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Threats to Amphibians in Tropical Wet Evergreen Forests of Assam, India

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Authors' contributions

This work was carried out in collaboration between both authors. Author MI designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author SS managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

A wide variety of amphibian species may be found in Assam's tropical wet evergreen woods, which can be found in the districts of Golaghat, Jorhat, Sibsagar, Tinsukia, and Dibrugarh as well as a little stretch in Lakhimpur and Dhemaji along foothills. These forests are crucial homes for amphibians, but many anthropogenic factors are putting them at greater risk. The main challenges facing frogs in the tropical wet evergreen forests of Assam are thoroughly reviewed in this paper, with an emphasis on how urgent it is to address these issues for the preservation of amphibian populations and the integrity of their ecosystems. In recent decades, there have been sharp population decreases and even extinctions of tropical amphibian species. Habitat loss, invasive species, pollution, infectious diseases, and climate change are some of the threats facing tropical amphibians. Lack of finance, a lack of political and social will, and a lack of knowledge about the precise risks that various amphibian species face are all obstacles to the successful conservation of the remaining amphibian populations. We can anticipate that too many amphibian species will become extinct in the upcoming decades if these issues aren't fixed, which would have an irreversible impact on the ecosystems of the planet.

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1. INTRODUCTION

To reduce habitat loss and fragmentation, it is essential to priorities the preservation and restoration of unaltered forest habitats, implement sustainable land-use techniques, and control logging and agriculture. The value of amphibians should be highlighted, prudent pesticide usage should be encouraged, and disease monitoring and management techniques should be put into practice. The successful execution of conservation measures and the long-term survival of amphibians in Assam's tropical wet evergreen forests depend on cooperation between governmental organizations, conservation groups, and local communities. Due to unsustainable practices, there have been well-documented population declines and extinctions across a wide range of species as a result of the rapid expansion of the human population in recent centuries [1]. The quantity and severity of threats have decreased in contemporary times, and human activities are increasingly being connected to the causes of species reduction in both terrestrial and marine settings. Invasive species [2] infectious diseases [3] and climate change [4] are some of the current threats to biodiversity. By the end of the century, it seems conceivable that we will lose a sizable amount of the biodiversity on earth if prompt and effective action is not taken to stop the present wave of extinctions. Ecological, economic, and sociopolitical solutions must be combined to address the environmental catastrophe [5].The most endangered taxa on the earth are amphibians. According to [6] species around the world are in danger of going extinct. Up to five species have gone extinct every year due to population decreases in recent decades [7]. Rapid declines in amphibian populations have been documented in North America [8], South America [9] Europe [10], and Africa [11] Australia [12]. Many declines and extinctions have occurred in protected wilderness areas like national parks and preserves, where no clear cause can be identified [13]. Unidentified processes threaten nearly half of the rapidly declining amphibian species [14]. In comparison to other regions, amphibian declines and extinctions have been more severe in the tropics [15]. At least eight extinctions have occurred in the past thirty years [16], and 32 frog species in Australia are currently classified as vulnerable due to population decreases [17]. At least 30 species of the Neotropical toad genus Atelopus are thought to be extinct since they have not been spotted in the past ten years [18]. Few long-term monitoring studies have been conducted in Africa or Asia, despite the fact that there have been very few reports of amphibian reductions or extinctions in these continents. Since many amphibian species on these continents are still unknown in terms of their danger status and population trends [19], we should be wary of drawing conclusions about the stability of amphibian populations on these continents). The tropics, where amphibian richness is highest [20], stand to lose the most species if the existing risks to amphibians are not reduced. Several reasons contribute to the significance of amphibian conservation. Amphibians are an essential component of the food chain. According to [21] tadpoles eat algae to keep streams clear, whereas adults eat a variety of invertebrates, including disease-carrying mosquitoes claim that several birds, snakes, fish, and other creatures also prey on amphibians. As a result, if they vanish, the environment might have negative effects [22]. Amphibians usually require environments that are both terrestrial and aquatic due to their permeable skin [25-27]. As a result, they are especially susceptible to various environmental disturbances. Because of this, they are regarded as reliable markers of environmental stress, and the health of their taxon is assumed to be a good indicator of the health of the biosphere as a whole [24]. Finally, using amphibians in medical research has led to significant improvements in human medicine [28]. For instance, three Australian frog species have skin secretions that totally suppress HIV. In this article, we look at the risks to tropical amphibians and make recommendations on how to stop future extinctions and decreases while also perhaps allowing some populations to regain their pre-decline levels. Assam's tropical wet evergreen woods, which may be found in the districts of Golaghat, Jorhat, Sibsagar, Tinsukia, and Dibrugarh as well as in a small area along the slopes of Lakhimpur and Dhemaji, are home to a wide variety of amphibian species [29,30-34]. During my research in this area, we encountered a knowledge gap- Basic Background Northeastern Indian state of Assam is well known for its abundant biodiversity and various environments. The tropical wet evergreen woods, which are among its amazing natural resources and are essential to the ecological balance of the area, are just one example [35]. These woods

