

Two Color Proportion in Nature

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Biography

Bryan Howell earned his MFA from UT Austin and BFA from BYU. He worked for frogdesign in Germany, USA and Singapore and for Dell Computer in Design & Engineering Management. He then ran his own consulting firm. He has been researching color proportion and teaching ID at BYU since 2005.

The purpose of this research is to understand two color proportion ratios in nature. Success in this endeavor would provide another key to understanding how nature orders itself and provide guiding principles for designers who look to nature for inspiration as they create.

This small, cross disciplinary team of researchers focused the study on two-color mammals, fish, reptiles, flowers and insects. After analyzing, charting and testing around 50 samples, they propose that nature exhibits six color proportion ratios.

Nature's Two-Color Proportion Ratios

1:1 | 1.23:1 / 1:1.23 | 1.618:1 | 3:1 | 4.5:1 | 6.9:1

An example of the above mentioned ratio 1.618:1 or 62% dark to 38% light can be seen in the rattlesnake image (Figure 1) and the Zebra image (Figure 2).

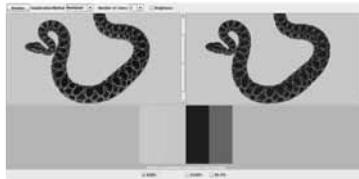


Figure 1. Rattlesnake Color Proportion 1.618:1



Figure 2. Zebra Color Proportion 1.618:1

The image on the left side of the screen is the original (with the background removed and replaced with a generic color); the image on the right side of the screen is the simplified two color version of the original. The blocks of color in the center, below the images, display the background color and the two colors of the measured object. Below those are the numerical percentages of the object (the background color is check marked which removes it from the ratio calculation of the remaining two colors).

Though scale, pattern and hue differ greatly between objects in nature, the team believes that Nature has an ordered method of color proportion use.

The paper explains the methodology and the custom made web tool used to obtain a robust method of measurement. It contains a collection of data samples and a list of ongoing questions about how nature uses color proportion. Finally, a URL and instructions on how to use the web tool are provided enabling readers to access the tool for their own studies.

Two Color Proportion in Nature

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Abstract

The purpose of this research is to understand two color proportion ratios in nature. Success in this endeavor would provide another key to understanding how nature orders itself and provide guiding principles for designers who look to nature for inspiration as they create.

This small, cross disciplinary team of researchers focused the study on two-color mammals, fish, reptiles, flowers and insects. After analyzing, charting and testing around 50 samples, they propose that nature exhibits six color proportion ratios.

Nature's Two-Color Proportion Ratios

1. 1:1
2. 1.23:1 / 1:1.23
3. 1.618:1
4. 3:1
5. 4.5:1
6. 9:1

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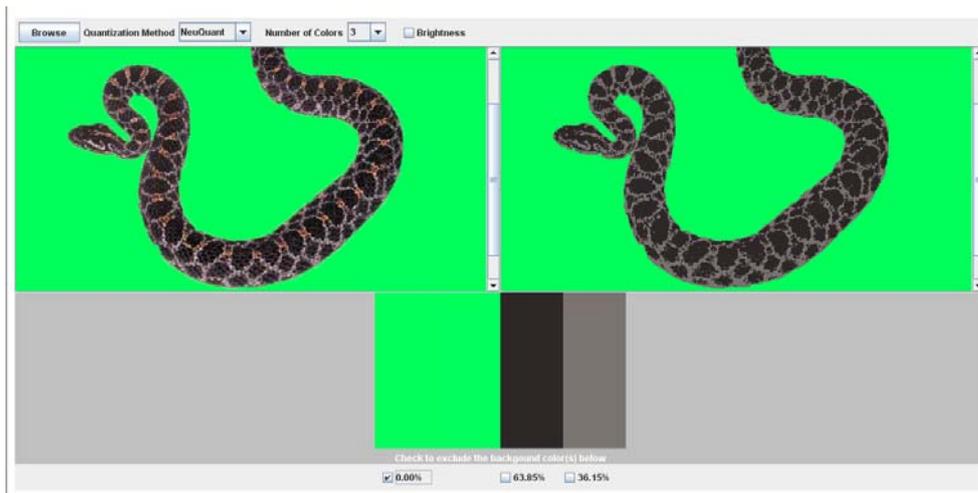


