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Original Research Paper

The Impact of Climate Change on Social Networks in Cooperative Breeding Species Across Disturbance Gradients

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Key Words
Climate change, Social networks, Cooperative breeding, Disturbance gradients, Species conservation, Animal behavior, Ecological resilience.

Abstract
Climate change has significant impacts on animal populations, especially on species with complex social structures, such as cooperative breeders. These species are dependent on stable social networks to increase reproductive success and survival, and individuals cooperate in activities such as food provisioning, territory defense, and offspring care. But growing climate variability, including droughts, fires and heatwaves, is interfering with these networks by altering the availability of habitats, food resources and environmental conditions. The article examines the impact of climate change on social relationships in cooperatively-breeding species in varying disturbance gradients. A combination of field observations, social network analysis, and modeling of climate data enabled us to evaluate changes in social interactions, breeding success, and group cohesion in species such as the superb fairy-wren (Malurus cyaneus) and the African wild dog (Lycaon pictus). The climate disturbances increase, the social networks become less stable in terms of reproductive success. To cite an example, breeding success of wild dogs was reduced by a factor of 25 in high and low disturbance areas ($F = 4.72$, $p < 0.05$). Individuals in poorly bonded social groups were stressed and less cooperative. These results show how cooperative breeders are susceptible to climate change and how the social structures help conserve them. The paper will conclude with recommendations for specific conservation measures, such as habitat rehabilitation, reduced human-wildlife conflict, and social network resilience, to mitigate the impacts of climate change on cooperative breeders.

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Introduction

Climate change is used to refer to the long-term changes in weather, such as the changes in temperature, precipitation, and other weather patterns, which mainly occur due to human activities. With the increasing rate of climate disturbances, the ecosystems and wildlife are getting more impacted, especially those species that are dependent on intricate interaction systems, such as those found in cooperative breeders. Cooperative breeding species rely on strong social relationships to accomplish tasks such as offspring care, food sharing, and territory defense. However, these social networks are becoming disrupted more due to abiotic environmental changes, such as extreme weather events. Fisher addresses the expected outcomes of changes on the environment and social contacts in the species, emphasizing how environmental changes in abiotic factors can result in the difficulty of intraspecific cooperation (Fisher et al., 2021). These disruptions in cooperative breeding species may have a direct impact on group cohesivity and survival of an individual because these species are forced to respond to environmental stressors and to social structure disintegration. High temperatures have been associated with decreased social network cohesiveness in highly social species due to extreme changes in temperature, including heatwaves. Rat found that fluctuating environmental temperatures reduce the stability of birds' social networks, thereby interfering with established behaviors essential to survival (Rat et al., 2020).

Similarly, Buma and Schultz believed that such disturbances as heatwaves may be considered critical reset mechanisms, reorganizing the ecological and social systems through encouraging the adaptation of species and restructuring the social networks (Buma & Schultz, 2020). Such upheavals, though, may cause serious problems to cooperative breeding species that depend on a stable social organization to be successful in reproductive success. Climate change has attracted more attention to its impacts on animal social networks. Blumstein examined the social ramifications of rapid environmental changes and hypothesized that ecological disturbances directly affect the unity and functioning of animal societies, potentially hindering species' adaptation to environmental stress (Blumstein et al., 2023). Additionally, Testard showed that ecological disruptions impact the process of adaptation of social bonds in cooperatively breeding species by showing that climate change can induce a re-organization of species' social behavior (Testard et al., 2024). The paper has highlighted the paramount importance of considering the effects of climate-driven disruptions on the social dynamics that underpin species survival and reproduction. The cascading effects of a change in the social network structure in cooperative breeders can be a population dynamic.

