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Supplementary material

Appendix 1

Plumage color measurements: Dove visual system, detailed methods and repeatability of the measures

Table A1. Mean and standard deviation (s.d.) values for each color parameter. “I.p.” stands for “Iridescent patch”.

Table A2. Matrices of Spearman’ rank correlation among color parameters in Zenaida doves. Upper diagonal part contains correlation coefficient estimates and lower diagonal part contains corresponding *P*-values. The *P*-values in bold are significant at $P < 0.05$.

Table A3. Effect of ringing sessions on color parameters of Zenaida doves: results of ANOVAs and corresponding Tukey’s post hoc tests. P-values in bold are significant at $P < 0.0111$ after a BY-FDR correction. HBS is for “high breeding season” and LBS is for “low breeding season”.

Discussion on the differences in color parameters between sessions

Table A4. Color distances (ΔS, chromatic contrasts of the reflectance spectra, Vorobyev et al. 1998) in units of just noticeable differences (JNDs) as viewed by rock dove visual system, calculated between all pairs of male/female, and all pairs of individuals within each sex for each measured body part. Minimum, mean ± s.d. and maximum values are given, with mean ΔS values > 1 highlighted in bold.

Figure A1. Reflectance spectra of Zenaida dove for (a) crown, (b), mantle, (c) breast, (d) belly, (e) dark streaks and (f) iridescent patches. Mean lines are in solid bold for females and dashed bold for males. Shaded areas (in dark grey for females and light grey for males) represent 95% confidence interval. Transparency of the shaded areas highlights the confidence interval overlap. Thin lines precisely distinguish the shaded areas (solid lines for females and dashed lines for males). See Supplementary materials for detailed methods of plumage color measurements.

Figure A2. Histograms of hue distribution for (a) crown, (b) mantle, (c) breast and (d) belly with data separated between sexes: females are in dark grey and males in light grey. Color-corresponding dot-dashed lines represent mean of each category. Stars signal significant differences between means.

Figure A3. Histograms of brightness distribution for (a) crown, (b) mantle, (c) breast, (d) belly and (e) dark streak with data separated by territorial status: non territorial individuals are in dark grey and territorial individuals are in light grey. The dot-dashed lines of corresponding colors represent the mean of each category. Stars and point signal significant differences and tendency between means, respectively.

Figure A4. Plots of color distances ΔS in units of just noticeable differences (JNDs) (a) among females and (b) among males, as viewed by the rock dove visual system. Dots and error bars indicate mean ± standard deviation chromatic distances between all pairs of different individuals. The dashed line marks JND = 1 above which the pair of color patches is considered to be discernible by birds.

Fig. A5. Plots of color distances ΔS in units of just noticeable differences (JNDs), between males and females as viewed by rock dove visual system, for (a) high breeding season 2012, (b) low breeding season 2012 and (c) high breeding season 2013 field sessions. Dots and error bars indicate mean ± standard deviation chromatic distances between all pairs of different sexes. The dashed line marks JND = 1, above which the pair of color patches is considered to be discernible by birds.

Fig. A6. Plots of color distances ΔS in units of just noticeable differences (JNDs), among females (left panel) and males (right panel) as viewed by rock dove visual system, for (a) high breeding season 2012, (b) low breeding season 2012 and (c) high breeding season 2013 field sessions. Dots and error bars indicate mean ± standard deviation chromatic distances between all pairs of different sexes. The dashed line marks JND = 1, above which the pair of color patches is considered to be discernible by birds.

Plumage color measurements

Dove visual system

Birds are tetrachromatic, and are better able to discriminate colors in the human visible light spectrum (400-700 nm), because the sensitivity functions of their visual pigments show less overlap than those of humans, in part due to oil droplets associated with their cone cells acting to sharpen color vision (Vorobyev 2003). Oil droplets indeed enhance color discrimination by reducing the overlap in sensitivity between visual pigments (Hart and Hunt 2007). As compared to humans, they possess an additional cell cone type in the retina, receptive to ultraviolet light (UV, 300-400nm, Chen et al. 1984). It has been shown that all avian families display feathers reflecting significant amount of UV light (Eaton and Lanyon 2003), and 15 out of 23 bird orders are able to detect UV information (see Table 1 in Mullen and Pohland 2008 for detailed references). This is particularly true of Columbidae species. For instance, the Rock pigeon (*Columba livia*) can see in the UV part of the spectrum as far as 320 nm (e.g. Blough 1957, Kreithen and Eisner 1978, Kawamura et al. 1999). However, although they can distinguish UV light, Columbidae possess the "VS" rather the "UVS" cone type, indicating that their maximum light absorption ranges between 402 and 426 nm rather than between 355 and 380 nm (Ödeen and Håstad 2013). Given that the closely related Wompoo fruit dove (*Ptilinopus magnificus*) presents a "VS" cone type (Ödeen and Håstad 2013) as well, it is likely that the Zenaida dove's vision is also sensitive to UV light, with, presumably, a "VS" visual system.

