The Taste for the Beautiful: Influence of Diet on the Evolution of Plumage in Tanagers

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Abstract. The diversity of animal shapes and colors raises questions about the mechanisms by which species acquire complex phenotypes considering that they evolve under both natural and sexual selection. Tanagers employ a diversity of signals in social interactions which, coupled with diverse diets that include fruits and flowers, make them an excellent group for studying how diet influences the evolution of communication signals. Using Bayesian linear mixed models, plumage reflectance data for 291 tanager species (∼77% of species), and appropriate techniques for compositional diet data, we show that percentage increases in frugivory and/or nectarivory dietary components are associated with higher hue disparity scores (a proxy of plumage coloration complexity). Additionally, evolutionary decreases in the percentage of seeds and arthropods, coupled with increases in fruits, are related to higher color complexity. The presence of structural coloration in plumage was related to high hue disparity and frugivory, but carotenoid-based coloration – contrary to expectations – was not associated with either. Our results support the hypothesis that the link between diet and plumage coloration arose not from a physiological constraint but from sensory (perceptual) biases of frugivores and nectarivores for detecting colorful baits in the forest, which resulted in preferences for chromatically diverse feather patterns.

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> [T]ropical forests are the scene of the most intense struggle for existence… some who have been impressed by the wealth of beautiful and bizarre animals and plants have pictured tropical forests as a place where life is so easy and food so plentiful that the most extravagant forms of life can develop unchecked. The truth, so far as we can see it, is somewhere between these two over-simplified extremes.
>
> D.W. SNOW, 1985

Introduction

Social selection – specifically sexual selection – has been considered the main mechanism that promotes complexity in signaling traits (Lyon & Montgomerie, 2012; West-Eberhand, 1983). Conspicuous traits are understood to evolve either by same-sex contests or by mate choice (Darwin, 1863). Signaling traits that evolve through intrasexual selection like same-sex contest competition include rival assessment traits and status badges (Rico-Guevara & Hurme, 2019). Intersexual selection promotes the evolution of exaggerated traits to attract mates, favoring ornamentation (Price, 2008; Prum, 2017). However, studies from the last two decades have shed light on the role of natural selection affecting the evolution of social interactions that result in signal complexity or conspicuousness (Gomez & Théry, 2004; Dale et al., 2015). Variables such as predation pressure and habitat, for example, are closely associated with the evolution of communication signals (Derryberry et al., 2012; Hegna et al., 2013; Marchetti, 1993; Marcondes & Brumfield, 2019; Cooney et al., 2022). As natural and social selection also shape the evolution of signaling traits, a wide array of ecological factors should be considered when studying the evolution of communication signals.

Diet may be an ecological factor shaping social interactions and, consequently, signal evolution (Endler, 1987). Trophic specialization influences a wide range of processes, including speciation (Burin et al; 2016) and dispersal (Levey & Stiles; 1992). For example, the effects of diet on phenotypic evolution have been extensively studied in both insular radiations (Grant et al., 1985; Jønsson et al., 2012; Tokita et al., 2017) and continental groups (Marki et al., 2019; Vinciguerra et al., 2021), showing that substantial morphological diversity can result from diversification into novel dietary niches. Likewise, evidence that specific diets can influence mate choice (Rodd et al., 2002) and drive the evolution of visual ornaments (Balakrishnan et al., 2026) suggests that the relationship between dietary specialization and phenotypic evolution may extend to communication traits.

The evolution of communication signals in birds, which primarily consist of song and plumage color, has been linked to diet in only a few cases, mainly through aspects of diet constraining communication signals or foraging adaptations. Studies of Darwin's finches have shown that birds that adapted to feed on thicker seeds evolved deeper and stronger bills (Grant & Grant, 1995; Schluter et al., 1985); at the same time, songs in these large-billed species have slower paced trills and lower frequencies (Podos & Nowicki, 2004). In estrildid finches, a preference for detecting small, round, whitish items resembling their favored prey, termites, may have triggered the evolution of white polka dots in plumage through the co-option of pre-existing perceptual biases during mate choice (Mizuno & Soma, 2020). These studies focused on small clades and demonstrated that diet, and foraging strategies in particular, can influence the evolution of communication signals either directly, as is in the case of bill size constraining aspects of song, or indirectly, through sensory biases. However, there are only a few studies on the influence of particular diets on the evolution of ornamentation in birds in a macroevolutionary context (*e.g.*, for carotenoid-based colors: Davis & Clarke, 2022; Delhey et al., 2023; Olson & Owens, 2005). This is particularly true of visual signals, in which most work has been done linking plumage traits with body size, habitat, predation and sexual interactions (Galvan et al, 2013, Gomez & Thery, 2004; Shultz & Burns, 2017).

Feather coloration results from light interacting with feather structures or by absorption of either synthesized or dietary pigments (Stoddard & Prum, 2011). Birds cannot synthesize carotenoids; hence carotenoid-based pigmentation requires acquiring these pigments stored in their food (Badyaev & Hill, 2000). Because of this direct relationship most studies of the influence of diet on plumage coloration have focused on the correlation between carotenoid intake and plumage color (Rincon-Rubio et al, 2023; Davis & Clarke, 2022; Cooney, et al 2022; Delhey et al, 2023; Olson & Owens, 2005). It has been proposed that large amounts of carotenoids must be consumed (*e.g.*, a frugivorous diet) to be successfully deposited in feathers (Olson & Owens, 2005), however, recent studies have shown that dietary intake may not be the determining factor for carotenoid pigmentation, as metabolism also plays an important role in determining which type of carotenoid is deposited (Koch & Hill, 2022). As carotenoid-based coloration tends to produce red, orange, and yellow hues (Stoddard & Prum, 2011), it has been hypothesized that a link between plumage ornamentation and diet exists in frugivorous birds as their diets are rich in carotenoids (Cooney, et al 2022; Delhey et al, 2023).

Colorful plumages can also arise via structural coloration: micro and nanostructures in feathers generate light scattering that results in a spectrum of colors beyond those of pigment-based colors (*e.g.*, Eliason et al., 2020; Sun et al., 2013). Structural coloration is found in non-iridescent plumage colorations rich in green, blue, and violet hues, and in a large spectrum of iridescent colors (Sun et al., 2013). Because micromorphology and melanin deposition are the key components that produce structural colors (Badyaev & Hill, 2000; McCoy et al., 2021), structural coloration has not been linked to the consumption of any particular nutrients (McCoy et al. 2021; Stoddard & Prum, 2011). Taken together, a direct link between diet and plumage coloration should be expected in birds with carotenoid-based pigmentation but not in those with structural coloration.

Sensory biases are another way that diet may affect plumage ornamentation. The sensory bias hypothesis posits that an organism's perception influences its preferences and social interactions (Fuller et al., 2005; Ryan, 2019). In guppies (*Poecilia reticulata*), it has been shown that females prefer orange spotted males over males with less saturated orange spots (Endler, 1987; Kodric-Brown, 1985). Orange-colored objects are preferred by both sexes of guppies, which may be a consequence of feeding on fallen fruits of these bright colors along streams (Grether et al., 2005; Rodd et al., 2002). Thus, in guppies, female preference for males with orange spots seems to have arisen from a foraging sensory bias (Rodd et al., 2002). Similarly, plants that employ birds for seed dispersal have evolved different mechanisms (*e.g.*, a variety of conspicuous colors) for successfully attracting avian frugivores (Levey & Stiles, 1992; Loiselle & Blake, 1991). Ripe fruits exploit avian visual systems by possessing conspicuous colors (*e.g.*, red, violet, blue and black), that contrast against forest green (Stournaras et al, 2013). Similarly, bird-pollinated plants take advantage of this channel of communication. These plants possess a diversity of colors that are conspicuous to birds (*e.g.*, red, orange, pink, violet) (Stiles, 1976), but not as easily detected by insects like bees (Castellanos et al. 2004), thus maintaining high nectar rewards for the desired avian pollinators. Therefore, frugivorous and nectarivorous birds may have sensory systems fine-tuned to detect a variety of conspicuous signals during foraging (Cazetta et al., 2009, Madden & Tanner, 2003, but see: Borgia & Keagy, 2006). Here, extending the sensory bias from strictly linking the same colors in the diet and body of the signaler, we propose that if sensory bias is related to variation in plumage patterns, then frugivorous and nectarivorous birds, which have diets associated with higher color diversity than others (such as insectivores and granivores; Zvereva, et al., 2019), should have evolved plumages with similarly diverse color patterns.

Tanagers and allies (Thraupidae) constitute one of the most diverse passerine families (Burns et al., 2014). This group serves as an excellent model for studying the relationship between diet and the evolution of communication signals, not only because it is a very diverse family (377 species; Clements et al., 2019) coupled with a well-supported phylogeny (Burns et al., 2014), but also because of its huge phenotypic, dietary, and ecological diversity (Winkler et al., 2020). In this family, almost all dietary guilds (except vertivory and scavenging) have evolved multiple times (Demery and Burns 2023). Thraupids exhibit large interspecific variation in bill shape, suggesting high levels of ecological adaptation to exploit different resources (Vinciguerra & Burns, 2021), and bill evolves convergently with diet throughout the clade (Demery and Burns 2023).

The extensive phenotypic variation in tanagers extends to their plumages (Mason et al., 2014; Shultz & Burns, 2017). There are species with color patterns that range from conspicuous (*e.g.*, most of the species in the genus *Tangara*), to drab (*e.g.*, Darwin's finches in the Coerebinae subfamily) (Shultz & Burns, 2017). In tanagers, plumage traits have been shown to evolve by sexual and natural selection (Shultz & Burns, 2017); however, no study has investigated whether there is a link between diet and color evolution in the family. Here, we seek to understand whether diet shapes patterns of plumage variation in the tanagers. We test whether patterns of plumage variation in tanagers are related to food elements as described by the composition of their diet. We hypothesize that increases in certain elements in the diet composition are correlated with the evolution of visual signals either by direct links to the presence of diet-derived pigmentation or through sensory biases.

Methods

To describe plumage coloration across the clade, we used published data from male and female museum specimens for 77% of all tanager species (Mason et al, 2014; Shultz & Burns, 2017; Table S1). This dataset consists of reflectance spectra measurements from nine standard patches across all species and any additional patches distinct to the human eye in each species (Figure S1). Reflectance spectra for each sex of each species were plotted in the avian tetrahedral color space and whole-plumage complexity measurements were taken, including average color span, maximum color span, color volume, average hue disparity, maximum hue disparity, average brilliance, and average chroma. To reduce the number of variables, we performed a correlation analysis of the color variables using the R package `corrplot` (Wei et al., 2017). We kept three variables that had low correlation scores (under 0.1): average hue disparity, average chroma, and average

brilliance (Figure S2, but see: Figure S3; Tables S2 and S3). Of the three variables used, chroma and brilliance – measurements of saturation and light reflection – are useful for measuring general plumage coloration, whereas hue disparity, a measurement of the difference between color angles present in plumage pattern, reflects its complexity (Stoddard & Prum, 2011). Our analytical framework assumes that complex color patterns in tanagers evolved as signals tuned to the avian visual system – the perceptual space of the primary agents of social and sexual selection – rather than to the dichromatic vision of potential mammalian predators.

Shultz and Burns (2017) demonstrated with a phylogenetically-controlled PCA that measurements of hue disparity, color volume, and color span all load strongly together and explain the majority of variation in plumage patterns across tanagers. High measurements of each of these variables correspond with high levels of human-perceived plumage complexity. Thus, hue disparity is an appropriate proxy of plumage coloration complexity that has been used in previous studies (*e.g.*, Price-Waldman et al., 2020) (Figure S2). For males of each species, we employed the categories used in Mason et al (2014) for coloration mechanism. Mason et al. (2014) categorized the presence of carotenoid-based and structural coloration based on a combination of color and the shape of reflectance curves. Birds with UV, blue, green, or violet hues were classified as structural if the corresponding reflectance spectra had one or two distinct peaks in the avian visual spectrum (300-700nm), and red, orange and yellow patches were classified as carotenoids only if the spectra had a distinct minimum in the shorter wavelengths, followed by a steep increase in higher wavelengths (Mason et al, 2014).

We used existing literature to extract information on the light environment of species' foraging habitats, strata, and diet. For light environment, we assigned each species to (0) understory, (1) canopy or (2) open areas, broad categories that likely reflect the availability of light on their preferred foraging habitat (open or forest), and strata (canopy or understory) for forest birds, assuming little variation of light wavelength within them (Shultz & Burns, 2017; Endler, 1993; Fialko & Price, 2025). We retrieved diet information from Wilman et al. (2014) and treated diet as a compositional variable composed of percentages of each diet element. We used the percentage of seeds, fruit, invertebrates, and nectar, with a final catch-all category of other diet elements that do not fit into these categories (such as leaves) so that the total diet of each species sums to 100%. For this study we did not treat diet as a discrete variable, as discretization may result in underestimating variation within categories, leading to oversimplified interpretation of results.

