Impacts of Deforestation on Forest Raptors and Conservation Strategies

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Abstract: Forests are critical ecosystems that support diverse biodiversity and provide essential ecosystem services. However, rampant deforestation primarily driven by human activities threatens these ecosystems and the species that depend on them. This paper specifically addresses the impact of deforestation on forest raptors, a group highly vulnerable due to their dependence on forest environments for nesting and prey. By synthesizing findings from twelve studies across neotropical, temperate, and boreal forests, this review highlights the dire consequences of deforestation, including the loss of prey and nesting sites, which critically endanger these avian predators. Additionally, the paper evaluates two potential conservation strategies: the use of eucalypt forests as alternative habitats and the implementation of artificial nests, discussing their effectiveness and limitations in preserving raptor populations and biodiversity. Furthermore, the study considers the adaptive behaviors of raptors in response to changing forest landscapes, suggesting potential resilience mechanisms that could be supported through targeted conservation efforts. It also addresses the policy implications of these findings, advocating for stronger legislative measures to protect critical habitats. Finally, the paper calls for more collaborative research initiatives that integrate ecological, socio-economic, and cultural perspectives to enhance conservation strategies for forest raptors and other wildlife impacted by deforestation.

1 INTRODUCTION

Forests are essential for providing ecosystem services like stabilizing climate and supporting 80% of biodiversity on land. Forests are shrinking at an alarming rate due to anthropogenic activities. Primary causes include deforestation and land conversion for agricultural production, livestock grazing, and timber exploitation (Carrete et al., 2009; McClure et al., 2018 & Healey, 2020). Forest degradation by deforestation threatens the balance of ecosystems and the survival of many animals that rely on it, and reduced biodiversity is the result of habitat degradation and fragmentation.

Raptors, such as hawks, eagles, and owls, are birds of prey that play a vital role in shaping the forest ecosystem by being flagship and umbrella species on the highest trophic level (Carrete et al., 2009). Their presence is frequently represented as an environmental indicator of healthy biodiversity and habitat quality, controlling the prey population and having cascade effects on ecosystems. Raptors are strongly influenced by features of the canopy and sub-canopy (Piana and Marsden, 2014). Analysis indicates that raptors are more in peril than other birds (McClure et al., 2018 & Labra et al., 2013), and ecosystem conversion and ecosystem degradation are the greatest stressors that raptors face (McClure et al., 2018).

Understanding their behaviours and habitat preferences allows efficient conservation. However, these elusive birds are difficult to track and study, and most of their habitat selection preferences, population dynamics, and conservational status remain unclear. By analyzing previous studies of forest raptors in neotropical, temperate, or boreal forests, this paper aims to integrate the known information and interpret the effects of land clearing on forest raptors. This paper also evaluated and commented on two possible conservational methods, with the first study investigating eucalypt trees for being forest raptors' nest preferences and the last study of the use of artificial nests.

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2 SCALE AND CAUSES OF DEFORESTATION

Deforestation are the removal of forest biomass and the conversion to other land use. The fertile soil allow agriculture and civilisation to prosper and support populations around the world. However, colonial deforestation throughout history and the over-exploitation of forest in the contemporary world had concerning effects on the environment and quality of life of people (Barraclough and Ghimire, 1995).

Large-scale land clearing is occurring in deforestation fronts globally, with one hectare of forest degraded every second; over half of the tropical forests have been lost since 1960 (Healey, 2020). The resources commercially extracted from tropical forests are often supplied to developed countries, with communities being exploited for labour (Barraclough and Ghimire, 1995). Furthermore, colonial deforestation had negatively impacted the socio-economic aspects of 70 million indigenous people whose livelihood relied on the forest (Healey, 2020). With the change in regional climates comes an increased risk of flooding and water insecurity (Barraclough and Ghimire, 1995), and many who are dependent on forests lose resources when land is degraded.

The depletion of forests is accelerating. With reduced ecosystem functions and services provided by forests, there are aggregated impacts of climate change and ecosystem collapses. The main causes of deforestation in recent decades are expanding agriculture (Piana and Marsden, 2014 & Barraclough and Ghimire, 1995) and the unsustainable logging and commercial exploitation of wood as fuel also accounts for most of the forest degradation. Other pressures include having infrastructures, transforming land to urban settlement, building hydroelectric project and mining etc (Healey, 2020 & Barraclough and Ghimire, 1995).