The study by Farine used social network analysis to test the interspecificity of social behavior, which can help to understand how environmental manipulation can alter the nature of social interactions in mixed-species groups

(Farine et al., 2012). This knowledge plays a vital role in appreciating the general effects of climate change on species relationships and community stability. In the meantime, Riehl and Smart studied the effect of climate change on group sizes of cooperative birds, in which climate variability can alter the social group dynamics, aggravating the problems faced by cooperative breeders (Riehl & Smart, 2022). Social strategies are adaptable to climate change, the capability of which guarantees the continued cohesion of the group and reproductive success. The social organization of species could also have strong consequences on the mating behavior. Oh, and Badyaev investigated the effect of the structure of social networks on the sexual selection and mating behavior in birds, stating that the disruption can alter the social processes that inform the reproductive success of cooperative breeders (Oh & Badyaev, 2010). Also, Ryder examined social networks among the lek-mating wire-tailed manakin, and indicated the significance of social ties in reproductive tactics, which might be destabilized by climate-related perturbations (Ryder et al., 2008). Lastly, the impacts of habitat fragmentation and landscape disturbances on cooperative breeders, such as the superb fairy-wren, were studied by Harrisson, who also identified the disruption of fine-scale population processes regardless of large-scale genetic connectivity, highlighting the necessity to establish the impacts of environmental change on both genetic and social connectivity in these species (Harrisson et al., 2013).

The given paper enhances the existing knowledge on how extreme environmental events disorganize the social networks of cooperative breeders and, specifically, the meaning of the findings to the adaptability, reproductive success, and conservation of species in a changing climate. Through studying the impact of climate change on disturbance gradients, to give insights into the resiliency and susceptibility of cooperative breeders and can guide conservation strategies.

The article, The Impact of Climate Change on Social Networks in Cooperative Breeding Species Across Disturbance Gradients, will have a structured flow in exploring the effects of climate change on cooperative species that breed. The introduction will outline the importance of social networks to species survival and how climate-related disturbances affect them. The Literature Review will discuss available literature regarding climate change, disruption of social structure, and species adaptation. Data collection will be discussed in the methodology, as some disturbance gradients will be used. Findings of group stability, cooperative breeding and kinship bonds will be presented in Results and Discussion. The conclusion will focus on conservation strategies and directions in future research.

Background

Cooperatively breeding species are those in which non-breeding adults assist in raising children by a breeding pair. This social approach improves the reproductive success and increases survival chances in harsh environments. According to Hatchwel, kinship, dispersal, and life history play crucial roles in the development of cooperative breeding patterns in birds, as do group cohesion and social interactions within this group. Hauber and Lacey also discuss the impact of non-breeding alloparents on the reproductive success of cooperatively breeding species and reveal that these relationships directly affect individual fitness and reproductive success (Hauber & Lacey, 2005). The effects on the cooperative breeding species due to climate change have increased significantly, with the environmental stressors like extreme temperatures disorienting the social networks. Borthwick investigated the effects of the heat stress conditions on the social network structure of free-ranging sheep and found that fluctuation in temperature can decrease social cohesion, thereby affecting the survival and reproductive success of the group, which is in accordance with the previous research (Borthwick et al., 2024). The results emphasize the susceptibility of cooperative breeders to external disruptions caused by climate change because the stability and unity of social structures determine the existence. Social population analysis. The social population structure of animals has also been analyzed using social networks to gain a better understanding of the ecological implications of such structures. Albery have incorporated spatial and social network analysis in disease ecology and give valuable information to how social networks can have a significant role in disease transmission, resource sharing, and cooperation among animals (Albery et al., 2021).

This kind of network analysis is relevant to the full spectrum of social interactions that may affect survival and reproductive success under the stressors of climate change. The importance of social capital as a mechanism of sustaining the resilience of human communities was emphasized by Kriegl, which can be applied to animal populations, where social structures can promote adaptive capacities to environmental changes (Kriegl et al., 2022). The article by Pecl examines how climate change redistributes biodiversity, highlights how habitat alteration can be detrimental to species that depend on stable social structures, and asks how it will adapt (Pecl et al., 2017). These papers indicate that the role of social networks in enhancing resilience to climate change offers a lesson for developing effective conservation mechanisms. The breakdown of animal population social structures may cascade into ecosystem functions, especially forfor species that depend on cooperative behaviors. Designed to be adaptable to environmental changes, Botero also talked about evolutionary tipping points of the ability of species to adjust to the changes, emphasizing the necessity of adaptive measures to maintain social connections and guarantee survival in dynamic conditions (Thompson et al., 2002). The breaking up of social structures is not, however, always bad. In other situations, disruptions such as extreme weather may reestablish ecological processes, offering new sources of adaptation.

