Coloration as an Indicator of Male Quality in the Dark-Winged Damselfly *Calopteryx maculata*

John R. Shorter

Department of Ecology and Evolutionary Biology

University of Michigan Ann Arbor, MI

Corresponding Author:

John R. Shorter

1798 Smith

Ypsilanti, MI, 48198

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Abstract

Calopteryx maculata, commonly known as the dark-winged damselfly, mate in a system based on quality of ovipositing patches. It has been observed in Europe that this genus uses a series of pre- and post-copulatory behavioral displays where males face females while showing their pigmented wings to indicate quality (Cordoba-Aguilar 2001). It may be possible that the iridescent coloration in the dark-winged damselfly can function as ornaments since fat-stores determine coloration and endurance in territory battles in the North American species, which hasn't been investigated previously. Fifteen pairs of mating and non-mating territorial males were caught and their abdomens were analyzed using a spectral optics program to determine if coloration was an indictor of mating status. Our results did not support the hypothesis, and coloration was not significantly correlated to mating status. The only significant result was a linear regression between body weight and coloration, the larger size corresponding to a lower spectrum wavelength. It appears that coloration does not correlate with female mating preference in *Calopteryx maculata,* but males who operate under an alternative reproductive strategy, sneaking, were not tested in this experiment, and could potentially change the distribution of the results.

Introduction

Signals of quality, expressed through badges or ornaments, are the best was to honestly identify good genetic expression (Grafen 1990). Many secondary sexual traits in males, like bright colors and courtship displays, evolved to influence female mate choice, and these traits should be costly to produce in order to prevent cheating of expressing these qualities (Dugatkin 2004). If there was cheating on a sexually selected trait, then it would eventually stop indicating quality and females would be selected against preferring that trait (Dugatkin 2004). In a study done on territorial blue tits, it was determined that many phenotypic traits, including body size, UV coloration and voice call, determine the quality of the individual by conspecifics (Poesel et al. 2007). For example, in the sexually dimorphic butterfly *Colias eurytheme*, iridescent UV coloration was found to be an indicator of phenotypic condition, which may be beneficial to females that seek a highly fertile mating partner in their promiscuous breeding system. It may be possible that UV coloration plays a role in determining quality in species with a different type of territorial breeding system as opposed to a promiscuous breeding system.

One striking example of a territorial breeding system are Dark-winged damselflies, *Calopteryx maculata*, which breed based on female choice in ovipositing sites along rivers and streams (Waage 1974). The inter-sexual selection by female damselflies appears to be related only to the male's ability to hold a high value territory. The presence of vegetation and fast moving water are essential to female ovipositing behavior (Gibbons and Pain 1992). However, it has recently been shown that *Calopteryx haemorrhoidalis*, a European damselfly, has wing pigmentation that relates to territory

and mating status (Cordoba-aguilar 2001). It could be possible that other Calopteryx species would use ornaments to indicate quality in addition to patch status.

Male *Calopteryx maculata* do not express variation in wing pigmentation, but they have a noticeably iridescent abdomen, which has been shown to indicate the amount fat stores (Fitzstephens and Getty 2000). Fat stores have been correlated to territorial fighting ability (Marden and Waage 1990; Marden and Rollins 1994), so it seems possible that this species could use coloration as an indicator of physical condition. This could suggest that male territorial battles, called wars of attrition, could actually be assessed by the participants through coloration signals across the abdomen. Females could also use this as an honest signal of quality, and judge the condition of a potential mate.

In this paper, I will set out to answer the questions of abdominal coloration on mating selection, on the ability of it to predict a mating status, and if coloration can be predicted by body mass. I hypothesize that abdomen coloration can be used to judge mating quality, but territoriality status would be a better predictor of mating status because territory quality is important in egg success. If abdomen coloration does not show a relation to mating status, then alternatively it is possible that coloration is not a cue in sexual selection.

Methods

This study was conducted along the Maple river in Emmet county, Michigan. Damselflies were collected in two locations, near a bridge site off of Douglas Lake road,

and near the Dam Site Inn on Woodland road. Male Dark-winged damselflies were collected between July 17 to July 31.