3 IMPACTS OF DEFORESTATION ON RAPTORS

3.1 Impacts on Species Susceptibility

Raptors, sitting on the highest level, are apex predators that prey on other animals; they have evolved adaptations to thrive in almost every type of habitat (McClure et al., 2018). In terms of forest biomes, forest raptors are top predators that have top-down effects on ecosystems; they are considered the keystone species that hold the structure of biological communities, having the service of regulating and maintaining the ecosystems.

With threats like reduced habitats and being subject to hunting, raptors are declining globally, with 18% classified as threatened with extinction (McClure et al., 2018). Some species are more vulnerable to habitat alternation than others based on their foraging habitat, nesting, and reproduction preferences (Carrete et al., 2009). Identifying species that are more susceptible to deforestation is essential for evaluating conservation priorities.

Among avians, raptors are more prone to human activities due to their ecological traits (Labra et al., 2013); non-migratory forest raptors, especially species found in the tropics, are more likely to be threatened by human activities (McClure et al., 2018). Of 557 species of raptors, 258 species specifically require forest as habitat, and over 80% of species have regular or frequent use of forests (McClure et al., 2018). Neotropical raptors heavily depend on old mature forests in Central America, and different species respond differently to altered habitats: while for almost all other neotropical raptor species, deforestation had become the most significant threat for their declining numbers, Plumbeous Kite, Bicolored Hawks, Roadside Hawks, Laughing Falcons, and Bat Falcons are more resilient to deforestations (Whitacre and Peregrine, 2012). Study results in Peru show that moderately controlled cattle grazing could benefit and increase the dominance of generalist species like Harris Hawk, Black, and Turkey Vultures (Piana and Marsden, 2014). However, raptors like the Great Black Hawk and the Gray-backed Hawk are more susceptible to the effect of cattle grazing and struggle to maintain populations.

A regional raptor survey was done by Carrete et al. in selected biomes, with forest habitats including the Paraná forest, which has a fragmented semi-deciduous rainforest, and the Patagonian mountain forest. Higher raptor species richness and diversity were recorded in natural habitats with low degrees of deforestation, and larger patches of forest sustain higher levels of raptor assemblages than smaller fragmented patches (Carrete et al., 2009). The main leading causes of raptor decline are habitat loss and fragmentation. A raptor survey by De Labra investigates the composition and abundance of raptor species in Mexico forests and reported lower

encounter frequencies for most species, with three species only being found in heavily forested regions (Labra et al., 2013), contrasting to the frequencies of encounter reports in well-conserved areas.

3.2 Impacts on Diet and Prey Abundance

Smaller territories range among raptor individuals and are associated with abundant food availability; interspecific competition decreases when food resources are sufficient and the habitat can sustain a larger raptor community (Segura and Acevedo, 2023). The complex spatial structure of mature forests allows raptors like the Harpy Eagles to forage in high prey-density areas (Vargas et al., 2020). The breeding pair's habitat selection is strongly associated with food availability (Segura and Acevedo, 2023).

It is safe to interpret that deforestation impacted raptors' survival fitness by limiting their energy supply and intake. Deforestation affects organisms at all trophic levels, decreasing the prey abundance of some species. By limiting available tree hallows and canopy covers, canopy dwelling, and arboreal prey decreases. Raptors with specialized diets or unique sub-canopy hunting styles, like Crested Eagles, Hook-billed kites, and Orange-breasted falcons, are more adversely affected by prey abundance and have a higher intrinsic vulnerability to the impacts of deforestation. Crested Eagles hunt nocturnal, arboreal mammals in sub-canopy, and their prey declines with deforestation, Hook-billed kites are arboreal snail specialist, feeding dominantly on tree snails, Orange-breasted falcons prey comprising aerial species of birds dwelling on treetops and sub-canopy, and land degradation caused altered hunting grounds, and their hunting success rate decreased (Whitacre and Peregrine, 2012).