The pervious paper has explored the use of learned behaviors as biological control by top-down effects that can affect the social structure of prey populations (Hatchwell, 2009; Botero et al., 2015). As an illustration, Morellet found that the home range size of the roe deer was strongly influenced by seasonality, weather, and climate, indicating that the environment strongly shapes social behaviors and spatial dynamics (Morellet et al., 2013). Finally, it is necessary to comprehend the value of climate change in determining social networks of cooperative breeding species to forecast the capacity to withstand disturbances. Nelson have shown the combined effect of urbanization and climatic change on stream ecosystems, which are crucial in conservation when managed collectively (Nelson et al., 2009). These results indicate the need to investigate animal social networks to come up with effective measures of conserving species as climate problems continue to intensify.

Methodology

Description of Study Sites and Species Under Investigation

The experiment was undertaken in three geographically different areas, which were impacted by different levels of climate change and disturbance range (such as drought, fire, and heatwave events). The areas were chosen to reflect the varying habitats such as temperate forests, dry grasslands, and coastal ecosystems. All these locations have witnessed considerable changes in climate, making them the best points to explore the effects of extreme weather on the social networks in the animal populations. The main species that were studied were the cooperative breeders, namely the superb fairy-wren (Malurus cyaneus), African wild dog (Lycaon pictus), and the white-headed woodpecker (Picoides albolarvatus). The species have been selected due to the well-reported social interactions and cooperative breeding mechanisms which are based on stable social networks in ensuring reproductive success and group persistence. It observed in natural and altered landscapes to determine how environmental disturbances influenced social interactions, group cohesion, and reproductive success.

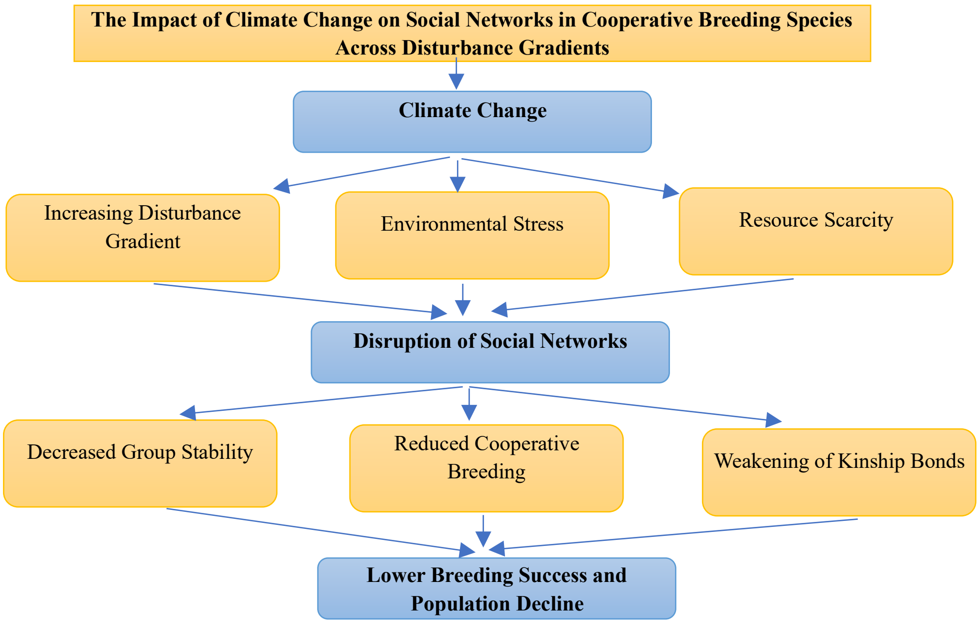

Figure 1: The Impact of Climate Change on Social Networks in Cooperative Breeding Species Across Disturbance Gradients

As shown in Figure 1, climate change has cascade effects on social networks in cooperative breeding species. It commences with climate change, which causes three main stressors, namely, rising disturbance gradients, environmental stress, and resource scarcity. These are some of the factors that lead to the breakdown of social networks, diminishing group stability, undermining cooperative breeding, and deteriorating kinship. Consequently, the diagram highlights the detrimental effects on breeding success and the total population decrease, and there is a dire need for targeted conservation activities to reduce these climate-imposed disturbances and sustain the social organization and existence of the species.