Comparative analysis

For comparative analyses, we used the species-level phylogenetic hypothesis proposed by Burns and collaborators et al. (2014). Data from 291 species were retrieved from Shultz & Burns (2017, available at: `10.5061/dryad.g4k83`). First, we fitted ancestral states for diet elements, using each diet element separately as a continuous independent trait. We performed ancestral state reconstruction analysis using the maximum likelihood framework for each node as implemented in the `ace` function in the R package `ape` (version 5.8) and interpolated these results for each edge using the `contMap` function in `phytools` (version 2.5), interpolating the trait values using Brownian motion along each edge (Paradis, et al., 2019; Revell, 2012).

To test whether diet explained variation in color variables, we fitted Bayesian Generalized Linear Mixed Models for each color variable (*i.e.*, hue disparity, average chroma, and average brilliance) using the R package `MCMCglmm` (version 2.36) (Hadfield, 2010). We modeled each color variable separately for each sex as a function of diet (as a set of collectively bounded continuous variables, omitting one diet category, the catch-all including plant matter, as a reference category for identification) and habitat category, with a correlation structure assuming a Brownian motion evolving along the phylogeny. Plumage coloration variables were scaled to have mean zero and standard deviation one; hue disparity and average chroma were log-transformed. For the phylogenetic and residual variance components, we specified weakly informative inverse-Wishart priors using a scale parameter of $V = 1$ and degrees of freedom $\nu = 0.02$. A Markov chain Monte Carlo algorithm was iterated 200,000 times, with a burn-in of 10,000 iterations and a thinning rate of 500 iterations. We estimated each model separately using fifty phylogenies from Burns et al (2014) to account for phylogenetic uncertainty and used the average values of estimates across these runs. We deemed marginal effects "statistically significant" when their 95% credibility intervals did not include zero; however, the compositional nature of the diet covariates means marginal effects are not always equivalent to individual coefficient estimates.

Marginal effects for compositional variables

The compositional nature of diet data – the sum of the dietary components x_k must always sum to 100%, regardless of any hypothetical increases in a specific dietary component – poses challenges for conventional interpretation of linear model coefficients as marginal effects (Adolph, 2013; Hron et al., 2012; Adolph et al, 2017). Specifically, it is not possible to treat an individual estimated β_j coefficient as a general estimate of

the marginal effect of increasing category j (say, fruit) as a share of a species' diet, as increasing fruit consumption requires reducing specific other dietary components by the same total amount.

Consider pairwise shifts between diet categories j and k which preserve the 100% constraint on total diet components: in this case, the pairwise marginal effect of a 1% shift from k to j must be $\beta_j - \beta_k$. This includes the special case where k is assumed to be the reference category (in our specification, the catch-all including plant matter), in which case $\beta_j - \beta_{\text{Reference}} = \beta_j - 0 = \beta_j$. That is, β_j represents a marginal effect only in the particular case of assuming a pairwise shift between j and the (arbitrarily selected) omitted category. But if increased fruit consumption replaces a different dietary component, such as seeds, the marginal effect is $\beta_{\text{Fruit}} - \beta_{\text{Seeds}}$, which may differ in sign, size, and statistical significance from β_{Fruit}.

As an illustration, a Bayesian GLMM controlling only for the dietary percentage of fruit suggests a positive relationship with hue disparity (Table S4: $\beta = 0.0055$, 95% CI [-0.0023, 0.0133] for males; see also Figure S4); in this case, the reference category is any food other than fruit. However, this signal can be lost when the full dietary composition is incorporated into a model using a more specific (but arbitrary) reference category (*e.g.*, plant matter) yielding no significant responses under conventional interpretation of coefficients as marginal effects (Table S5), despite having superior goodness-of-fit by the deviance information criterion (DIC). Nevertheless, the full information regarding the marginal effects of pairwise shifts between dietary categories is still present in the coefficients of a model controlling for the full dietary composition but can only be revealed by computing each *pairwise* marginal effect (a method which is insensitive to the choice of reference category).

To interpret Bayesian GLMMs correctly when the covariates of interest are compositional, we employ three complementary techniques as alternative specifications of the model:

First, to produce a single coefficient summarizing how color variables respond to increases in the relative proportion of colorful reward-based food items, we used a biologically motivated isometric log-ratio (ILR) balance of diet composition (Egozcue, et al; 2003). The ILR balance allows the analyst to compare the impact of two groups of components, D_1 and D_2, by taking the log of the ratio of their geometric means, multiplied by a scaling factor; groupings are often selected based on subject expertise (Greenacre, et al; 2021). We group together two colorful, reward-based food items (nectar and fruit), two non-reward items (seeds and invertebrates), and then define *diet*

conspicuousness as the ILR balance between these groups of components:

$$\text{Diet Conspicuousness} = \sqrt{\frac{|D_1| \times |D_2|}{|D_1| + |D_2|}} \log \left(\frac{\left(\prod_{d \in D_1} x_d\right)^{\frac{1}{|D_1|}}}{\left(\prod_{d \in D_2} x_d\right)^{\frac{1}{|D_2|}}} \right) \tag{1}$$

where $|D_1|$ and $|D_2|$ indicate the number of components in each group. Because $|D_1| = |D_2| = 2$, this simplifies to:

$$\text{Diet Conspicuousness} = \frac{1}{2}\left(\log x_{\text{Nectar}} + \log x_{\text{Fruit}}\right) - \frac{1}{2}\left(\log x_{\text{Seeds}} + \log x_{\text{Invertebrates}}\right)$$

Positive values indicate diets rich in nectar and fruit, whereas negative values indicate diets dominated by seeds and invertebrates. This single ILR balance was included as a predictor in Bayesian linear mixed models in place of the individual diet components, yielding a one-dimensional summary of the effect of diet on plumage coloration at the price of assuming that Nectar and Fruit consumption each have the same effect and that Seed and Invertebrate consumption have a similar effect of opposite sign.

Second, because ILR balances can be difficult to interpret (Greenacre, et al; 2021) and to develop a more detailed picture of how dietary mix relates to coloration without assuming any diet category has similar effects to any other, or imposing patterns on the signs of relationships, we directly control for the dietary components (omitting a reference category) and present estimates of each possible pairwise shift in diet as pairwise marginal effects. This is our most detailed presentation of marginal effects.

Third, to produce an easily interpreted estimate for the unique marginal effect of each dietary component, we adopt a methodology from quantitative social science to estimate the marginal effects of specific shifts in mathematically analogous compositions such as budgets shares. This approach begins by noting that all logically possible marginal effects of a perturbation in diet composition increasing consumption of category j at the expense of other categories must satisfy $\beta_j - \sum_{k \neq j} w_k \beta_k$, where the change in each other category satisfies $\sum w_k = 100\%$. (Pairwise marginal effects are a special case where only a single w_k is greater than zero.) An attractive choice of $w_k = \bar{x}_k / \sum_{\ell \neq j} \bar{x}_\ell$ uniquely preserves the ratios among all other dietary components when consumption in category j increases. Adolph (2013) and Adolph et al (2017) recommend this method of computing ratio-preserving marginal effects as a neutral estimate of the effect of each component. In turn, these estimates validate the ILR balance approach to the extent the marginal effects of fruit and nectar are similar in

magnitude and positive, and the marginal effects of seeds and invertebrates are similar and negative.

Analysis of diet composition and color mechanisms

We tested whether the presence of either coloration mechanism (carotenoid pigment-based or structure-based coloration) was associated with within-plumage variation or dietary elements. For these analyses, we focused on male plumage data only (Mason et al., 2014, available at `10.5061/dryad.7mj61`), which scored the presence or absence of carotenoid and structural-based coloration for male tanagers. We again estimated Bayesian linear mixed models using the R package `MCMCglmm` (Hadfield, 2010). First, we treated hue disparity as the response variable and the presence of carotenoid pigment-based or structural-based coloration as predictors in two separate models, using the same priors as above. Then, to test whether a certain type of diet was related to the presence of either coloration mechanism, we estimated another set of models in which the presence or absence of each coloration mechanism was the response variable, and diet variables were the predictors. For the latter, we adjusted the models to run assuming a binomial error distribution. We fitted each model separately over fifty phylogenies obtained from the Bayesian posterior distribution of trees given in Burns et al. (2014) to account for phylogenetic uncertainty and present the average values of each estimate of each component. To compute appropriate marginal effects for changes in diet composition, we again computed ratio-preserving marginal effects following Adolph (2013).

Results

Ancestral state reconstruction

For 229 of 291 tanager species examined, more than 50% of the diet was composed of fruits or invertebrates, making these the two most common diet items in the family (Table S1). Ancestral state reconstructions of the proportion of fruits and invertebrates suggest the diet of the most recent common ancestor of all Thraupidae was composed mostly of insects (45%) and a small percentage of fruits (23%), with numerous deviations across clade history (Figure 1). For example, fruit-rich diets have appeared at the basal nodes of the core tanagers (Subfamily: Thraupinae) and blue tanagers (subfamily: Dacninae). However, frugivorous species have also evolved in at least two other clades

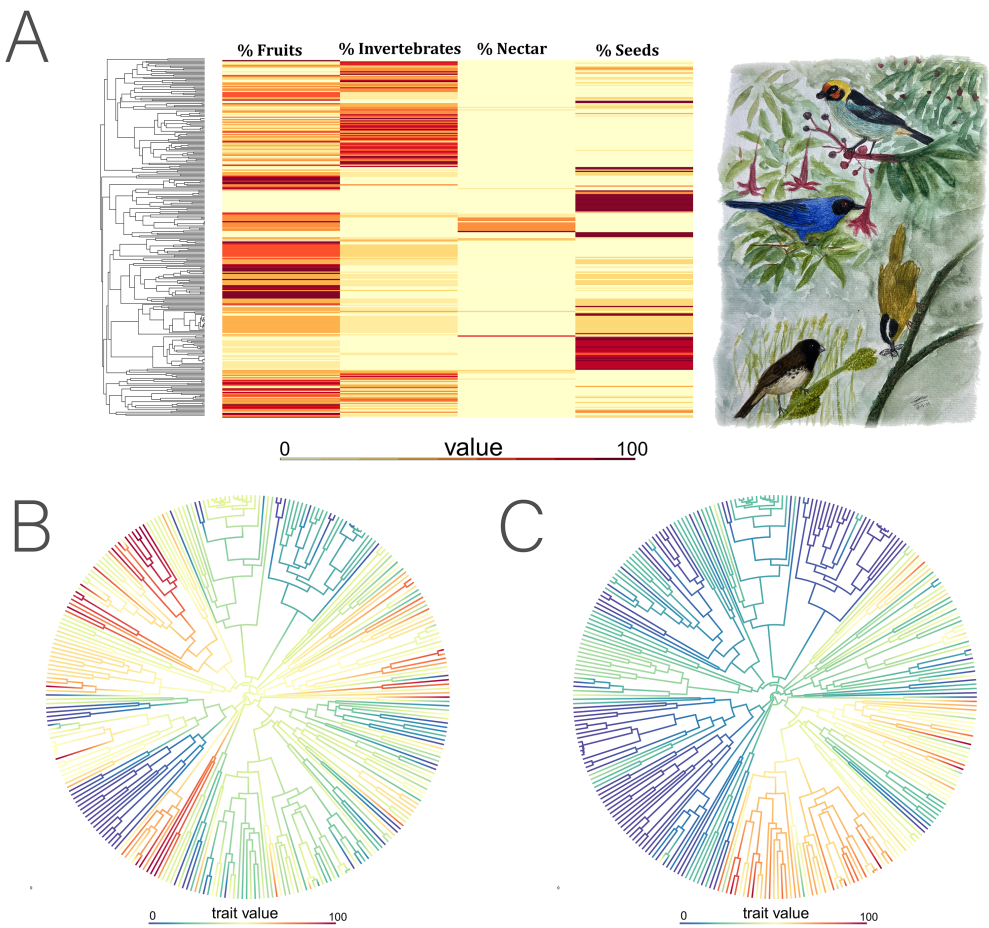

Figure 1. *Birds in Thraupidae exhibit great diversity of dietary specializations.* The wide variation of diet composition in the family can be seen in (A). The two most common diet elements present in Thraupidae are invertebrates (B) and fruits (C); ancestral state reconstructions show a high consumption of invertebrates is the ancestral state, and diet variations have appeared numerous independent times across the phylogeny. Graphics made using the R package `phytools`. Illustration highlighting the diversity of diet specializations in the family, featuring from top to bottom: *Tangara parzudakii*, *Diglossa cyanea*, *Kleinothraupis atropileus*, and *Sporophila nigrirostris* by Carlos Arcila.

within Thraupidae, as in Orchesticinae (*Parkerthraustes humeralis*) and in Tachyphoninae (*Ramphocelus sp.* and *Loriotus sp.*) (Figure 2; Figure S5).

