Mike Kemp, Joseph Kim, Timothy Le and Summer Kubba

Dr. Rodrigue

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The Correlation Between Sexual Selection and Pigeon Morphology

I. Introduction - Mike Kemp

Feral pigeons have adapted to life in the wild, in urban areas, and in every other kind of environment in-between. These birds are of particular interest because pigeons show extreme plumage variation--which originated from artificial selection of domestic stock--and while their populations have been established in North America for over 200 years and for thousands of years on other continents, they are unlike any other feral animal because they have retained these domestic colorations for more than just a few generations (Derelle et al., 2013). They have never reverted to the colors of their wild Mediterranean and Middle-Eastern relatives. The original color morph, called “blue-bar”, is distinguished by dark gray stripes (e.g. “wing bars”) that overlay their light gray wings, but domestic colorations vary from fully black to fully white, and diverse morphs with checkers or other patterns (LaBranche, 1999). The purpose of this paper is to examine data collected in previous classes from 2000-2018 using a Chi-square test, to determine whether or not sexual selection is the mechanism that determines why all feral pigeons are not “blue-bars”.

II. Literature Review - Mike Kemp

To investigate feral pigeons, it is important to understand that ecologists have several possible explanations of why organisms match their environments. The first is natural selection:

e.g. individuals that are easily detected by predators--due to a conspicuous coloration--are less likely to survive and produce similarly colored offspring than individuals who are not easily seen. This theory is supported by the fact that most feral species revert to their "wild-type" colors after several generations. Feral pigeons, or *Columba livia*, are driven toward a single morph by stabilizing selection against deviations from the normal pattern, yet they still exhibit a huge variety of common morphs, with differing patterns and colors (LaBranche, 1999). One reason why feral pigeons may have retained their diverse morphs is that colorations are highly heritable, and are only weakly influenced by environmental conditions beyond wild habitats. Additionally, melanin-based colors of pigeons are influenced by several life-history traits, suggesting that differently colored individuals may have different fitness in alternative environments, which could further explain the maintenance of polymorphism (Derelle et al., 2013).

Another possibility is that certain morphs have better immune system functions. Research has suggested that melanin-based (ashy-red and dark) colorations were significantly correlated with lower blood-parasite intensity (e.g. there were fewer parasites measured in the blood of these birds than lighter colored ones like white or blue-bars). A higher immune system response was also observed in these melanin-based morphs than non-melanin-based morphs: which suggests that these domesticated colorations have not been eradicated through disease because these individuals are less susceptible (Jacquin, Lisa, et al., 2011).

Alternatively, particular colors could indicate dominance within a flock. Thus, when there is food shortage, dominant individuals eat more and are therefore more likely to reproduce. Because colorations are inherited, the colors of dominant individuals determine the coloration of future generations. After several generations, some colors are expected to disappear entirely from feral populations (LaBranche, 1999).

While these hypotheses provide important insight into the prevalence of polymorphism in feral pigeons, we believe that sexual selection is ultimately the determining factor of pigeon morphs. A study from 2006 found a correlation of phenotype-dependent selection of juvenile feral pigeons. According to this study, over 57% of the feral Pigeons were of colorations also shown by wild Rock Pigeons with Blue-Bars and Blue Checkers comprising 30% and 27.5% respectively. The study found significant differences in the frequencies of color morphs between juvenile and adult feral pigeons. In comparison to the reference wild type, pigeons with the T-Pattern and the additional factors Spread and Bronze showed a significant increase in frequency with age. In contrast, birds with the checker pattern decreased in frequency between juvenile and adult ages in an urban environment. A potential positive additive effect on the survival of bronze and checkers could explain the high frequency of checkers (31.5%) in the population. The data is aligned with our hypothesis, suggesting that the observed changes in plumage morph frequencies are associated with sexual selection episodes taking place between adolescence and independent adulthood (Haag-Wackernagel, et al., 2006). This hypothesis examines whether individuals with particular colors might be preferred as mates and thus produce more offspring than other colorations.

III. Data and Methods - Summer Kubba

The data was collected by the biogeography students of Dr. Rodrigue through the years 2000 to 2018. Observations were made at a large variety of locations, (including: parks, beaches, freeway underpasses, schools, industrial sites, and commercial sites such as restaurants and shopping centers) and each observer stayed at each study location for at least fifteen minutes. At each location, two counts were done; one for the total number of birds, and one count to track how many of each color morph was present. The observer would also note the amount of courtships that took place onsite, as well as what color morphs took part in the courtship. Observers noted the courtship interactions between the different color morphs, as well. In total, throughout the years 2000 to 2018, 6102 pigeons were counted. Of these, 5796 birds with known color morphs were counted and 610 courtships in total were counted. In terms of color morphs, 2203 blue-bars were tallied, 517 red-bars, 1050 spreads, 152 reds, 1332 checkers, 434 pieds, and 108 white birds were counted total.

