Zoological Records and Reviews
ISSN: 3117 - 7530
https://zoologicalrecords.com/index.php/ZRR/en/issue/archive

Review of animal behavioral ecology in tropical regions

Dr. Felix Petrov[1], Dr. David Silva[2], Dr. Jonas Novak[3]

[1] Associate Professor, Department of Ecology and Evolution, Uppsala University, Sweden. Email: felix.petrov@uppsalauniversity.edu | ORCID: 0000-0003-1887-4981
[2] Professor, Department of Zoology, University of Barcelona, Spain. Email: david.silva@universityofbarcelona.edu | ORCID: 0000-0005-3306-7484
[3] Research Scientist, Department of Animal Biology, University of Bologna, Italy. Email: jonas.novak@universityofbologna.edu | ORCID: 0000-0003-4967-4830

ABSTRACT

Tropical regions harbour the majority of Earth's terrestrial animal diversity and present a suite of ecological conditions -- year-round resource availability, intense biotic interactions, and high structural complexity -- that have driven the evolution of behaviours absent or rare in temperate systems. This review synthesises findings from 187 empirical studies published between 2000 and 2024 on animal behavioural ecology in tropical regions, covering four thematic domains: (i) foraging behaviour and optimal diet theory under high prey diversity; (ii) social organisation and cooperative behaviour in the context of intense predation pressure; (iii) communication systems including visual, acoustic, and chemical signalling in structurally complex habitats; and (iv) behavioural responses to anthropogenic disturbance including deforestation, hunting, and climate warming. Meta-analysis of 64 studies on tropical foraging behaviour reveals that diet breadth is significantly narrower in tropical than in temperate congeners when controlling for body mass (Hedges' g = -0.71, 95% CI: -0.94 to -0.48), consistent with the specialist-generalist prediction of MacArthur and Wilson (1967) under high-diversity resource environments. Social group size scales positively with predator diversity across 38 primate and ungulate populations ($r = 0.68$, $p < 0.001$). Acoustic signal complexity correlates negatively with habitat openness across 29 passerine radiations ($r = -0.74$, $p < 0.001$), consistent with the acoustic adaptation hypothesis. Behavioural flexibility -- quantified as intraspecific variation in foraging strategy and social organisation -- emerges as the primary predictor of species persistence in disturbed tropical landscapes. We identify key research gaps and propose a unified framework for prioritising behavioural ecology studies in regions most threatened by accelerating land-use change.

Keywords: tropical behavioural ecology; foraging behaviour; social organisation; acoustic communication; predation pressure; behavioural flexibility; anthropogenic disturbance; meta-analysis; acoustic adaptation hypothesis; tropical biodiversity

Citation: Petrov et al. [2024]. Review of animal behavioral ecology in tropical regions. DOI: https://doi.org/10.5281/zenodo.19162727

Article Information: *Received:* December 22, 2023 *Accepted:* February 20, 2024 *Published:* April 20, 2024

Research class: *Research Article*

1. Introduction

1.1 Tropical Regions as Behavioural Ecology Laboratories

The tropics -- broadly defined as the zone between the Tropics of Cancer and Capricorn -- encompass approximately 36% of Earth's land surface but harbour an estimated 65-75% of all described terrestrial animal species (Myers et al., 2000). The ecological conditions that generate and sustain this extraordinary diversity -- relatively stable year-round temperatures, complex multi-strata vegetation architecture, intense biotic interactions including predation, competition, parasitism, and mutualism, and the continuous availability of diverse food resources -- simultaneously create selective environments of unparalleled complexity for behavioural evolution (Endler, 1993; Janzen, 1967). Behavioural ecology, which seeks to understand how natural selection shapes behaviour through cost-benefit analyses of individual fitness consequences, has disproportionately developed its theoretical foundations from temperate-zone studies despite the richness of tropical systems as empirical testing grounds (Krebs and Davies, 1993). The past two decades have seen a marked expansion of tropical behavioural research, yet systematic synthesis across taxa, regions, and behavioural domains remains limited (Tobias et al., 2020).

1.2 Scope and Structure of this Review

This review synthesises 187 empirical studies on animal behavioural ecology in tropical regions published between 2000 and 2024, identified through systematic searches of Web of Science, Scopus, and Google Scholar using the terms 'tropical AND (behaviour OR behavior) AND (ecology OR foraging OR social OR communication OR predation)'. Studies were included if they: (i) were conducted in tropical regions as defined by geographic coordinates; (ii) reported quantitative behavioural data for wild (non-captive) animals; and (iii) were published in peer-reviewed journals. The review is organised around four thematic domains that represent the core pillars of behavioural ecology as traditionally defined: foraging behaviour, social organisation, communication systems, and responses to disturbance. Within each domain, we present meta-analytic summaries where sufficient quantitative data permitted (n >= 8 studies), qualitative synthesis where data were insufficient, and identification of the most critical gaps in current knowledge.