Bayesian linear models and marginal effects of diet composition

Among the plumage color outcomes, only brilliance was related to habitat structure (Table S6; $\beta_{\text{Open areas vs Canopy/Understory}}$ Females: 0.189, CI [0.005, 0.373]; Males: 0.23 CI [0.09, 0.37]). Birds of both sexes that inhabit open areas tend to be lighter than forest birds independently of the strata they live in.

As noted above, whereas controlling only for fruit consumption and no other diet components may suggest a strong positive relationship with hue disparity in both sexes, direct interpretation of estimated coefficients in models with a full set of diet covariates requires specifying appropriate shifts among diet components to preserve the compositional constraint. All three methods of computing marginal effects of diet composition found similar effects of diet on hue disparity.

Diet conspicuousness scores based on ILR-derived balance contrasting nectar and fruit against seeds and invertebrates show a positive effect on hue disparity for both males and females (Figure 3A; Table S7; Males: β = 0.099, 95% CI [0.045, 0.157]; Females: β = 0.066, 95% CI [0.009, 0.124). Species with diets high in nectar or fruit exhibited higher hue disparity than to species whose diets were dominated by seeds and invertebrates. Diet composition did not explain variation in either chroma (Table S7; Males: β = -0.014, 95% CI [-0.061, 0.029]; Females: β = -0.001, 95% CI [-0.032, 0.028]) or brilliance (Table S7; Males: β = -0.009, 95% CI [-0.044, 0.017]; Females: β = -0.017, 95% CI [-0.045, 0.003]).

Our second method computes every pairwise marginal effect using the coefficients from Table S5 and assuming a 10% increase in one diet category coupled with a corresponding reduction in another (Figure 3B-C). We found that shifting 10% from invertebrates to fruits is associated with higher hue-disparity scores in male and female tanagers ($p < 0.05$). Similarly, 10% shifts from granivory to frugivory diets increase hue-disparity ($p < 0.05$). Finally, a shift of 10% from seeds to nectar is associated with an increase in hue disparity in males ($p < 0.05$) and, with less certainty, in females ($p < 0.1$). These relationships scale linearly in the size of the dietary shift between categories (Figure 4).

Finally, for our third method, we compute ratio-preserving marginal effects for each diet category and find significant positive associations between hue disparity and fruit diet share in males and females (Figure S6, $p < 0.05$) and significant negative associ-

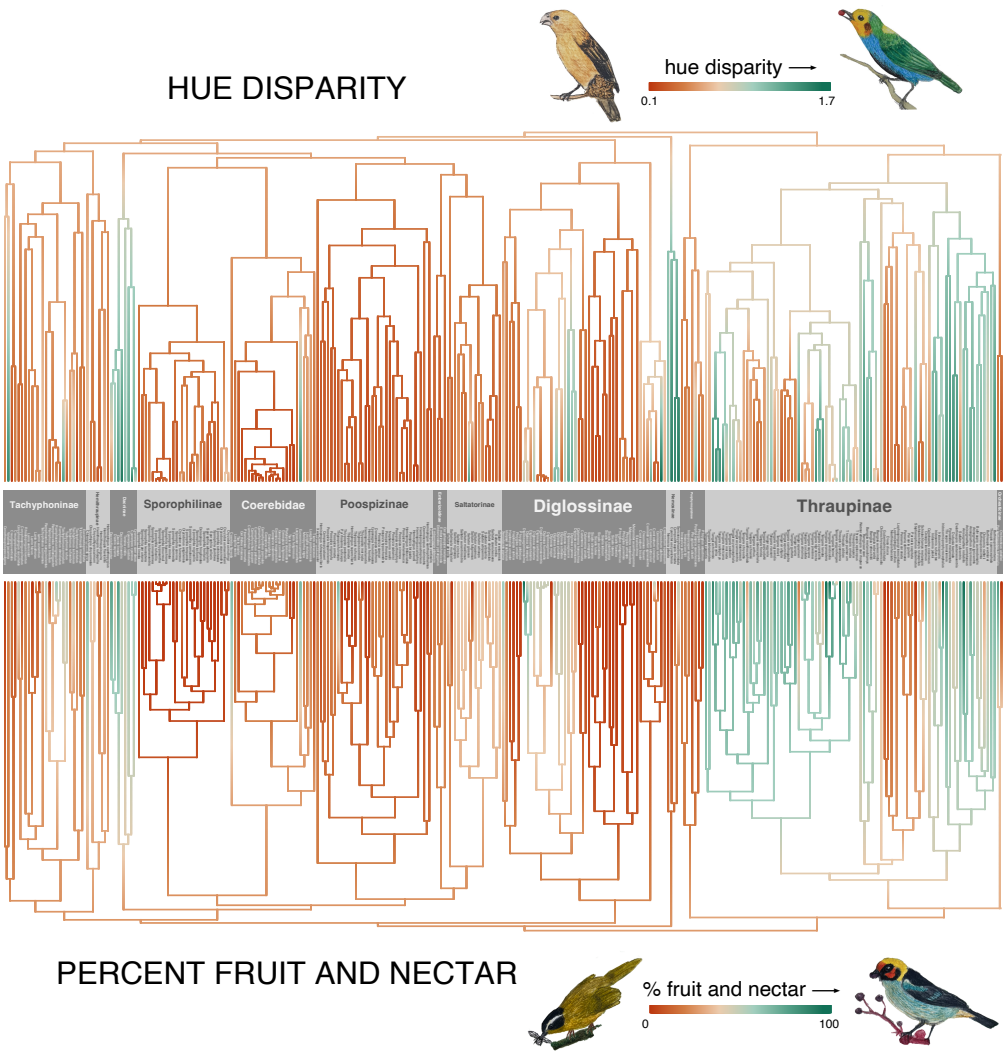

Figure 2. *Ancestral state reconstruction of percent sugar in the diet versus hue disparity in Tanagers.* Appearance of frugivorous and nectarivorous diets are associated with higher scores of hue disparity in both sexes, mainly because of the integration of structural coloration into plumage.

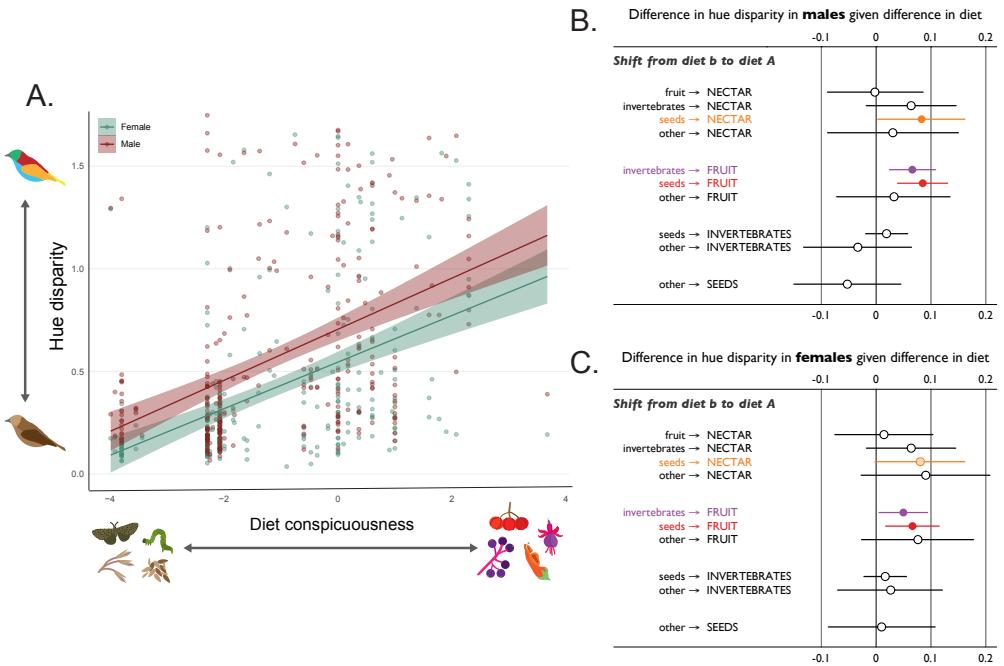

Figure 3. *More consipicuous diets are associated with hue disparity in Tanagers.* (A) Linear regression of hue disparity against a diet visual conspicuousness score (derived from the ILR balance of diet composition), showing higher hue disparity in females (green) and males (red) of Thraupidae species with diets rich in fruit and nectar. (B-C) Marginal effects and 95% credible intervals for male (B) and female (C) hue disparity associated with 10% pairwise shifts between specified dietary components. Filled dots indicate statistically significant relationships. Shifts from invertebrates and seeds to fruit are associated with increases in hue disparity. Additionally, shifts from seeds to nectar are also associated with increases in hue disparity. Pairwise shifts from category k to category j are computed using $\beta_j - \beta_k$ from Bayesian linear mixed models reported in Table S5.

Figure 4. *Effects on hue disparity associated with pairwise shifts in diet of varied size from seeds to nectar, invertebrates to fruit, and seeds to fruit.* Results expand the 10% marginal effects shown for male and female Thraupidae in Figure 3B and 3C to a range of possible sizes of dietary shift. Dark regions indicate 95% credible intervals; lighter regions indicate 90% credible intervals. $p<0.05$ (or $p<0.1$) indicates the 95% (or 90%) credible interval does not include zero. Pairwise shifts from category k to category j computed by multiplying the shift by $\beta_j - \beta_k$ using estimates from Bayesian linear mixed models reported in Table S5. All other diet categories are assumed to remain constant.

ations between hue disparity and seeds diet share in both sexes (Figure S6, $p < 0.05$). The magnitude of ratio-preserving marginal effects on hue disparity for fruit and nectar diet shares was similar (for males, +0.050 and +0.068, respectively; for females, +0.056 and +0.053, respectively), helping validate the diet conspicuousness measure used above. However, the magnitudes of ratio-preserving marginal effect for invertebrates and seeds differed more substantially (for males, -0.27 versus -0.48; for females, -0.017 versus -0.037), while still being correctly signed.

Diet and plumage coloration mechanism

We tested whether higher levels of hue disparity are found in males with either carotenoid pigment-based or with structural coloration. Among measured tanager species, 48% had carotenoid pigment-based coloration as part of their plumage patterns and 39% had structural-based coloration. We found that higher hue disparity scores are more likely to be found in birds with structural coloration in their plumages (Table S8; β = 1.07, 95% CI [0.90, 1.24]), but no relationship was found for birds with carotenoid-based plumage coloration (Table S8; β = -0.05, 95% CI [-0.19, 0.09]).

Next we fitted Bayesian linear models of structural and carotenoid pigment-based coloration in male plumage to see whether the presence of these colorations is associated with diet (Table S9). We computed ratio-preserving marginal effects for each diet category and found that higher proportions of fruit are associated with the appearance of structural colors in plumage coloration (Figure 5, $p < 0.05$), whereas a higher proportion of seeds reduces the probability of having structural colors (Figure 5, $p < 0.05$). Conversely, there was no association between the proportion of fruit or seeds and the presence of carotenoid-based coloration (Figure 5). These relationships also scale linearly in the size of the shift to a given dietary category (Figure S7).

Discussion

We found that diet composition in tanagers is associated with plumage appearance, particularly with variables related to plumage complexity. Species with a high percentage of fruit or nectar in their diet were more likely to exhibit plumages rich in hues different from each other. Further, by introducing appropriate methods for computing marginal effects of compositional data in a comparative framework, we show that not only is a frugivorous diet associated with higher hue disparity scores, but it is also associated with the presence of structural coloration. Together, these results suggest the

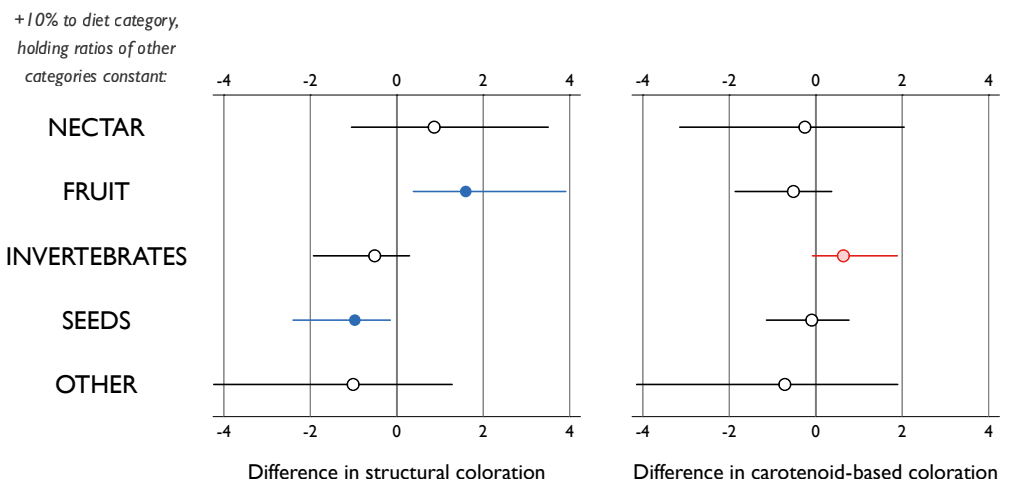

Figure 5. *Marginal effect on type of coloration of 10% increases in each dietary component in Thraupidae, neutrally replacing other diet components.* Horizontal lines show 95% credible intervals; filled circles indicate significant differences from zero at the 0.05 level, and shaded circles indicate significance at the 0.1 level. Higher fruit diet shares are associated with the appearance of structural coloration on birds, whereas diets with higher portions of seeds are associated with the absence of structural coloration. Neither fruit nor seed consumption was related to the appearance of carotenoid-based coloration, but there is weak evidence for association with invertebrate consumption. Estimates computed using coefficients from the Bayesian linear mixed models reported in Table S9. Ratio-preserving marginal effects for diet component x_j computed using $\beta_j - \sum_{k \neq j} w_k \beta_k$, where $w_k = \bar{x}_k / \sum_{\ell \neq j} \bar{x}_\ell$ and $\bar{x}_k$ indicates the average diet share across species for category k.

link between color and diet is not driven by dietary pigment consumption, but rather that it is consistent with the sensory bias hypothesis.