IV. Statistical Analysis - Joseph Kim

The analysis was based on the class data from 2000 up to 2018. Our testing hypothesis is whether there is a preference of sexual selection of pigeons based on similar traits. Since traits are a categorical variable, the Chi-Square Test of Independence was utilized. A Chi-square test is based on utilizing degrees of freedom, selected *alpha* level, effect size, critical Chi-square value, and also the probability value.

For the first hypothesis testing, our degrees of freedom was four. Degrees of freedom is the allowance of individual data inputs to vary. An alpha level also known as the significance level is the acceptable probability that the test will make a Type 1 error. A Type 1 error is rejecting a true null hypothesis. The selected alpha level was designated as 0.05. By putting the significance level at 0.05, the test is simply allowing a five percent chance of a rejection of the null hypothesis to be false. Raising the significance level to 0.10 would make the test more strict on finding differences; however, it would increase the possibility of making a Type 1 error by ten percent. Alternatively, selecting an alpha level at 0.01 would decrease making a Type 1 error to one percent, but would make the test less susceptible in finding differences.

Utilizing this information, we ran a Chi-square test on our first hypothesis at 0.05 significance level to determine if there was a preference of assortative mating between the categories of wild-type, melanic, and odd traits. Our results showed a X^2 calculated value of 50.099 which is greater than the X^2 critical value of 9.488. Since the calculated value is greater, it is safe to reject the null hypothesis which states that there is no preference in mating among pigeons. However, because the test had a low chance of making a Type 1 error, it is important to look at mitigating Type 2 errors. This is where power comes into play. The closer a power value is to one, the higher the chance is in avoiding a Type 2 error. Referring to Table 1, the power value is at 0.999 which is safe to say that a Type 2 error was avoided. Both Type 1 and Type 2 errors were avoided. In conclusion, with a Chi-square value of 50.099 at 4df, these results were highly significant (p value of $0.0 < 0.05$). The effect size was slightly smaller than expected (0.207); however, the sample size (n=587) was large enough to maintain a high enough power (0.999).

To test the second hypothesis which is to see if there is a significant difference between assortative mating of sexes (males, females) among the wild-types, melanic, and odd traits, the same procedure of Chi-square analysis was used. Referring to Table 2, the calculated X^2 value of 21.359 is significantly larger than the criterion X^2 value of 5.999. It is safe to reject the null hypothesis that there is no preference of assortative mating of sexes among body types. The test must also again take into consideration power. Referring back to Table 2, the power value was 0.990, a value very close to 1. It is safe to say that a Type 2 error was also avoided. In conclusion, with a Chi-square value of 21.359 at 2df, these results were highly significant (p value of $0.00002 < 0.05$). The effect size was slightly smaller (0.191); however, the sample size (n=587) was large enough to maintain a high power (0.990).

V. Conclusion

The purpose of this experiment was to test whether there was any correlation between sexual selection and pigeon morphology. To perform this several classes over several years, under Professor Rodrigue's tutelage, went out to collect data. The data included everything from environmental factors to pigeon morphology and courtships. The data was then transcribed to datasheets to include weather, type of habitat, location, ground coverage, types of trees, and so forth. Using the aggregate data from the most recent and previous years figures were formulated for a visual representation. Showing trends that pigeon courtships preferred other pigeons of the same morphology, which is inline with the testing hypothesis; there is a significant difference between sexual selection and pigeon morphology. Therefore, the null hypothesis states there is no significant difference between sexual selection and pigeon morphology. Calculations were then conducted using the Chi-Square Test of Independence to test the hypothesis, using a confidence interval of 0.05. The first test looked to see if there was a preference between the different sorts of morphologies, wild type, melanic, and odd. The test concluded to reject the null hypothesis with a p-value of 0.0 with a high power level (0.999) yielding the test to be reliable, however, it has a very weak effect (0.207). The second test determined whether there was a preference between assortative mating of sexes among the different pigeon morphologies. Using the same test with the same confidence level of 0.05, the test again concluded to reject the null hypothesis with a probability of 0.00002. Unlike the first test, the second had a strong enough power level (0.990) to be deemed reliable and again similarly with the first test a weak effect (0.191). Therefore with certainty it may be said that the null hypothesis was rejected. In conclusion, the aggregated data collected throughout the years was statistically analyzed and it was found that there was a significant difference between sexual selection and pigeon morphology.