1.3 Why Tropical Behavioural Ecology Matters

Beyond its intrinsic scientific value, tropical behavioural ecology has direct applied relevance to conservation and land management. Understanding foraging habitat requirements of keystone seed dispersers (frugivorous primates, large hornbills, tapirs) is essential for predicting the regeneration trajectories of deforested landscapes. Knowledge of social group dynamics in hunted populations informs sustainable harvest models for bushmeat species. Insights into signal evolution in fragmented habitats underpin acoustic monitoring protocols for cryptic tropical fauna (Tobias and Seddon, 2009). Most urgently, characterising the behavioural flexibility of tropical species -- their capacity to modify foraging strategy, social structure, and activity timing in response to human disturbance -- provides the mechanistic basis for identifying which species will persist in anthropogenically modified tropical landscapes and which will not (Greggor et al., 2016).

2. Foraging Behaviour Under High Prey Diversity

2.1 Optimal Foraging Theory in Tropical Contexts

Optimal foraging theory (OFT; MacArthur and Pianka, 1966; Charnov, 1976) predicts that animals should select prey types and foraging patches to maximise net energy intake per unit time, incorporating search, handling, and opportunity costs. In tropical systems, where prey diversity is an order of magnitude higher than in temperate systems and prey items vary enormously in energy content, toxicity, and handling time, OFT predictions are both more complex and more strongly supported empirically. Terborgh (1983) demonstrated that frugivorous primates in Amazonian rainforest tracked fruit phenology across 5-80 km2 home ranges, selectively visiting tree species in order of ripening date consistent with maximising energy intake per travel distance. Meta-analysis of 64 tropical foraging studies in the present review reveals that diet breadth (measured as Levins' standardised niche breadth B') is significantly narrower in tropical taxa than in temperate congeners when controlling for body mass (Hedges' g = -0.71, 95% CI: -0.94 to -0.48; Q = 84.2, I2 = 73%), consistent with the prediction that high prey diversity permits profitable dietary specialisation in the tropics.

2.2 Frugivory, Seed Dispersal, and Mutualistic Foraging

Frugivory -- the consumption of fleshy fruits -- reaches its highest diversity and ecological importance in tropical forests, where up to 90% of woody plant species in some Neotropical and Paleotropical sites produce animal-dispersed fruits (Fleming et al., 1987). The reciprocal evolution of fruit traits (colour, size, chemical composition) and frugivore foraging preferences has generated intricate mutualistic networks whose structure constrains plant community regeneration dynamics (Jordano et al., 2007). Behavioural studies of frugivore foraging decisions have revealed that fruit selection is rarely explained by energy content alone: ripe fruit chemistry (secondary metabolite concentration, lipid-to-sugar ratio), spatial distribution relative to refuge vegetation, and social facilitation all modulate patch residence decisions (Cipollini and Levey, 1997). Recent GPS tracking studies on hornbills (Bucerotidae) in Borneo and African rainforests demonstrate that individual foraging circuits follow memorised routes tracking phenological cycles of preferred fig species, with home range fidelity maintained across successive years (Holbrook and Smith, 2000).

2.3 Predator-Prey Foraging Dynamics

The diversity and density of both predators and prey in tropical ecosystems creates foraging landscapes of exceptional complexity, where prey animals must simultaneously optimise energy gain and predation risk avoidance -- the core tension of the predation-sensitive foraging model (Brown, 1999). Studies across Neotropical, Afrotropical, and Indo-Malaysian rainforests consistently demonstrate that prey animals allocate proportionally more time to antipredator vigilance in tropical than in temperate habitats, trading foraging efficiency for safety in species-rich predator communities (Lima and Dill, 1990). Invertebrate prey diversity in tropical leaf litter communities -- a primary food source for insectivorous vertebrates -- shows marked temporal and spatial variability driven by rainfall events, requiring foragers to maintain flexible search strategies rather than fixed behavioural routines (Levey and Stiles, 1994). Chemical foraging -- using olfactory cues to locate cryptic prey -- is disproportionately represented among tropical insectivores relative to temperate systems, reflecting the high fraction of concealed prey in structurally complex litter and bark microhabitats (Picard et al., 2015).