Detailed methods

Feather coloration was assessed in the field using an Ocean Optics JAZ-EL200 spectrometer. It was supplied with a Jaz PX pulsed short arc Xenon lamp module and a 400 µm fibre-optic probe (QR400-7-SR-BX) fitted with a self-made black cap that insulated the probe from the surrounding light and kept it at a constant distance (2 mm) and a constant angle (90°) from the plumage surface. Iridescence is classically assessed in the lab using varying angles of feather illumination (Andersson and Prager 2006, Meadows et al. 2011). Given the relatively small size of iridescent patches displayed by the Zenaida dove (Fig.1b), we preferred not to sample feathers, but rather measured color directly on live birds in the field. In that case, the ideal procedure is impractical. We therefore used the same 90° angle of illumination as for other body parts, following recommendation by Andersson and Prager (2006), as coincident normal measuring appears to be the most easily standardized method when using a handheld probe (as reflected by the very high and significant values of repeatability obtained for measures of reflectance of the iridescent patch, see below).

Calibration was made before measuring each bird using a Spectralon white standard (WS-1-SL, Labsphere) and a piece of black velvet. To survey the complete spectral range covered by avian vision, reflectance spectra were recorded from 300 nm to 700 nm, with percentage of reflectance at each 0.4 nm interval calculated with respect to white and dark references, as $R(\lambda) = 100 \times [(\text{sample} - \text{white}) / (\text{white} - \text{dark})]$. The white standard was cleaned according to the manufacturer's instruction before each session, to ensure maximum reflectance in the ultraviolet range, as any dirt or wear will decrease its UV reflectance and consequently increase UV reflectance of the sample measured. It is therefore to be kept in mind that the shape and intensity of reflectance in the UV depends on the quality of the white standard used. Data acquired by the spectrometer were concurrently sent to a computer and monitored with the software Spectrasuite (all equipment purchased from Ocean Optics, IDIL Fibres Optiques, Lannion, France).

Measurement repeatability

For the crown, mantle, breast and lower belly, the repeatability of measurements, calculated as the intra-class correlation coefficient (Lessells and Boag 1987), was always highly significant (all $F_{123,248} > 7.68$ and $P < 0.0001$), with the following values: brightness (crown: 0.77, mantle: 0.86, breast: 0.87, belly: 0.72), UV chroma (crown: 0.96, mantle: 0.93, breast: 0.94, belly: 0.83), hue (crown: 0.99, mantle: 0.99, breast: 0.97, belly: 0.69).

For the iridescent patch and the dark streaks, repeatability was also highly significant (all $F_{123,248} > 1.5$ and $P < 0.0001$), but consistently lower on the left side than on the right side (probably due to the difficulty in handling the bird and the measurement probe on the bird's left): black streaks brightness, right: 0.68, left: 0.58; iridescent patch, brightness: right: 0.80, left: 0.73; UV spectral position, right: 0.78, left: 0.14, UV chroma, right: 0.91, left: 0.83; blue-green spectral position, right: 0.79, left: 0.70, blue-green chroma, right: 0.79, left: 0.37; red spectral position, right: 0.81, left: 0.23; red chroma, right: 0.76, left: 0.64. Average values for the three measures (or six, for the right and left iridescent patches and dark streaks) per individual were used in subsequent statistical analyses.

Mean values and correlations among color parameters

Mean values for hue of the crown, mantle, breast and lower belly ranged from 29.6° ± 3.22° to 49.68° ± 6.47° corresponding to tints between red (0°) and yellow (90°), with a higher proportion in the reddish hues (Table A1). Spectral positions of the UV peak of iridescent patches varied between a minimum of 308 nm and a maximum of 342.4 nm with a mean of 323 nm (see Table A1 for detailed results).

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Quinard et al. Appendix, Table A1

	Crown hue	Mantle hue	Breast hue	Belly hue	Crown brightness	Mantle brightness	Breast brightness
mean	29.60	40.40	29.99	49.68	3653.48	3477.57	9305.41
s.d.	3.22	2.13	3.64	6.47	1110.74	733.17	2484.62

	Belly brightness	Dark streak brightness	Crown UV chroma	Mantle UV chroma	Breast UV chroma	Belly UV chroma
mean	16777.04	1503.88	0.17	0.17	0.18	0.16
s.d.	4214.39	435.08	0.03	0.03	0.03	0.03

	Crown yellow-red chroma	Mantle yellow-red chroma	Breast yellow-red chroma	Belly yellow-red chroma
mean	0.54	0.51	0.4	0.46
s.d.	0.04	0.03	0.04	0.03

	l.p. brightness	l.p. UV chroma	l.p. UV spectral position	l.p. blue chroma	l.p. blue spectral position	l.p. red chroma	l.p. red spectral position
mean	6178.40	0.25	323.03	0.37	444.74	0.38	698.02
s.d.	1793.19	0.04	6.53	0.02	11.24	0.04	1.85