Evolution of diet and plumage in Thraupidae

We showed that darker tanagers are found in the forest interior rather than in open habitats, a pattern consistent with previous studies on tanagers and other groups (Gomez & Thery, 2007; Lyon & Montgomerie, 2012, Shultz and Burns 2017, Cooney et al, 2022). However, contrary to previous studies that found a relationship between plumage complexity–conspicuousness and habitat across several families of birds (Gomez & Thery, 2007; Scott et al, 2024; Beco et al, 2021), we showed that variables related to plumage complexity do not follow this pattern in Thraupidae. Using model-fitting

methods, Shultz and Burns (2017) found weak support for an association between plumage complexity and habitat but could not distinguish between that and a model that did not include habitat variables. The lack of a relationship using Bayesian methods further supports a lack of any pattern. While several studies have investigated the influence of light environment on plumage variation, few studies have incorporated influences related to sensory biases. Thus, to understand what other factors may influence plumage evolution, we tested the relationship between diet and visual communication signals, an idea that has been around since the mid-1970s (Snow, 1971) but has not received much attention.

We show that species with diets characterized by high percentages of fruit and/or nectar tend to have higher hue disparity scores (*i.e.*, colorfulness). This pattern is consistent with previous studies using additional metrics of color complexity (*e.g.*, Cooney et al., 2022), which found that the plumage of species with high fruit and nectar consumption occupies a larger proportion of the avian color space. Furthermore, we show that males of frugivorous birds are more likely to exhibit conspicuous structural-based colors in their plumage, which increases the diversity of colors exhibited. Interestingly, we failed to find a link between the presence of carotenoid pigment-based coloration and measurements of plumage coloration or diet, despite previous reports of a role for carotenoids in signal complexity evolution in tanagers (e.g, an inverse relationship between song complexity and carotenoid pigment-based coloration) (Badyaev & Hill, 2000; Mason et al., 2014).

Carotenoid-based ornaments are the result of external assimilation (Svensson & Wong, 2011) and have historically been thought to be honest signals for individual immune system function and antioxidant performance. Still, recent studies suggest that this is not always the case (Koch et al., 2019), especially because some birds (*e.g.*, the tanager genus *Ramphocelus*) change receptor perception of colors by changing feather microstructures that enhance carotenoid-based signals rather than the composition of carotenoids (McCoy et al., 2021). Evidence that colorful birds forage preferentially for carotenoid-rich food is mixed (Catoni et al., 2011; Walker et al., 2014), consistent with our results in tanagers. Some species with carotenoid pigment-based ornaments do not consume high levels of fruit, as carotenoids can also be assimilated from other sources such as seeds and arthropods (Goodwin, 1980; Grether, 2010; Hudon, 1994). Investigations of which specific types of carotenoids in plumage, such as dietary or metabolized carotenoids, relates to plumage complexity and then to diet may be necessary to further understand a relationship that seems to be more complex than once thought.

Surprisingly, we found that structural-based plumage coloration is related to both diet and hue disparity. Male tanagers tend to have higher hue disparity scores when they exhibit structural coloration in their plumage, which is more likely to appear on frugivorous lineages. Similarly, Delhey et al (2023) found that males of frugivorous birds are more likely to exhibit plumages in blue and purple hues, which are colors that must be produced by feather structures. Recent studies have proposed that the relationship between frugivory and complex plumages is a product of external nutrient ingestion that is reflected by species phenotypes (Cooney et al., 2022). However our results indicate the opposite, which opens up the possibility of sensory biases being a driver of the evolution of certain signaling phenotypes.

Sensory biases may explain plumage color complexity in frugivores

If we take a closer look at the most common elements in the diets of Thraupidae we notice two large groups. On one hand, most flowers and bird-dispersed fruits are highly ornamented to enhance conspicuousness and often exhibit red and blue colorations (Stournaras, 2013). On the contrary, visually conspicuous arthropods are often aposematic and thus non-preferred by insectivores (Evans-Blake, et al., 2025; Dell'Aglio, et al., 2016); resulting in bird-predated arthropods and seeds usually being cryptic colored to avoid detection (Janzen, 1971; White & Midgley, 2022). The dichotomy between the coloration of preferred dietary items (colorful vs. not) among these feeding habits categories, favors the evolution of particular foraging adaptations that may explain part of the variation in plumages among diets in tanagers.

In exchange for pollination and dispersal services, fruits and flowers usually offer nutritious rewards to their consumers (Morton, 1975). To increase detectability, ornithocorous fruits usually employ visual cues that can be followed by frugivores, who have evolved visual systems that aid in the detection of colors characterizing ripe fruits (Melin et al., 2014; Osorio et al., 2004; Schaefer et al., 2006). Coevolution between avian frugivores and ornithocorous plants may have triggered the evolution of highly contrasting plumages by sensory biases of avian consumers. A similar rationale would apply for the evolution of conspicuous plumages rich in red hues in avian pollinators following their bias to detect floral advertisements in ornithophilous plants (Burd et al., 2014).

The sensory (or perceptual) bias hypothesis proposes that preexisting sensory preferences influence an animal's choice in mate selection and social interactions (Basolo, 1990; Ryan & Cummings, 2013). Evidence for the sensory bias hypothesis in nature

is mainly found in fishes, where in lab and field experiments, certain species such as guppies and sticklebacks prefer certain colors during foraging and sexual interactions (Houde & Endler, 1990; Ryan, 2019); however, evidence can also be found on insects, spiders and even birds (Vahed, 2007; Mizuno & Soma, 2020). Few studies have successfully tested how well birds discriminate specific colors during foraging (*e.g.*, Stiles 1976); showing that while insectivores favor cryptic colored prey (Zvereva, et al., 2019); frugivorous birds prefer fruits of contrasting coloration (Cazetta et al., 2009; Hazell et al, 2023), matching sexual signals. Experiments with Fish Crows (*Corvus ossifagus*) and free ranging rainforest birds have shown that contrasting chromatic objects are preferred by birds (Cazetta et al., 2009; Schaefer et al., 2006). These experiments alone do not support the sensory bias hypothesis but confirm that even though avian vision is thought to be rather conserved across guilds (Casalia et al, 2020; Kelber, 2019), fruit-eating birds favored blue and black objects that contrast against forest backgrounds. This, along with the fact that most frugivorous tanager clades exhibit species with plumages rich in red and blue hues (*e.g.*, *Tangara*; *Dacnis*; *Ramphocelus*) (Mason et al, 2014), suggests that sensory bias could be a plausible hypothesis for the evolution of complex plumages in fruit-eating tanagers.

In Thraupidae, previous studies demonstrated that both natural and sexual selection shape the evolution of plumage coloration (Shultz & Burns, 2017). Here we add an additional layer, diet. Based on our results we propose that in tanagers, adaptations for fruit-eating may have triggered the evolution of complex plumages as frugivores would have favored mates with phenotypes in the range of the diverse colors exhibited in their diets, which in time would have contributed to the spectacular gamut of colors exhibited in the plumages of frugivorous species. Thus, future studies should test whether the colors exhibited in plumages of frugivorous and nectarivorous species are similar to those of the fruits and flowers they consume, or whether they are simply selecting for many colors generally.

Nectarivory as a case study for the sensory bias hypothesis

Nectarivorous tanagers offer great insight into the role that sensory bias may have on the evolution of communication signals within the family. In a similar fashion to fruits, bird-pollinated flowers benefit from possessing conspicuous coloration and structures that enhance detectability (Burd et al., 2014; Stournaras et al., 2013). If sensory bias influences mate choice in tanagers, one would expect that nectarivorous tanagers, although few, would exhibit higher scores of hue disparity than other tanagers, except

for those that feed on fruits. However, our results do not support this hypothesis: we do not find that hue disparity scores were higher in nectarivorous species. In Thraupidae, nectar-feeding specializations have evolved multiple times within different subfamilies (Hewes et al, 2022). Even though the most famous nectarivorous tanagers are those in the flowerpiercer (*Diglossa*) radiation, nectarivory has arisen in the subfamilies Dacninae, Coerebinae, Saltatorinae, and Thraupinae (>25–50% nectar in diet) (Wilman et al., 2014). In tanagers, nectarivory has evolved either from a frugivorous or a granivorous ancestor, except in the case of Coerebinae, where it evolved from an omnivorous ancestor that consumed a high percentage of seeds (Figure S3).

Pairwise marginal effects examining tradeoffs between specific dietary categories suggest plausible explanations for the evolution of plumage coloration in nectar-feeding clades. In these birds, especially males, hue disparity tends to be higher when nectar consumption increases at the expense of seed consumption. On the contrary, hue disparity does not change when nectar consumption rises at the expense of fruit. Based on our data for Thraupidae, we hypothesize that once there is a shift into a diet that includes visually conspicuous items (in this case, sugary food), birds tend to evolve more visually complex plumages. The ancestor of flowerpiercers and other nectar-feeding birds such as Bananaquits (*Coreba flaveola*) was probably a finch-like bird specialized in feeding on seeds and to a lesser extent invertebrates, and this ancestral bird likely had few colors in its plumage (Figure 1; Figure 2). On the other hand, the ancestor of all honeycreepers was probably frugivorous (Figure 2), which could have previously evolved preferences for colorful fruits in the forest. This hypothetical bird would already have evolved colorful plumage, which is further supported by our ancestral state reconstruction analyses (Figure 3). The ancestor of honeycreepers would have previously evolved a diet based on a resource that was likely colorful, and thus the integration of a new resource such as nectar into their diet may have not triggered the evolution of colorful plumages, as this had already happened when frugivory first evolved in the clade.

Appropriate marginal effects for compositional data

Studying how dietary composition affects the evolution of traits is challenging given the nature of compositional data. We show that Bayesian phylogenetic analyses coupled with appropriate techniques for computing marginal effects for shifts within compositions reveal that diet is linked with higher scores of within-plumage color contrast, a proxy for overall colorful plumage. These methods are promising for further stud-

ies seeking to understand evolutionary patterns of diet and other compositional variables, and we hope these methods will assist with further work using databases with percentage-based variables, such as Elton traits, to answer a variety of evolutionary questions (Wilman et al., 2019).

Conclusion

Using plumage reflectance data of the largest oscine radiation, we illustrate how diet correlates with the evolution of visually complex communication signals in birds. Dietary preferences have long been known to be associated with phenotypic evolution in animals, and our results show that this relationship goes beyond feeding adaptations. We tested the sensory bias hypothesis and found a link between hue disparity and diets with different conspicuous colors, suggesting that sensory biases acting on visual signals of species whose diet preferences are rich in conspicuous colors, such as nectarivorous and frugivorous birds, may have enabled the evolution of similarly diverse color patterns in the birds themselves. Fruits and flowers advertise themselves to consumers as they benefit from consumption for dispersion and pollination, respectively, and most plants that depend on birds for these functions use contrasting coloration to advertise their sugary rewards. Birds whose diet have shifted to frugivory or nectarivory probably evolved visual systems apt for detecting contrasting-colored resources in the forest, and these adaptations would over time benefit the evolution of diverse-colored birds as individuals with contrasting plumages would be preferred for mating by the choosing sex's visual system.

There is still much work to be done to successfully understand the different mechanisms behind signal evolution. However, our study demonstrates that introducing appropriate statistical methods for compositional data can reveal undescribed patterns. We show that signal complexity may be mediated by foraging adaptations. Our results support the sensory bias hypothesis, and future work should test this hypothesis in other lineages, in controlled scenarios or with field experiments.