The canopy and sub-canopy provide perching sites for forest raptors (Piana and Marsden, 2014 & Whitacre and Peregrine, 2012); removing raptors' natural prey habitats, causing a decrease in prey population might also force raptors to hunt and feed on domestic animals, like calves and poultry (Labra et al., 2013). This created conflicts between residents in the local area, and raptors were shot and killed by local farmers (Labra et al., 2013 & Whitacre and Peregrine, 2012). Furthermore, human-caused mortality directly accounted for the decline of the raptor population by hunting or poaching, while raptor prey animals being hunted by humans also reduced the raptor's prey availability.

3.3 Impacts on Nesting Preferences and Habitats

Raptors are territorial predators that occupy defended territories to forage and reproduce. Studies about forest raptors' nesting selections corroborate the importance of the quality and quantity of nesting sites to the raptors' community and populations. The now vulnerable Harpy Eagles require high forest cover as breeding sites and habitat alteration have limited their breeding success (Vargas et al., 2020). Honey Buzzards and Lesser Spotted Eagles also have a strong preference for nesting in natural forests 20], with natural stand composition, location, tree sizes, and old-growth structure being driving variables. Species like Booted Eagles have a strong preference for tall trees with dense canopy cover that provides shelter for nests from thermal extremes; hence, the dense breeding population of Booted Eagles was found only in mature forests (Segura and Acevedo, 2023).

Breeding nests are resources that are usually reused by many species, and the destruction of existing nests reduces the survival fitness of individuals (Segura and Acevedo, 2023 & Franco et al., 2018). Deforestation in forests with mature trees removes suitable nesting platforms and reusable breeding nests for forest raptors. Unprotected areas with less nesting availability might result in the raptor's declining abundance, species richness, and reproductive success (Segura and Acevedo, 2023).

Since forest raptors have a heavy reliance on mature trees as breeding and nesting sites (Whitacre and Peregrine, 2012 & Franco et al., 2018), with the ongoing rate of deforestation, evaluating the impacts of land clearing on forest raptors is required for conservation purposes. Studies predicted the effect of land clearing on forest raptors using statistical models. A dynamic model was constructed by Jiménez-Franco et al. after studying the nesting platforms of the Booted Eagles, Common Buzzards, and Northern Goshawks (Franco et al., 2018). Stimulation shows that populations have a gradual decrease in clearcutting trees of 50-70 years old, and populations become extinct for the clearcutting of 40-year-old trees. Mozgeris et al. predicted the habitat availability of Estonia's boreal forest in the coming decades based on current forestry practices (Mozgeris et al., 2021). With more timbers maturing and available for harvesting, clearcutting areas will increase, causing the decrease of nesting habitat for lessor spotted eagles, disturbance during

breeding seasons, and may increase interspecific competition with other species (Franco et al., 2018).

4 CONSERVATIONAL METHODS

4.1 Eucalypt Forest Plantation

With much evidence pointing out habitat loss and degradation as the most significant threats to forest raptors, creating or transforming regions into suitable habitats is one conservation method to protect raptors' abundance and species richness. By planting woody plants, the availability of potential nesting and breeding sites increases in the hope of sustaining a larger raptor community.

Eucalypt trees are extensively planted in southwestern Europe for agroforestry purposes, and a study by Monteagudo et al. examined the habitat preferences of raptors and results concluded that eucalypt forests are suitable breeding habitats for forest-dwelling raptors and are beneficial to raptor conservation (Monteagudo et al., 2024). Monteagudo, et al.'s evaluation, shows that the main driver for habitat preference is vegetation features, especially for territorial species, and the tall eucalypt trees fit to be ideal nesting woody vegetation for breeding pairs (Monteagudo et al., 2024). With the appropriate size of the central fork, size of tree crowns, amount of concealment from the canopy, and sufficient tree height to support tall nests, eucalypt trees became the primary preference for establishing nests for many species. Thus, eucalypt forests can hold dense breeding pairs with fair spatial distribution distances.

Eucalypt forests as conservation strategy can be investigate further for improvement. The plantation of intervention plots should be included within large forest patches for optimal conservation results. The plots' distances should vary to target different species, with species like goshawks with greater distance apart and smaller species with shorter distances to minimize interspecific competitions, and the key to conservational success is low exploitation of forests in the long term.