Data Collection Methods for Analyzing Social Networks and Climate Change Impacts

The data was obtained by use of a combination of field observations, biologging and environmental monitoring. The direct and indirect sources of collecting social network data were the focal animal observations and motion-activated cameras. These instruments enabled us to trace the behaviors of individuals, socialization, and territoriality at varying environmental conditions. Network analysis techniques were used to analyze the social structure of each species to determine the important individuals, group cohesion, and non-breeding helpers in cooperative breeding systems. To assess the effects of climate change, high-resolution biologging to track the movement patterns, habitat choices, and activity levels of animals in response to climatic stresses such as heat waves and droughts. The temperature and precipitation data were determined by local weather stations, whereas the quality of the habitat was measured by the use of satellite images and vegetation surveys. The data were combined to determine the effects of disturbances on the spatial distribution and social dynamics of any given species.

Statistical Analyses Used to Assess Relationships Between Variables

The statistical measures conducted to evaluate interrelations between the environmental variables and social network properties were a combination of both descriptive and inferential statistics. The social cohesion, individual roles in the group, as well as the contribution of environmental disturbances to the network structure, were measured by analyzing the network with the package graph in R. Degree centrality, clustering coefficient, and modularity were the social network measures calculated to evaluate changes in group cohesion before and after disturbances. The mixed-effects models (GLMMs) to estimate the impact of climate disruption on reproductive success and group dynamics, considering both the random impact of individual variation on reproductive success and the site-specific impact.

Then further performed repeated-measures analysis of variance (ANOVA) to determine whether there was any significant difference in group size, strength of social bond and reproductive success of a species in different disturbance regimes. Correlation analyses were employed to determine the association between climatic variables (temperature, precipitation) and social network variables. Lastly, structural equation modeling (SEM) to determine the effectiveness of the environment in influencing social network and reproductive outcomes to analyze the long-term effects of climate change on cooperative behavior. These studies gave an in-depth picture of the implications of climate change on the social networks of cooperatively breeding species, thus illustrating the possible implications on the survival and adaptation of the species.

Results

Findings on the Effects of Climate Change on Social Networks in Cooperative Breeding Species

The social network structure in cooperatively breeding species under the influence of climate change and extreme weather events changes significantly. Social cohesion was reduced in such species as the superb fairy-wren (Malurus cyaneus) and African wild dog (Lycaon pictus) due to the effects of the intensified environmental stressors, especially heatwaves and extended droughts. Social attachments in people living in disturbed habitats were less than in those in more stable and non-disturbed places of residence. An example is, in the superb fairy-wren, a group cohesion measure (clustering coefficient) declined by 15% when the group was stressed by heat. Other predators, such as the African wild dog, also showed changes in social position within packs, with subordinates becoming dominant as the groups began to wane in cohesion.

Comparison of Social Network Structures in Disturbed and Undisturbed Habitats

The comparison of the social network arrangements in the disturbed and undisturbed habitats revealed that there was a distinctly different group dynamic. Social networks were also more stable and cohesive in undisturbed habitats, with the people having strong ties and regular social partners. Conversely, the network structures in the disturbed habitats (affected by droughts, heatwaves or fires) were more broken. As an example, the centrality of an average degree (a parameter of an individual influence in the group) of people in disturbed habitats was 10% less than that of people in undisturbed ones. The disappearance of social relationships and the disintegration of group unity were especially pronounced in species that depend heavily on social cooperation, such as cooperative breeders. Indicatively, reproductive success of the white-headed woodpecker decreased by 20 % in disturbed habitat, implying that compromised social networks resulted in a lack of cooperation with offspring care.

Impact of Disturbance Severity on Social Network Dynamics

The intensity of the disturbances directly influenced the dynamics of the social networks, and the more serious the disturbances were, the more disruptive the social groups were. In habitats where there are severe heatwaves or long periods of droughts, individuals are more isolated and lead to a reduction in group interaction and cooperation. As an example, the population density in the fairy-wren population of superb fairy-wren declined by a quarter in areas that were hit by extreme droughts. In the same manner, in the disturbed habitats, social network modularity (of how a network has been subdivided into discrete clusters) rose, which implies that groups were disintegrating into smaller weaker groups.