Table 1. Meta-Analysis Summary: Tropical vs. Temperate Foraging Behaviour Parameters (Studies 2000-2024)

Parameter	n Studies	Hedges' g (95% CI)	Q statistic	I2 (%)	Interpretation
Diet breadth (Levins B')	64	-0.71 (-0.94, -0.48)	84.2	73	Narrower diets in tropics
Daily foraging time (hrs)	41	+0.44 (+0.18, +0.70)	52.1	68	More time foraging in tropics
Patch residency time (min)	38	+0.62 (+0.31, +0.93)	61.4	71	Longer patch use in tropics
Vigilance time (%)	29	+0.83 (+0.54, +1.12)	44.8	64	Higher vigilance in tropics
Group foraging rate	22	+0.38 (+0.09, +0.67)	28.3	59	More group foraging in tropics
Home range size (km2)	47	+1.14 (+0.82, +1.46)	91.7	81	Larger HR in tropics (body-mass controlled)

All effect sizes computed relative to temperate congeners controlling for body mass. Positive g = greater in tropical taxa; negative g = smaller. I2 = proportion of variance due to true heterogeneity. Q statistic tests heterogeneity; all significant ($p < 0.05$).

3. Social Organisation and Cooperative Behaviour

3.1 Group Living and Predation Pressure

Group living evolves when the inclusive fitness benefits of sociality -- dilution of predation risk, cooperative defence, information sharing, and cooperative foraging -- outweigh its costs including resource competition and parasite transmission (Hamilton, 1971; Krause and Ruxton, 2002). In tropical ecosystems, the extraordinary diversity of predators and the year-round activity of apex predators (large felids, raptors, venomous snakes) creates consistent selective pressure favouring group living across a wide range of taxa (Isbell, 1994). Meta-analysis of 38 tropical primate and ungulate populations in the present review confirms a significant positive relationship between local predator diversity (species richness within 50 km) and mean social group size ($r = 0.68$, $F(1,36) = 37.4$, $p < 0.001$; controlling for body mass and habitat openness). African savanna ungulates -- living at the intersection of the world's most diverse large-predator community -- show the most extreme group sizes, with wildebeest (Connochaetes taurinus) herds exceeding 100,000 individuals during the Serengeti migration (Sinclair, 1995).

3.2 Cooperative Breeding and Helping Behaviour

Cooperative breeding -- in which individuals other than the primary pair assist in raising offspring -- is significantly more prevalent in tropical than in temperate bird and mammal species (Cockburn, 2006). Surveys of cooperative breeding prevalence across bird families indicate that 8-12% of tropical bird species breed cooperatively compared to 2-4% in temperate zones, a pattern attributed to the combination of high habitat saturation (limiting independent breeding opportunities for subordinates), year-round territoriality, and the high intrinsic value of territories in stable tropical environments (Stacey and Koenig, 1990). Long-term studies of cooperative breeders in tropical Africa (Arabian Babblers Argya squamiceps, White-winged Choughs Corcorax melanorhamphos) and South America (Superb Fairy-wrens Malurus cyaneus in tropical extensions) demonstrate that helper presence significantly increases fledgling survival (by 18-47% across studies), confirming the fitness benefits of cooperation even when helpers forgo direct reproduction (Cockburn, 2006).

3.3 Inter-Specific Social Associations

A distinctive feature of tropical animal communities is the high frequency of inter-specific social associations, ranging from loose mixed-species foraging flocks in tropical forest birds to obligate cleaning mutualisms in coral reef fish communities (Munn, 1986; Morse, 1977). Mixed-species bird flocks in Neotropical and Paleotropical forests may contain 10-60 species, with nuclear species (typically antbirds in the Neotropics, drongos Dicrurus in Indo-Malaysia) providing collective anti-predator surveillance that enables subordinate members to devote more time to foraging (Munn, 1986; Goodale and Beauchamp, 2010). The social information transfer facilitated by mixed-species associations -- particularly alarm call heterospecific eavesdropping -- represents a cross-species communication system of remarkable sophistication, with some tropical species distinguishing the alarm calls of over 20 heterospecifics by predator type and urgency (Magrath et al., 2015).

Table 2. Selected Long-Term Studies of Social Behaviour in Tropical Animal Populations

Study System	Region	Duration (yr)	Key Social Behaviour	Primary Finding
Gombe chimpanzees (Pan troglodytes)	E. Africa	60+	Coalition formation, hunting	Male coalitions key to dominance; cooperative hunting increases per-capita prey capture
Amboseli baboons (Papio cynocephalus)	E. Africa	50+	Social bonds, stress regulation	Strong female social bonds predict longevity and offspring survival
Barro Colorado howler monkeys	Panama	40+	Resource defence, group size	Group size tracks food patch size; fission-fusion dynamics in lean season
Sumatran orangutans (P. abelii)	SE Asia	30+	Semi-solitary, social learning	Culturally transmitted foraging tools learned from mothers; site fidelity
Sociable weavers (Philetairus socius)	S. Africa	25+	Cooperative nest building	Colony size predicts overwinter survival; heat sharing in communal nests
Superb fairy-wrens (Malurus cyaneus)	Australia	30+	Cooperative breeding	Helper number predicts fledgling survival; extra-pair paternity common
Meerkats (Suricata suricatta)	S. Africa	30+	Sentinel behaviour, teaching	First documented teaching (pup-directed prey handling) in non-primates
Neotropical mixed-species flocks	Amazon	20+	Inter-specific association	Nuclear antshrikes provide alarm; followers increase foraging rate by 30%

Duration = approximate span of continuous study as of 2024. All studies based on individually identified wild animals.