VI. Figures and Tables

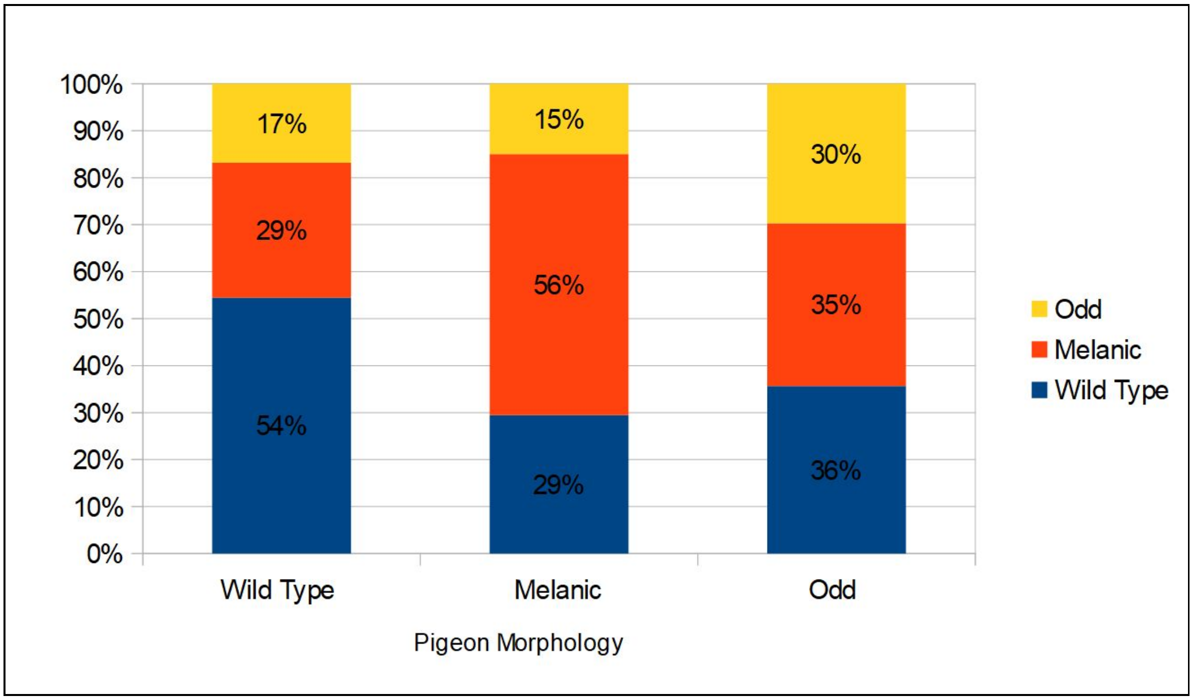

Figure 1. Aggregated courting by pigeon morphology from Fall 2000 through Spring 2018. Trends show that Wild Type and Melanic pigeons each prefer courting pigeons with a similar morphology, whereas the Odd pigeons may prefer other than their own.