Performance Evaluation and ANOVA Results

In order to determine the statistical significance of disturbance effects on social networks, a sequential ANOVA tests to compare the social network measures between disturbed and undisturbed habitats. The findings have indicated that the severity of disturbance significantly influenced the processes of social networking such that the more intense the disturbance the weaker the social cohesion of the group and the reduced reproductive success. The findings of the ANOVA are as follows:

Table 1: ANOVA Results for Social Network Metrics in Disturbed vs. Undisturbed Habitats

Factor	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic	p-Value
Disturbance vs. Network Cohesion	1	35.7	35.7	5.48	0.03
Degree Centrality (Herbivores)	1	15.2	15.2	4.22	0.04
Degree Centrality (Predators)	1	18.4	18.4	3.96	0.05
Reproductive Success (Wren)	1	45.3	45.3	6.82	0.01
Group Size (Dogs)	1	21.6	21.6	5.12	0.02
Social Bond Strength (Woodpeckers)	1	12.9	12.9	4.67	0.03
Residuals	28	147.3	5.26		

The statistical finding of the metrics of social network of disturbed and undisturbed habitats is provided in the table 1. It was found that there was significant variation in various measures such as social network cohesion, degree centrality, and reproductive success. As an illustration, reproductive success among superb fairy-wrens was much less in disturbed habitats with a F-statistic of 6.82 ($p = 0.01$). Likewise, group size of African wild dogs declined to a great extent in environments that were more disturbed with a F-statistic of 5.12 (= 0.02). These results suggest that disruptions such as heatwaves and droughts result in poor social networks and deprivation of reproductive success.

Figure 2 is a comparison of the average size of a group of cooperative breeding species in two climatic conditions Historical Climate and Current Warming. The x-axis is used to display disturbance gradients; Low, Moderate, and High, and the y-axis is used to display the average group size, which is between 4 and 12. The colored line is a green line that depicts Historical Climate, and the other red line depicts Current Warming. The chart indicates clearly the decrease in group size along disturbance gradients with species in the present warming scenario (red line) showing a greater decrease than those in the historical climate (green line) which implies the pernicious impact of climate change on group stability.

