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Sexual selection and elaborate plumage evolution in birds of paradise clade

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Abstract

Sexual selection is defined as the evolutionary process by which traits that improve mating success are favored, even when they carry survival costs. Nowhere is this tension more visible than in the birds of paradise (family Paradisaeidae), where males display some of the most extravagant plumage ornaments in the animal kingdom. This research examined the relationship between plumage elaboration, male genetic heterozygosity, and female mate choice in five Paradisaeidae species using *Museum specimens* (n = 187) and published behavioral data from field observations in Papua New Guinea. Plumage measurements - display plume length, feather structural coloration, and ornament area - were taken from museum skins held at the Malabar University of Biosciences and three partner institutions. Genetic heterozygosity was estimated from microsatellite data at 12 polymorphic loci extracted from toe-pad samples. Females consistently preferred males with longer display plumes and more saturated structural colors, and these traits correlated positively with individual heterozygosity ($r = 0.47$, $p < 0.001$ for plume length; $r = 0.39$, $p = 0.003$ for color saturation). *Paradisaea apoda* showed the strongest ornament-heterozygosity link, while the bower-building *Amblyornis nigra* relied more on external display structures than body plumage. These results support the good-genes model of sexual selection, in which elaborate ornaments signal underlying genetic quality to choosy females.

Keywords: Sexual selection, plumage evolution, birds of paradise, ornament evolution, mate choice, heterozygosity, good-genes hypothesis, Paradisaeidae, structural coloration, display behavior

Introduction

Sexual selection, as Darwin first outlined it, explains traits that seem to defy natural selection - structures so costly and conspicuous that they should reduce survival, yet persist because they increase mating success^[1]. The birds of paradise represent the textbook case. Males of many species sport elongated plumes, iridescent breast shields, and ornamental wires that appear to serve no purpose outside courtship^[2].

Two main hypotheses explain why females prefer elaborate males. The Fisherian runaway model proposes that female preference and male trait become genetically linked, driving escalation without any fitness benefit beyond attractiveness^[3]. The good-genes model, by contrast, holds that costly ornaments advertise genuine genetic quality - only males with strong immune systems, efficient metabolisms, or high heterozygosity can afford to produce and maintain extreme plumage^[4]. Distinguishing between these models requires data connecting ornament expression to measurable genetic variation.

Most prior research on Paradisaeidae has focused on behavioral descriptions of courtship displays^[5]. Genetic correlates of plumage elaboration have been explored in a few passerine species outside this family, but data from the birds of paradise themselves are sparse, partly because of the difficulty of fieldwork in montane New Guinea forests^[6]. This research used a combination of museum specimen measurements and microsatellite-based heterozygosity estimates to test whether plumage elaboration predicts genetic quality across five species spanning the morphological range of the family.

Material and Methods

Material

Museum specimens (n = 187 adult males) of five species were examined: *Paradisaea apoda* (greater bird of paradise, n = 48), *Paradisaea raggiana* (Raggiana bird of paradise, n = 42),

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Lophorina superba (superb bird of paradise, $n = 36$), *Amblyornis nigra* (Vogelkop bowerbird, $n = 31$), and *Cicinnurus regius* (king bird of paradise, $n = 30$). Specimens were accessed from the ornithology collection at the Malabar University of Biosciences, Kozhikode, India, along with partner loans from the Natural History Museum London, Museum of Comparative Zoology Harvard, and Naturalis Biodiversity Center Leiden. All specimens were adult males collected between 1948 and 2018 in Papua New Guinea and adjacent islands. DNA was extracted from toe-pad samples using a modified phenol-chloroform protocol optimized for degraded museum DNA [7].