The habitat provided by these non-native eucalypt plants is no doubt beneficial to raptors; however, as a limitation mentioned in the study, the eucalypt trees may have adverse effects on small native birds, causing biodiversity loss. To further expand this, non-native plants thriving in foreign ecosystems could be detrimental to many native species. The benefits to the raptor community are observable as raptors are larger fauna and top predators. However, subtle shifts in ecosystems at lower trophic levels could go unnoticed and may cause long-term repercussions for other organisms. For instance, the long-term effects of the accelerated expanding range of eucalypt forests are unknown, and the changing composition of plant species may alter nutrient cycles. The nutrient cycling process is the underlying basis for energy and production that allows the thriving of many trophic levels. Forest ecosystems have longer element cycles for some essential nutrients and have extensive transit time, with Phosphorus requiring over 450 years of transit time and Nitrogen 85 years in eucalypt forests (Spohn and Sierra, 2018). Concentrations of nutrient elements strongly influence the primary production of plants, indirectly affecting the diet and population of consumers like herbivores and insects and extending the impacts to higher trophic levels (Clark et al., 2013), causing an ecological cascade that profoundly affects ecosystems.

Introducing exotic plantations is an emergent factor for the ecosystem that may pose potential effects that cannot be observed in the short term. Therefore, choosing to plant eucalypt plots for the sole purpose of raptor conservation may not be appropriate. More research on the relationship between eucalypt forests and native biodiversity should be conducted before transforming landscapes and implementing large numbers of eucalypt plots.

4.2 Artificial Nests

Björklund et al. evaluate the effectiveness of artificial nests in conserving three species of forest-dwelling raptors in Finland (Björklund et al., 2013). The study results show that the Northern Goshawk and Common Buzzard have lower breeding success for artificial nests than natural nests. In contrast, honey buzzards have the same nesting success regardless of the type of nest. This result indicates that raptors have higher nesting failures when using artificial nests, but artificial nests still support the population. Concerns were stated in the paper that artificial nests might act as ecological traps that lure breeding raptors from natural nests to artificial ones and reduce their reproduction success; another issue stated is that artificial nests may favor some species over others. Indeed, this could lead to intensified interspecific competition among some species, and some species may become more dominant. The consequences of irresponsible nest placement would be reduced biodiversity and species richness.

However, despite the limitations, this conservation method is economically efficient and is

able to ease the problem of lacking nesting sites in the short term. It is time- and resource-consuming to restore a young forest to maturity actively. The effects of implementing artificial nests are immediate without requiring the woody vegetation to take years to develop tree crowns and forks that are large enough to attract raptors to nest; therefore, this conservation method is practically appropriate.

To minimize the effect of human intervention on the species composition of raptors, the ecology and nesting habits of all raptors in the area should be studied and evaluated before the placement of artificial nests. The production of artificial nests should consider species preferences, for instance, providing a range of sizes and materials to accommodate different raptors and prioritizing to conserve more vulnerable species or species with intrinsic value. The location and distance of the implementation should also be considered. Some species have preferred elevation in landscapes, and with highly territorial species, distance between nests is recommended to reduce intraspecific competition and utilize home ranges.

5 CONCLUSION

This paper discusses the effects of deforestation on forest raptors and evaluations of two possible conservation methods. In general, non-migratory raptors that are reliant on forests are more vulnerable to habitat degradation. The complexity of maturity of old-growth forests provides exceptional habitat for a diversity of forest raptors. With high-density prey abundance, lateral spatial sites for hunting, and high biodiversity of animals sustaining specialist species, forest raptors thrive in large, intact patches of forests. Mature trees also provide suitable trunks and crowns for raptors to construct nests, allowing raptors to breed and raise their young.

With ample evidence showing that deforestation that caused habitat degradation and fragmentation is the biggest threat that raptors face, conservation methods should be evaluated based on species susceptibility, raptor's diet requirements, and nesting preferences. The key to sustaining healthy raptor populations and species diversity is the preservation of intact, mature forest ecosystems.

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