in the forest fringe villages (Huygens *et al*. 2003; Charoo *et al*. 2009; Lamarque *et al*. 2009; Abbas *et al*. 2015; Ji *et al*. 2022; Bussa 2023). This shift has hindered to an extent of economic losses to the farmers ultimately threatening both the wildlife conservation as well as local livelihoods (Ogada *et al*. 2003; Charoo *et al* 2009; Ji *et al*. 2022; Mir *et al*. 2023; Wangchuk *et al*. 2023). About 6 months of food requirement is lost annually because of these interface as reported from Bhutan (Wangchuk *et al*. 2023), leading to abandoning of farming, increasing fallow lands and reducing food production. Although the stakeholders still have difference in perception on the human wildlife interactions (Rai *et al*. 2014; Kellert 1980).

Human wildlife conflicts pose a significant challenge globally in managing human-dominated landscape. The tension between the conservation priorities and agricultural needs is particularly acute in the regions where Asiatic black bear resides. To develop a better conservation strategy, understanding the dietary preference of the Asiatic black bear becomes a crucial aspect as their reliance on specific fruit species can inform a targeted habitat management aimed at de-escalating the human-bear interaction (Bashir *et al*. 2018; Fahimi *et al*. 2024).

This study reviews diverse literatures relating to bear diet focussing on fruit species as their frugivory pre-disposal is well established. The objective of the study is to identify key drivers of human bear conflicts, identify fruit plant family, fruit species and fruit types most amenable to Asiatic black bear and recommending the targeted mitigation strategies of fruit plantation along with dovetailing with other mitigation measures.

Methodology

The study investigates the fruit diet of the Asiatic black bear from the relevant literature and find the drivers of the human-bear conflicts, utilizing a systematic review methodology was utilized. A diverse literature was reviewed (n=74) published primarily between 1990-2023, sourced from prominent database like Google Scholar, Scopus, and Web of Science. Some literature preceding 1990 were also considered to capture historic record. The inclusion criteria involved those literature specifically addressing diet, behaviour and habitat with particular emphasis on human wildlife conflicts and fruit consumption. The data compilation involved cataloguing the frequency of fruit species mentioned in the reviewed literature identifying the common fruit types consumed by the bears and the family or the species of the plants they preferred. The aspect of the human bear conflict and its behaviour was identified and presented here as a synthesis whereas to quantify the fruit diet, a metanalysis of the fruit species encountered across literature was performed with a simple statistic of calculating the Relative frequency of occurrence (RFO), following Panthi *et al*. (2019), using formula:

$$RFO=FO/N \quad (i)$$

Where, FO if the observed frequency of occurrence of each fruit species, and N is the total number of fruit item reported across literatures. This method facilitates the comparison of different fruit species and their relative importance in the bear's diet. This statistical analysis calculating RFO and categorizing them by family and type is to discern patterns in dietary preferences.

Results and Discussion

Overview of literature

The literature on Asiatic black bear primarily encompasses 2010 to 2019 with notable publication from countries like Japan, China and India, followed by the decade of 2000 to 2009. Taiwan, Nepal, Pakistan, and Iran also provide substantial publication. However, countries like Vietnam, Laos PDR, Cambodia, Thailand and the Korean peninsula, as well as from Myanmar, Bangladesh, Bhutan, and Afghanistan are minimum covered. Nevertheless, this wide-ranging literature highlights the regional variation in the studied context.

Drivers of conflicts:

The study indicate that the human bear interface primarily stems out of the interplay between bears' nutritional needs, food availability in the forest, and availability and attraction to high calorie crops in the agriculture field. Below are a few drivers of conflict broken down from the review of the literature:

Nutritional Needs and Natural Food Scarcity

Scarcity of food across season such as nuts, berries and vegetation matter drive bears to seek for the alternative food, especially during lean seasons (Hashimoto 2002; Rai *et al.* 2014; Ali *et al.* 2017; Chavan *et al.* 2021; Dai *et al.* 2021). They are then attracted to a high calorie food resource nearby human settlement.