Quinard et al. Appendix, Table A2

Hue	Crown	Mantle	Breast	Belly
Crown	*****	0.36	0.12	0.04
Mantle	**< 0.001**	*****	-0.17	-0.05
Breast	0.08	0.05	*****	0.28
Belly	0.65	0.59	**0.002**	*****

Brightness	Crown	Mantle	Breast	Belly	Dark streak
Crown	*****	0.50	0.46	0.49	0.57
Mantle	**<0.001**	*****	0.47	0.40	0.42
Breast	**<0.001**	**<0.001**	*****	0.57	0.35
Belly	**<0.001**	**<0.001**	**<0.001**	*****	0.34
Dark streak	**<0.001**	**<0.001**	**<0.001**	**<0.001**	*****

Yellow-red chroma	Crown	Mantle	Breast	Belly
Crown	******	0.61	0.56	0.48
Mantle	**<0.001**	******	0.51	0.40
Breast	**<0.001**	**<0.001**	******	0.67
Belly	**<0.001**	**<0.001**	**<0.001**	******

UV Chroma	Crown	Mantle	Breast	Belly
Crown	*****	0.67	0.60	0.54
Mantle	**<0.001**	*****	0.62	0.54
Breast	**<0.001**	**<0.001**	*****	0.79
Belly	**<0.001**	**<0.001**	**<0.001**	*****

Iridescent patch	Brightness	UV spectral position	UV chroma	Blue spectral position	Blue chroma	Red spectral position	Red chroma
Brightness	*****	-0.008	0.22	-0.037	0.23	0.25	-0.30
UV spectral position	0.93	*****	0.29	0.87	0.67	0.39	-0.51
UV chroma	**0.02**	0.10	*****	0.32	-0.11	-0.46	-0.68
Blue spectral position	0.68	**<0.001**	**0.02**	*****	0.48	0.30	-0.48
Blue chroma	**0.01**	**<0.001**	0.23	**<0.001**	*****	0.57	-0.42
Red spectral position	**0.006**	**<0.001**	**<0.001**	**0.001**	**<0.001**	*****	0.03
Red chroma	**0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.72**	*****

Quinard et al. Appendix, Table A3

Hue	Crown		Mantle		Breast		Belly	
	F_{df}	*P*	F_{df}	*P*	F_{df}	*P*	F_{df}	*P*
ANOVA	$6.04_{2,119}$	**0.003**	$1.93_{2,119}$	0.14	$3.43_{2,119}$	0.03	$10.76_{2,119}$	**<0.001**
Tukey	Diff	*P*	Diff	*P*	Diff	*P*	Diff	*P*
HBS 2012 - LBS 2012	0.75	0.56	0.99	0.12	0.23	0.95	6.10	**<0.001**
HBS 2012 - HBS 2013	-1.43	0.13	0.65	0.39	1.87	0.07	5.88	**<0.001**
LBS 2012 - HBS 2013	-2.19	**0.002**	-0.33	0.71	1.64	0.06	-0.21	0.98

Brightness	Crown		Mantle		Breast		Belly		Dark streak	
	F_{df}	*P*	F_{df}	*P*	F_{df}	*P*	F_{df}	*P*	F_{df}	*P*
ANOVA	$28.20_{2,119}$	**<0.001**	$6.34_{2,119}$	**0.002**	$4.09_{2,119}$	0.02	$2.22_{2,119}$	0.11	$16.61_{2,119}$	**<0.001**
Tukey	Diff	*P*	Diff	*P*	Diff	*P*	Diff	*P*	Diff	*P*
HBS 2012 - LBS 2012	1256.22	**<0.001**	374.76	0.07	408.34	0.76	556.51	0.84	498.98	**<0.001**
HBS 2012 - HBS 2013	1625.69	**<0.001**	597.43	**0.002**	993.77	0.20	1924.23	0.13	460.26	**<0.001**
LBS 2012 - HBS 2013	369.48	0.13	222.66	0.28	1402.11	0.02	1367.72	0.25	38.72	0.88

Yellow-red chroma	Crown		Mantle		Breast		Belly	
	F_{df}	*P*	F_{df}	*P*	F_{df}	*P*	F_{df}	*P*
ANOVA	$38.93_{2,119}$	**<0.001**	$14.79_{2,119}$	**<0.001**	$9.69_{2,119}$	**<0.001**	$9.67_{2,119}$	**<0.001**
Tukey	Diff	*P*	Diff	*P*	Diff	*P*	Diff	*P*
HBS 2012 - LBS 2012	0.05	**<0.001**	0.02	0.0009	0.02	0.11	0.02	0.03
HBS 2012 - HBS 2013	0.06	**<0.001**	0.03	**<0.001**	0.03	**<0.001**	0.03	**<0.001**
LBS 2012 - HBS 2013	0.02	0.02	0.01	0.12	0.02	0.03	0.01	0.12