Figure 1. Rattlesnake Color Proportion 1.618:1

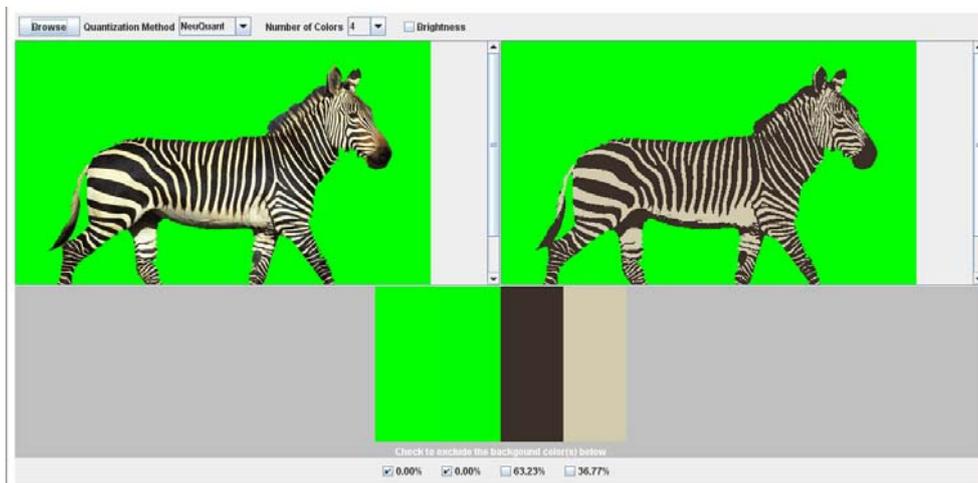


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Though scale, pattern and hue differ greatly between objects in nature, the team believes that Nature has an ordered method of color proportion use.

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Keywords: nature, two color, proportion, ratio

1. Introduction

The purpose of this research is to understand two color proportion ratios in nature. Success in this endeavor would add another key to understanding how nature orders itself and provide guiding principles for designers who look to nature for inspiration as they create.

The small, cross disciplinary team of researchers focused the study on two-color mammals, fish, reptiles, flowers and insects. After analyzing, charting and testing nearly 50 samples, they wish to propose that nature exhibits the following six color proportion ratios.

Nature's two-color, Color Proportion Ratios

1. 1:1
2. 1.23:1 / 1:1.23
3. 1.618:1
4. 3:1
5. 4.5:1
6. 9:1

The figures below are captured images from our custom web tool. They exhibit two samples from each of the six color proportion ratios.

2. Ratio sets

The reader may notice that the color percentages between the two ratio samples are not always numerically identical. This is typical and expected of all the samples. These differences can be caused or explained in multiple ways.

Image quality greatly influences the outcome of the analysis. Image quality can include things like the photographers perspective, how much foreground in front of the object hinders an accurate reading of the object, how shadow and highlights on the object are read by the tool, how much of the object was removed during the masking process to place the object on a colored background. It has also been found that there is minor analysis difference when using the web tool on a Mac or a PC.

To determine the acceptable range of numerical sameness amongst the various samples, the team used a statistical analysis tool to quantify each sample which matched and placed them in their respective ratio group. Determining the ratio sets will be explained further in section 4.

2.1 Ratio set 1:1

Examples of the first ratio set of 1:1 can be seen by analysis of the Zebra Fish (Figure 1) and the Rothschild Giraffe (Figure 2) which are significantly different animals in size, shape, pattern and color. However, they are statistically identical in color proportion, both wear 50% dark and 50% light colors, for color proportion ratio of 1:1.



