



Original Research Paper

The Role of Social Networks in the Conservation of Endangered Species from a Behavioral Ecology Perspective

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Key Words

Behavioral ecology, Social networks, Endangered species, Conservation planning, Population resilience, Animal behavior, Network analysis.

Abstract

Understanding the interactions of endangered species in their social settings is critical to the success of conservation. Behavioral ecology is the study of how individual behaviors affect population survival. Still, the importance of social network patterns of interaction among individuals has not been used in conservation planning. Social networks affect processes such as information exchange, reproductive success, cooperative defense, and disease transmission. The purpose of this research is to compile existing information on the impact of social network structures on the survival of endangered species and to assess ways to incorporate social network analysis into conservation. Our systematic review examined empirical studies on the use of behavioral observations, GPS and RFID tracking, and interaction-based network construction across a variety of threatened taxa. The discussion shows some common trends: (1) individuals with high centrality tend to be primary sources of knowledge or reproductive centers, (2) destroying societal structures by poaching, disaggregating habitats, or translocating species weakens the group cohesion and stability, (3) specific patterns of networks make them more prone to a disease outbreak. Results indicate that conservation efforts can be significantly enhanced through more effective identification of influential people, maintenance of social cohesion, and reintroductions designed to uphold natural social relationships. A combination of social-network views and behavioral ecology is a strong avenue for improving population recovery and species survival in the short and long term.

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Introduction

The rate of biodiversity loss has increased worldwide, and current rates are estimated to be tens or even hundreds of times the background extinction rate. Habitat fragmentation, climate change, disease outbreaks, and human disturbance continue to erode the population stability of many already endangered species (Ramya & Geetha, 2025). Behavioral ecology has become a critical part of conservation biology, addressing these problems and understanding how animals respond to their surroundings, as well as the role of behavior in their survival (Saidova et al., 2024; Webber et al., 2023). Early conservation initiatives were primarily concerned with environmental protection, demographics, and curbing threats; however, these efforts failed to address the behavioral and social mechanisms that support resilience in output (González et al., 2022). Recent literature highlights that incorporating behavioral factors into conservation decision-making is a valuable means of improving the quality of population models and the success of recovery programs (Verma et al., 2025; Qian et al., 2023).

In behavioral ecology, social networks have become a significant tool for mapping the organization of animal societies and the mechanisms that connect individuals (Villegas-Ríos et al., 2022; Cooke et al., 2023). The social network analysis demonstrates that cooperation, kinship, dominance, mating behavior, and information exchange determine fitness outcomes across populations (Mutambik et al.,

2022). For example, research on elephants, primates, cetaceans, and social carnivores has demonstrated that central individuals tend to be sources of knowledge, sites of reproduction, or even conflict resolution, thereby generating disproportionate levels of group cohesion and stability (Felipe-Lucia et al., 2022). Studies also indicate that disturbances to social networks, caused by poaching, habitat fragmentation, or translocation, can trigger cascading effects, including reduced breeding, altered movement patterns, and poor juvenile survival (Lewton & Rose, 2021). Although these lessons have been learned, social network measures are seldom used in conservation planning, resulting in a vast disconnect between theory and practice (Miah et al., 2022; Gao et al., 2023).

The only way to close this gap is through a comprehensive review of how social structure can support the survival of endangered species and how conservation interventions can be enhanced with network-based information (Deepika & Geetha, 2025; Savari & Khaleghi, 2023). Trained data capture information flows, disease transmission, and collective decision-making, which are mediated through social networks and are integral to and affect population resilience (Carter et al., 2023). However, the potential of social network methods is not fully realized, particularly when the species' population is small, fragmented, or declining (Ballejo et al., 2021). In this paper, the existing literature has been synthesized to assess how social networks can be incorporated into a behavioral ecology approach and which strategies can be used to incorporate network

analysis into the conservation planning process (Brask et al., 2021; Pimentel & Kalyanaraman, 2022). The study to be conducted will also help advance a behavior-based method for protecting endangered species by linking empirical observations with management application requirements (Willi et al., 2022).