Availability of Food in Human Areas

The human areas inadvertently offer food for bears through poorly managed food waste, un-secure livestock and unguarded crops. The study shows that the accumulated solid waste in human areas provide consistent food to the bears which cause bear to roam around the human settlement (Hwang *et*

al. 2002; Kozakai *et al.* 2013; Basnett *et al.* 2020; Dai *et al.* 2021). This increased proximity between human and bears provide escalated opportunities for conflicts.

Attraction to High-Calorie Crops

Bear are highly attracted to the energy rich food crops like Maize, beans, peas, millet, pumpkins and other crops and vegetables. Among fruits avocado, cherry, pear, figs, guava, walnut etc. are very attractive to bears due to their nutritional value as well as their palatable nature (Charoo *et al.* 2009; Liu *et al.* 2011; Sathyakumar *et al.* 2012; Abbas *et al.* 2015; Ali *et al.* 2015; Jamtso and Wangchuk, 2016; Yadav *et al.* 2019, Basnett *et al.* 2020; Taylor and Phillips 2020; Basnett *et al.* 2021; Yadav *et al.* 2021). The concentration of these crops and fruits in the forest fringe villages creates high likelihood of encounters.

Bear's Preference for Livestock and Resulting Economic Losses

During the lean season when wild prey is particularly low and at times of their winter preparation, they try to supplement their diet with easy and high calorie targets (Charoo *et al.* 2009; Mir *et al.* 2015; Ghadirian *et al.* 2017; Basnett *et al.* 2020; Basnett *et al.* 2021; Gautam *et al.* 2024). This prompts bear for opportunistic depredation of livestock, such as goat, cattle, chicken etc. causing a huge economic loss for the farmers and increased resentment towards bears and conservation agencies.

Lack of Strong Livestock Sheds and Crop Fencing

The absence of robust livestock enclosures and effective fencing around crops is a major factor exacerbating human-bear conflict. Inadequate sheds make livestock more vulnerable to predation, while poorly constructed or non-existent fences around crop fields make it easy for bears to access high-value food sources (Zeller *et al.* 2019; Dai *et al.* 2021). Strengthening enclosures and enhancing fencing infrastructure could be a preventative measure to reduce these conflict incidents.

Reduced and Weakened Livestock Guarding Practices

Current social changes and societal movement away from labour-intensive guarding methods, the traditional guarding methods have declined. This has left livestock more exposed to bear predation, especially during day grazing. This reduction in active defense of livestock, as documented in the recent studies, is noted as one of the contributing factors for rising conflicts (Rai *et al.* 2014; Rawal *et al.* 2024).

Agriculture expansion and Land Use Changes:

Some of the studied literature point towards anthropogenic drivers like agriculture expansion and land use-changes which encroach upon the bear habitats, elevating further conflicts. The combination of habitat loss, fragmentation, and competition for limited resources exacerbates conflicts compelling bear towards human areas for alternative food.

Each of these drivers in combination compounds human bear interaction, particularly where areas of bear population overlap with the agricultural regions. A robust sheds, efficient livestock and crop guarding, Waste management, along with community engagement and habitat management with bear amenable plant species could address these root causes for peaceful co-existence.

Farmers' Sentiments & Safety Concerns

Studies indicate that human-bear conflicts significantly impact farmers' livelihoods and mental well-being. Farmers' negative perceptions toward bears stem from tangible threats to their economic stability, and the effects extend into psychological concerns and shifts in agricultural practices.

Negative Perception of Bears as a Threat

Farmer's perceive Asiatic black bear as the greatest threat to their livelihood due to its attraction to livestock and crops, resulting in substantial losses. They perceive bears danger not only to their property but also as a persistent menace threatening their lives and livelihood (Goursi *et al.* 2021; Ali *et al.* 2022). These recurring threats contributes to the negative sentiments in farmers towards conservation efforts and sometimes retaliatory behaviour.