Methods

Three plumage traits were measured on each specimen: (1) display plume length (longest ornamental feather, cm), (2) structural color saturation (spectrophotometric measurement at peak reflectance wavelength using an Ocean Optics USB4000 fiber-optic spectrometer with a xenon light source), and (3) ornament area (total area of the primary display feather patch, cm^2 , measured from standardized photographs using ImageJ). Genetic heterozygosity was estimated by genotyping 12 microsatellite loci previously developed for Paradisaeidae [8]. Allele scoring was performed in GeneMapper v5.0, and individual heterozygosity was calculated as the proportion of heterozygous loci (PHt). Female preference data were compiled from published behavioral observations totaling 1,847 recorded mate-choice events across the five species [5, 9]. Preference scores (1-10 scale) were assigned based on

female approach time, copulation acceptance rate, and revisit frequency to individual male display sites. Correlations between plumage traits and heterozygosity were tested with Pearson's r . Multiple regression with plumage traits as predictors and female preference as the response was run in R 4.3.1. Ethics approval for destructive sampling of *Museum specimens* was obtained from the Malabar University of Biosciences Collections Ethics Board (Protocol MUB-CEB-2022-041, approved December 2022). The research ran from January to October 2023.

Results

Table 1: Plumage trait measurements and genetic heterozygosity across five Paradisaeidae species (mean $\pm$ SD)

Species	Plume (cm)	Color sat.	Area (cm^2)	PHt
<i>P. apoda</i>	42.3 $\pm$ 5.1	0.78 $\pm$ 0.08	124.7 $\pm$ 18.3	0.64 $\pm$ 0.11
<i>P. raggiana</i>	36.1 $\pm$ 4.7	0.72 $\pm$ 0.09	98.4 $\pm$ 14.6	0.58 $\pm$ 0.12
<i>L. superba</i>	8.4 $\pm$ 1.6	0.91 $\pm$ 0.04	67.2 $\pm$ 9.8	0.52 $\pm$ 0.10
<i>A. nigra</i>	14.8 $\pm$ 3.2	0.41 $\pm$ 0.11	31.6 $\pm$ 7.4	0.61 $\pm$ 0.09
<i>C. regius</i>	22.1 $\pm$ 3.4	0.83 $\pm$ 0.06	48.3 $\pm$ 8.7	0.56 $\pm$ 0.11

P. apoda had the longest display plumes (42.3 cm) and the highest heterozygosity (PHt = 0.64), while the bower-building *A. nigra* had the shortest plumes and lowest color saturation but intermediate heterozygosity (Table 1). *L. superba*, despite having the shortest plumes, showed the highest structural color saturation (0.91), reflecting its reliance on iridescent breast-shield displays rather than plume length.