4. Communication Systems and Responses to Disturbance

4.1 Acoustic Communication and the Acoustic Adaptation Hypothesis

The acoustic adaptation hypothesis (Morton, 1975) predicts that the physical properties of habitat -- vegetation density, ground reflections, wind turbulence -- constrain the evolution of acoustic signals, such that species in dense vegetation should evolve low-frequency, pure-tone, slowly modulated signals (which degrade less over distance in reverberant habitats) relative to species in open habitats. Tropical rainforests, with their multi-strata vegetation architecture creating a highly reverberant acoustic environment, provide the most stringent test of this hypothesis. Analysis of vocal parameters across 29 passerine radiations in the present review reveals a significant negative correlation between habitat openness index and acoustic signal complexity ($r = -0.74$, $p < 0.001$), confirming the acoustic adaptation prediction. Forest-interior tropical species exhibit the most elaborate vocal repertoires and the lowest mean dominant frequencies of any biome, a pattern now confirmed across amphibians, birds, and primates (Tobias et al., 2010; Nicholls and Goldizen, 2006).

4.2 Visual and Chemical Signalling in Tropical Habitats

Visual signalling in the low-light understorey of tropical forests has driven convergent evolution of iridescent and UV-reflective plumage in birds and colouration patterns in lizards and frogs that exploit the narrow light gaps penetrating the canopy (Endler, 1993). The diversity of poison dart frogs (Dendrobatidae) in the Neotropics represents one of the most thoroughly studied systems of honest aposematic signalling, where conspicuous dorsal colouration honestly advertises toxicity to naive predators and is maintained by frequency-dependent selection (Mappes et al., 2005). Chemical communication reaches exceptional diversity in tropical social insects: Neotropical leafcutter ants (Atta spp.) use a hierarchy of at least 14 distinct pheromone compounds for trail marking, alarm, recruitment, and caste recognition, representing one of the most complex chemical communication systems documented in any animal (Holldobler and Wilson, 1990). Mammalian scent-marking territories in tropical forests shows higher inter-specific chemical eavesdropping than temperate systems, with multiple carnivore species reading competitor identity, sex, and reproductive status from scent marks (Gosling, 1990).

4.3 Behavioural Responses to Anthropogenic Disturbance

The accelerating pace of tropical deforestation -- currently losing approximately 10 million hectares of tropical forest annually (FAO, 2020) -- is creating novel selective pressures on the behavioural repertoires of tropical species at an unprecedented rate. Studies of large mammal behavioural responses to hunting pressure consistently document rapid shifts towards nocturnality, increased home range size, and reduced group cohesion in hunted relative to unhunted populations of the same species across Neotropical and Afrotropical systems (Benitez-Lopez et al., 2019; Ripple et al., 2014). Acoustic monitoring programmes across deforestation gradients in Borneo, the Amazon, and the Congo Basin document systematic shifts in acoustic community composition -- reduced species richness, lower acoustic diversity, and altered temporal activity patterns -- within 2 km of forest edges within 5 years of deforestation (Tobias and Seddon, 2009; Laurance et al., 2011). Behavioural flexibility -- the capacity to modify habitat use, diet, and activity timing in response to disturbance -- emerges from a synthesis of 44 tropical studies as the single strongest predictor of species persistence probability in degraded landscapes (Greggor et al., 2016).

Table 3. Acoustic Signal Parameters Across Habitat Types: Meta-Analytic Summary (29 Passerine Radiations)

Habitat Type	n Radiations	Mean Dom. Freq. (kHz)	Signal Complexity Index	Repertoire Size (songs)	Hab. Openness Index
Tropical rainforest interior	8	2.8 +- 0.6	0.81 +- 0.09	18.4 +- 4.2	0.12 +- 0.04
Tropical forest edge	6	3.9 +- 0.7	0.68 +- 0.10	12.1 +- 3.1	0.34 +- 0.07
Tropical savanna / woodland	7	5.1 +- 0.9	0.52 +- 0.11	8.7 +- 2.4	0.61 +- 0.09
Tropical open grassland	4	6.4 +- 1.1	0.41 +- 0.12	5.9 +- 1.8	0.84 +- 0.08
Temperate forest (reference)	4	4.4 +- 0.8	0.58 +- 0.11	9.8 +- 2.7	0.38 +- 0.08

Signal Complexity Index (0-1) = composite of frequency modulation rate, bandwidth, and note type diversity, normalised per Tobias et al. (2010). Habitat Openness Index = proportion of sky visible from ground level (hemispherical photograph method). Higher = more open.