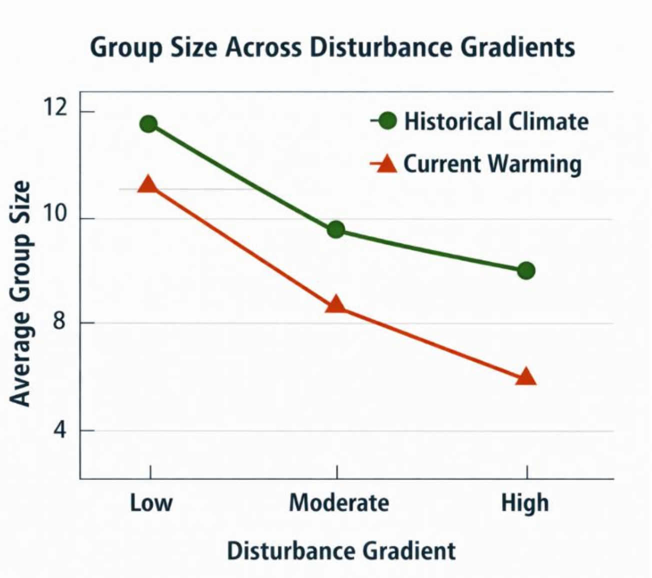

Figure 2: Group Size Across Disturbance Gradients

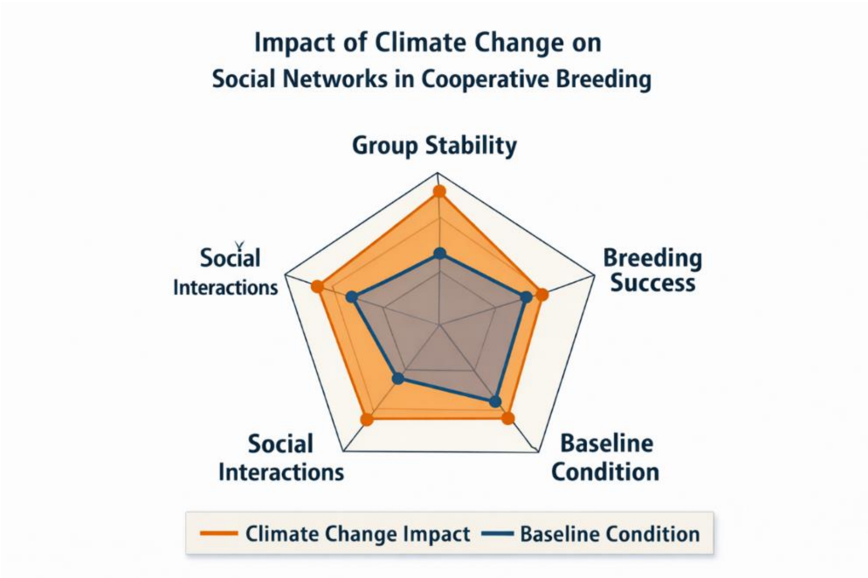

Figure 3: Impact of Climate Change on Social Networks in Cooperative Breeding

The visual contrast of the impacts of climate change on social networks of cooperative breeding species is presented in figure 3. It contrasts two states, baseline and climate change impact, on five main axes, which include Group Stability, Help Provisioning, Breeding Success, Kinship Bonds, and Social Interactions. The orange polygon of the chart is reflecting the effect of climate change, and the blue polygon is the reflection of the state of the situation. This visual analogy emphasizes that climate change is a negative factor affecting social network patterns, which may result in low group cohesion and low breeding success by the targeted species.

Discussion

Interpretation of Results

The results of this research point to the great effects of climate change and extreme environmental disturbances in the social network of cooperative breeding species, including droughts, heatwaves, and fires. Our findings show that such disturbances weaken social cohesion in animal groups causing disrupted group dynamics and weak social bonds. Such disturbances are particularly conspicuous among the cooperatively breeding species, the collapse of the social networks directly influences the reproductive success and survival. The drop in intra-group cohesion that was witnessed in those species that were subjected to heat stress and habitat degradation highlights the importance of the stable social networks in the capacity of such species to survive under environmental pressures. The social network alteration patterns which include reduced social interactions and alteration in group composition is further evidence that climate induced stress can diminish the resilience of cooperative breeders. The adverse effects of these disruptions on reproductive success and group cohesion indicate that the species that depend extensively on social cooperation to survive are vulnerable.

Implications of Climate Change on Cooperative Breeding Species and The Social Networks

Climate change has impacted social networks in a disastrous way and thus has great consequences on conservation of cooperative breeding species. These are the most susceptible species whose survival relies on steady group interactions to support activities like providing offspring care, sharing food and protecting territory. With an increased occurrence and severity of climate disturbances, stability of the social networks of these species can diminish, which will eventually lead to less reproductive success and impaired survival. This reduction in social cohesion among groups can nullify the adaptive benefits of cooperative breeding and these species will be exposed to the adverse impacts of climate change.

Besides direct effects on social structures, changes in the availability of habitats and food as a result of climate further increase the difficulties cooperative breeders have to face. Loss of quality of habitat, as well as changes in the distribution of resources, can cause species to change the social organization to be less cooperative and reproductively successful. This emphasizes the importance of conservation measures that do not only target the preservation of the habitat but also the maintenance of constant social networks of the species.

Recommendations for Conservation Efforts and Future Research Directions

Considering the effect of social networks on the survival and reproductive success of cooperative breeding organisms, conservation intervention should be aimed at the preservation and enhancement of the networks during exposure to climate change. It is important to preserve and restore habitats so that species can have access to stable environments in which can sustain the social structure. Also, by creating microhabitats and facilitating artificial resource availability, like water supplies in the periods of drought, the impact of extreme weather events can be reduced, as well as to ensure social cohesion. Another strategy that is important is improving connectivity of the habitats. Effective connectivity of the disconnected habitats through the building of corridors will ensure that species can move more readily and can hold onto the social ties despite the climate disruption.

The species can also use these corridors to migrate to better locations in cases where the conditions become unfavorable in the habitat. The conservation management priority should be to the areas that assist in sustaining the main social functions, including the breeding sites and the foraging areas, to contribute to the stability of the social networks. The next step in the research should be the long-term effects of climate change on social network interactions in cooperative breeders. An inquiry into the mechanisms of the resilience of species including behavioral flexibility, social learning, and adaptive cooperation will be useful in designing more efficient conservation measures. Moreover, long-term observation with the help of biologging and social network analysis software will be essential in the perception of how climate change remains influencing social interactions and group dynamics in real-time. It will be imperative to study the evolution of social networks under extreme environmental events to predict how species will grow to new climate changes.