Supplementary material. Supplementary material is available online at *Evolution*.

Data availability. All data associated with this study are already archived in association with previous publications (`https://doi.org/10.5061/dryad.7mj61` & `https://doi.org/10.5061/dryad.g4k83`).

Author contributions. CDA, OL and ARG designed the study, CDA and CA implemented analyses and made the graphs with assistance and support from OL, ARG and AS. AS provided additional data. All authors edited the manuscript and gave approval for publication.

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Supplement to Arcila et al, "The taste for the beautiful: Influence of diet on the evolution of plumage in tanagers."

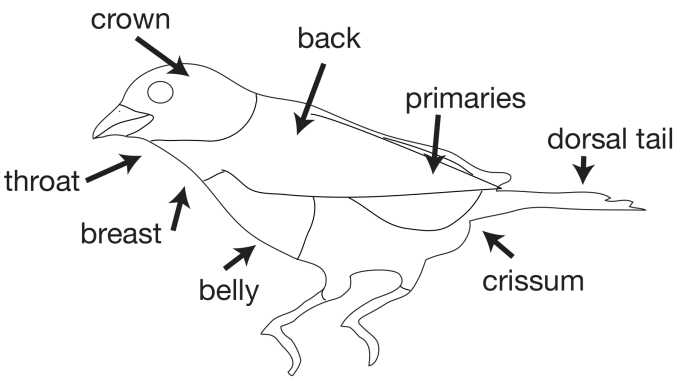

Figure S1. *Examples of patches measured in reflectance data gathering.* For color patches outside those shown, additional measures were taken.

Figure S2. *Correlation plot of the color variables used in Mason et al. (2014).* Average brilliance and average chroma were the variables with the smallest correlations with the other variables. Additionally, we used average hue disparity, as it has the highest correlation scores with the other variables.

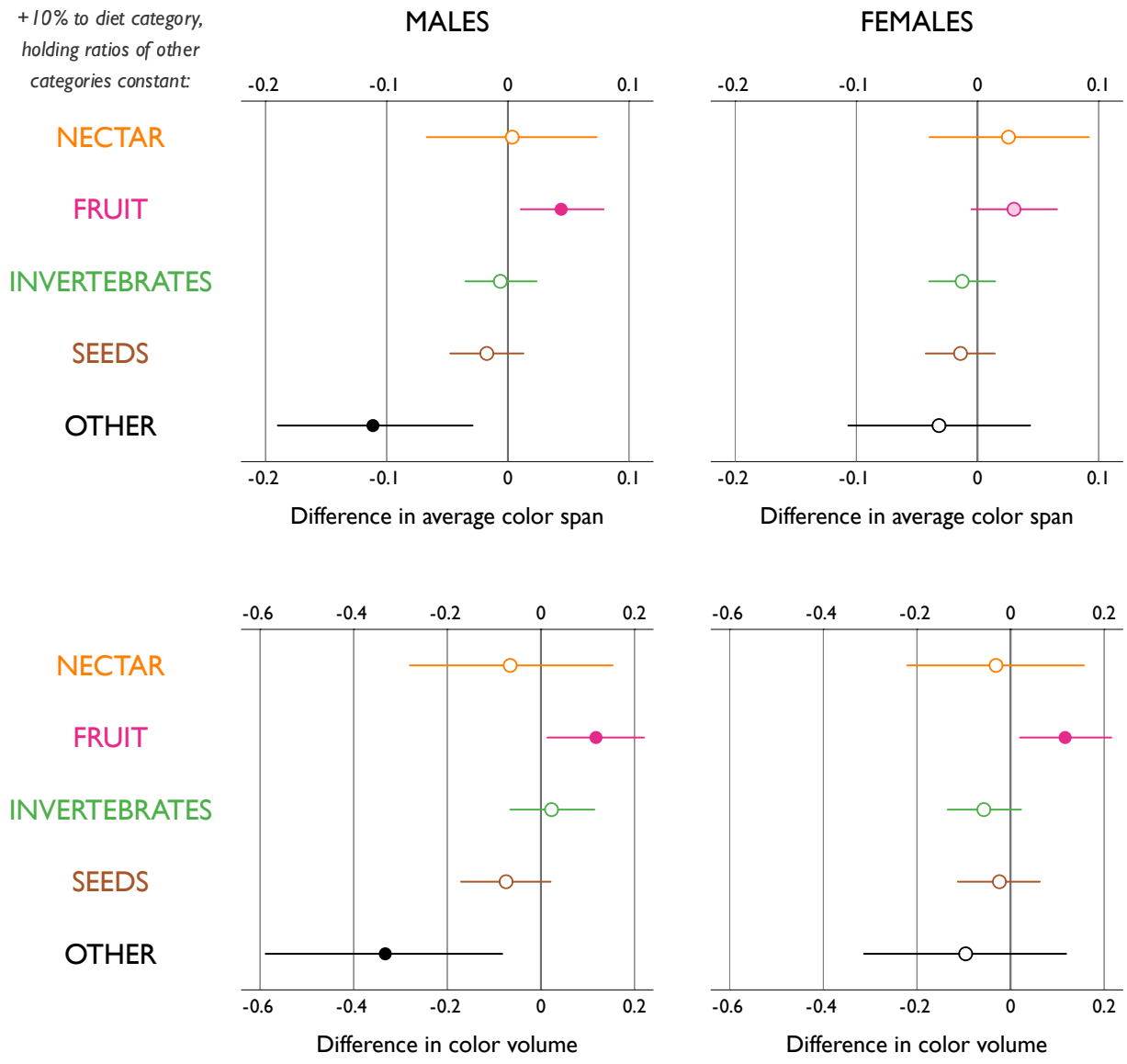

Figure S3. *Marginal effects on average color span and color volume of 10% increases in each dietary component by sex in Thraupidae, with neutral (ratio-preserving) replacement of other diet components.* Filled dots indicate the 95% credible interval does not include zero; shaded dots indicate the 90% credible interval does not include zero. Only increases of fruit are associated with changes in average color span and color volume for both sexes. Estimates computed using coefficients from the Bayesian linear models reported in Tables S2 and S3. Ratio-preserving marginal effects for diet component x_j computed using $\beta_j - \sum_{k \neq j} w_k \beta_k$, where $w_k = \bar{x}_k / \sum_{\ell \neq j} \bar{x}_\ell$ and $\bar{x}_k$ indicates the average diet share across species for category k.

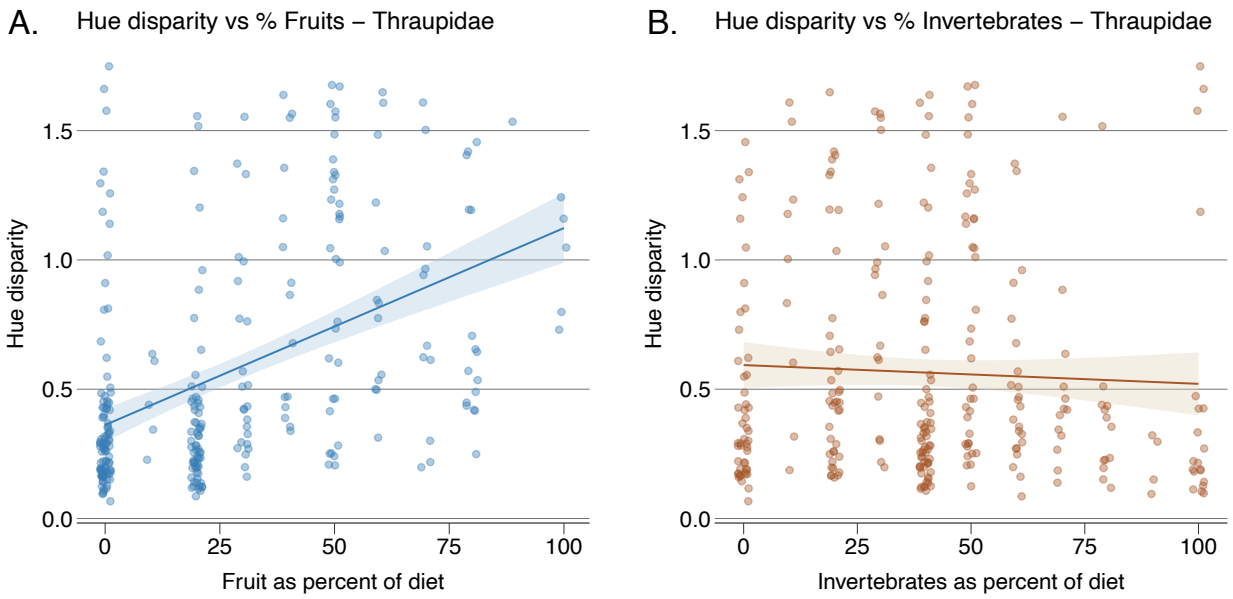

Figure S4. *Linear regression of hue disparity against fruit and invertebrate diet shares for males in Thraupidae.* (A) A positive relationship appears between the amount of fruit ingested and hue disparity; (B) however, this relationship is not found for the amount of invertebrates in diet.

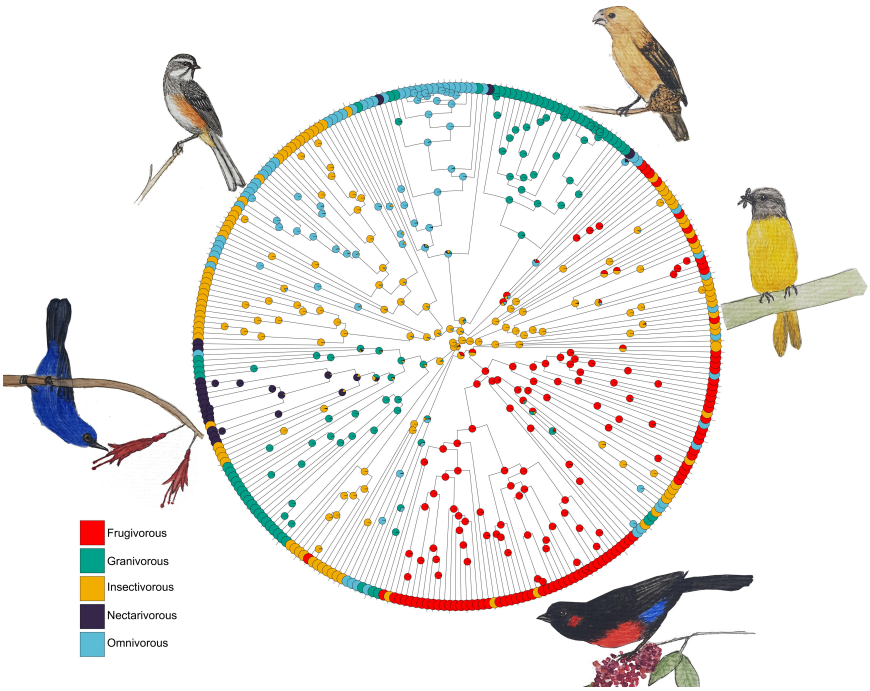

Figure S5. *Ancestral state reconstruction of diet specialization in Thraupidae.* The common ancestor of the family was likely an invertivore. Illustrations are watercolors by Carlos Arcila showing (clockwise from top right): *Sporophila telasco* (Granivore), *Eucometis penicillata* (Insectivore), *Chlorochrysa nitidissima* (Frugivore), *Diglossa glauca* (Nectarivore) and *Poospiza boliviana* (Omnivore).