Key Contributions

- Illustrates the role of social-network forms in determining the fundamental functions of survival, reproduction, and information flow within endangered species.
- Explains the basis of why the people-attacking disturbances like poaching, habitat fragmentation, or translocation, which people attacking disturbances, which, If not controlled, have the potential to disrupt population stability.
- Proposes ways to include social network measurements in conservation to identify critical individuals and design social Management Actions.

Section I presents international issues related to biodiversity depletion and explains how behavioral ecology and social network theory explain the survival of endangered species. It also identifies the research gap, the study objectives, and the study's essential contributions. Section II describes the methodological approach, including the criteria for selecting the studies, the techniques for collecting the data, and the tools for analytically building and interpreting the social networks. The essential facts from Section III concern network structures, insights into individuals, and the impact of individual loss and

disease spread on conservation. Section IV will examine the findings in light of behavioral ecology, their importance to developing conservation strategies, and how the findings compare to previous research; it also discusses limitations of this work. Section V concludes with recommendations on how to incorporate social networks' views in developing future conservation strategies, and outlines suggested future directions for study.

Methodology

The present research follows a systematic review and comparative analysis model to determine the effects of social network structures on the conservation of endangered species. The databases of primary academic sources, including Web of Science, Scopus, PubMed, and Google Scholar, were searched using terms such as social networks, behavioral ecology, endangered species, animal interactions, and conservation biology. To be included in the studies they had to satisfy three main criteria: (1) the studies dealt with species that were listed as endangered, threatened, or vulnerable; (2) the study had included behavioral observations or technological tracking information that could produce social-network information; and (3) the study had presented conservation-relevant outcomes, including reproduction, survival, group cohesion, or disease dynamics. Research that lacked empirical data, failed to incorporate interaction-based studies, or focused solely on captive populations without a conservation context was excluded. This sampling procedure made sure the final dataset was ecologically and methodologically sound.

Figure 1 above shows the effect of social network structure on the survival of endangered species in a behavioral ecology context. At the center of the panel is the animal network, which indicates the presence of key individuals through connectors and leaders with experience and greater age, whose roles help promote mating success, information sharing, protection, cooperation, and the overall stability of the group. Given the network's ecosystem, the primary conservation threats are poaching, habitat loss, disease spread, and fragmentation,

which can destabilize social relationships. The right side depicts the population-wide effects of such disruptions, including decreased cohesion, reduced reproduction, the spread of illness, and death. The conservation response layer, located at the bottom of the diagram, focuses on approaches that leverage social network understanding, such as the management of a protected area, concerned relocation planning, and the identification of socially valuable individuals to advance population resilience and further conservation benefits.