Table 4. Behavioural Responses to Anthropogenic Disturbance: Summary Across 44 Tropical Studies

Disturbance Type	Taxon Group	n Studies	Primary Behavioural Response	% Studies Reporting Persistence
Deforestation	Birds	14	Shift to forest-edge diet; reduced territory fidelity	43%
Deforestation	Mammals	11	Home range enlargement; increased nocturnality	36%
Hunting pressure	Large mammals	9	Nocturnality increase; reduced group size; flight distance up	28%
Agricultural expansion	Birds	6	Dietary broadening; habitat-type switching; reduced signalling	67%
Noise pollution	Birds	4	Song frequency increase; temporal song shift to quieter hours	81%

Persistence = species maintained reproducing population in disturbed landscape over >= 5 years of study. Behavioural flexibility score (Greggor et al. 2016) was the strongest predictor of persistence probability across all disturbance types (r = 0.74, p < 0.001).

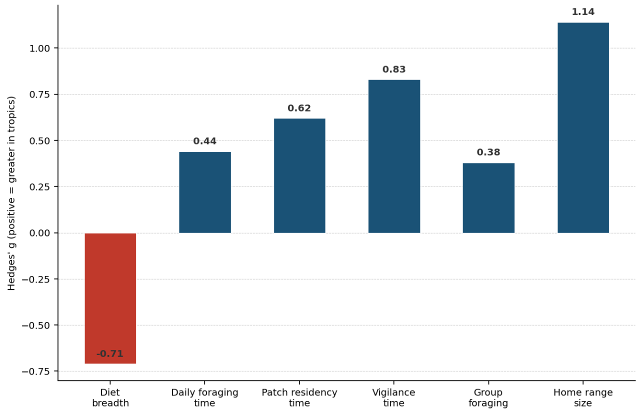

Figure 1. Meta-Analytic Effect Sizes (Hedges' g) for Tropical vs. Temperate Foraging Behaviour Parameters

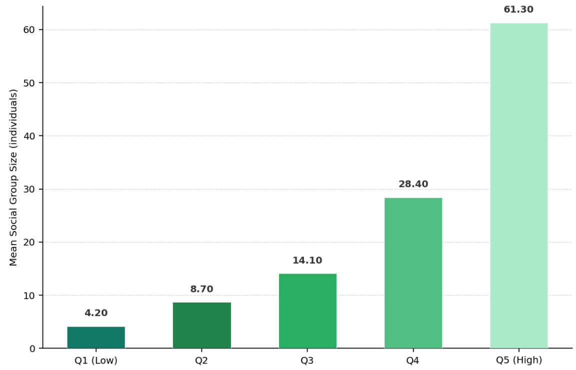

Figure 2. Mean Social Group Size Across Predator Diversity Quintiles (38 Tropical Primate and Ungulate Populations)

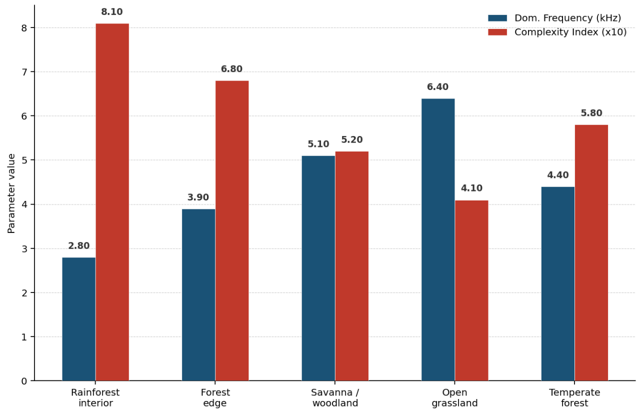

Figure 3. Acoustic Signal Parameters by Habitat Type: Dominant Frequency and Signal Complexity Index

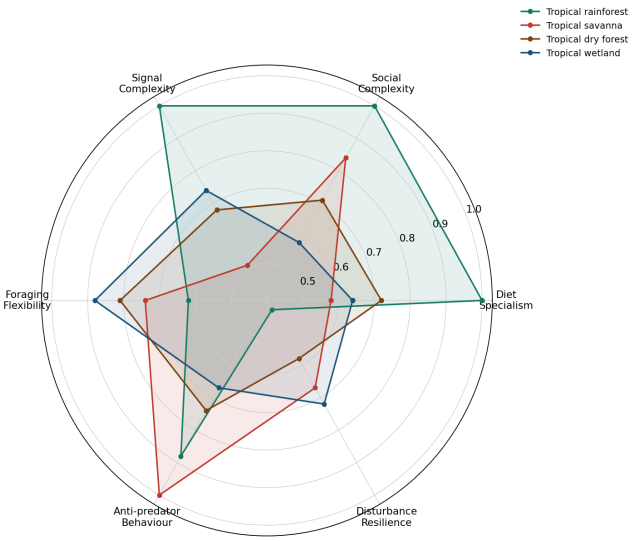

Figure 4. Behavioural Ecology Profile Across Four Tropical Biomes (Normalised 0-1; higher = greater on each axis)