are a vital part of Assam's distinctive natural heritage because of its lush vegetation, abundant rainfall, and evergreen canopy. Knowledge Gap: There have been few thorough investigations of the species diversity and distribution trends within the tropical wet evergreen forests of Assam [36-39]. Here are a few factors that contribute to the knowledge gap: Species Diversity and Distribution, Ecosystem Services Assessment, Threats to Conservation, Climate Change Resilience, Human-Wildlife Interactions, Conservation Strategies and Policy Analysis, Community Engagement, and Sustainable practices, among others [40-43]. The goal of this study is to advance knowledge of these distinctive ecosystems, increase public awareness of the need for their conservation, and provide information to help shape legislation that will ensure their continued existence for future generations [44].

2. METHODS

Study Area: Golaghat, Jorhat, Sibsagar, Tinsukia, Dibrugarh, and a small portion of Lakhimpur and Dhemaji districts were the sites of the study. The study area's location is as follows: Eastern Assam is where Golaghat is situated. Latitude: roughly 26.5115° North; longitude: roughly 93.9735° East. In the middle of Assam, not far from Golaghat, is the city of Jorhat (Latitude: Approximately 26.7570° N & Longitude: Approximately 94.2094° E). Northeastern Assam is home to Sivasagar, commonly known as Sibsagar (approximate latitude: 26.9810° N; approximate longitude: 94.6282° E). In the northeastern region of Assam, close to the Arunachal Pradesh border, is Tinsukia (Latitude: approximately 27.4840° N & Longitude: approximately 95.3632° E). Near Tinsukia in eastern Assam is where you'll find Dibrugarh.

Population Decline: A species' geographic range may be reduced (for example, as a result of habitat destruction) or its population abundance may be decreased (for example, as a result of overharvesting). Population decreases will ultimately result in the extinction of species. The lack of previous systematic, quantifiable surveys (number of individuals observed, distance surveyed, time surveyed, weather conditions, etc.) presents a substantial challenge to measuring decreases [45]. Population sizes in some species can vary by several orders of magnitude in different years, and met populations can go extinct and be recolonized [46]. So it is important to take natural variation in population parameters into account when documenting population declines. Most of the records that are currently in existence are based on museum specimens and brief follow-up surveys, the outcomes of which may or may not correctly reflect the population state of each species at that time. This emphasizes how crucial it is to start and maintain thorough surveys and monitoring to guarantee an accurate evaluation of species status [47]. The difference between "population size" (the number of individuals within a population) and "number of populations" must be taken into account when evaluating amphibian populations [48]. Without long-term data, it might be challenging to assess changes in amphibian populations due to their stochastic nature [49]. Contrarily, quantifying the latter (rather than counting individuals within populations, by scanning for amphibian populations' existence or absence on a broad scale) enables the quick evaluation of a species' population state [50]. Despite the challenges involved in measuring population reductions, one trend is evident: falling species coexist with non-declining species in a given location, and within a species, some populations may experience declines while others do not. It is obvious that certain species and populations are more vulnerable to extinction and population decrease [51]. In fact, numerous researchers have found commonalities between the spatial and life-history characteristics of diminishing amphibian populations. According to Hero and Morrison, 85 percent of the threatened frog species in the world live at high altitudes Worldwide, montane amphibian populations have been declining quickly [52]. In Australia, 41% of highland species and only 8% of lowland species are threatened. Upland populations of at least four species, as well as lowland populations, have drastically decreased. Litoria nannotis, L. rheocola, Nyctimystes dayi, and Taudactylus eungellensis populations have remained steady [53], indicating that the cause of the rapid decreases may be limited to high altitudes. The majority of the recent rapid amphibian reductions have occurred in very clean, protected locations (such as national parks and preserves), where no clear reason has been found [54]. Therefore, it is unlikely that simply giving a location-protected area status will be adequate for amphibian conservation in the twenty-first century. Williams and Hero discovered that in frogs from Australia's Wet Tropics, low fecundity (small clutch size), high habitat specificity (a restriction to specific vegetation associations that