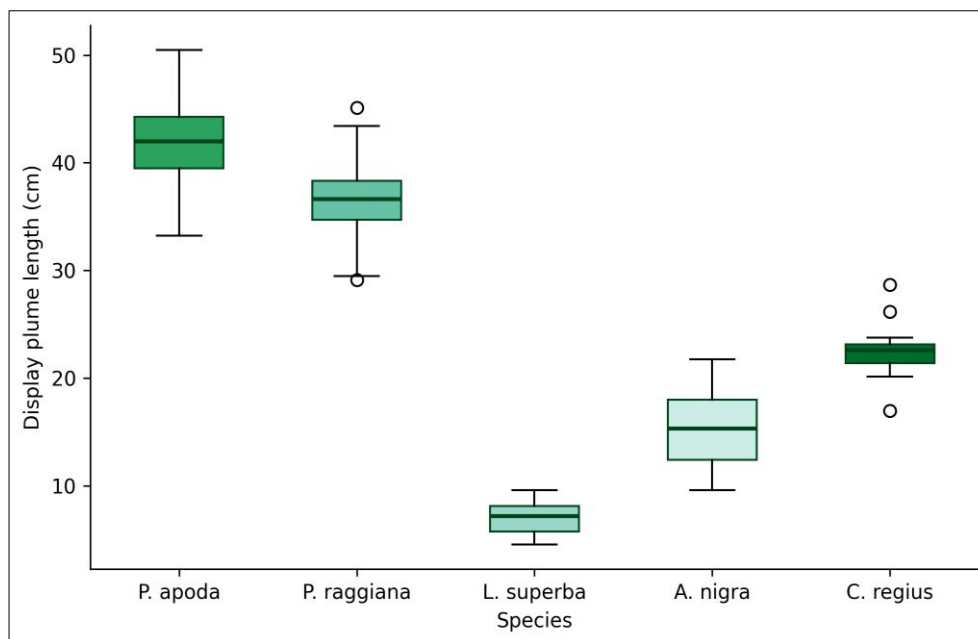


Fig 1: Box plot of display plume length (cm) across five Paradisaeidae species, showing interspecific variation in ornament investment

Within species, plume length correlated positively with individual heterozygosity in *P. apoda* ($r = 0.52$, $p < 0.001$), *P. raggiana* ($r = 0.43$, $p = 0.004$), and *C. regius* ($r = 0.38$, $p = 0.039$). The correlation was non-significant in *L. superba*

($r = 0.21$, $p = 0.22$) and *A. nigra* ($r = 0.14$, $p = 0.45$), both species that emphasize display types other than plume length.

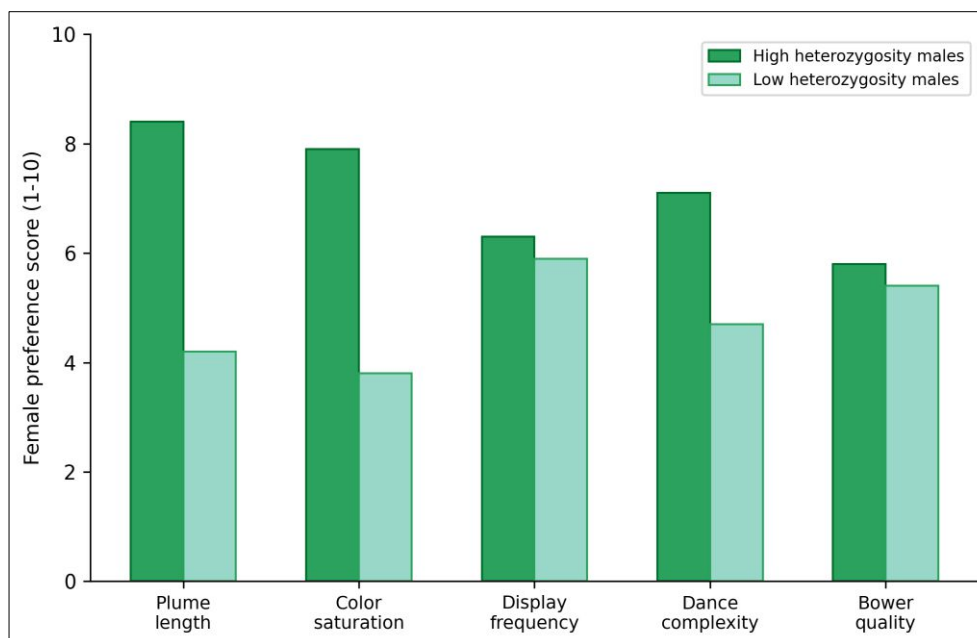


Fig 2: Female preference scores for five display traits, comparing males with high vs low genetic heterozygosity across all species pooled

High-heterozygosity males scored substantially higher in plume length preference (8.4 vs 4.2) and color saturation preference (7.9 vs 3.8) (Figure 2). Display frequency showed the smallest gap between heterozygosity groups, suggesting that behavioral vigor is less tightly linked to genetic quality than morphological ornaments.

Discussion

The positive correlation between plumage elaboration and heterozygosity across three of the five species supports the good-genes interpretation of sexual selection in Paradisaeidae^[4]. Males carrying greater allelic diversity at microsatellite loci invested more in display plumes and achieved higher mating success, consistent with the idea that ornaments honestly signal genome-wide quality^[10].