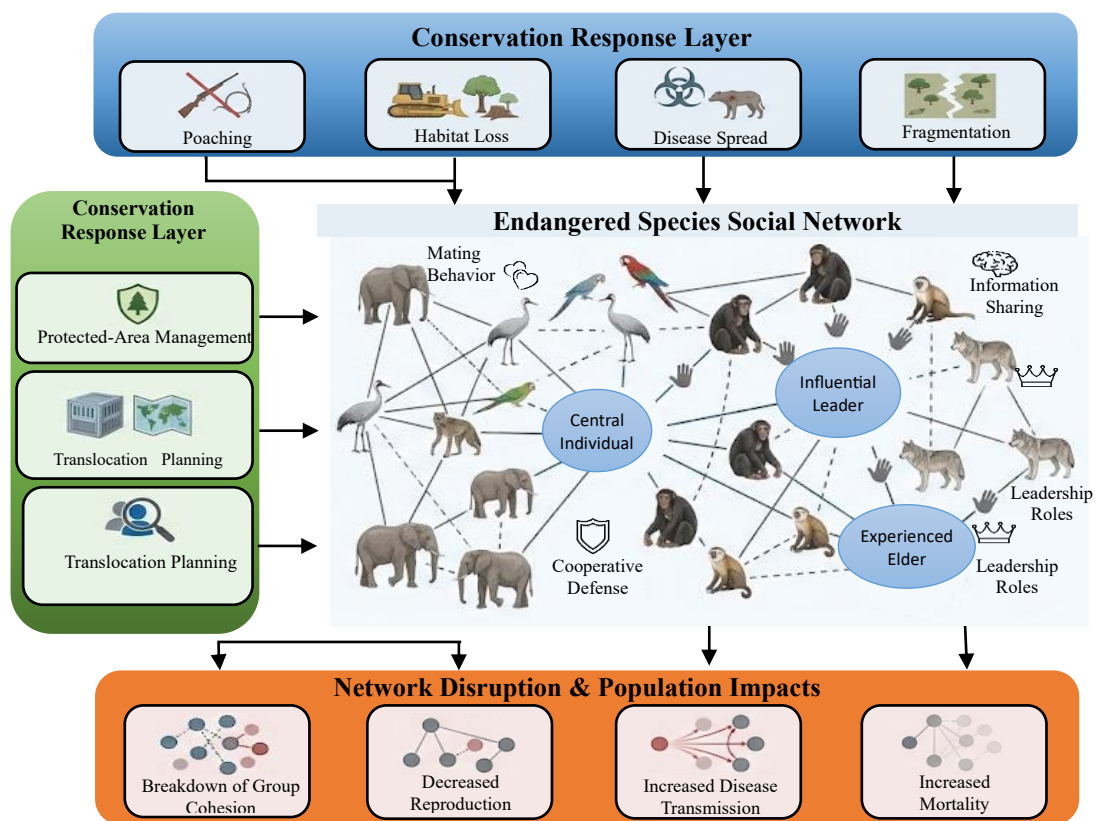


Figure 1: Conceptual Framework Illustrating the Role of Social Networks in Endangered Species Conservation

Data Collection

Studies used different data collection techniques, but each relied on comprehensive behavioral or spatial observations from which interactions among individuals could be

measured. Affiliative behaviors (including grooming and cooperative foraging), agonistic encounters, mating events, and vocal communication were recorded by direct observation. Alongside this, there were

contributions made by technological tools in the form of GPS collars, RFID tags, proximity loggers, and automated camera traps in many of these situations because of the lack of reliable movement and association data within a large or cryptic species. These measures enabled scholars to record small-scale trends of co-occurrence, spatial resemblance, and temporal correlation. Interaction logging usually led to association matrices where rows and columns were individuals, and the value in a cell was the frequency or strength of interaction. The standard protocol allowed comparative building of social networks, and their construction across research and trees.

Social Network Construction

After the data collection, social networks were built following conventional network-mapping techniques that view interactions as nodes (people) linked by edges (relationships). The nature of interaction that constituted an edge was species biology-specific and study objective-specific, and included such measures as grooming frequency, common foraging incidences, duration of time in close association, cooperative behaviors, or synchronized movement patterns. Depending on the availability of data, the networks were developed as either unweighted (presence or absence of interaction) or weighted (strength or frequency of interaction). Widely known techniques, like force-directed layouts used to create a visualization or clustering based on modularities to discover the subgroups, were used to expose the structural features. The process of construction of the network was ecologically

valid because the interaction thresholds, association indices, and grouping criteria were designed to correspond to the biological and social properties of individual species.

Analytical Methods

The methods of analysis aimed at measuring structural characteristics of the social networks and correlating them with the results of conservation. The most important measures of the network were the degree centrality (number of connections), betweenness centrality (ability to control information flows), proximity centrality (efficiency to access other key persons), and eigenvector centrality (influence due to connection with other significant individuals). The analyses of community structures served to find cohesive subgroups, whereas network density and modularity gave evidence about the overall connectedness. Generalized linear mixed models (GLMMs), permutation tests, correlation analysis, and survival/reproduction models were used as statistical tests to test the relationship between network measures and measures of fitness. Where feasible, cross-population, cross-temporal, and cross-disturbance networks were compared to determine the effects of environmental/anthropogenic change on social processes. These methods of analysis allowed the strict quantitative evaluation of the resistance of the population to the social structure.