are geographically restricted in the area), and an association with flowing streams were significant predictors of declining population status [55]. Hero evaluated more than 60 frog species from highland regions of eastern Australia and discovered that stream-dwelling behaviour and small clutch sizes were the main traits of declining species [56]. Additionally, phylogenetic history was a strong predictor of falling status (a relatively high number of declining species were found in several genera). In their study of Central American amphibians discovered that the degree of linkage with aquatic habitat was a reliable indicator of a falling population state [57]. Similarly, Stuart discovered that the vulnerable amphibian species that like moving water are seeing a significant decline in numbers [58]. According to Williams and Hero amphibian species with small geographic ranges are more vulnerable to extinction than amphibian species with wide distributions [59]. However, it should be highlighted that being restricted to a certain area is probably the long-term effect of the ecological conditions that caused vulnerability in the short term. Why do these traits make a species more vulnerable to extinction than sympatric species? How do these traits relate to the reasons for the decline? While continuing research attempts to answer these concerns, amphibian conservation efforts should focus on protecting populations that exhibit the above-mentioned features (e.g. stream-dwelling frog species in the mountains of the Brazilian Atlantic forest) [60] .

Causes of Amphibian Declines: According to Hero and Shoo, amphibian declines can be distinguished into two categories: (1) declines of primarily lowland species, for which habitat loss is the main culprit, and (2) unexplained declines of amphibians from relatively pristine natural habitats at high altitudes. The rapid decreases and extinctions that have been observed in comparatively untouched areas over the past few decades are not thought to be primarily caused by habitat loss [61]. Finding the reason for the puzzling decreases has proven difficult. The causes in many parts of the world currently seem to be complex. Introduced salmonid fish that prey on frogs, infections (such as the chytrid fungus Batrachochytrium dendrobatidis), and environmental change, such as increasing UV-B radiation and global warming, are some of the causal factors linked to the reduction of high-altitude amphibian populations [62]. More intricate theories are also conceivable. For instance, the disease may not be the sole cause but rather the outcome of amphibians' stress levels being elevated due to increased UV radiation or local climate changes or vice versa [63].

Habitat Loss: According to Tillman, humans currently use more than one-third of the biomass produced by terrestrial ecosystems and about half of the worlds freshwater that can be used for human consumption. The rapid increase in the human population also shows no indications of slowing. Therefore, it should come as no surprise that one of the biggest threats to terrestrial biodiversity is habitat loss [64]. By clearing forests, emptying marshes, paving grasslands, damming rivers, and introducing weeds and cattle, among other things, humans change and destroy habitats [65]. Clearly, deforestation is the main factor contributing to habitat loss, and it is concentrated in tropical areas with the highest biodiversity [66]. In the world's tropical regions, extensive deforestation is still occurring in both industrialized and developing nations. It is very challenging to stop since, according to Alexanderratos, the subsequent development of infrastructure and agriculture is considered the first essential step towards economic growth and the alleviation of poverty and food insecurity [66]. Due to high rates of urban development and intensive agriculture, extensive clearance in the tropics is mostly found in lowland areas [67], with coastal areas being especially vulnerable. The ecosystem integrity in the Atlantic forests of Brazil, the southern plains of Brazil and Argentina, and the coastal plains of Ecuador and Peru have all been severely compromised by deforestation, which has been followed by intensive cattle grazing and unsustainable agriculture [68]. The world's tropical forests are logged on an average of 6 million hectares per year [69]. More than half of the world's surviving tropical forests are found in the Amazon, but this forest is losing ground quickly; just in the Brazilian Amazon, 2 million hectares are removed annually [70]. Worldwide amphibian population decreases and species extinctions are probably mostly caused by habitat loss, change, and fragmentation. According to Hero and Morrison habitat alteration in Australia is the main factor driving population declines in lowland frogs, which negatively affects 11 of the 12 threatened lowland species [70]. Habitat modification is also linked to declines in 18 of the 40 threatened species. Altering the habitat might obstruct access to amphibian breeding and feeding regions or actually destroy them [71]. According to Corn Bury and other researchers, deforestation affects amphibian species