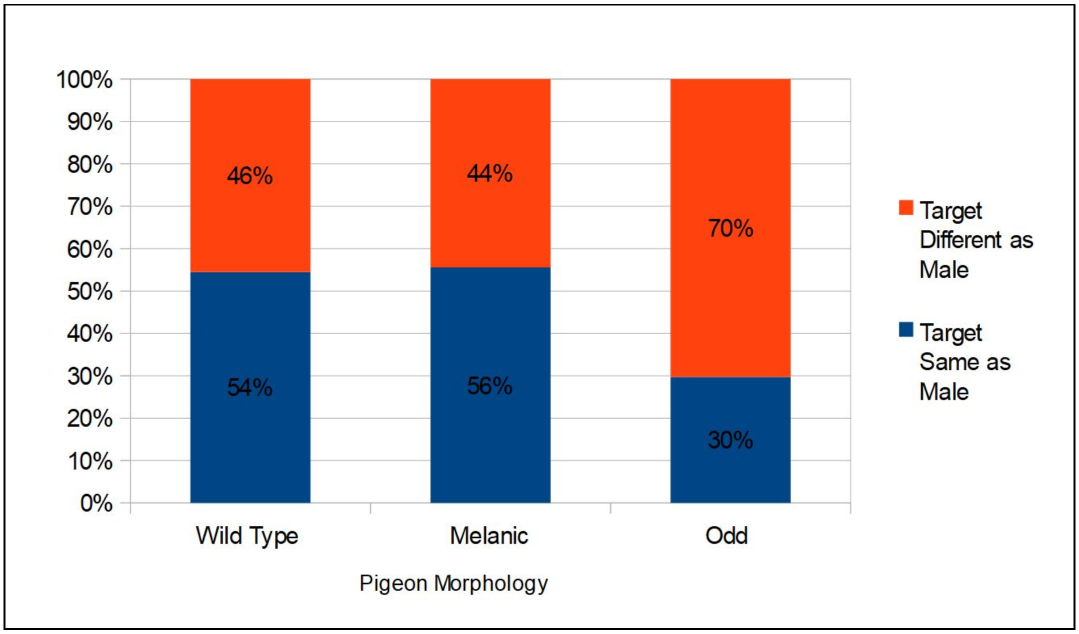

Figure 2. Aggregated pigeon courting by similarity or difference. Trends show that Wild Type and Melanic pigeons prefer targets with the same morphology as themselves over 50%. Odd pigeons prefer courting pigeons different from themselves by a 70% margin.

Table 1. Pigeon courting by each morphology. Where VAR1 begins with (top to bottom) Wild Type, Melanic, and Odd. VAR2 (left to right) Wild Type, Melanic, and Odd.

X^2 — Enter data and *alpha* in yellow cells only

VAR 1	VAR 2			*
	a	b	c	
Obs	152	80	47	279
Exp	*118.349*	*109.319*	*51.332*	
	d	e	f	
Obs	61	115	31	207
Exp	*87.807*	*81.107*	*38.085*	
	g	h	i	
Obs	36	35	30	101
Exp	*42.843*	*39.574*	*18.583*	
*	249	230	108	587

Percentage of expected counts < 5 (if > 20%, collapse data rows)	0.00 %
Number of expected counts ≤ 1 (if there are any, collapse rows)	0

β/α: ratio of Type II to Type I error probability 1645320.242

Outputs in blue cells

Cell	O	O sq.	E	O sq./E
a	152	23104	118.349	195.219
b	80	6400	109.319	58.544
c	47	2209	51.332	43.033
d	61	3721	87.807	42.377
e	115	13225	81.107	163.056
f	31	961	38.085	25.233
g	36	1296	42.843	30.250
h	35	1225	39.574	30.955
i	30	900	18.583	48.432
				637.099

X^2_{calc}	50.099
alpha	0.05
df	4
X^2_{crit}	9.488
prob	0.000
k (min r or c)	3
(effect size measure) Cramér's V	0.207
(effect size measure) φc or w	0.292
Noncentrality (λ)	25.049
Estimated power (1-β)	1.000
Corrected power (Rodrigue)	0.999

Table 2. Pigeon courting by similarity or difference. Where VAR1 begins with (top to bottom) Wild Type, Melanic, and Odd. With VAR2 (left to right) as Target Same as Male and target Different as Male.

X^2	Enter data and *alpha* in yellow cells only		
VAR 1	VAR 2		*
	a	b	
Obs	152	127	279
Exp	*141.164*	*137.836*	
	c	d	
Obs	115	92	207
Exp	*104.734*	*102.266*	
	e	f	
Obs	30	71	101
Exp	*51.102*	*49.898*	
*	297	290	587

Percentage of expected counts < 5 (if > 20%, collapse data rows)	0.00 %
Number of expected counts ≤ 1 (if there are any, collapse rows)	0

β/α: ratio of Type II to Type I error probability 416.795

Outputs in blue cells				
Cell	**O**	**O sq.**	**E**	**O sq./E**
a	152	23104	141.164	163.668
b	127	16129	137.836	117.015
c	115	13225	104.734	126.272
d	92	8464	102.266	82.765
e	30	900	51.102	17.612
f	71	5041	49.898	101.027
				608.359

X^2_{calc}	**21.359**
alpha	**0.05**
df	**2**
X^2_{crit}	**5.991**
prob	**0.00002**
k (min r or c)	2
(effect size measure) Cramér's V	**0.191**
(effect size measure) φc or w	0.191
Noncentrality (λ)	21.359
Estimated power (1-β)	0.992
Corrected power (Rodrigue)	**0.990**

VII. Bibliography

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