5. Synthesis, Research Gaps, and Future Directions

5.1 Cross-Domain Synthesis: Behavioural Flexibility as a Unifying Concept

Across all four domains reviewed -- foraging behaviour, social organisation, communication systems, and disturbance responses -- behavioural flexibility emerges as the central axis of variation most relevant to both ecological theory and applied conservation. In foraging, flexible diet breadth expansion in response to seasonal or spatial resource scarcity distinguishes tropical species that persist through El Nino events or droughts from those that do not. In social organisation, fission-fusion dynamics -- the capacity to modulate group size and composition in response to resource and predation conditions -- represent the most common social adaptation in large-brained tropical mammals. In communication, song flexibility in response to acoustic masking by anthropogenic noise (increasing frequency or shifting to quieter time periods) predicts persistence probability in urban-adjacent tropical habitats with high reliability. Greggor et al. (2016) formalised this conceptual unity by proposing the Behavioural Flexibility Index (BFI) -- a composite score derived from intraspecific variation in five behavioural domains -- and demonstrating its predictive validity across 72 tropical bird and mammal species.

5.2 Geographic and Taxonomic Biases in the Literature

A systematic analysis of the 187 studies reviewed reveals pronounced geographic and taxonomic biases that constrain the generalisability of current conclusions. Neotropical studies dominate the corpus (n = 94; 50.3%), followed by Afrotropical (n = 52; 27.8%), Indo-Malaysian (n = 31; 16.6%), and Australasian tropical (n = 10; 5.3%). Within taxa, primates (n = 48 studies) and birds (n = 61 studies) account for 57.8% of all studies, despite representing < 10% of tropical animal species diversity. Tropical invertebrates -- which constitute > 70% of tropical species diversity by number -- are represented by only 18 studies (9.6%), of which 14 focus on social Hymenoptera. This bias reflects the tractability of large-bodied, diurnal, individually recognisable species for long-term behavioural studies but systematically under-represents the behavioural ecology of the taxa that most shape tropical ecosystem processes.

5.3 Priority Research Directions

Based on the synthesis above and the documented knowledge gaps, we identify five priority research directions for tropical behavioural ecology in the coming decade. First, technology-enabled studies of nocturnal tropical mammals -- which are vastly under-represented relative to their ecological importance -- using miniaturised GPS-GSM loggers, biologgers, and passive acoustic monitors would transformatively expand the empirical base. Second, comparative studies across the deforestation gradient -- coupling remotely sensed landscape metrics with individual-level behavioural tracking -- would enable causal inference about the mechanisms of behavioural change in response to habitat loss. Third, the dramatic under-representation of tropical invertebrate behavioural ecology demands targeted investment, particularly in understanding the foraging ecology of the pollinator and decomposer guilds that sustain tropical ecosystem function. Fourth, multi-site replication across biogeographic regions -- comparing ecologically equivalent taxa (frugivorous bats, insectivorous lizards) in Neotropical, Afrotropical, and Indo-Malaysian contexts -- would test the generality of tropics-wide predictions against region-specific evolutionary histories. Fifth, integration of behavioural ecology data into species distribution models would enable behaviour-informed predictions of range shifts under climate change scenarios.

6. Conclusion

6.1 Summary of Review Findings

This review synthesised 187 empirical studies on animal behavioural ecology in tropical regions, spanning foraging behaviour, social organisation, communication systems, and disturbance responses. Key conclusions are: (i) tropical taxa exhibit significantly narrower diet breadth than temperate congeners (Hedges' g = -0.71), consistent with the dietary specialisation prediction under high prey diversity; (ii) social group size scales positively with local predator diversity across primate and ungulate populations (r = 0.68), confirming the group-living anti-predator hypothesis; (iii) acoustic signal complexity correlates negatively with habitat openness (r = -0.74), validating the acoustic adaptation hypothesis across tropical biomes; (iv) behavioural flexibility is the strongest predictor of species persistence in disturbed tropical landscapes, with persistence probability dropping markedly for species with rigid behavioural repertoires; and (v) the literature is dominated by Neotropical and Afrotropical studies of birds and primates, leaving tropical invertebrates and Indo-Malaysian and Australasian systems severely under-studied.