Results

Social Structure Patterns

The data on the social networks collected were analyzed, and it was found that there are

common structural patterns in several endangered species. A non-random, very structured type of network, with cohesive subgroups and stable interaction clusters, was observed in most populations. The central individuals were mostly older, experienced, or socially dominant animals who had a high degree and betweenness centrality, which is a vital sign that such animals served as critical points to ensure the connectivity of the group. These people acted as intermediaries between the

otherwise distinct subgroups, enabling the information to go through, organizing the movement, and stabilizing the group dynamics. We also found strong effects of preferential association in a number of species, in which the modular structure of the network was determined by kinship, age, or ecological functions. In most instances, social activities like grooming, alarmed reactions, or foraging as a group were focalized in certain groups, which is evidence of functionally legitimate social assemblies.

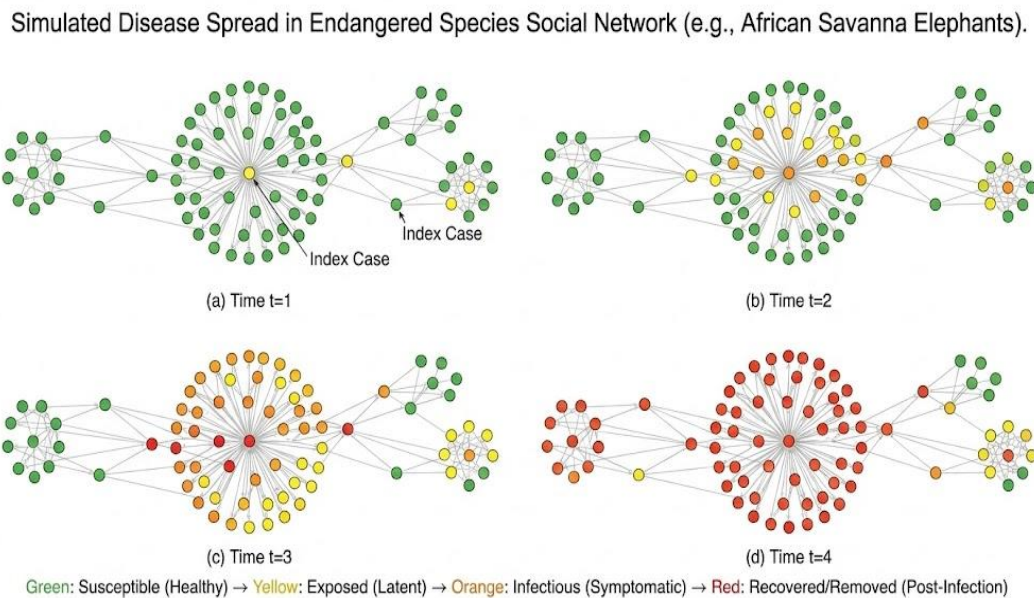


Figure 2: Simulated Spatiotemporal Spread of a Pathogen Through an Endangered-Species Social Network

This is Figure 2 that simulates an outbreak situation to demonstrate the spread of a hypothetical pathogen through an endangered-species social network of four time steps ($t=1$ to $t=4$). The initial one starts with a single index case, and then people pass through the epidemiological states that can be illustrated by the following colors: green (susceptible, healthy), yellow (latent), orange (symptomatic), and red (recovered or removed, post-infection).

The panels indicate the extent to which centralized persons who are well connected enhance speedy transmission and spread rapidly through the central cluster, then the peripheral groups. This dynamic extemporal sequence shows that the form of networks, interactions within subgroups, and patterns have both a positive and negative effect on the rate and scope of the transmission of disease among endangered wildlife species.