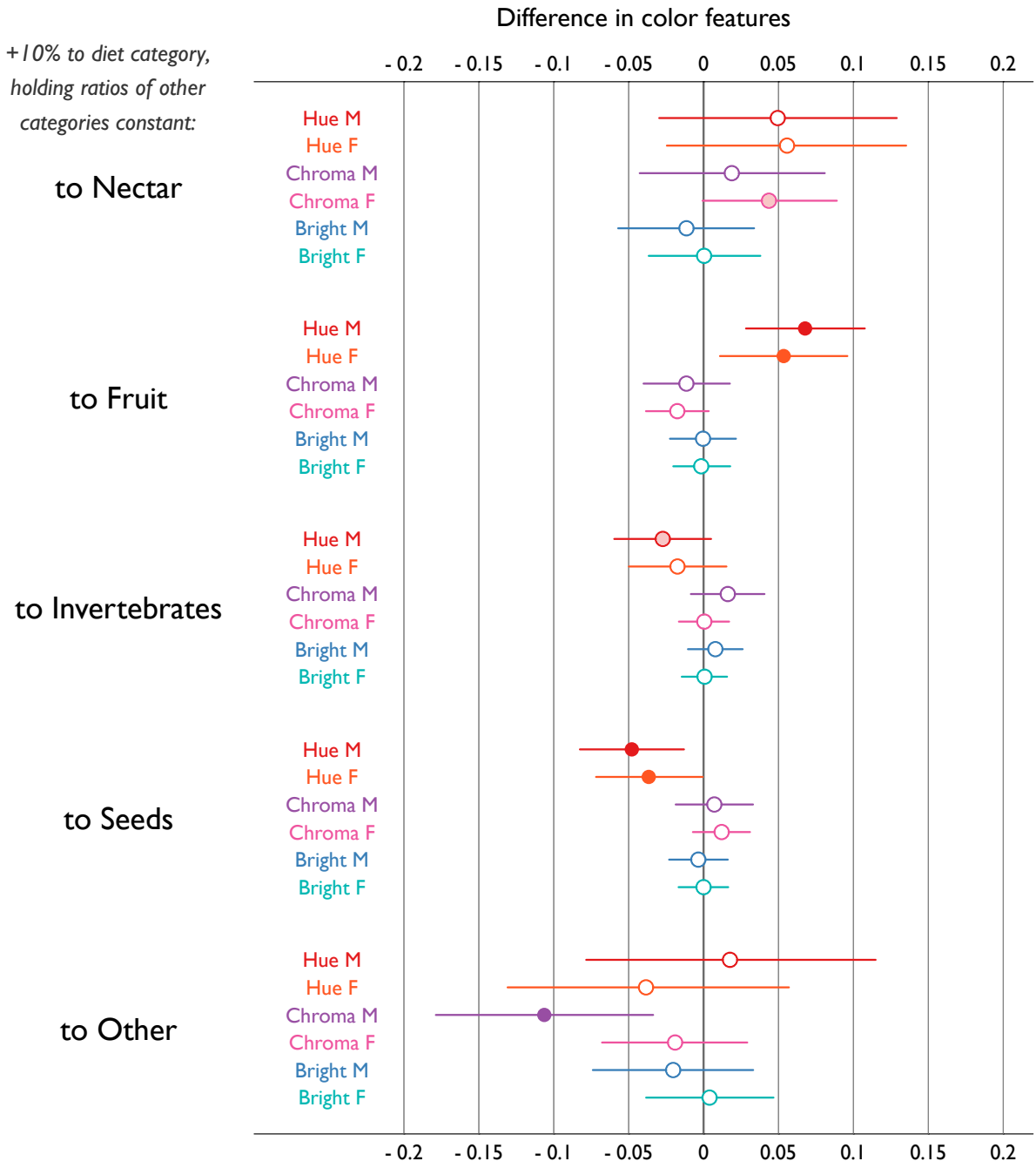

Figure S6. *Marginal effects on hue, chroma, and brilliance of 10% increases in each dietary component by sex in Thraupidae, with neutral (ratio-preserving) replacement of other diet components.* Filled dots indicate the 95% credible interval does not include zero; shaded dots indicate the 90% credible interval does not include zero. Increases in fruit percentages are associated with increases in hue disparity scores for both sexes, whereas seed consumption is associated with decreases in hue disparity for both sexes. Estimates computed using coefficients from the Bayesian linear models reported in Tables S5, S6, and S10. Ratio-preserving marginal effects for diet component x_j computed using $\beta_j - \sum_{k \neq j} w_k \beta_k$ where $w_k = \bar{x}_k / \sum_{\ell \neq j} \bar{x}_\ell$ and $\bar{x}_k$ indicates the average diet share across species for category k.

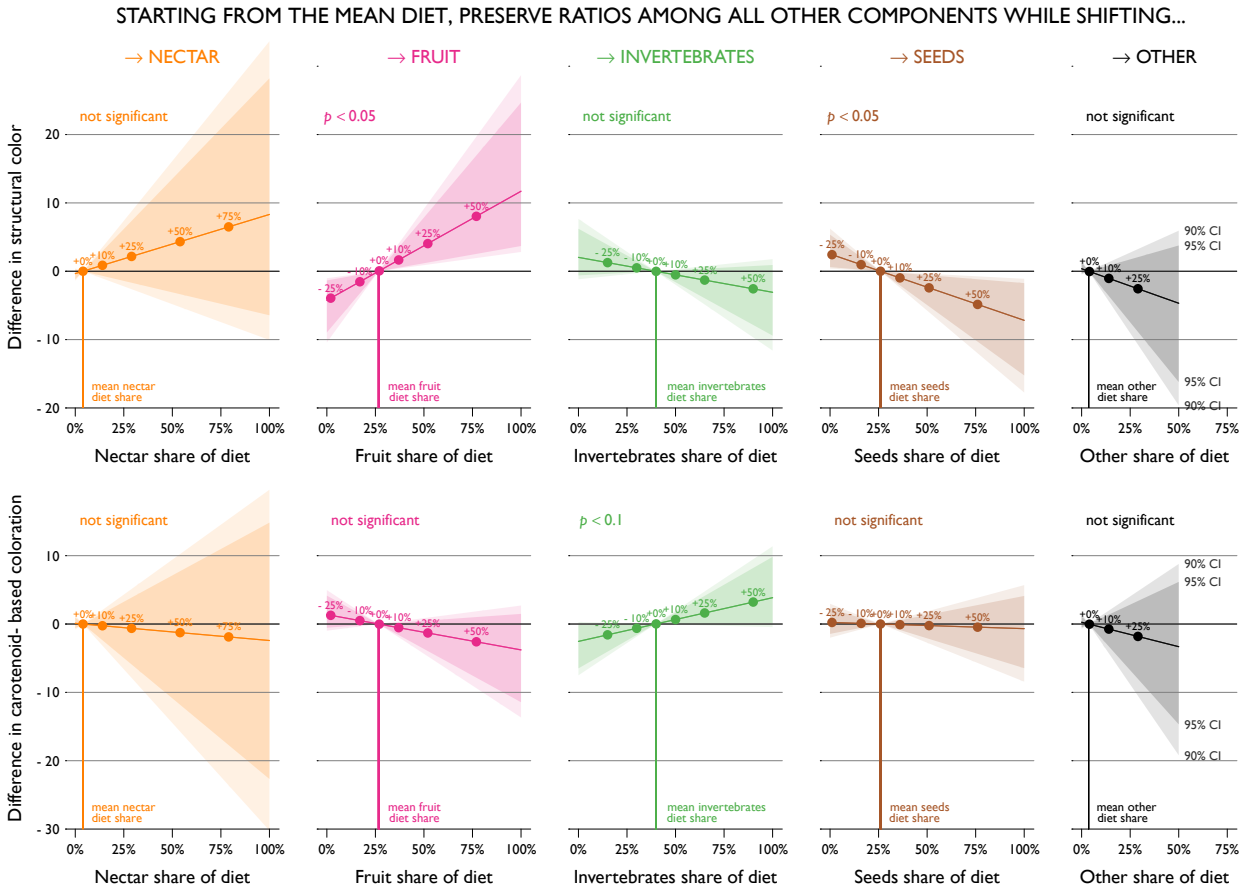

Figure S7. *Marginal effects on the presence of structural coloration (top row) and carotenoid-based coloration (bottom row) of increases in each dietary component by sex in Thraupidae, with neutral (ratio-preserving) replacement of other diet components.* Dark regions indicate 95% credible intervals; lighter regions indicate 90% credible intervals. Estimates computed using coefficients from the Bayesian linear models reported in Table S9. Ratio-preserving marginal effects for diet component x_j computed by multiplying the size of the shift to j by $\beta_j - \sum_{k \neq j} w_k \beta_k$, where $w_k = \bar{x}_k / \sum_{\ell \neq j} \bar{x}_\ell$ and $\bar{x}_k$ indicates the average diet share across species for category k.

Table S1. Diet composition of the 291 species of Thraupids measured. 78 species were frugivorous, 58 were granivorous, 82 insectivorous, 16 nectarivorous, and 57 omnivorous.

	Diet composition (percentages)					
Species	Nectar	Fruit	Invert.	Seed	Other	Diet Type
Anisognathus igniventris	0	50	10	20	70	Frugivorous
Anisognathus lacrymosus	0	80	20	0	80	Frugivorous
Anisognathus notabilis	0	100	0	0	100	Frugivorous
Anisognathus somptuosus	0	50	10	40	50	Frugivorous
Bangsia arcaei	20	60	20	0	80	Frugivorous
Bangsia aureocincta	0	40	40	20	40	Omnivorous
Bangsia edwardsi	0	40	30	30	40	Omnivorous
Bangsia melanochlamys	10	50	20	20	60	Frugivorous
Bangsia rothschildi	20	50	0	30	70	Frugivorous
Buthraupis aureodorsalis	0	50	10	40	50	Frugivorous
Buthraupis eximia	0	50	0	50	50	Frugivorous
Buthraupis montana	0	70	10	20	70	Frugivorous
Buthraupis wetmorei	0	50	50	0	50	Frugivorous
Calochaetes coccineus	0	40	50	10	40	Insectivorous
Camarhynchus heliobates	0	20	40	30	30	Omnivorous
Camarhynchus pallidus	0	20	40	30	30	Omnivorous
Camarhynchus parvulus	0	20	40	30	30	Omnivorous
Camarhynchus pauper	0	20	40	30	30	Omnivorous
Camarhynchus psittacula	0	20	40	30	30	Omnivorous
Catamenia analis	0	0	0	100	0	Granivorous
Catamenia homochroa	0	0	0	50	50	Granivorous
Catamenia inornata	0	0	0	100	0	Granivorous
Certhidea olivacea	0	20	40	30	30	Omnivorous
Chlorochrysa phoenicotis	0	40	60	0	40	Insectivorous
Chlorophanes spiza	10	60	20	0	80	Frugivorous
Chlorornis riefferii	0	30	40	30	30	Omnivorous
Chrysothlypis chrysomelas	0	40	20	40	40	Omnivorous
Chrysothlypis salmoni	0	40	60	0	40	Insectivorous

Table S1. continued.

Species	Diet composition (percentages) Nectar	Fruit	Invert.	Seed	Other	Diet Type
Cissopis leverianus	0	70	30	0	70	Frugivorous
Cnemoscopus rubrirostris	0	0	80	20	0	Insectivorous
Coereba flaveola	70	0	30	0	70	Nectarivorous
Compsospiza baeri	0	20	40	30	30	Omnivorous
Compsothraupis loricata	0	0	100	0	0	Insectivorous
Conirostrum albifrons	0	0	100	0	0	Insectivorous
Conirostrum bicolor	0	0	50	0	50	Insectivorous
Conirostrum cinereum	0	50	50	0	50	Frugivorous
Conirostrum ferrugineiventre	0	10	70	10	20	Insectivorous
Conirostrum rufum	0	0	100	0	0	Insectivorous
Conirostrum sitticolor	0	0	50	50	0	Insectivorous
Conirostrum speciosum	0	10	70	10	20	Insectivorous
Conothraupis speculigera	0	0	70	30	0	Insectivorous
Coryphaspiza melanotis	0	20	40	30	30	Omnivorous
Coryphospingus cucullatus	0	50	0	50	50	Frugivorous
Coryphospingus pileatus	0	0	50	50	0	Insectivorous
Creurgops dentatus	0	0	100	0	0	Insectivorous
Creurgops verticalis	0	20	80	0	20	Insectivorous
Cyanerpes caeruleus	30	30	40	0	60	Nectarivorous
Cyanerpes cyaneus	20	40	40	0	60	Omnivorous
Cyanerpes lucidus	20	40	40	0	60	Omnivorous
Cyanicterus cyanicterus	0	0	100	0	0	Insectivorous
Cypsnagra hirundinacea	0	20	80	0	20	Insectivorous
Dacnis albiventris	0	50	50	0	50	Frugivorous
Dacnis cayana	0	40	50	0	50	Insectivorous
Dacnis flaviventer	20	60	20	0	80	Frugivorous
Dacnis lineata	0	80	20	0	80	Frugivorous
Delothraupis castaneoventris	0	50	50	0	50	Frugivorous
Diglossa albilatera	50	0	40	0	60	Nectarivorous

Table S1. continued.

Species	Diet composition (percentages) Nectar	Fruit	Invert.	Seed	Other	Diet Type
Diglossa baritula	50	0	50	0	50	Nectarivorous
Diglossa brunneiventris	50	0	50	0	50	Nectarivorous
Diglossa caerulescens	10	20	70	0	30	Insectivorous
Diglossa carbonaria	50	0	50	0	50	Nectarivorous
Diglossa cyanea	20	20	60	0	40	Insectivorous
Diglossa glauca	20	30	50	0	50	Insectivorous
Diglossa gloriosa	50	0	50	0	50	Nectarivorous
Diglossa gloriosissima	100	0	0	0	100	Nectarivorous
Diglossa humeralis	50	0	50	0	50	Nectarivorous
Diglossa indigotica	20	30	50	0	50	Insectivorous
Diglossa lafresnayii	50	0	50	0	50	Nectarivorous
Diglossa major	0	0	100	0	0	Insectivorous
Diglossa mystacalis	50	0	50	0	50	Nectarivorous
Diglossa plumbea	50	0	50	0	50	Nectarivorous
Diglossa sittoides	50	0	50	0	50	Nectarivorous
Diuca diuca	0	0	0	100	0	Granivorous
Dolospingus fringilloides	0	0	0	100	0	Granivorous
Donacospiza albifrons	0	20	40	30	30	Omnivorous
Dubusia taeniata	0	40	30	30	40	Omnivorous
Emberizoides herbicola	0	20	40	30	30	Omnivorous
Emberizoides ypiranganus	0	20	40	30	30	Omnivorous
Embernagra platensis	0	20	40	30	30	Omnivorous
Eucometis penicillata	0	20	80	0	20	Insectivorous
Euneornis campestris	30	40	30	0	70	Nectarivorous
Geospiza conirostris	0	20	40	30	30	Omnivorous
Geospiza difficilis	0	20	40	30	30	Omnivorous
Geospiza fortis	0	20	40	30	30	Omnivorous
Geospiza fuliginosa	0	20	40	30	30	Omnivorous
Geospiza magnirostris	0	20	40	30	30	Omnivorous

Table S1. continued.