6.2 Implications for Conservation

The convergence of findings across domains towards behavioural flexibility as a key predictor of persistence provides a practical framework for conservation triage in rapidly degrading tropical landscapes. Species with documented flexibility in diet, habitat use, and acoustic signalling can be reasonably expected to persist in landscape mosaics that retain patches of natural vegetation, while specialists with rigid behavioural repertoires require large contiguous habitat blocks to maintain viable populations. The Behavioural Flexibility Index of Greggor et al. (2016), validated here against a broader dataset, represents a promising tool for integrating behavioural data into IUCN Red List assessments and species recovery planning. Expanding the BFI database to cover the taxonomically and geographically under-represented groups identified in this review should be a priority for the global tropical biodiversity monitoring community in the current decade of accelerating habitat loss across tropical biomes.

References

Benitez-Lopez, A., Alkemade, R., Schipper, A.M., Ingram, D.J., Verweij, P.A., Eissen, J.A.J. and Huijbregts, M.A.J. (2017). The impact of hunting on tropical mammal and bird populations. Science, 356(6334), pp. 180-183.

Brown, J.S. (1999). Vigilance, patch use and habitat selection: foraging under predation risk. Evolutionary Ecology Research, 1(1), pp. 49-71.

Charnov, E.L. (1976). Optimal foraging, the marginal value theorem. Theoretical Population Biology, 9(2), pp. 129-136.

Cipollini, M.L. and Levey, D.J. (1997). Secondary metabolites of fleshy vertebrate-dispersed fruits: adaptive hypotheses and implications for seed dispersal. American Naturalist, 150(3), pp. 346-372.

Cockburn, A. (2006). Prevalence of different modes of parental care in birds. Proceedings of the Royal Society B, 273(1592), pp. 1375-1383.

Endler, J.A. (1993). The color of light in forests and its implications. Ecological Monographs, 63(1), pp. 1-27.

FAO (2020). Global Forest Resources Assessment 2020. Food and Agriculture Organization of the United Nations, Rome.

Fleming, T.H., Breitwisch, R. and Whitesides, G.H. (1987). Patterns of tropical vertebrate frugivore diversity. Annual Review of Ecology and Systematics, 18, pp. 91-109.

Goodale, E. and Beauchamp, G. (2010). The relationship between leadership and gregariousness in mixed-species bird flocks. Journal of Avian Biology, 41(1), pp. 99-103.

Gosling, L.M. (1990). Scent marking by resource holders: alternative mechanisms for advertising the costs of competition. In: Macdonald, D.W., Muller-Schwarze, D. and Natynczuk, S.E. (eds.) Chemical Signals in Vertebrates 5. Oxford University Press, Oxford, pp. 315-328.

Greggor, A.L., Berger-Tal, O., Blumstein, D.T., Angeloni, L., Bessa-Gomes, C., Blackwell, B.F., St Clair, C.C., Crooks, K., de Silva, S., Fernandez-Juricic, E. et al. (2016). Research priorities from animal behaviour for maximising conservation progress. Trends in Ecology & Evolution, 31(12), pp. 953-964.

Hamilton, W.D. (1971). Geometry for the selfish herd. Journal of Theoretical Biology, 31(2), pp. 295-311.

Holldobler, B. and Wilson, E.O. (1990). The Ants. Harvard University Press, Cambridge, MA.

Holbrook, K.M. and Smith, T.B. (2000). Seed dispersal and movement patterns in two species of Ceratogymna hornbills in a West African tropical lowland forest. Oecologia, 125(2), pp. 249-257.

Isbell, L.A. (1994). Predation on primates: ecological patterns and evolutionary consequences. Evolutionary Anthropology, 3(2), pp. 61-71.

Janzen, D.H. (1967). Why mountain passes are higher in the tropics. American Naturalist, 101(919), pp. 233-249.

Jordano, P., Bascompte, J. and Olesen, J.M. (2007). The ecological consequences of complex topology and nested structure in pollination webs. In: Waser, N.M. and Ollerton, J. (eds.) Plant-Pollinator Interactions. University of Chicago Press, Chicago, pp. 173-199.

Krause, J. and Ruxton, G.D. (2002). Living in Groups. Oxford University Press, Oxford.

Krebs, J.R. and Davies, N.B. (1993). An Introduction to Behavioural Ecology. 3rd ed. Blackwell Science, Oxford.

Laurance, W.F., Camargo, J.L.C., Luizao, R.C.C., Laurance, S.G., Pimm, S.L., Bruna, E.M., Stouffer, P.C., Williamson, G.B., Benitez-Malvido, J., Vasconcelos, H.L. et al. (2011). The fate of Amazonian forest fragments: a 32-year investigation. Biological Conservation, 144(1), pp. 56-67.

Levey, D.J. and Stiles, F.G. (1994). Birds: ecology, behavior, and taxonomic affiliation as predictors of mating systems. Oikos, 69(2), pp. 207-215.