The area along the river that held male territories was marked out with flags, and a map of males' territory was constructed after each male was captured and marked with an individual number. All males were marked with a colored marking pen on the same wing, respectively, and therefore it was unlikely that this marking had any influence on mating status. This would also negate any increased predation effects across the population since all the marks were done in the same manner. Numbering would help identify males throughout the experiment as they fly around, engaging in territorial battles and copulations.

Collection and Analysis

Males were grouped into two categories, mating or non-mating territorial males. Because the population wasn't significantly large, almost all males held territory and therefore sneaker males weren't abundant. Territorial males that were observed to be copulating were caught and their nearest non-mating territorial male was also caught. In order to best analyze female choice, we would want to compare males that would have potentially been compared with each other. These non-territorial males were only a few meters away, as indicated by marked flags throughout the river.

These males were then brought back to the lab, freeze killed, and then weighed. All were analyzed using a spectral analysis program, Ocean Optics OOIBase32 and a USB2000 spectrometer. Reflected light samples were standardized on Spectralon® white standard and were collected from the second, fourth and the sixth abdominal segments

along with the thorax. The value of reflected light at UV and visible light wavelengths was then run through TigerSpectre v.1.07, a program that calculated the average values for hue, chroma and brightness in all specimens.

Results

We collected 15 pairs of mating and non-mating territorial damselflies. The population of damselflies wasn't large enough to have the sneaker male strategy because of the abundance of territorial patches. Weight and abdominal length were compared to mating status to look for a potential relationship. Weight and abdominal length did not predict mating status (weight: T = 0.017, df = 26, p = .987 mean mating (g) = 0.0717, mean non-mating (g) = 0.0712; abdominal length T=0.0287, df = 28, p = 0.777 mean mating (mm) = 34.59, mean non-mating (mm) = 34.74)

Coloration of the abdomen, in the UV, visible light and combined wavelengths were then compared to the mating status. An independent T-test on all three abdominal and thorax segments, looking at hue, chroma and brightness across UV and visible light wavelengths showed no significant values. (See tables for complete list of all values)

Comparing the mass of the damselfly to coloration was also conducted through a linear regression, showing a positive correlation between UV reflectance and mass (F_{25} = 5.239, R^2 = .173, p =. 031).

Discussion

I have shown that body mass and abdominal length does not indicate the mating status of male damselflies, which is consistent with the findings of other studies (Marden

and Waage 1990). However, coloration of the abdomen was shown to not correlate with mating status in territorial males. I also showed that mass of the damselfly was directly related to UV coloration. This finding is consistent with the study showing body color as a cue to fat reserves (Fitzstephens and Getty 2000). This is interesting because fat stores might be a cue for other quality signals that have not been looked into yet.

Coloration is a result of fat stores, and fat stores are likely related to endurance in territory battles, so when males are engaged in prolonged aerial battles, it may be possible that as their fat stores are reduced, it is expressed through their coloration. It was hypothesized that damselflies could use coloration as an indicator quality in an opponent or a mate partner, but the results refute this idea. If the results are to be accepted, then this indicates that color in abdomens of males is not an ornament of quality. Females may use an ornament of quality if this species does display courtship, but the ornament does not appear to be abdomen coloration.

The data are missing an important variable in this mating system, and that would be the presence of males acting in the alternative reproductive strategy; sneaking. Sneaker males, which lack much of the fat reserves of territorial males (Forsyth and Montgomerie 1987), could have a reduction in abdomen color, thus signaling their departure from territory holding status. It could be possible that the distinction in coloration is not apparent between territory holders, but it could be apparent between males using different reproductive strategies. Females may be able to distinguish territorial and sneaker males in the limited courtship displays, but the results in this study couldn’t possibly evaluate this hypothesis.

Age in male damselflies could also influence the coloration of their abdomen. Wing pigmentation in *Calopteryx haemorrhoidalis* was shown to change throughout the life-span of males (Cordoba-Aguilar 2001). Males who reach sexual maturity and first move into a territory to compete for mates could be a brighter color than older males because they are fresher and haven't been exposed to the wear-and-tear of battles. This could be interesting to investigate further since age might show a varying influence on mating ability and battle experience.