Species	Diet composition (percentages) Nectar	Fruit	Invert.	Seed	Other	Diet Type
Geospiza scandens	0	20	40	30	30	Omnivorous
Gubernatrix cristata	0	0	0	100	0	Granivorous
Haplospiza rustica	0	0	0	100	0	Granivorous
Haplospiza unicolor	0	0	0	100	0	Granivorous
Hemispingus atropileus	0	0	90	10	0	Insectivorous
Hemispingus calophrys	0	0	90	0	10	Insectivorous
Hemispingus frontalis	0	0	100	0	0	Insectivorous
Hemispingus melanotis	0	0	80	20	0	Insectivorous
Hemispingus parodii	0	0	100	0	0	Insectivorous
Hemispingus rufosuperciliaris	0	0	70	30	0	Insectivorous
Hemispingus superciliaris	0	0	90	10	0	Insectivorous
Hemispingus trifasciatus	0	0	100	0	0	Insectivorous
Hemispingus verticalis	0	20	80	0	20	Insectivorous
Hemispingus xanthophthalmus	0	0	100	0	0	Insectivorous
Hemithraupis flavicollis	0	40	60	0	40	Insectivorous
Hemithraupis guira	0	10	80	10	10	Insectivorous
Hemithraupis ruficapilla	0	20	80	0	20	Insectivorous
Heterospingus xanthopygius	0	20	70	10	20	Insectivorous
Idiopsar brachyurus	0	20	40	30	30	Omnivorous
Incaspiza ortizi	0	20	40	30	30	Omnivorous
Incaspiza personata	0	20	40	30	30	Omnivorous
Incaspiza pulchra	0	20	40	30	30	Omnivorous
Iridosornis analis	0	30	40	30	30	Omnivorous
Iridosornis jelskii	0	50	30	20	50	Frugivorous
Iridosornis porphyrocephalus	0	100	0	0	100	Frugivorous
Iridosornis rufivertex	0	50	50	0	50	Frugivorous
Lanio aurantius	0	0	100	0	0	Insectivorous
Lanio fulvus	0	0	80	20	0	Insectivorous
Lanio leucothorax	0	30	70	0	30	Insectivorous

Table S1. continued.

Species	Diet composition (percentages) Nectar	Fruit	Invert.	Seed	Other	Diet Type
Lanio versicolor	0	30	70	0	30	Insectivorous
Lophospingus griseocristatus	0	20	40	30	30	Omnivorous
Lophospingus pusillus	0	20	40	30	30	Omnivorous
Loxigilla noctis	0	20	40	30	30	Omnivorous
Loxigilla portoricensis	0	20	40	30	30	Omnivorous
Loxigilla violacea	0	20	40	30	30	Omnivorous
Loxipasser anoxanthus	0	20	40	30	30	Omnivorous
Melanodera melanodera	0	0	0	50	50	Granivorous
Melanodera xanthogramma	0	0	0	50	50	Granivorous
Melopyrrha nigra	0	20	40	30	30	Omnivorous
Nemosia pileata	0	0	100	0	0	Insectivorous
Neothraupis fasciata	0	10	80	10	10	Insectivorous
Nephelornis oneilli	0	0	90	0	10	Insectivorous
Orchesticus abeillei	0	0	100	0	0	Insectivorous
Oreomanes fraseri	20	0	80	0	20	Insectivorous
Oryzoborus angolensis	0	20	0	60	40	Granivorous
Oryzoborus crassirostris	0	0	0	100	0	Granivorous
Oryzoborus funereus	0	20	0	60	40	Granivorous
Oryzoborus maximiliani	0	0	0	100	0	Granivorous
Oryzoborus nuttingi	0	10	0	80	20	Granivorous
Parkerthraustes humeralis	0	80	20	0	80	Frugivorous
Paroaria capitata	0	20	60	0	40	Insectivorous
Paroaria coronata	0	20	60	0	40	Insectivorous
Paroaria dominicana	0	20	60	0	40	Insectivorous
Paroaria gularis	0	20	60	0	40	Insectivorous
Phrygilus alaudinus	0	0	0	100	0	Granivorous
Phrygilus atriceps	0	0	0	100	0	Granivorous
Phrygilus carbonarius	0	0	0	100	0	Granivorous
Phrygilus fruticeti	0	0	0	100	0	Granivorous

Table S1. continued.

Species	Diet composition (percentages) Nectar	Fruit	Invert.	Seed	Other	Diet Type
Phrygilus patagonicus	0	0	0	100	0	Granivorous
Phrygilus plebejus	0	0	0	100	0	Granivorous
Phrygilus punensis	0	0	0	100	0	Granivorous
Phrygilus unicolor	0	0	0	100	0	Granivorous
Pinaroloxias inornata	0	20	40	30	30	Omnivorous
Pipraeidea melanonota	0	50	30	20	50	Frugivorous
Platyspiza crassirostris	0	20	40	30	30	Omnivorous
Poospiza cabanisi	0	20	40	30	30	Omnivorous
Poospiza caesar	0	20	40	30	30	Omnivorous
Poospiza cinerea	0	20	40	30	30	Omnivorous
Poospiza erythrophrys	0	20	40	30	30	Omnivorous
Poospiza hispaniolensis	0	20	40	30	30	Omnivorous
Poospiza hypochondria	0	20	40	30	30	Omnivorous
Poospiza melanoleuca	0	20	40	30	30	Omnivorous
Poospiza nigrorufa	0	20	40	30	30	Omnivorous
Poospiza ornata	0	20	40	30	30	Omnivorous
Poospiza thoracica	0	20	40	30	30	Omnivorous
Poospiza torquata	0	20	40	30	30	Omnivorous
Porphyrospiza caerulescens	0	20	40	30	30	Omnivorous
Pyrrhocoma ruficeps	0	0	100	0	0	Insectivorous
Ramphocelus bresilius	0	50	50	0	50	Frugivorous
Ramphocelus dimidiatus	0	40	30	30	40	Omnivorous
Ramphocelus melanogaster	0	60	40	0	60	Frugivorous
Ramphocelus nigrogularis	0	50	50	0	50	Frugivorous
Ramphocelus sanguinolentus	0	20	40	30	30	Omnivorous
Rhodospingus cruentus	0	20	40	30	30	Omnivorous
Saltator albicollis	10	30	60	0	40	Insectivorous
Saltator atriceps	10	30	60	0	40	Insectivorous
Saltator atricollis	10	30	60	0	40	Insectivorous

Table S1. continued.

Species	Diet composition (percentages) Nectar	Fruit	Invert.	Seed	Other	Diet Type
Saltator atripennis	10	30	60	0	40	Insectivorous
Saltator aurantiirostris	10	30	60	0	40	Insectivorous
Saltator cinctus	10	30	60	0	40	Insectivorous
Saltator coerulescens	0	0	100	0	0	Insectivorous
Saltator fuliginosus	10	30	60	0	40	Insectivorous
Saltator grossus	10	30	60	0	40	Insectivorous
Saltator maxillosus	10	30	60	0	40	Insectivorous
Saltator maximus	10	30	60	0	40	Insectivorous
Saltator nigriceps	10	30	60	0	40	Insectivorous
Saltator orenocensis	30	40	0	0	100	Nectarivorous
Saltator rufiventris	10	30	60	0	40	Insectivorous
Saltator similis	10	30	60	0	40	Insectivorous
Saltator striatipectus	0	0	70	0	30	Insectivorous
Saltatricula multicolor	0	20	40	30	30	Omnivorous
Schistochlamys melanopis	0	50	50	0	50	Frugivorous
Schistochlamys ruficapillus	0	50	50	0	50	Frugivorous
Sericossypha albocristata	0	20	70	10	20	Insectivorous
Sicalis auriventris	0	0	0	100	0	Granivorous
Sicalis citrina	0	0	0	100	0	Granivorous
Sicalis columbiana	0	0	0	100	0	Granivorous
Sicalis flaveola	0	0	0	100	0	Granivorous
Sicalis lebruni	0	0	0	100	0	Granivorous
Sicalis lutea	0	0	0	100	0	Granivorous
Sicalis luteocephala	0	0	0	100	0	Granivorous
Sicalis luteola	0	0	0	100	0	Granivorous
Sicalis olivascens	0	0	0	100	0	Granivorous
Sicalis uropygialis	0	0	0	100	0	Granivorous
Sporophila albogularis	0	0	20	80	0	Granivorous
Sporophila bouvreuil	0	0	0	100	0	Granivorous

Table S1. continued.

Species	Diet composition (percentages) Nectar	Fruit	Invert.	Seed	Other	Diet Type
Sporophila caerulescens	0	0	20	80	0	Granivorous
Sporophila castaneiventris	0	0	20	80	0	Granivorous
Sporophila cinnamomea	0	0	20	80	0	Granivorous
Sporophila collaris	0	0	20	80	0	Granivorous
Sporophila corvina	0	0	20	80	0	Granivorous
Sporophila frontalis	0	0	20	80	0	Granivorous
Sporophila hypochroma	0	0	20	80	0	Granivorous
Sporophila hypoxantha	0	0	20	80	0	Granivorous
Sporophila intermedia	0	0	20	80	0	Granivorous
Sporophila leucoptera	0	0	20	80	0	Granivorous
Sporophila lineola	0	0	0	100	0	Granivorous
Sporophila luctuosa	0	0	20	80	0	Granivorous
Sporophila minuta	0	0	10	90	0	Granivorous
Sporophila nigricollis	0	0	20	80	0	Granivorous
Sporophila peruviana	0	0	20	80	0	Granivorous
Sporophila plumbea	0	0	20	80	0	Granivorous
Sporophila ruficollis	0	0	20	80	0	Granivorous
Sporophila schistacea	0	0	20	80	0	Granivorous
Sporophila torqueola	0	0	20	80	0	Granivorous
Stephanophorus diadematus	0	50	20	0	80	Frugivorous
Tachyphonus coronatus	0	20	60	20	20	Insectivorous
Tachyphonus cristatus	0	50	30	10	60	Frugivorous
Tachyphonus luctuosus	0	20	80	0	20	Insectivorous
Tachyphonus rufiventer	0	50	50	0	50	Frugivorous
Tachyphonus rufus	0	30	60	10	30	Insectivorous
Tachyphonus surinamus	0	40	50	10	40	Insectivorous
Tangara argyrofenges	0	50	50	0	50	Frugivorous
Tangara arthus	0	60	40	0	60	Frugivorous
Tangara callophrys	0	80	20	0	80	Frugivorous

Table S1. continued.

Species	Diet composition (percentages) Nectar	Fruit	Invert.	Seed	Other	Diet Type
Tangara cayana	0	90	10	0	90	Frugivorous
Tangara chilensis	0	80	20	0	80	Frugivorous
Tangara chrysotis	0	70	30	0	70	Frugivorous
Tangara cucullata	0	60	40	0	60	Frugivorous
Tangara cyanicollis	0	80	20	0	80	Frugivorous
Tangara cyanocephala	0	100	0	0	100	Frugivorous
Tangara cyanoptera	0	80	20	0	80	Frugivorous
Tangara cyanotis	0	80	20	0	80	Frugivorous
Tangara cyanoventris	0	50	50	0	50	Frugivorous
Tangara desmaresti	0	60	40	0	60	Frugivorous
Tangara dowii	0	50	50	0	50	Frugivorous
Tangara florida	0	70	30	0	70	Frugivorous
Tangara guttata	0	70	30	0	70	Frugivorous
Tangara gyrola	0	70	30	0	70	Frugivorous
Tangara heinei	0	80	20	0	80	Frugivorous
Tangara icterocephala	0	80	20	0	80	Frugivorous
Tangara inornata	0	60	40	0	60	Frugivorous
Tangara labradorides	0	30	70	0	30	Insectivorous
Tangara larvata	0	60	40	0	60	Frugivorous
Tangara mexicana	0	50	50	0	50	Frugivorous
Tangara nigrocincta	0	80	20	0	80	Frugivorous
Tangara nigroviridis	0	20	80	0	20	Insectivorous
Tangara palmeri	0	80	20	0	80	Frugivorous
Tangara parzudakii	0	60	40	0	60	Frugivorous
Tangara preciosa	0	60	40	0	60	Frugivorous
Tangara punctata	0	70	30	0	70	Frugivorous
Tangara rufigula	0	70	30	0	70	Frugivorous
Tangara schrankii	0	60	20	20	60	Frugivorous
Tangara seledon	0	80	20	0	80	Frugivorous

Table S1. continued.