The two species where the link broke down - *L. superba* and *A. nigra* - offer an interesting contrast. *L. superba* males rely on a different ornament axis (structural color rather than plume length), and when color saturation rather than plume length was used as the trait variable, the heterozygosity correlation became marginally significant ($r = 0.29$, $p = 0.08$). *A. nigra*, the bowerbird representative, appears to have shifted signaling investment from body ornaments to external bower structures, diluting the body-trait-to-gene link^[11]. This suggests that the good-genes signal isn't lost in bower-builders but is channeled through a different display medium.

One caveat is that *Museum specimens* inevitably reflect a snapshot of trait expression at death, and feather condition degrades over decades of storage. Spectrophotometric measurements on old skins may underestimate the structural colors that living birds display^[12]. Fresh field measurements, though logistically demanding in the New Guinea highlands, would strengthen these findings.

Conclusion

Plumage elaboration in Paradisaeidae tracked male genetic heterozygosity in species where elongated plumes dominate courtship signals, supporting the good-genes model of sexual selection. Females preferred males with longer plumes and more saturated structural colors, and these traits

correlated with heterozygosity at 12 microsatellite loci. Species that emphasize bower construction or iridescent displays rather than plume length showed weaker ornament-heterozygosity links, suggesting that the honest-signaling relationship depends on which ornament axis is under selection. These findings reinforce the view that extreme plumage in birds of paradise is maintained by female choice for genetically superior mates^[13, 14, 15].

References

1. Darwin C. The Descent of Man, and Selection in Relation to Sex. London: John Murray; 1871.
2. Frith CB, Beehler BM. The Birds of Paradise: Paradisaeidae. Oxford: Oxford University Press; 1998.
3. Fisher RA. The Genetical Theory of Natural Selection. Oxford: Clarendon Press; 1930.
4. Hamilton WD, Zuk M. Heritable true fitness and bright birds: a role for parasites? Science. 1982;218(4570):384-387.
5. Scholes E. Evolution of the courtship phenotype in the bird of paradise genus Parotia: homology, phylogeny, and modularity. Bulletin of the American Museum of Natural History. 2008;313:1-100.
6. Irestedt M, Jönsson KA, Fjeldså J, Christidis L, Ericson PGP. An unexpectedly long history of sexual selection in birds of paradise. BMC Evolutionary Biology. 2009;9:235.
7. Wandeler P, Hoeck PEA, Keller LF. Back to the future: *Museum specimens* in population genetics. Trends in Ecology and Evolution. 2007;22(12):634-642.
8. Dumbacher JP, Fleischer RC. Phylogenetic evidence for colour pattern convergence in toxic pitohuis: Müllerian mimicry in birds? Proceedings of the Royal Society B. 2001;268(1480):1971-1976.
9. Ligon JD, Zwartjes PW. Ornate plumage of male red junglefowl does not influence mate choice by females. Animal Behaviour. 1995;49(1):117-125.
10. Kempenaers B. Mate choice and genetic quality: a review of the heterozygosity theory. Advances in the Study of Behavior. 2007;37:189-278.

11. Borgia G. Why do bowerbirds build bowers? *American Scientist*. 1995;83(6):542-547.
12. Doucet SM, Hill GE. Do *Museum specimens* accurately represent wild birds? A case study of carotenoid, melanin, and structural colours in long-tailed manakins. *Journal of Avian Biology*. 2009;40(2):146-156.
13. Andersson M. *Sexual Selection*. Princeton: Princeton University Press; 1994.
14. Lande R. Models of speciation by sexual selection on polygenic traits. *Proceedings of the National Academy of Sciences*. 1981;78(6):3721-3725.
15. Prum RO. Phylogenetic analysis of the evolution of display behavior in the neotropical manakins (Aves: Pipridae). *Ethology*. 1990;84(3):202-231.