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Independent Samples Test In All Spectrum

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Seg2Hue	Equal variances assumed	2.922	.099	-.699	27	.491	-.04995	.07145	-.19656	.09667
	Equal variances not assumed			-.709	24.412	.485	-.04995	.07046	-.19524	.09535
Seg2Choma	Equal variances assumed	.009	.925	.191	27	.850	.00796	.04177	-.07775	.09367
	Equal variances not assumed			.193	24.310	.848	.00796	.04118	-.07698	.09289
Seg2Brightness	Equal variances assumed	2.589	.119	-1.338	27	.192	-.02142	.01601	-.05426	.01142
	Equal variances not assumed			-1.323	23.519	.198	-.02142	.01619	-.05487	.01203
Seg4Hue	Equal variances assumed	.134	.717	-.029	27	.977	-.00160	.05557	-.11561	.11241
	Equal variances not assumed			-.029	26.329	.977	-.00160	.05511	-.11482	.11162
Seg4Chroma	Equal variances assumed	.633	.433	.865	27	.394	.04643	.05365	-.06365	.15651
	Equal variances not assumed			.886	19.680	.386	.04643	.05239	-.06296	.15583
Seg4Brightness	Equal variances assumed	.350	.559	-.440	27	.664	-.00614	.01396	-.03477	.02250
	Equal variances not assumed			-.438	26.079	.665	-.00614	.01401	-.03494	.02266
Seg6Hue	Equal variances assumed	9.412	.005	-.490	27	.628	-.02271	.04631	-.11773	.07231
	Equal variances not assumed			-.504	17.947	.620	-.02271	.04506	-.11741	.07199
Seg6Chroma	Equal variances assumed	.968	.334	.213	27	.833	.01212	.05690	-.10462	.12886
	Equal variances not assumed			.219	18.673	.829	.01212	.05545	-.10407	.12831
Seg6Brightness	Equal variances assumed	.673	.419	-1.417	27	.168	-.01061	.00749	-.02598	.00476
	Equal variances not assumed			-1.408	25.569	.171	-.01061	.00754	-.02612	.00489
ThoraxHue	Equal variances assumed	.682	.416	-.275	27	.785	-.01278	.04644	-.10806	.08250
	Equal variances not assumed			-.274	25.820	.786	-.01278	.04668	-.10875	.08320
ThoraxChroma	Equal variances assumed	.222	.641	.585	27	.563	.02474	.04229	-.06204	.11152
	Equal variances not assumed			.595	22.805	.558	.02474	.04156	-.06127	.11075
ThoraxBrightness	Equal variances assumed	1.337	.258	-1.732	27	.095	-.01317	.00760	-.02877	.00243
	Equal variances not assumed			-1.752	25.413	.092	-.01317	.00752	-.02864	.00230
AbdomenAverage	Equal variances assumed	.498	.487	-1.235	27	.227	-.01272	.01030	-.03386	.00841
	Equal variances not assumed			-1.225	24.661	.232	-.01272	.01039	-.03414	.00869