UV Chroma	Crown		Mantle		Breast		Belly	
	F_{df}	*P*	F_{df}	*P*	F_{df}	*P*	F_{df}	*P*
ANOVA	$52.27_{2,119}$	**<0.001**	$31.86_{2,119}$	**<0.001**	$28.44_{2,119}$	**<0.001**	$29.93_{2,119}$	**<0.001**
Tukey	Diff	*P*	Diff	*P*	Diff	*P*	Diff	*P*
HBS 2012 - LBS 2012	0.02	**<0.001**	0.01	**<0.001**	0.02	**<0.001**	0.02	**<0.001**
HBS 2012 - HBS 2013	0.03	**<0.001**	0.02	**<0.001**	0.03	**<0.001**	0.03	**<0.001**
LBS 2012 - HBS 2013	0.003	0.37	0.004	0.10	0.007	0.03	0.005	0.22

Iridescent patch	Brightness		UV Chroma		UV spectral position		Blue chroma		Blue spectral position		Red chroma		Red spectral position	
	F_{df}	*P*	F_{df}	*P*	F_{df}	*P*	F_{df}	*P*	F_{df}	*P*	F_{df}	*P*	F_{df}	*P*
ANOVA	$28.84_{2,119}$	**<0.001**	$48.07_{2,119}$	**<0.001**	$4.61_{2,119}$	**0.01**	$36.91_{2,119}$	**<0.001**	$1.54_{2,119}$	0.21	$8.18_{2,119}$	**<0.001**	$76.1_{2,119}$	**<0.001**
Tukey	Diff	*P*	Diff	*P*	Diff	*P*	Diff	*P*	Diff	*P*	Diff	*P*	Diff	*P*
HBS 2012 - LBS 2012	791.63	0.07	0.02	**<0.001**	4.36	**0.01**	0.03	**<0.001**	4.38	0.23	0.04	**<0.001**	2.60	**<0.001**
HBS 2012 - HBS 2013	1507.75	**<0.001**	0.03	**<0.001**	3.87	0.03	0.04	**<0.001**	4.05	0.28	0.02	**0.04**	3.61	**<0.001**
LBS 2012 - HBS 2013	2299.38	**<0.001**	0.006	0.04	0.49	0.93	0.006	0.24	0.33	0.98	0.01	0.18	1.00	**<0.001**

Quinard et al. Appendix, Table A4

	Between sexes			Among females			Among males		
	ΔS_{min}	ΔS_{mean}	ΔS_{max}	ΔS_{min}	ΔS_{mean}	ΔS_{max}	ΔS_{min}	ΔS_{mean}	ΔS_{max}
Crown	0.04	**1.14. ± 0.79**	5.19	0.03	**1.10 ± 0.86**	5.44	0.01	**1.12 ± 0.78**	4.37
Mantle	0.02	0.88. ± 0.63	3.73	0.02	0.90 ± 0.64	3.81	0.02	0.87 ± 0.60	3.38
Breast	0.03	**1.03. ± 0.76**	5.09	0.01	0.97 ± 0.80	5.38	0.02	**1.08 ± 0.74**	4.07
Belly	0.01	0.83. ± 0.58	3.29	0.02	0.87 ± 0.62	2.92	0.01	0.81 ± 0.55	3.19
Dark streaks	0.06	**2.01 ± 1.38**	8.44	0.09	**1.83 ± 1.27**	7.61	0.05	**2.16 ± 1.46**	8.69
Iridescent patches	0.13	**3.57 ± 1.94**	11.76	0.20	**3.50 ± 1.94**	11.42	0.16	**3.55 ± 1.85**	10.95

Discussion on the differences in color parameters between sessions.

After checking for potential sampling bias, arising from differences in sample sizes between sexes or sampling sites, and a potential impact of material wear (i.e. spectrometer), the most plausible cause we may suggest is an effect of particular environmental factors. Previous studies focusing on seasonal changes in plumage coloration showed variations in UV saturation (Kniprath 1967, Delhey et al. 2010) and chroma (Örnborg et al. 2002, Delhey et al. 2006, Delhey et al. 2010). Feather structure and composition and, thus, color parameters, can be affected by external factors such as abrasion, bacterial degradation or dirt (e.g. Shawkey et al. 2007, Pérez-Rodríguez et al. 2011). In the closely-related mourning dove (*Zenaida macroura*) successive treatments of hydration and dehydration applied on brown and iridescent feathers led to an increase in brightness and chroma in iridescent feathers, but had no effect on brown ones (Shawkey et al. 2011). Weather in Barbados is characterized throughout the year by a dry season lasting from November to May and a wet season lasting from June to October with hot temperatures ranging from 25°C to 35°C. In the Zenaida dove, molt probably occurs mainly after spring as breeding activity peaks from January to April (Wiley 1991, F. Cézilly unpublish. data). While in 2012 rainfall and temperatures did not differ from means recorded during the previous decades (CIMH 2013), 2011 was the wettest season ever recorded since 1942 and had particularly high temperatures (CIMH 2012). These particular weather conditions during and just after molt in 2011 might have affected plumage characteristics and might explain the differences detected in plumage color between birds captured during high breeding season 2012 and those captured during low breeding season 2012 and high breeding season 2013. Alternatively, age variation could partly explain this

seasonal effect. We were able to control for age, through distinguishing between adults and yearlings or fledglings. However, we have no information about variation in plumage color with age in adults in pigeons and doves, and this possibility would need to be further investigated.