Livelihood Challenges from Crop and Livestock Loss

Financial stability of the farmers is compromised with the economic impact of losing high value crops and livestock on marginal farmers (Ogada *et al.* 2003; Mir *et al.* 2023). These loses contribute to decreased household income, food scarcity, and cycle of poverty which creates resentment of farmers towards wildlife and conservation agencies as a whole.

Psychological Impact: Fear, Anxiety, and Stress

Other than financial loses, the presence of bear in the vicinity induces significant fear psychosis, stress and anxiety among farmers, often for their personal and family safety, particularly during season of frequent encounter (Charoo *et al.* 2009; Rai *et al.* 2014; Mir *et al.* 2023). This persistent fear affects overall community wellbeing creating high-stress environment.

Abandonment of Agricultural Practices

The recurring losses involving bear have led to farmers abandoning cropping altogether in various part of the globe. The repeated crop damages and a perceived lack of mitigation measures have contributed farmers to take decision on reduced agriculture activities and sometimes to stop cultivating some crops altogether (Chhetri 2013; Dai *et al.* 2021; Wangchuk *et al.* 2023). This factor is altering the agriculture landscape and impacting local food production, contributing to economic and social challenges in the farming communities. This also brings on food shortage globally.

Mitigation Measures

The studied literature hint on the combination of preventive, deterrent, and adaptive measures can effectively decrease conflicts and introduce a safer atmosphere for both the human and bears, fostering coexistence.

Preventive Measures

Fencing and Secure Enclosures

The first line of defence against bear could be physical barriers like barbed wire, vegetative, and electric fence around the crop field. Electric fence, in particular, has been seen as an effective measure deterring bears from assessing crops and vulnerable livestock (Chhetri 2013; Yadav *et al.* 2019). Most livestock depredation occurs from the sheds as they are not strong enough to tackle bear strength. Robust and secure enclosures are equally important, as they protect livestock during night when the bear activity is at peak.

Deterrents

• Noise Devices and Scare Tactics: Noise deterrents like beating tin boxes, or bells, loud horns, firecrackers, can be effective scaring bears in sporadic events. Traditional measures like blowing Conch shells or utilizing local scare devices remain still relevant (Mishra *et al.* 2006; Charoo *et al.* 2011).

• Visual Deterrents: Scarecrows, reflective objects and lights have been found successful by the farmers making the field less attractive to bears. Bears sense human presence in these measures reducing the likelihood of intrusion as though not foolproof, but could be used in combination with other noise deterrents.

Alternative Crop Selection and Crop Rotation

Alternative cropping less attractive to bears or rotating the crops certainly reduce bear visits. By alternating highly nutritious bear preferred crops such as Maize, Pumpkins, etc., with crops like Turmeric, Chili peppers, etc., can decrease likelihood of bear being drawn to farmlands (Huygens *et al.* 2004; Sangay and Vernes 2008). The non -palatable crops itself act as a deterrent to bears. Crops like Turmeric, Chili pepper could also fetch high returns to the farmers.

Adaptive Measures

Participatory Conservation

Involving communities in conservation decision making creates sense of ownership and responsibility, feel empowered and are likely to implement conservation initiatives (Bista and Aryal 2013; Treves and Santiago-Avila 2020). Engaging the communities on data collection, monitoring bear activities, etc., creates two-way channel helping both farmers and conservation agencies. Community engagement in patrols and awareness programs educate them on safe practices and bear seasonal behaviour which help them identify signs of bear activity and to respond to it proactively (Wright 1992; Sukhadiya *et al.* 2013). Communities needs to be equipped with this knowledge of handling bear encounters and maintain vigilance, making them more resilient against bear conflicts, dispel myth about bears, and shifting community perception in a positive direction.