Independent Samples Test For UV Spectrum

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Seg2Hue	Equal variances assumed	5.692	.024	1.183	27	.247	.21411	.18093	-.15713	.58535
	Equal variances not assumed			1.214	18.645	.240	.21411	.17632	-.15540	.58362
Seg2Choma	Equal variances assumed	4.171	.051	-1.057	27	.300	-.37100	.35110	-1.09140	.34941
	Equal variances not assumed			-1.020	13.168	.326	-.37100	.36373	-1.15577	.41377
Seg2Brightness	Equal variances assumed	.237	.630	-.636	27	.530	-.00242	.00380	-.01022	.00538
	Equal variances not assumed			-.643	25.569	.526	-.00242	.00376	-.01015	.00532
Seg4Hue	Equal variances assumed	.161	.691	.062	27	.951	.01652	.26732	-.53198	.56502
	Equal variances not assumed			.062	26.984	.951	.01652	.26687	-.53106	.56410
Seg4Chroma	Equal variances assumed	.300	.588	.092	27	.927	.00303	.03295	-.06457	.07063
	Equal variances not assumed			.094	20.494	.926	.00303	.03222	-.06408	.07014
Seg4Brightness	Equal variances assumed	.089	.768	-.875	27	.389	-.00324	.00370	-.01083	.00435
	Equal variances not assumed			-.886	25.149	.384	-.00324	.00366	-.01076	.00429
Seg6Hue	Equal variances assumed	.899	.351	-.201	27	.842	-.04788	.23845	-.53715	.44139
	Equal variances not assumed			-.198	21.674	.845	-.04788	.24216	-.55052	.45476
Seg6Chroma	Equal variances assumed	.011	.917	-.613	27	.545	-.03350	.05461	-.14554	.07855
	Equal variances not assumed			-.614	26.967	.544	-.03350	.05454	-.14540	.07841
Seg6Brightness	Equal variances assumed	.808	.377	-.485	27	.631	-.00146	.00300	-.00762	.00470
	Equal variances not assumed			-.495	22.303	.626	-.00146	.00295	-.00756	.00465
ThoraxHue	Equal variances assumed	1.089	.306	-.123	27	.903	-.01305	.10635	-.23126	.20517
	Equal variances not assumed			-.121	20.977	.905	-.01305	.10816	-.23800	.21191
ThoraxChroma	Equal variances assumed	3.218	.084	-.840	27	.408	-.25710	.30619	-.88535	.37114
	Equal variances not assumed			-.812	13.648	.431	-.25710	.31676	-.93814	.42393
ThoraxBrightness	Equal variances assumed	.507	.483	-1.144	27	.263	-.00396	.00346	-.01105	.00314
	Equal variances not assumed			-1.158	25.196	.258	-.00396	.00342	-.01099	.00308
AbdomenAverage	Equal variances assumed	.431	.517	-.702	27	.489	-.00237	.00338	-.00930	.00456
	Equal variances not assumed			-.713	23.885	.483	-.00237	.00333	-.00924	.00450

Independent Samples Test For Visible Light Spectrum

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Seg2Hue	Equal variances assumed	.885	.355	-.702	27	.489	-.06771	.09648	-.26568	.13026
	Equal variances not assumed			-.706	26.750	.486	-.06771	.09591	-.26458	.12916
Seg2Choma	Equal variances assumed	.040	.844	.081	27	.936	.00236	.02920	-.05756	.06228
	Equal variances not assumed			.081	26.277	.936	.00236	.02896	-.05713	.06185
Seg2Brightness	Equal variances assumed	2.896	.100	-1.345	27	.190	-.02621	.01949	-.06619	.01377
	Equal variances not assumed			-1.329	23.084	.197	-.02621	.01973	-.06701	.01459
Seg4Hue	Equal variances assumed	.269	.608	-.224	27	.824	-.01792	.08002	-.18212	.14628
	Equal variances not assumed			-.223	26.501	.825	-.01792	.08021	-.18265	.14681
Seg4Chroma	Equal variances assumed	.045	.834	.563	27	.578	.02161	.03842	-.05721	.10044
	Equal variances not assumed			.572	23.500	.573	.02161	.03780	-.05649	.09972
Seg4Brightness	Equal variances assumed	.368	.549	-.408	27	.687	-.00688	.01688	-.04151	.02775
	Equal variances not assumed			-.406	25.956	.688	-.00688	.01695	-.04173	.02797
Seg6Hue	Equal variances assumed	.899	.351	-.201	27	.842	-.04788	.23845	-.53715	.44139
	Equal variances not assumed			-.198	21.674	.845	-.04788	.24216	-.55052	.45476
Seg6Chroma	Equal variances assumed	.083	.776	-.571	27	.573	-.05533	.09689	-.25412	.14346
	Equal variances not assumed			-.574	26.837	.571	-.05533	.09637	-.25313	.14246
Seg6Brightness	Equal variances assumed	.206	.653	-.015	27	.988	-.00055	.03670	-.07586	.07476
	Equal variances not assumed			-.015	22.286	.988	-.00055	.03602	-.07520	.07410
ThoraxHue	Equal variances assumed	1.179	.287	-.734	27	.469	-.05333	.07260	-.20230	.09565
	Equal variances not assumed			-.727	24.150	.474	-.05333	.07332	-.20461	.09795
ThoraxChroma	Equal variances assumed	.001	.977	.535	27	.597	.01535	.02870	-.04353	.07423
	Equal variances not assumed			.539	26.288	.594	.01535	.02846	-.04311	.07381
ThoraxBrightness	Equal variances assumed	.999	.326	-1.689	27	.103	-.01551	.00918	-.03435	.00333
	Equal variances not assumed			-1.706	25.814	.100	-.01551	.00909	-.03420	.00318
AbdomenAverage	Equal variances assumed	.683	.416	-1.242	27	.225	-.04601	.03705	-.12204	.03001
	Equal variances not assumed			-1.229	24.039	.231	-.04601	.03743	-.12325	.03123

Figure Legend

Figure 1: Mating status is not significantly related to abdomen coloration across all spectrum.