assemblages and decreases species diversity on a landscape scale [72]. According to Jansen and Healey, livestock grazing can lower the quality of wetland habitat and subsequently species diversity [75]. The stream flood mitigation method, which eliminates vegetation and the natural ponds connected to stream habitats, is particularly concerning [76]. Ephemeral wetlands, which house distinctive amphibian assemblages but frequently receive little legal protection, are another significant issue. Crooks and Soule both suggest that changes in land use may increase the likelihood of domestic animals preying directly on humans. While safeguarding breeding sites (such as ponds and streams) has been the main emphasis of amphibian conservation, it is also important to maintain the habitats used by the other stages of an amphibian's life cycle, including the egg, larva, juvenile, and adult stages [73,74,77]. Although some amphibian species experience a rapid decline in population when the forest cover is lost, the majority of species experience a slow decline in population, and the overall effects are not noticed until the species has vanished from a sizable portion of its former geographic range "Death by a thousand cuts" has been used to characterize the progressive loss of suitable habitat caused by small-scale habitat loss (urban and rural growth) [80]. While no single development (such as a housing complex or shopping Centre) is to blame, the accumulation of numerous little developments over time causes the species' original habitat to completely disappear. The ability of species to evolve to adapt to environmental changes like global warming is reduced as a result of the loss of local populations and subsequent reduction in the area of occupancy for each species [81]. Monitoring habitat degradation and the ensuing decrease in the area occupied by threatened species is crucial for determining the state of species conservation [78,79].

Over-harvesting: According to numerous studies, over-harvesting by humans has led to the decline and extinction of a wide variety of mammal, bird, fish, and shellfish species [82-84]. Many amphibian species are also currently in danger [85]. Brightly coloured species that are highly prized in the pet trade (like dendrobatidis) and huge, edible species are of special concern. Although it is challenging to estimate, there is probably a sizable number of amphibians collected each year for the food market [87]. The unrestricted harvesting of amphibians in many developing nations is undoubtedly a factor in amphibian decreases. For instance, in a single year, nearly six million Chinese Edible Frogs (Hoplobatrachus rugulosus) from Thailand were brought to Hong Kong; the bulk of these frogs were probably caught in the wild [88].

Introduced Species: Introduced species pose a serious threat to biodiversity in both terrestrial and marine environments and have a detrimental effect on a wide variety of taxa. For instance, according to Burgman and Lindenmayer, introduced foxes and rabbits have aided in the extinction and decline of a number of Australian mammal species [89]. The global loss of amphibians has also been linked to introduced species. By competing for food sources, spreading illness, serving as hazardous prey, and predating on frogs, introduced fish, crayfish, and amphibians can affect native amphibians [90]. Species may be accidentally introduced, such as when a fisherman's live bait escapes, or purposely introduced, such as in fish stocking programmes or the release of pets into the wild [91]. Although the mechanisms by which invasive species cause declines are well understood, the issue is difficult to solve because once an invasive species has established itself, it frequently proves impossible to eradicate it, as is the case with bullfrogs (Rana catesbeiana) and rainbow trout (Oncorhynchus mykiss) in the western United States and cane toads (Bufo marinus) in Australia. Salmonidae fish introductions have been linked to decreases in amphibian populations in Australia [94]. They are also assumed to be to blame for the extinction of numerous Atelopus species in Costa Rica. The demise of ranid frog species in North America has been attributed in part to the introduction of trout [95]. The decline of amphibians in southern Chile is also assumed to be mostly due to the introduction of several fish species, including salmonids, European carp (Cyprinus carpio), Odonthestes bonariensis, and catfish (Ictalurus spp.) [94]. after being introduced to eastern Australia in 1935, the cane toad (Bufo marinus) has greatly expanded its range to encompass much of tropical and subtropical Australia [96]. Cane toads can grow to enormous proportions (>150mm) and can live in extraordinarily dense populations. As a result, they act as a huge nutrient sink, drastically lowering the diversity and number of invertebrates [99]. This has an adverse effect on local amphibians since they are fierce competitors for food supplies. Rana muscosa's decrease in the western United States has been attributed to competition with the introduced bullfrog (Rana catesbeiana) [101].