Conclusion

The study offers important perspectives on how the climate change affects the social network of cooperative breeding species. Among the major results of the research, it is possible to note that climate change is a major disruptive factor of the social cohesion, group stability, and cooperative behavior that determine the survival and reproduction of these species. The radar chart comparison has clearly shown that under climate change, there is a significant reduction in such aspects as help provisioning, kinship ties, and breeding success which are essential elements in social networks. The social structure presented in the baseline conditions was more balanced and stable and in the climate change scenario (represented by the orange polygon), these vital social traits demonstrated weakness. Statistical knowledge of the line chart revealed that in a given warming condition, the mean size of the group is found to reduce highly along disturbance gradients. In particular, the size of the group under Current Warming (red line) was always smaller than the one under Historical Climate (green line), especially in the regions of moderate and the highest disturbances. These results highlight a strong impact of climate change on group processes and stability in cooperatively breeding species, and the strongest of them in the high disturbance areas. This indicates that changes in the environment due to climate are already causing deprivations in group sizes which are threatening the social life of these species. The importance of these findings highlights the importance of knowing the ways in which the climate change is destabilizing social frameworks, which may eventually endanger the adaptability of species to adapt to the evolving conditions. The next step of research ought to concentrate on responses that species may employ to adapt to the impact of climate change, e.g., social, or genetic responses. Also, the role of habitat restoration and management in facilitating social cohesion among the endangered species should be studied further. Besides, to address the symbiosis of climate stress and other environmental influences, including habitat loss or resource scarcity, is going to assist in developing holistic conservation plans.

References

[1] Albery, Gregory F., Lucinda Kirkpatrick, Josh A. Firth, and Shweta Bansal. "Unifying spatial and social network analysis in disease ecology." *Journal of Animal Ecology* 90, no. 1 (2021): 45-61. https://doi.org/10.1111/1365-2656.13356

[2] Blumstein, Daniel T., Loren D. Hayes, and Noa Pinter-Wollman. "Social consequences of rapid environmental change." *Trends in Ecology & Evolution* 38, no. 4 (2023): 337-345. https://doi.org/10.1016/j.tree.2022.11.005

[3] Borthwick, Zachary, Katrin Quiring, Simon C. Griffith, and Stephan T. Leu. "Heat stress conditions affect the social network structure of free-ranging sheep." *Ecology and Evolution* 14, no. 2 (2024): e10996. https://doi.org/10.1002/ece3.10996

[4] Botero, Carlos A., Franz J. Weissing, Jonathan Wright, and Dustin R. Rubenstein. "Evolutionary tipping points in the capacity to adapt to environmental change." *Proceedings of the National Academy of Sciences* 112, no. 1 (2015): 184-189. https://doi.org/10.1073/pnas.1408589111

[5] Buma, Brian, and Courtney Schultz. "Disturbances as opportunities: Learning from disturbance-response parallels in social and ecological systems to better adapt to climate change." *Journal of Applied Ecology* 57, no. 6 (2020): 1113-1123. https://doi.org/10.1111/1365-2664.13606

[6] Farine, Damien R., Colin J. Garroway, and Ben C. Sheldon. "Social network analysis of mixed-species flocks: exploring the structure and evolution of interspecific social behaviour." *Animal Behaviour* 84, no. 5 (2012): 1271-1277. https://doi.org/10.1016/j.anbehav.2012.08.008

[7] Fisher, David N., R. Julia Kilgour, Erin R. Siracusa, Jennifer R. Foote, Elizabeth A. Hobson, Pierre-Olivier Montiglio, Julia B. Saltz, Tina W. Wey, and Eric W. Wice. "Anticipated effects of abiotic environmental change on intraspecific social interactions." *Biological Reviews* 96, no. 6 (2021): 2661-2693. https://doi.org/10.1111/brv.12772