Figure 2: Mass is directly related to average UV coloration across the abdomen.

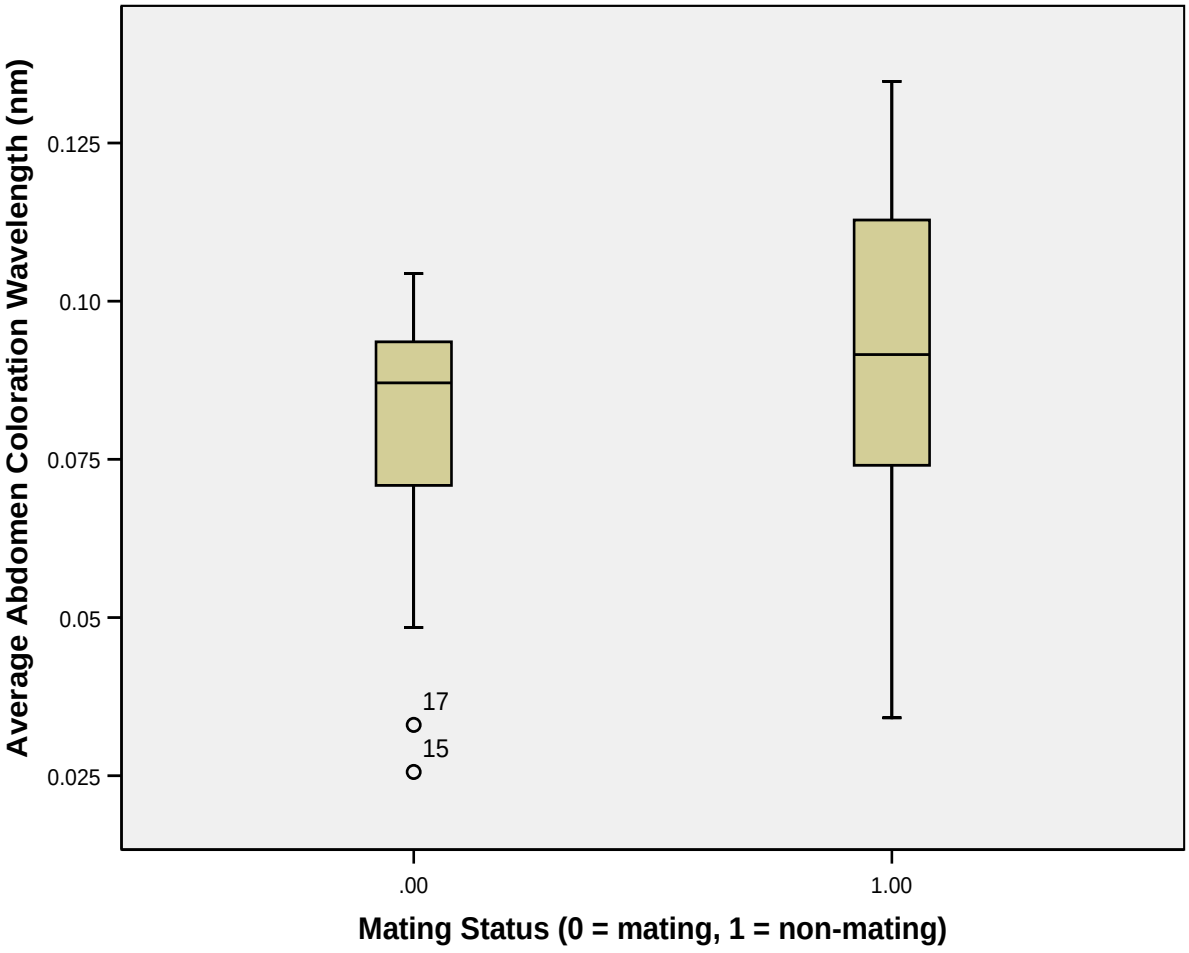
Average Abdomen Coloration Wavelength (nm)
0.125
0.10
0.075
0.05
0.025
17
15
.00
1.00
Mating Status (0 = mating, 1 = non-mating)