Species	Diet composition (percentages) Nectar	Fruit	Invert.	Seed	Other	Diet Type
Tangara varia	0	50	50	0	50	Frugivorous
Tangara vassorii	0	70	30	0	70	Frugivorous
Tangara velia	0	100	0	0	100	Frugivorous
Tangara viridicollis	0	50	50	0	50	Frugivorous
Tangara vitriolina	0	30	70	0	30	Insectivorous
Tangara xanthocephala	0	80	20	0	80	Frugivorous
Tangara xanthogastra	0	50	50	0	50	Frugivorous
Tersina viridis	0	70	30	0	70	Frugivorous
Thlypopsis fulviceps	0	0	100	0	0	Insectivorous
Thlypopsis inornata	0	0	100	0	0	Insectivorous
Thlypopsis ornata	0	0	100	0	0	Insectivorous
Thlypopsis pectoralis	0	0	100	0	0	Insectivorous
Thlypopsis ruficeps	0	0	100	0	0	Insectivorous
Thlypopsis sordida	0	30	50	20	30	Insectivorous
Thraupis abbas	0	50	50	0	50	Frugivorous
Thraupis bonariensis	0	80	0	10	90	Frugivorous
Thraupis cyanocephala	0	70	30	0	70	Frugivorous
Thraupis cyanoptera	0	100	0	0	100	Frugivorous
Thraupis episcopus	0	50	40	0	60	Frugivorous
Thraupis ornata	0	80	20	0	80	Frugivorous
Thraupis palmarum	10	60	10	20	70	Frugivorous
Thraupis sayaca	0	50	10	40	50	Frugivorous
Tiaris bicolor	0	0	10	70	20	Granivorous
Tiaris fuliginosus	0	0	0	90	10	Granivorous
Tiaris obscurus	0	0	0	100	0	Granivorous
Tiaris olivaceus	0	0	0	90	10	Granivorous
Trichothraupis melanops	0	20	70	10	20	Insectivorous
Volatinia jacarina	0	20	40	30	30	Omnivorous
Wetmorethraupis sterrhopteron	0	50	50	0	50	Frugivorous

Table S1. continued.

	Diet composition (percentages)					
Species	Nectar	Fruit	Invert.	Seed	Other	Diet Type
Xenodacnis parina	40	20	40	0	60	Nectarivorous
Xenospingus concolor	0	20	40	30	30	Omnivorous

Table S2. Bayesian linear model estimates of plumage average color span across species of Thraupidae for each sex as a function of diet composition and habitat.

	Average Color Span (Males)			Average Color Span (Females)		
	est	95% CI	*p*	est	95% CI	*p*
Nectar	0.011	±0.01	0.038	0.0055	±0.009	0.23
Fruit	0.038	±0.008	0.005	0.005	±0.008	0.22
Invertebrates	0.01	±0.008	0.01	0.002	±0.007	0.55
Seed	0.009	±0.001	0.02	0.002	±0.007	0.59
Understory × Canopy	0.01	±0.25	0.88	-0.08	±0.23	0.15
Understory × Open	-0.35	±0.27	0.014	-0.41	±0.26	0.005
Intercept	-3.42	±0.827	0.005	3.58	±1.51	0.005
N	291			291		
DIC	351.622			292.705		

95% credible intervals and pseudo *p*-values are shown for each estimated coefficent. Entries in blue are deemed "significant"; i.e., the 95% credible interval does not include zero. However, because dietary variables are compositional, care should be taken in interpreting marginal effects, which for most hypothetical changes in diet depend on the combination of multiple non-zero diet coefficients (See Figure S3, top). DIC is the deviance information criterion. Estimation by `MCMCglmm`.

Table S3. Bayesian linear model estimates of plumage color volume across species of Thraupidae for each sex as a function of diet composition and habitat.

	Volume (Males)			Volume (Females)		
	est	95% CI	*p*	est	95% CI	*p*
Nectar	0.02	±0.03	0.11	0.006	±0.027	0.65
Fruit	0.04	±0.026	0.008	0.01	±0.02	0.13
Invertebrates	0.03	±0.02	0.01	0.005	±0.02	0.61
Seed	0.026	±0.024	0.039	0.007	±0.02	0.52
Understory × Canopy	0.41	±0.72	0.28	0.53	±0.69	0.14
Understory × Open	-0.077	±0.84	0.84	-0.46	±0.81	0.25
Intercept	14.05	±2.37	0.005	-11.94	±2.26	0.005
N		291			291	
DIC		920.1			859.73	

95% credible intervals and pseudo *p*-values are shown for each estimated coefficent. Entries in blue are deemed "significant"; i.e., the 95% credible interval does not include zero. However, because dietary variables are compositional, care should be taken in interpreting marginal effects, which for most hypothetical changes in diet depend on the combination of multiple non-zero diet coefficients (See Figure S3, bottom). DIC is the deviance information criterion. Estimation by `MCMCglmm`.

Table S4. Bayesian linear model estimates of plumage hue disparity across species of Thraupidae for each sex as a function of fruit as a percentage of diet.

	Hue Disparity (Males)			Hue Disparity (Females)		
	est	95% CI	*p*	est	95% CI	*p*
Fruit	0.0055	[0.0015, 0.0096]	0.008	0.00713	[0.0033, 0.01096]	<0.001
Intercept	-1.354	[-1.6411, -1.0767]	<0.001	-0.92737	[-1.1989, -0.6518]	<0.001
N		291			291	
DIC		362.098			332.856	

95% credible intervals and pseudo *p*-values are shown for each estimated coefficent. Entries in blue are deemed "significant"; i.e., the 95% credible interval does not include zero. DIC is the deviance information criterion. Estimation by `MCMCglmm`.

Table S5. Bayesian linear model estimates of plumage hue disparity across species of Thraupidae for each sex as a function of diet composition and habitat.

	Hue Disparity (Males)			Hue Disparity (Females)		
	est	95% CI	*p*	est	95% CI	*p*
Nectar	0.003	±0.011	0.60	0.009	±0.011	0.12
Fruit	0.003	±0.009	0.53	0.007	±0.0094	0.12
Invertebrates	-0.003	±0.009	0.48	0.002	±0.009	0.57
Seed	-0.005	±0.009	0.26	0.001	±0.009	0.82
Understory × Canopy	-0.13	±0.28	0.36	-0.085	±0.28	0.56
Understory × Open	-0.15	±0.31	0.35	-0.21	±0.30	0.19
Intercept	-0.43	±0.96	0.38	-1.45	± 0.94	0.006
N		291			291	
DIC		373			348.14	

95% credible intervals and pseudo *p*-values are shown for each estimated coefficent. Entries in blue are deemed "significant"; i.e., the 95% credible interval does not include zero. However, because dietary variables are compositional, care should be taken in interpreting marginal effects, which for most hypothetical changes in diet depend on the combination of multiple non-zero diet coefficients (See Figure S6). DIC is the deviance information criterion. Estimation by `MCMCglmm`.

Table S6. Bayesian linear model estimates of plumage brilliance across species of Thraupidae for each sex as a function of diet composition and habitat.

	Brilliance (Males)			Brilliance (Females)		
	est	95% CI	*p*	est	95% CI	*p*
Nectar	0.0009	±0.005	0.795	-0.00029	±0.005	0.901
Fruit	0.002	±0.005	0.49	-0.0004	±0.004	0.83
Invertebrates	0.0025	±0.005	0.36	-0.0003	±0.004	0.88
Seed	0.001	±0.005	0.53	-0.0004	±0.004	0.83
Understory × Canopy	0.08	±0.166	0.36	0.09	±0.13	0.19
Understory × Open	0.189	±0.184	0.05	0.23	±0.14	0.006
Intercept	-2.21	±0.55	0.005	-1.98	±0.44	0.005
N		291			291	
DIC		62.05			-103.39	

95% credible intervals and pseudo *p*-values are shown for each estimated coefficent. Entries in blue are deemed "significant"; i.e., the 95% credible interval does not include zero. However, because dietary variables are compositional, care should be taken in interpreting marginal effects, which for most hypothetical changes in diet depend on the combination of multiple non-zero diet coefficients (See Figure S6). DIC is the deviance information criterion. Estimation by `MCMCglmm`.

Table S7. Bayesian linear model estimates of plumage variables across species of Thraupidae for each sex as a function of diet conspicuousness scores.

	Hue Disparity		Chroma		Brilliance	
	Male	Female	Male	Female	Male	Female
Diet conspicuousness	0.099 [0.045, 0.157]	0.066 [0.009, 0.124]	-0.014 [-0.061, 0.029]	-0.001 [-0.032, 0.028]	-0.009 [-0.044, 0.017]	-0.017 [-0.045, 0.003]
Intercept	-0.638 [-0.858, -0.379]	-1.145 [-1.42, -0.088]	-2.291 [-2.124, -2.505]	-2.169 [-2.307, -1.99]	-1.908 [-2.059, -1.772]	-1.904 [-2.031, -1.794]
N	291	291	291	291	291	291

95% credible intervals are shown below each estimated coefficent. Entries in blue are deemed "significant"; i.e., the 95% credible interval does not include zero. DIC is the deviance information criterion. Estimation by `MCMCglmm`.

Table S8. Bayesian linear model estimates of plumage hue disparity across species of Thraupidae as a function of pigmentation type.

	Hue Disparity		
	est	95% CI	*p*
Carotenoid-based color	-0.05	±0.14	0.49
Structural color	1.07	±0.17	0.005
Intercept	-1.16	±0.20	0.005
N		291	
DIC		343.82	

95% credible intervals and pseudo *p*-values estimated are shown for each estimated coefficent. Entries in blue are deemed "significant"; i.e., the 95% credible interval does not include zero. DIC is the deviance information criterion. Estimation by `MCMCglmm`.

Table S9. Bayesian linear model estimates of structural coloration across species of Thraupidae as a function of diet compositon.

	Structural Color			Carotenoid-based Color		
	est	95% CI	*p*	est	95% CI	*p*
Nectar	0.143	[-0.060, 0.431]	0.161	-0.025	[-0.440, 0.373]	0.859
Fruit	0.159	[-0.022, 0.422]	0.075	-0.032	[-0.380, 0.025]	0.884
Invertebrates	0.055	[-0.133, 0.249]	0.472	0.056	[-0.237, 0.396]	0.688
Seeds	0.020	[-0.191, 0.207]	0.774	0.008	[-0.253, 0.359]	0.955
Intercept	-10.347	[-30.095, 7.862]	0.251	-1.744	[-34.419, 25.055]	0.915
N		291			291	
DIC		104.045			98.927	

95% credible intervals and pseudo *p*-values estimated are shown for each estimated coefficent. Entries in blue are deemed "significant"; i.e., the 95% credible interval does not include zero. However, because dietary variables are compositional, care should be taken in interpreting marginal effects, which for most hypothetical changes in diet depend on the combination of multiple non-zero diet coefficients (See Figure 5 in the main text). DIC is the deviance information criterion. Estimation by `MCMCglmm`.

Table S10. Bayesian linear model estimates of plumage chroma across species of Thraupidae for each sex as a function of diet composition and habitat.

	Chroma (Males)			Chroma (Females)		
	est	95% CI	*p*	est	95% CI	*p*
Nectar	0.012	± 0.008	0.011	0.005	±0.006	0.06
Fruit	0.009	± 0.007	0.001	0.0004	±0.005	0.85
Invertebrates	0.01	± 0.007	0.005	0.001	±0.004	0.49
Seed	0.0109	± 0.007	0.006	0.002	±0.004	0.25
Understory × Canopy	-0.056	±0.203	0.60	0.02	±0.144	0.77
Understory × Open	-0.21	±0.23	0.07	-0.1	±0.15	0.18
Intercept	-3.19	± 0.7	0.005	-2.3	± 0.48	0.005
N		291			291	
DIC		189.02			-144.72	

95% credible intervals and pseudo *p*-values are shown for each estimated coefficent. Entries in blue are deemed "significant"; i.e., the 95% credible interval does not include zero. However, because dietary variables are compositional, care should be taken in interpreting marginal effects, which for most hypothetical changes in diet depend on the combination of multiple non-zero diet coefficients (See Figure S6). DIC is the deviance information criterion. Estimation by `MCMCglmm`.