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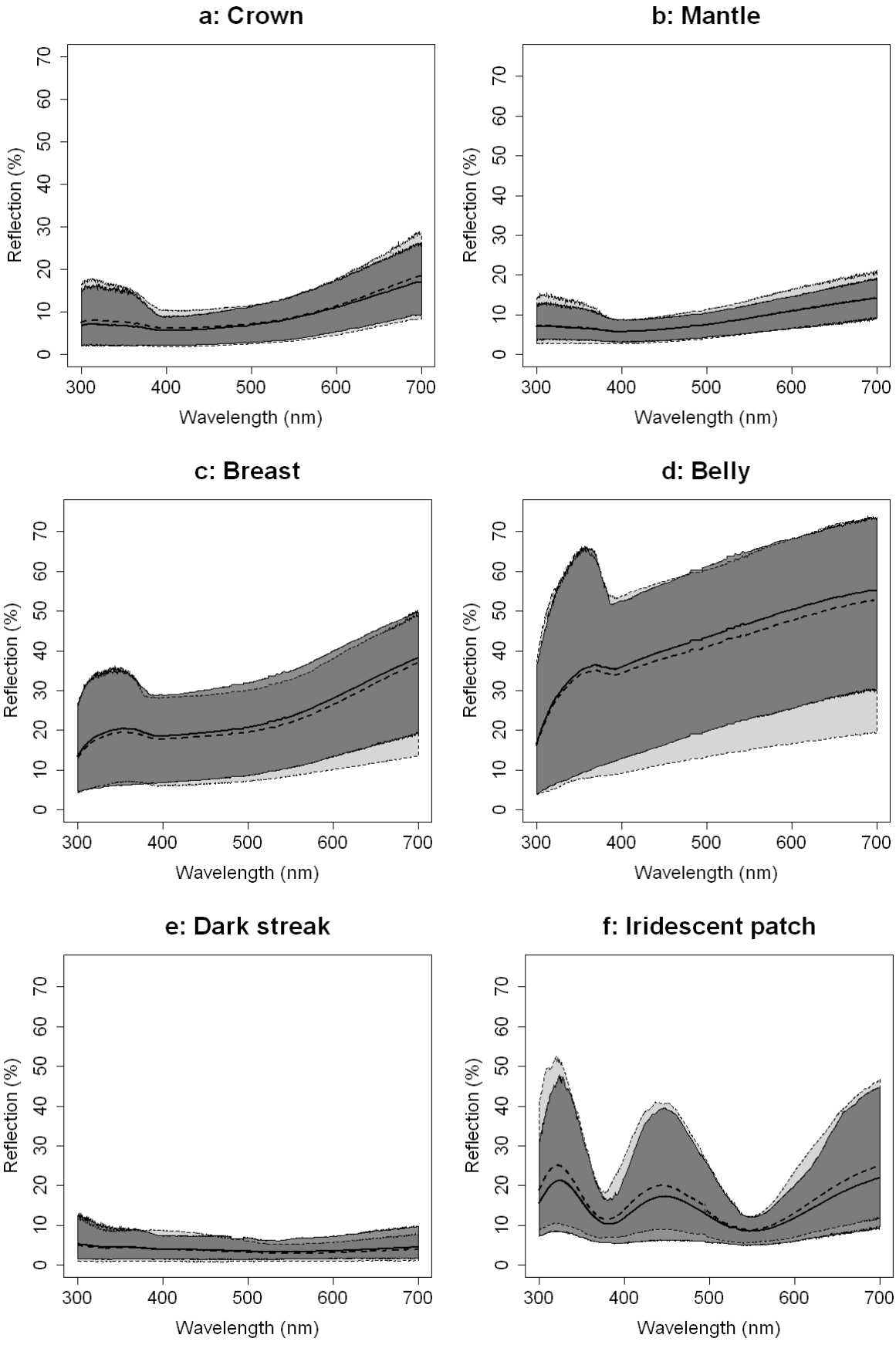
Quinard et al. Appendix, Figure A1