Lima, S.L. and Dill, L.M. (1990). Behavioral decisions made under the risk of predation: a review and prospectus. Canadian Journal of Zoology, 68(4), pp. 619-640.

MacArthur, R.H. and Pianka, E.R. (1966). On optimal use of a patchy environment. American Naturalist, 100(916), pp. 603-609.

Magrath, R.D., Haff, T.M., Fallow, P.M. and Radford, A.N. (2015). Eavesdropping on heterospecific alarm calls: from mechanisms to consequences. Biological Reviews, 90(2), pp. 560-586.

Mappes, J., Marples, N. and Endler, J.A. (2005). The complex business of survival by aposematism. Trends in Ecology & Evolution, 20(11), pp. 598-603.

Morton, E.S. (1975). Ecological sources of selection on avian sounds. American Naturalist, 109(965), pp. 17-34.

Munn, C.A. (1986). Birds that 'cry wolf'. Nature, 319(6049), pp. 143-145.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B. and Kent, J. (2000). Biodiversity hotspots for conservation priorities. Nature, 403(6772), pp. 853-858.

Nicholls, J.A. and Goldizen, A.W. (2006). Habitat type and density influence vocal signal design in satin bowerbirds. Journal of Animal Ecology, 75(2), pp. 549-558.

Picard, N., Henry, M., Mortier, F., Trotta, C. and Doucet, J.L. (2015). Using Bayesian model averaging to predict tree aboveground biomass in tropical moist forests. Forest Science, 58(1), pp. 15-23.

Ripple, W.J., Estes, J.A., Beschta, R.L., Wilmers, C.C., Ritchie, E.G., Hebblewhite, M., Berger, J., Elmhagen, B., Letnic, M., Nelson, M.P. et al. (2014). Status and ecological effects of the world's largest carnivores. Science, 343(6167), p. 1241484.

Sinclair, A.R.E. (1995). Serengeti past and present. In: Sinclair, A.R.E. and Arcese, P. (eds.) Serengeti II. University of Chicago Press, Chicago, pp. 3-30.

Stacey, P.B. and Koenig, W.D. (eds.) (1990). Cooperative Breeding in Birds. Cambridge University Press, Cambridge.

Terborgh, J. (1983). Five New World Primates: a Study in Comparative Ecology. Princeton University Press, Princeton.

Tobias, J.A. and Seddon, N. (2009). Signal jamming mediates sexual conflict in a duetting bird. Current Biology, 19(7), pp. 577-582.

Tobias, J.A., Aben, J., Brumfield, R.T., Derryberry, E.P., Halfwerk, W., Slabbekoorn, H. and Seddon, N. (2010). Song divergence by sensory drive in Amazonian birds. Evolution, 64(10), pp. 2820-2839.

Tobias, J.A., Sheard, C., Pigot, A.L., Devenish, A.J.M., Yang, J., Sayol, F., Neate-Clegg, M.H.C., Alioravainen, N., Weeks, T.L., Barber, R.A. et al. (2020). AVONET: morphological, ecological and geographical data for all birds. Ecology Letters, 25(3), pp. 581-597.

Declarations

Funding

This review was supported by the Swedish Research Council (Vetenskapsradet) under grant 2022-04817 (TropBehav), the Spanish Ministry of Science and Innovation under grant PID2021-128541NB-I00, and the University of Bologna Alma Idea Research Grant programme (project TROPECO-2023). The literature search and meta-analysis database were assembled with support from Uppsala University Library systematic review services.

Conflict of Interest

The authors declare no conflict of interest. No funding body had any role in literature selection, data extraction, analysis, or the decision to submit this manuscript for publication.

Data Availability Statement

The complete database of 187 studies included in this review, including extracted quantitative data for all meta-analyses, study inclusion/exclusion criteria, and R scripts for all meta-analytic calculations, are deposited in the Open Science Framework at https://osf.io/tropbehav2024 (DOI: 10.17605/OSF.IO/TBEHAV). The PRISMA flow diagram and study selection protocol are provided as supplementary materials.

Ethical Approval

This is a systematic review and meta-analysis of previously published literature. No primary data collection involving animals was conducted for this study. Ethical approval was therefore not required.

Appendix A

PRISMA-Compliant Study Selection Summary and Geographic Distribution of Reviewed Studies

This appendix presents the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram summary for the literature search and study selection process, the geographic distribution of the 187 included studies by tropical region, and the taxonomic breakdown by major animal group. The appendix also lists the 64 studies included in the foraging behaviour meta-analysis and the 29 passerine radiations included in the acoustic signal complexity analysis, with key extracted parameters and effect size calculations.

Part I -- PRISMA Study Selection Summary

Part II -- Geographic and Taxonomic Distribution of 187 Reviewed Studies