Figure 1

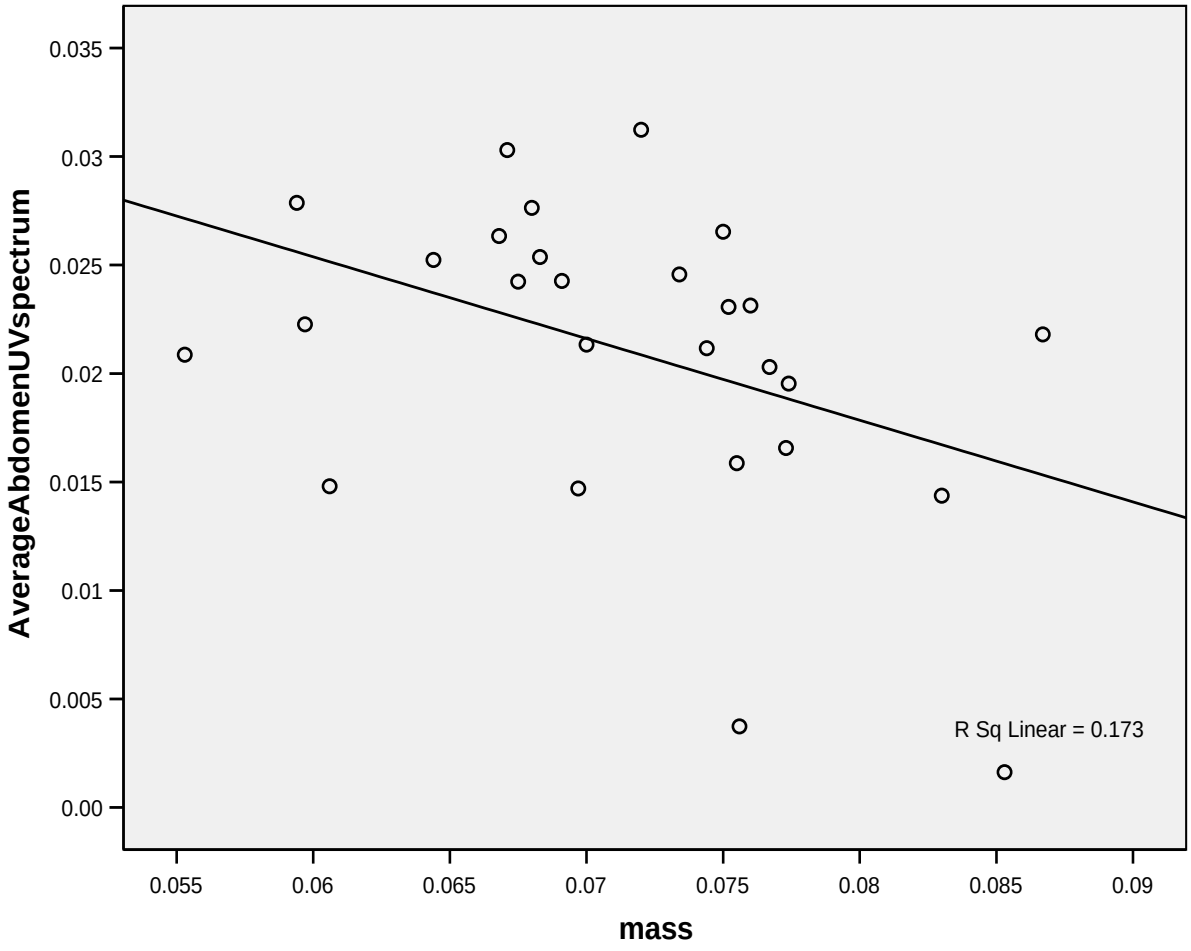
AverageAbdomenUVspectrum
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0.00
R Sq Linear = 0.173
0.055
0.06
0.065
0.07
0.075
0.08
0.085
0.09
mass

Figure 2