a: Crown
b: Mantle
c: Breast
d: Belly
e: Dark streak
f: Iridescent patch
Reflection (%)
Wavelength (nm)
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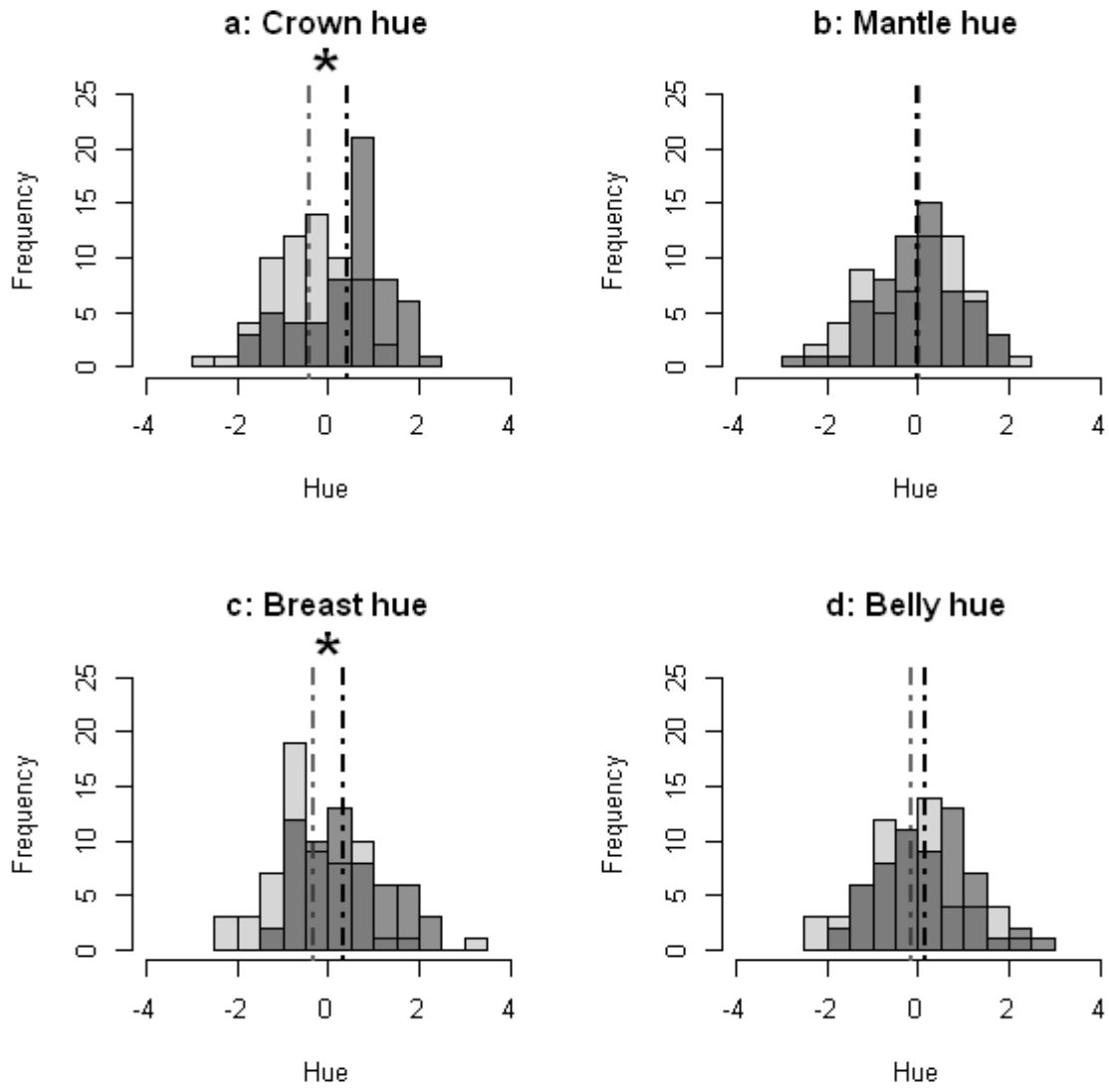
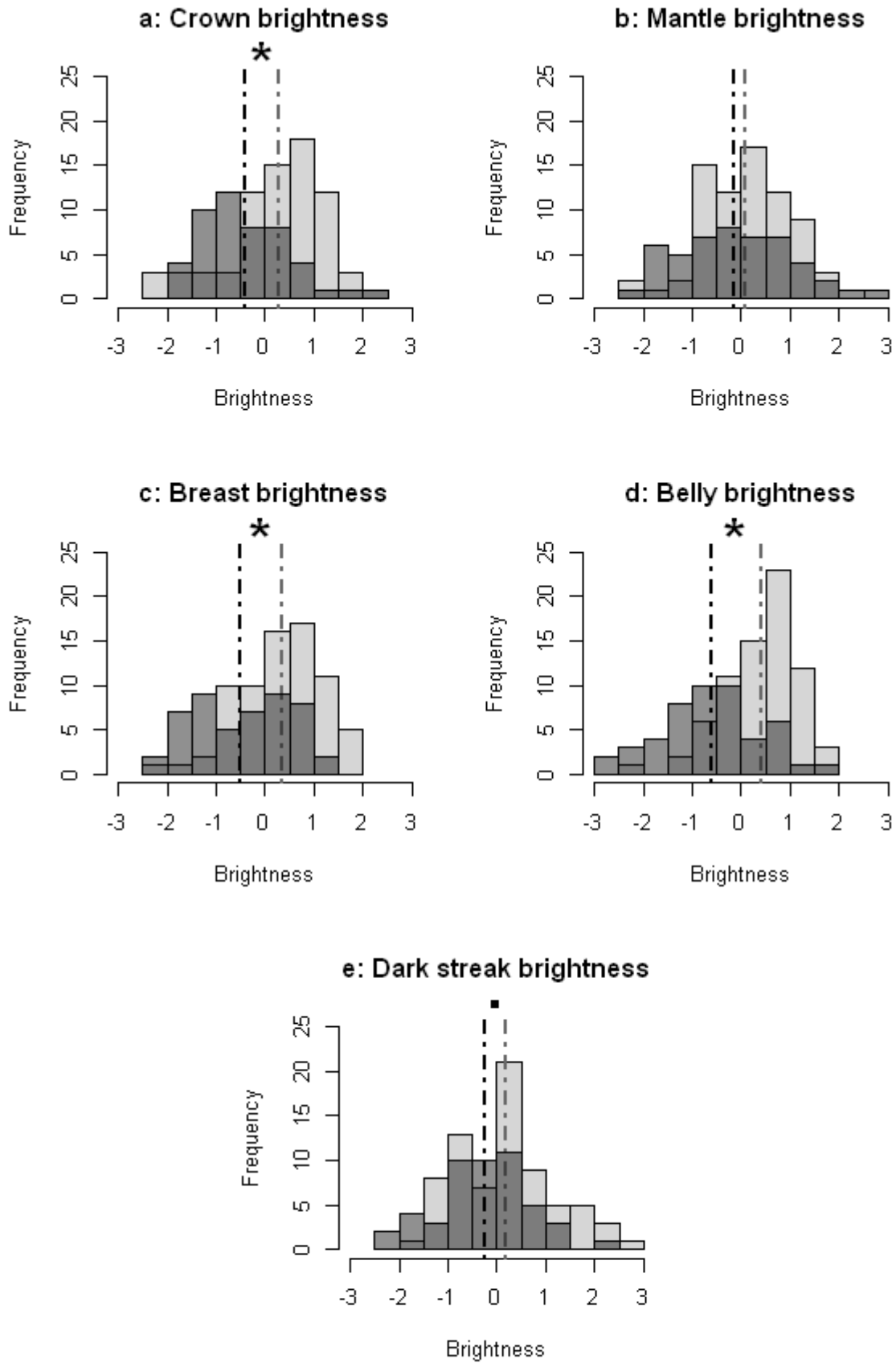
10
20
30
40
50
60
70
300
400
500
600
700