Following the establishment of Rana catesbeiana wild populations that were recently imported to China, similar effects can be anticipated. It has also been suggested that introduced species, such as Rana catesbeiana, Bufo marinus, and Xenopus laevis, may act as chytrid fungal disease vectors [102]. These invasive amphibian species are most likely to be blamed for the rapid spread of the disease among innocent amphibian populations in many parts of the world since they can carry the disease without dying.

Pollution: According to Boone and Bridges, pesticides (insecticides and herbicides) may be crucial to understanding amphibian decreases. Pesticides are widely used and affect terrestrial wildlife in both deadly and non-lethal ways [103]. Frogs' immune systems can be fatally suppressed by pesticides at even low concentrations [105]. Government agencies frequently approve pesticides without testing them on amphibians, and when testing is done, it frequently only looks at the deadly effects. Researchers may therefore easily miss any potential sub-lethal consequences [107]. Through windborne transfer, pesticides and other chemicals that are utilized all over the world have the potential to contaminate geographically distinct areas. A link between agrochemicals and population decreases is clearly suggested by recent research by Davidson and Davidson and Knapp that showed an association between amphibian declines and the amount of upwind pesticide use [109].

3. RESULTS AND DISCUSSION

Assam's tropical wet evergreen forests play a significant role in watershed management, climate regulation, and wildlife preservation. They do, however, confront serious dangers that demand quick attention and action. In order to guarantee the long-term preservation of these priceless ecosystems, stakeholders including governmental organizations, regional communities, and conservation organizations must coordinate their efforts. A wide variety of amphibian species can be found in the tropical wet evergreen forests of Assam, India, but their populations are in danger due to a number of serious challenges. The protection of amphibians and the general health of these distinctive habitats depend on an understanding of and response to these threats. Deforestation and Habitat Loss: Amphibian habitat has been severely lost as a result of deforestation in Assam's evergreen forests, which is being caused by logging, agriculture, and infrastructural development. The complicated ecological balance is upset by this loss of forest cover, which has an adverse effect on amphibian populations. Populations become more isolated as a result of habitat fragmentation, which also reduces gene flow and raises the danger of extinction. Deforestation must be stopped, intact forest habitats must be preserved, and sustainable land-use methods must be promoted. Degradation of Habitat and Fragmentation the difficulties amphibians in Assam face are made worse by the fragmentation of wooded regions. Amphibian migration is restricted by fragmented habitats, which also expose them to edge effects, changed microclimates, and higher predation danger. Amphibians' typical reproductive cycles are thrown off when breeding habitats like wetlands and tiny streams are lost, which has an even greater effect on amphibian numbers. In order to lessen the consequences of habitat fragmentation, it is essential to restore the connection between habitat patches and safeguard important breeding locations. Climate Change: The tropical wet evergreen forests of Assam are under increasing threat from climate change for amphibians. Amphibian physiology, behaviour, and life cycles may be significantly impacted by rising temperatures, changed rainfall patterns, and an increase in the frequency of extreme weather events. These modifications may alter food availability, diminish acceptable habitats, and alter breeding patterns. Amphibians have transparent skin, making them extremely sensitive to environmental changes. Even little changes in temperature or moisture can have a negative impact on an amphibian's ability to survive. The protection of forest cover to control microclimates and the promotion of landscape connectivity to aid in species movement are examples of climate change adaptation and mitigation measures that should be incorporated into conservation efforts. Contamination & Pollution: Amphibians in Assam's evergreen woods are seriously threatened by pollution from industrial waste, agricultural runoff, and pesticides. Chemical contaminants can build up in bodies of water, deteriorating water quality and impacting the health, development, and reproduction of amphibians. Frogs can be extremely toxic to pesticides and herbicides in particular, which can cause population decreases and even local extinctions. To reduce the effects of pollution, it is crucial to enforce stronger laws on the use of chemicals, encourage sustainable farming practices, and provide protected areas with access to clean water.