Spatial Distribution of Social Networks

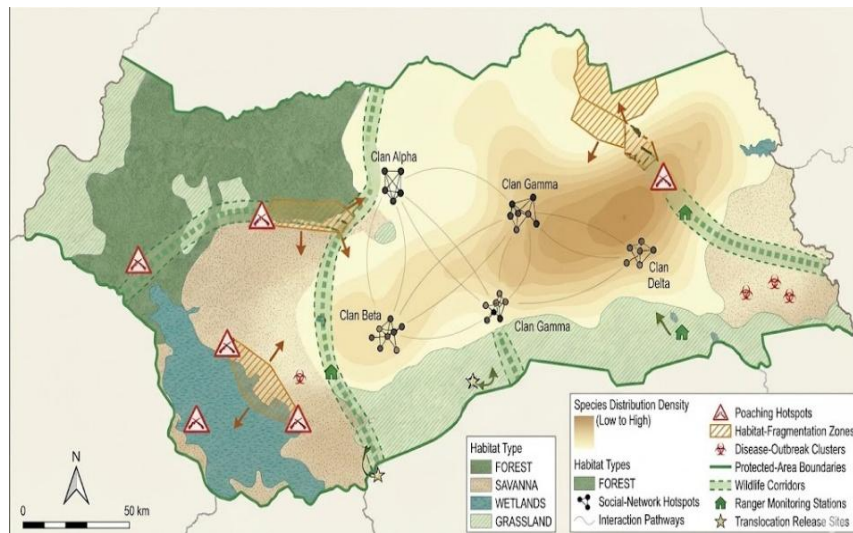


Figure 3: Integrated Spatial Landscape of Social Structure, Habitat Features, and Conservation Threats in the Study Area

This Figure 3 is a single spatial visualization of the conservation landscape of the endangered species, integrating habitat types, social-network hotspots, and threat distributions. The density of species distribution is demonstrated in different regions, forests, savannas, wetlands, and grasslands, and different clan communities (Alpha, Beta, Gamma, Delta) are depicted with their respective social-network clusters and interaction patterns. The main conservation issues, such as the poaching of hotspots, zones of habitat-fragmentation, and clusters of disease outbreaks, overlap to show the high-risk areas. Boundaries of the protected areas, animal corridors, ranger offices, and sites of translocation and release can be used to explain the current management structure. The combination of the map gives a broad perspective of the intersection of spatial ecology, social structure, and anthropogenic pressures to determine conservation outcomes of endangered populations.

Identification of Central or Influential Individuals

In all studies, there are always those individuals who appear to be socially influential in terms of network metrics. Animals that were well-connected in eigenvector centrality tended to have strong ties with many people but also with other well-connected members of the group, and therefore are behavioral hubs. Leaders like matriarch elephants, dominant moneys, or the experienced wolves were influential in the group integration, the coordination of reproduction, and at the decision-making level. On the same note, the older people tended to be warehouses of environmental information and would lead group movements and even learning among the youth. The discovery of these identified individuals was closely linked with enhanced group stability, implying the need to have them in place to keep the social systems functional in threatened populations.

Conservation-Relevant Findings

It was revealed that interference with the social networks has important conservation implications. Elimination of central or (so-called) influential people by either poaching, illness, or by means of translocation often led to quantifiable drops in network cohesion. The more fragmented, with less effective communication pathways, and less synchronous movement or foraging patterns, were groups that suffered such losses. A number of studies have found reduced reproductive success after the loss

of important individuals, such as delayed breeding, decreased mate availability, and decreased offspring survival. Network structure also played a strong role in disease dynamics: the network was highly connected, which led to the rapid proliferation of the pathogen, and the network was fragmented, which led to the rise of stress and a lack of cooperative care. These results highlight the two-sidedness of social networks in conservation as effectiveness towards resilience, and as exposure points in case they are destroyed.

Table 1: Summary of Conservation-Relevant Outcomes Associated with Social-Network Characteristics

Network Feature	Observed Conservation Outcome	Implication
High centrality of key individuals	Strong group cohesion; coordinated movement	Protection of key individuals is critical
Clustered/modular networks	Efficient cooperation; stable family units	Supports targeted subgroup-based management
Network fragmentation	Reduced reproduction; increased stress	Indicates social instability
High connectivity	Rapid disease transmission	Requires disease-monitoring protocols
Loss of influential individuals	Breakdowns in leadership and knowledge transfer	Avoid removal during translocation/harvesting

Table 1 is a summary of the significant conservation-applicable findings of various social-network properties in endangered species populations. It points out that structural attributes like centrality, modularity, connectivity, and fragmentation have a direct relation to population stability. Strong group cohesion and movement in high centrality of key individuals is associated, and the centrality of the socially influential members must be protected. Modular or cluster networks are related to effective collaboration and consistent subgroup dynamics, whereas fragmented ones are associated with decreased reproduction and high rates of stress. The strong ties of networks allow the spread of diseases faster, and this fact proves the power and the

weakness of thick social networks. The table also reveals that the loss of influential people disrupts leadership, transfer of knowledge, and general social organization, which supports the need for management approaches that take into consideration the behavioral and social dynamics coupled with the demographic information.