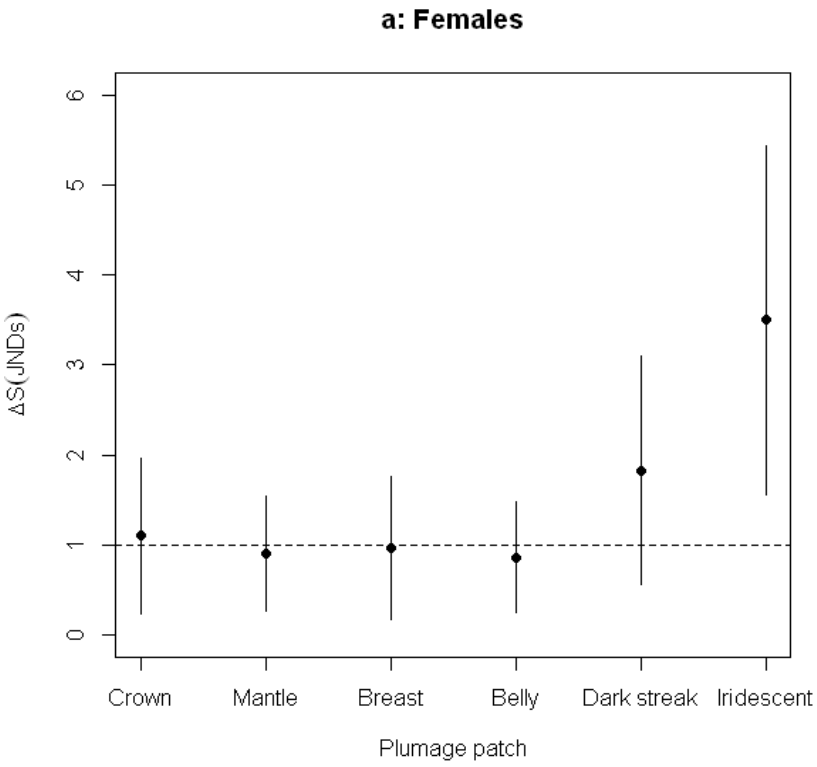
Quinard et al. Appendix, Figure A2

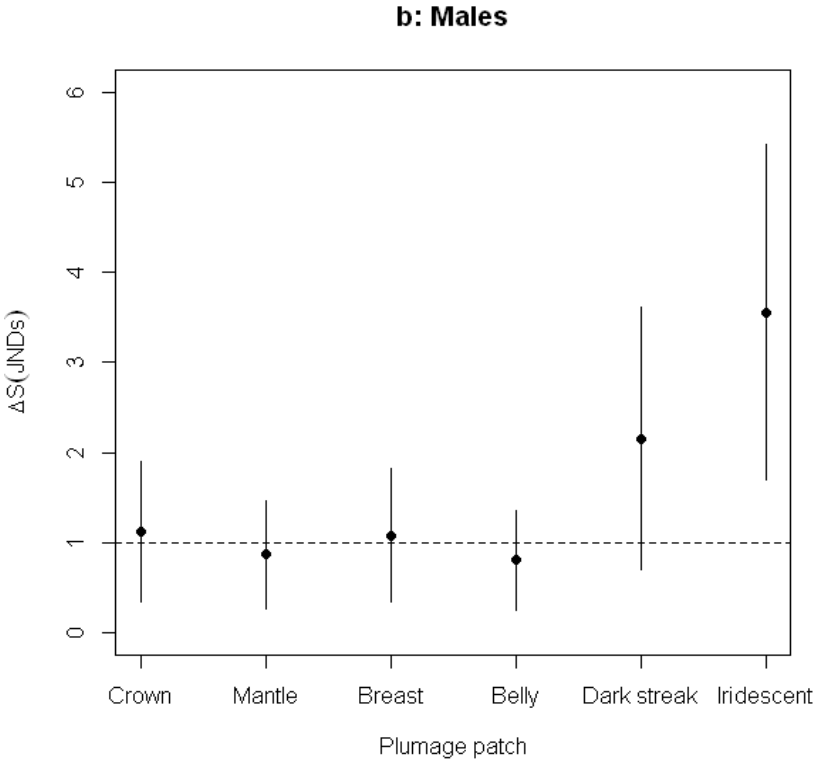


Quinard et al. Appendix, Figure A3



Quinard et al. Appendix, Figure A4





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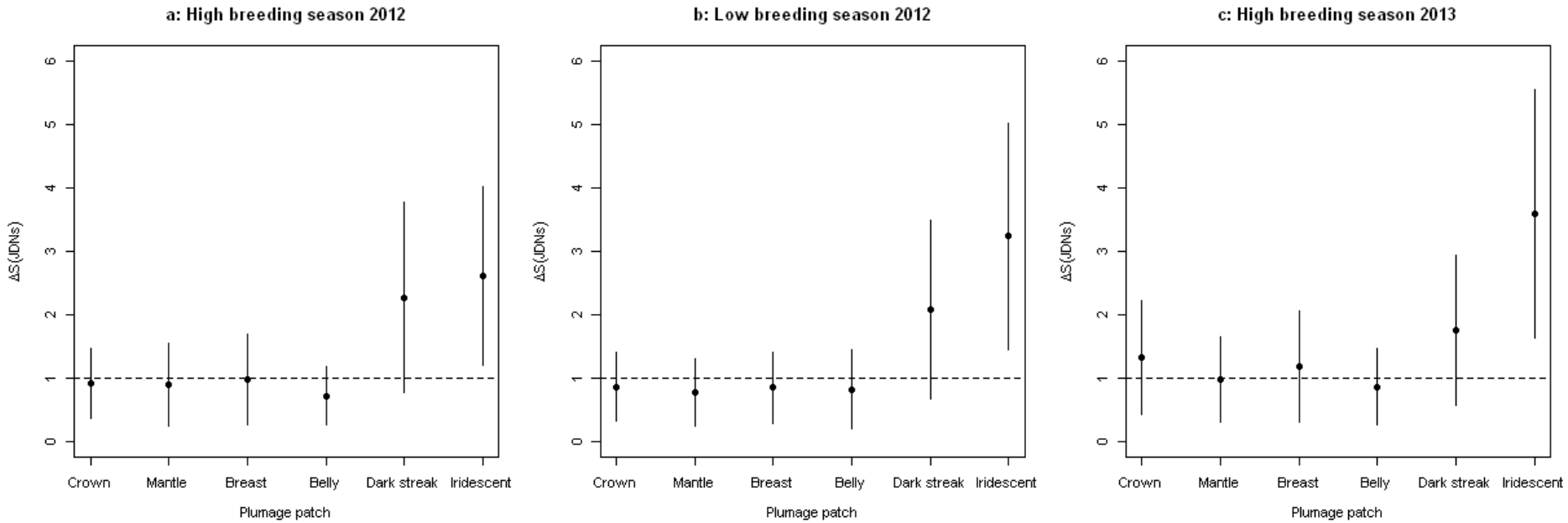

Quinard et al. Appendix, Figure A6