Overexploitation: Assam faces a major threat from the unsustainable harvesting of amphibians for use in traditional medicine, the pet trade, and local food. Overfishing can destroy amphibian populations and alter ecological processes. Additionally harming local populations is the introduction of illnesses and parasites brought about by the illegal trade in amphibians. To decrease the demand for amphibian products, it is critical to enforce animal protection laws, increase public knowledge of the value of amphibian conservation, and promote sustainable livelihood alternatives [86,92,93]. Emerging Infectious Diseases: In Assam's evergreen woods, amphibians are vulnerable to newly emerging infectious illnesses like chytrid fungus. Globally, populations of amphibians have seen extensive decreases and extinctions as a result of these infections. A favourable habitat for pathogen survival and propagation can be found in Assam due to the region's high humidity levels and favourable weather conditions. Manage and reduce the effects of infectious illnesses on amphibian populations by keeping an eye out for disease outbreaks, putting biosecurity measures in place, and researching disease dynamics.

4. CONCLUSION

The tropical wet evergreen woods of Assam are home to a variety of linked and multidimensional dangers to amphibians. Intact forest habitats should be protected, deforestation should be stopped, sustainable land use should be encouraged, and climate change should be mitigated. A wide variety of amphibians live in the tropical wet evergreen forests of Assam, India, but their populations and the well-being of their ecosystems are jeopardized by several threats. Significant obstacles for amphibians in this area include deforestation and habitat loss, habitat fragmentation, climate change, pollution, overexploitation, and newly emerging infectious illnesses. The natural ecological balance is disturbed by the disappearance of forest cover and habitat fragmentation, which isolates amphibian populations and reduces gene flow. Climate change impacts temperature and precipitation patterns, which have an impact on amphibian breeding, habitat suitability, and food availability. Pesticides, industrial waste, and other pollutants affect water sources, causing health problems and population decreases [104,106,108]. Amphibians are further threatened by overexploitation for traditional medicine, the pet trade, and local consumption, which disturbs ecological dynamics. In the evergreen forests of Assam, emerging infectious illnesses like chytrid fungus pose a serious threat to amphibians. Disease monitoring and control techniques must be put in place since disease outbreaks can result in severe population losses and even local extinctions. To lessen the effects of deforestation and habitat loss, conservation efforts must prioritise the protection of intact forest habitats, the restoration of connectivity between fragmented areas, and sustainable land-use practices. Methods to combat climate change, and the preservation of suitable habitats for amphibians depend on factors like conserving forest cover and fostering landscape connectivity [97,98,100]. For the health and reproduction of amphibians, it is also essential to reduce pollution through stronger restrictions, promote sustainable agriculture, and protect clean water supplies. Enforcement of wildlife protection legislation, education about the value of amphibian conservation, and the provision of alternative livelihood opportunities are all necessary in the fight against overexploitation. For the sake of conserving amphibian populations and preventing disease outbreaks, it is crucial to monitor and manage developing infectious illnesses. To execute efficient conservation measures, cooperation between governmental organizations, environmental organisations, researchers, and local people is crucial. It is possible to protect the diverse amphibian biodiversity of Assam's tropical wet evergreen forests and secure the long-term survival of these intriguing and critically essential creatures by tackling these challenges thoroughly and implementing proactive conservation measures.

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