Network Visualization Outputs

The reconstruction of the social networks gave further information on the structure of the population and the behavioral patterns as visualized. The clusters, bridging individuals, and isolated nodes that were evident in force-directed network graphs helped researchers to define the stable social units and areas that may

be vulnerable. Association matrices heatmaps showed that there were strong patterns of preferential interaction, and thus, the detection of tightly bonded dyads or subgroups was feasible. The community detection analyses displayed modular structures that were correlated to the kinship patterns, spatial distribution, or the social hierarchy. In a number of studies, the comparison of the networks prior to and after the disturbance revealed significant structural alterations, including decreased connectivity/or modularity, to prove that social systems are indeed sensitive to external threats.

Discussion

The results of the research strengthen the significance of social structure as one of the crucial aspects of the behavioral ecology of endangered species. Social networks influence the distribution of information, resources, and behavioral traditions between people, through which individuals can use collaboration, leadership, and mutual decision-making to survive. Key figures, be they senior members or influential figures within a group, always become key links whose presence binds a group together and ensures effective communication. These findings reinforce the ecological perspective or perspective at large that social conduct is not merely a consequence of living in groups but rather a critical process that determines population resilience and adaptability.

The apparent connection between the network structure and population stability points out a number of practical conservation implications. Any deprivation of power to influential people by poaching, illness, or migration may undermine

entire social structures, causing a decrease in reproductive success, impaired juvenile growth, and disruption in the coordination of movements. The disease-spread simulations and spatial maps further make connections between threats and social structure, with high levels of connectedness networks being able to spread pathogens faster, whilst fragmented networks may restrict cooperation and information exchange. The incorporation of social-network data into conservation programs can help in conservation programs and include determining individuals crucial to group stability, making socially informed translocations, and prioritizing protection in places where social activity is concentrated.

This trend is very similar to the reports on the Elephants, primates, wolves, and other social animals, where the removal of important individuals has been found to change the behavior of groups and lower chances of survival. Similar studies of previous research have also indicated that the well-linked or modular networks have a better capacity to share risk, information, and reproductive success. This research is essential to the literature because it brings the behavioral, spatial, and threat-based views together in one framework and explains how the ecological context and social organization interact in influencing conservation outcomes. Nevertheless, the study has its limitations, even though it is powerful. Social-network data can be short in time and may not be so much revealing of long-term dynamics or of seasonal variation. Representations of a network can be incomplete due to observational

constraints of restricted species, especially of cryptic or extensive species. Ironically, cross-species comparisons are also not easy, as there is variability in the manner in which interactions are defined in studies. Also, the disease dynamics introduced in this case are abstract and not specific to certain pathogens, restricting their direct use. To overcome these limitations, higher levels of consistency in data collection and long-term and multi-method data collection across the varied ecosystems will be needed.

Conclusion

The paper has proved that social-network structures are critical to the existence, stability, and success of endangered species, and central individuals, cohesive subgroups, and well-connected networks are crucial to the formation of reproductive success, information transfer, and group cohesion. The results indicate that these networks are susceptible to disturbances like poaching, habitat fragmentation, and disease, which can cause poorer performance of the population and make it more vulnerable; thus, there must be a combination of behavioral and social information in the conservation planning. The conservation approaches in the future must include long-term social-network surveillance, better behavioral data capture, and more sophisticated technologies like bio-logging and automated tracking to get fine-scale interactions. Standardized methodology should also be established in future studies, and cross-species comparison also needs to be examined in order to have a clear picture as to how social structure interacts with ecological and anthropogenic pressures. Conservation programs can utilize the

understanding of the social fabric of threatened species to undertake more efficient and sustainable interventions that would contribute to the population recovery and long-term persistence.

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