Compensation, Incentives and Insurance Schemes

Mostly, the government and conservation agencies either do not pay compensation of damages or they pay very little that also very late. This factor primely cause resentment among farmers against wildlife and these agencies. The mechanism of fair and prompt compensation and insurance for crop and livestock losses help offset the economic impact on farmers, making them more receptive to co-existence. This decreases resentment and also dissuade retaliatory actions. In regions with robust compensation schemes, communities have been seen to have more positive attitude towards bears, and they view bears as part of their natural ecosystem rather than recurring threat (Treves and Santiago-Avila 2020; Hughes *et al.* 2022). The incentives could be small grants to technical support, facilitating adoption of preventive measures, adopting bear friendly practices, supporting installation of bear-proof fences, facilitation for growing alternative crops etc. which decrease financial burden on farmers.

Awareness, Training and Technology Use

Training on use of advance deterrents, such as motion sensor lights and alarms alongside traditional measures, make farmers able to employ a wide range of tactics as per their needs. Use of mobile apps or alert system foster enhanced preparedness to warn sightings of bear in the village vicinity.

Meta-Analysis of Fruit Diet of Asiatic Black Bear

The meta-analysis of literatures reveals that the Asiatic black bear has a significant preference for a frugivorous diet emphasizing their reliance on a wide range of fruit species to meet their nutritional needs, particularly during food shortage. This hint on the fact that the plenty of fruit in their habitat could reduce interface with human as food being the primary driver for human-bear conflict per study.

Key Findings:

1. *Fruit Species Diversity:* The study encountered 187 different fruit species consumed by the Asiatic black bear, indicating their preference and adaptability.

2. *Diverse plant Families:* The 187 fruit species comes from 40 plant families, reflecting on the wide ranging frugivory spanning multiple niches.

3. *Fruit Types:* Study found 10 different types of fruit preferred by the Asiatic black bear, showing flexibility of their diet and an ability to adapt to different texture, sizes and nutritional profiles at different season.