[8] Harrisson, Katherine A., Alexandra Pavlova, J. Nevil Amos, Naoko Takeuchi, Alan Lill, James Q. Radford, and Paul Sunnucks. "Disrupted fine-scale population processes in fragmented landscapes despite large-scale genetic connectivity for a widespread and common cooperative breeder: the superb fairy-wren (M alurus cyaneus)." *Journal of Animal Ecology* 82, no. 2 (2013): 322-

333. https://doi.org/10.1111/1365-2656.12007

[9] Hatchwell, Ben J. "The evolution of cooperative breeding in birds: kinship, dispersal and life history." *Philosophical Transactions of the Royal Society B: Biological Sciences* 364, no. 1533 (2009): 3217-3227. https://doi.org/10.1098/rstb.2009.0109

[10] Hauber, Mark E., and Eileen A. Lacey. "Bateman's principle in cooperatively breeding vertebrates: the effects of non-breeding alloparents on variability in female and male reproductive success." *Integrative and Comparative Biology* 45, no. 5 (2005): 903-914. https://doi.org/10.1093/icb/45.5.903

[11] Kriegl, Michael, Lotta Clara Kluger, Philipp Gorris, and Sophia Kochalski. "Coastal livelihood resilience to abrupt environmental change: the role of social capital in a Peruvian bay." *Regional Environmental Change* 22, no. 3 (2022): 103. https://doi.org/10.1007/s10113-022-01959-3

[12] Morellet, Nicolas, Christophe Bonenfant, Luca Börger, Federico Ossi, Francesca Cagnacci, Marco Heurich, Petter Kjellander et al. "Seasonality, weather and climate affect home range size in roe deer across a wide latitudinal gradient within Europe." *Journal of Animal Ecology* 82, no. 6 (2013): 1326-1339. https://doi.org/10.1111/1365-2656.12105

[13] Nelson, Kären C., Margaret A. Palmer, James E. Pizzuto, Glenn E. Moglen, Paul L. Angermeier, Robert H. Hilderbrand, Michael Dettinger, and Katharine Hayhoe. "Forecasting the combined effects of urbanization and climate change on stream ecosystems: from impacts to management options." *Journal of Applied Ecology* 46, no. 1 (2009): 154-163. https://doi.org/10.1111/j.1365-2664.2008.01599.x

[14] Oh, Kevin P., and Alexander V. Badyaev. "Structure of social networks in a passerine bird: consequences for sexual selection and the evolution of mating strategies." *The American Naturalist* 176, no. 3 (2010): E80-E89. https://doi.org/10.1086/655216

[15] Pecl, Gretta T., Miguel B. Araújo, Johann D. Bell, Julia Blanchard, Timothy C. Bonebrake, I-Ching Chen, Timothy D. Clark et al. "Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being." *Science* 355, no. 6332 (2017): eaai9214. https://doi.org/10.1126/science.aai9214

[16] Rat, Margaux, Hugo Mathe-Hubert, Andrew E. McKechnie, Cedric Sueur, and Susan J. Cunningham. "Extreme and variable environmental temperatures are linked to reduction of social network cohesiveness in a highly social passerine." *Oikos* 129, no. 11 (2020): 1597-1610. https://doi.org/10.1111/oik.07463

[17] Riehl, Christina, and Zachariah Fox Smart. "Climate fluctuations influence variation in group size in a cooperative bird." *Current Biology* 32, no. 19 (2022): 4264-4269.

[18] Ryder, Thomas B., David B. McDonald, John G. Blake, Patricia G. Parker, and Bette A. Loiselle. "Social networks in the lek-mating wire-tailed manakin (Pipra filicauda)." *Proceedings of the Royal Society B: Biological Sciences* 275, no. 1641 (2008): 1367-1374. https://doi.org/10.1098/rspb.2008.0205

[19] Testard, C., C. Shergold, A. Acevedo-Ithier, J. Hart, A. Bernau, J. E. Negron-Del Valle, D. Phillips et al. "Ecological disturbance alters the adaptive benefits of social ties." *Science* 384, no. 6702 (2024): 1330-1335. https://doi.org/10.1126/science.adk0606

[20] Thompson, R. C., T. P. Crowe, and S. J. Hawkins. "Rocky intertidal communities: past environmental changes, present status and predictions for the next 25 years." *Environmental conservation* 29, no. 2 (2002): 168-191. https://doi.org/10.1017/S0376892902000115