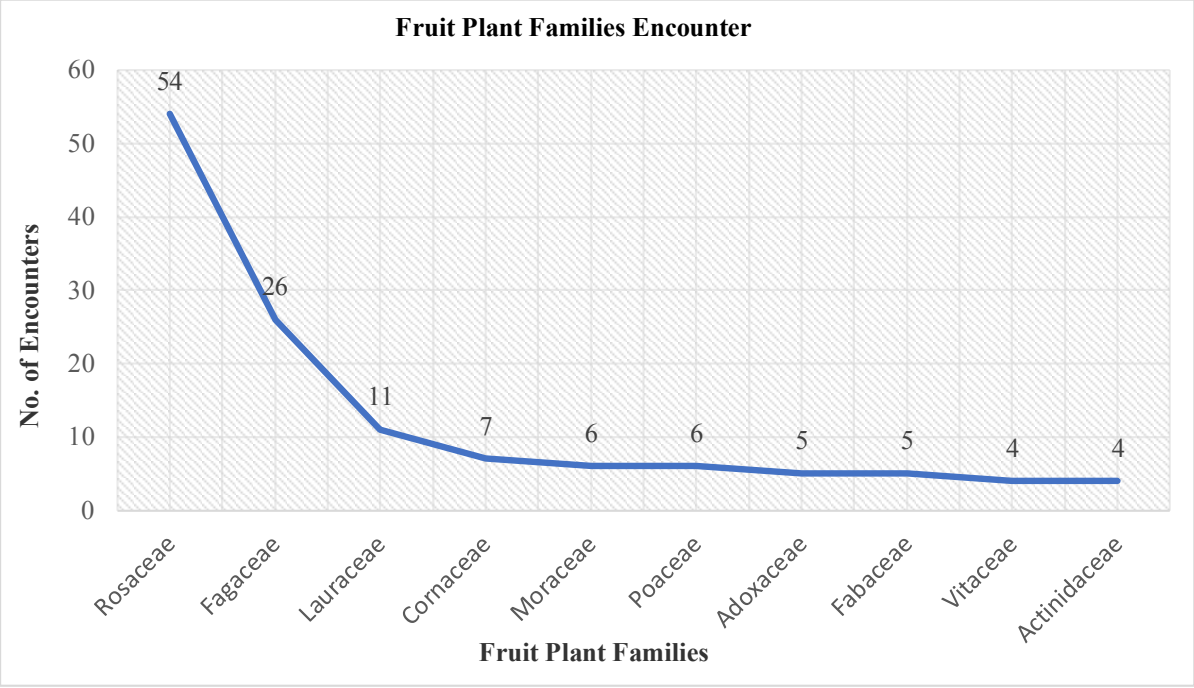

Figure 1: Frequency of occurrence of the fruit plant families among number of recorded encounters (n=187)

Figure 1 indicates Asiatic black bear's high frugivory and strong preference for certain plant families. Rosaceae family finds leading encounters in the study among 187 recorded encounters highlighting fruits from this family as dietary staples due to their availability and nutritional value. Fagaceae ranking second with 26 occurrences, features acorns and nuts that provide essential fats and carbohydrates during autumn, especially significant for their winter preparation. Lauraceae family contributing 11 encounters add to its diversity of food. Cornaceae (7 occurrences), Moraceae and Poaceae (6 occurrences each) provide dietary variety helping bear to adapt seasonal shifts.

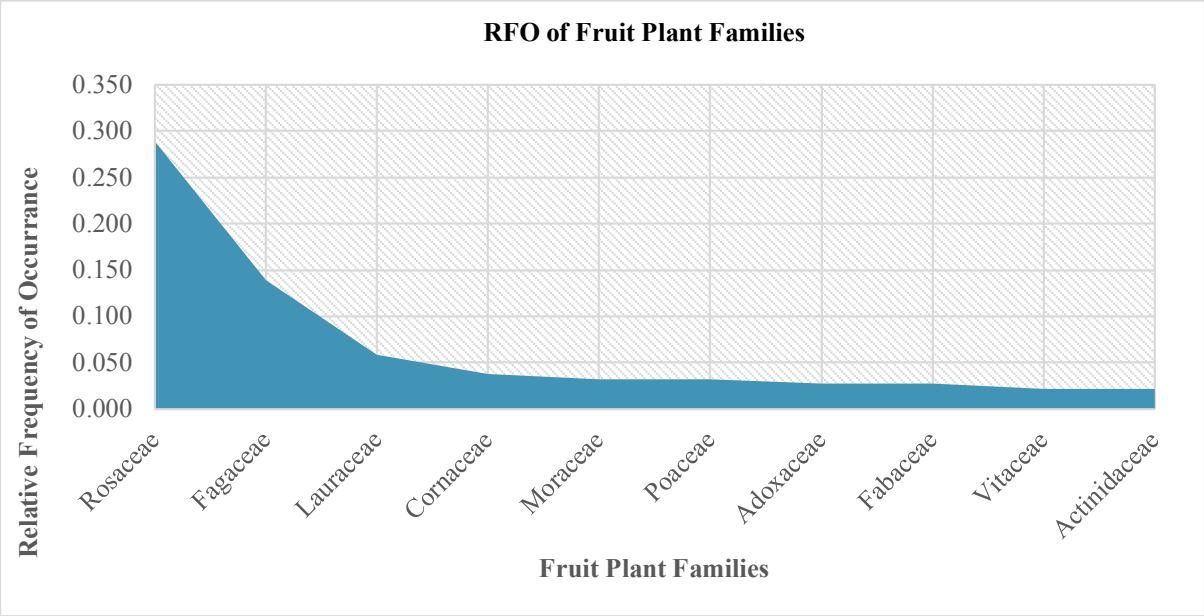

Figure 2: Relative frequency of occurrence (RFO) of the fruit plant families

This preference of the bear signifies the importance of the plant families Rosaceae, Fagaceae and Lauraceae in bear's sustenance and reduced foraging needs in human areas. A relative frequency of occurrence (RFO) in Figure 2 reflects the significance of the family Rosaceae (RFO 28.9) as a primary source of food, with Fagaceae (RFO 0.139) and Lauraceae (RFO 0.059) next following. Family Cornaceae, Moraceae and Poaceae (RFO ranging from 0.32 to 0.37). Modestly contributes to bear diet, maintaining nutritional variety. Family like Adoxaceae, Fabaceae and Vitaceae (RFO ranging from 0.21 to 0.27) adds further diversity and contributing during crucial scarcity periods.

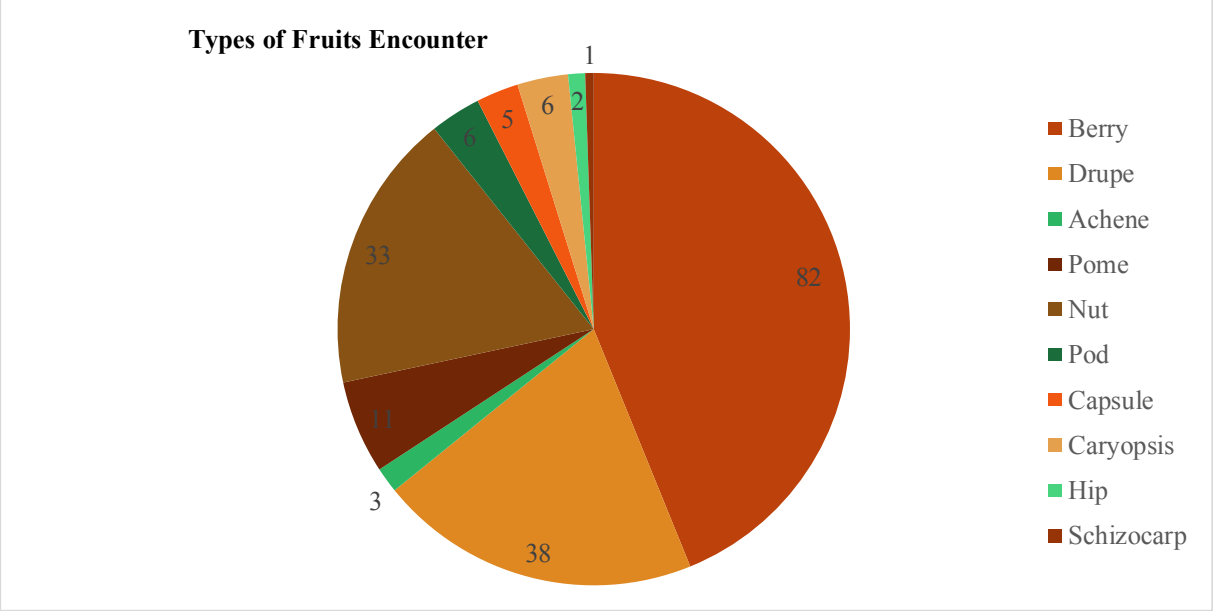

Figure 3: Frequency of occurrence of fruit types

Figure 3 illustrates that the berry type fruits with 82 encounters dominates bear preference with drupes (38 occurrences) and nuts (33 occurrences) contributing significantly. This preference could be out of their availability and nutritional content with nuts particularly valuable during autumn for their energy

buildup. Pomes (21 occurrences), Capsules (11 Occurrences) and minor fruits like achenes, pods, and schizocarps add to the variety and occasionally consumed.

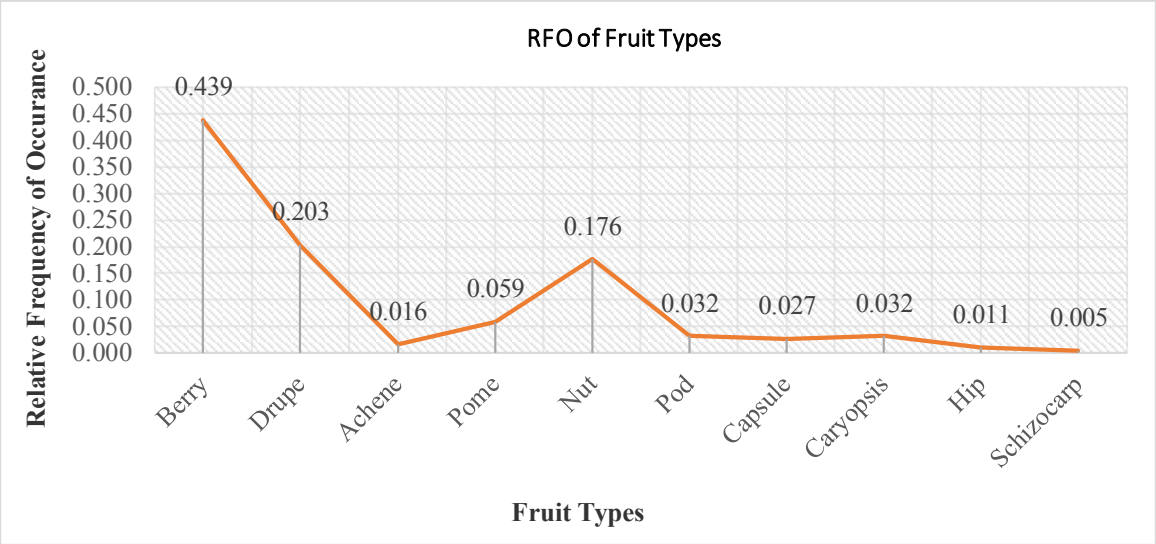

Figure 4 Relative frequency of occurrence of the fruit types

RFO data (Figure 4) further validate the preference for berries (RFO 0.439), drupes (0.203), nuts (0.176), and Pomes having a moderate RFO of 0.059, indicating the importance of conserving habitats with diverse fruit types to meet the bears' dietary needs and promote ecosystem health.

The fruit types pods, caryopses, capsules, and achenes, hips and schizocarps have lower RFOs ranging between 0.0005 and 0.032, indicating they are less frequently consumed but may serve as supplementary foods for opportunistic consumption, based on the availability.

Conclusion and Recommendation

The study finds that the diet of the Asiatic black bear is highly frugivorous, consuming fruits from 40 different plant families, particularly favouring families Rosaceae, Lauraceae and Fagaceae. These preferences indicate the bear's adaptation to wide range of fruit-based diet, notably with more reliance on nutrient rich berries, drupes, and nuts. During seasons of food scarce and especially pre-hibernation, bears are inclined to foraging on the livestock and anthropogenic crops, factor leading to human wildlife conflicts and an economic blow to the poor farmers.

Habitat restoration with bear amenable fruit species and types, particularly from the family Rosaceae, Lauraceae and Fagaceae, provides natural food for bears, reducing reliance on anthropogenic food. Seasonal food plots well within the forest cores support bear's dietary and habitat needs and thus keep them well within their boundaries.

Community-centric initiatives, participatory conservation, fair and prompt compensation for loses, supporting pro-active safety measures, and reducing their financial burden, strengthen co-existence. Preventive measures including a robust enclosures, fencing and efficient livestock guarding reduces the chances of bear intrusion and crop and livestock loses.

Encouraging region specific alternative crops like tea, turmeric, ginger, cardamom, medicinal plants etc., may offer better economic benefits without attracting bears, while promoting eco-tourism generates income and incentivize conservation. Long term strategies like creating connectivity corridors facilitates safe bear movements, while buffer zones around villages serves as a cushion for either side, improve genetic diversity, minimize human-bear interface, and address local concerns over economic loses and psychological stress among farming communities.

The comprehensive and an integrated conservation strategy, strengthening active community-driven co-existence, offers a sustainable solution that not only ensures a stable food source for the bears but also augment agriculture resilience.

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