Figure 1. Zebra Fish, Ratio of 1:1

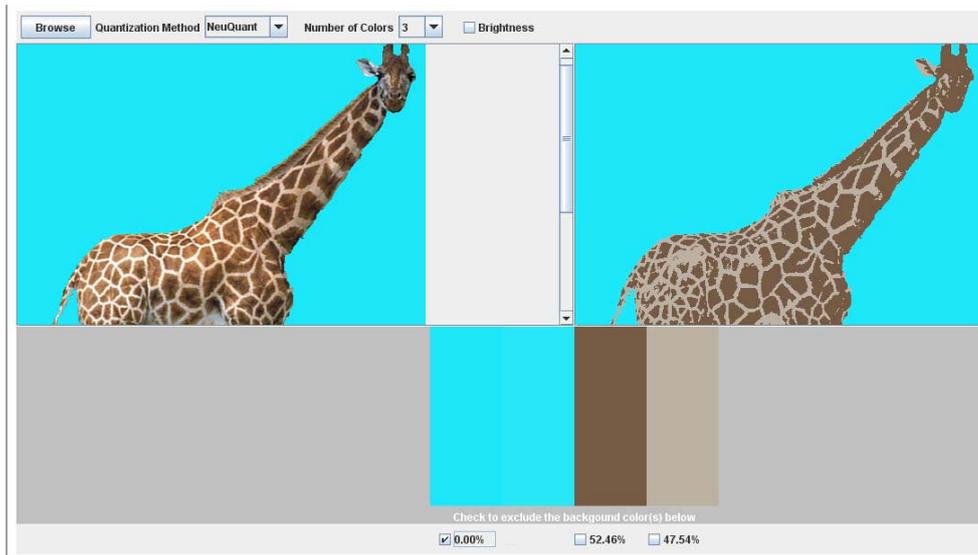


Figure 2. Rothschild Giraffe, Ratio of 1:1

2.2 Ratio set 1.23:1 / 1:1.23

The combined ratio set of 1.23:1 / 1:1.23 can be seen in the analysis of a Grevy's Zebra (Figure 3) and a Squat Lobster (Figure 4). These are also significantly different samples, one being a mammal and the other a shellfish, yet again, their use of color proportion is statistically identical. However, the Grevy's Zebra uses 55% dark color and 45% light color, while the Squat Lobster use 55% light color and 45% dark color.

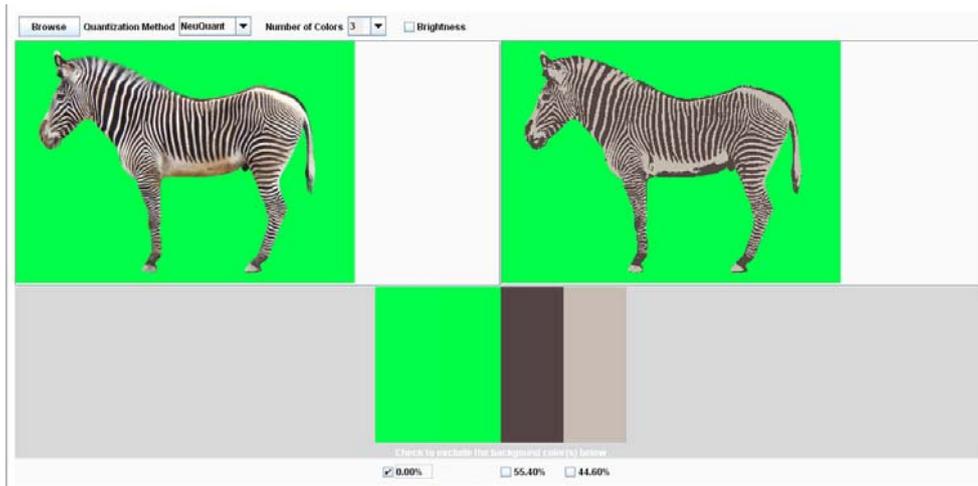


Figure 3. Grevy's Zebra, Ratio of 1.23:1

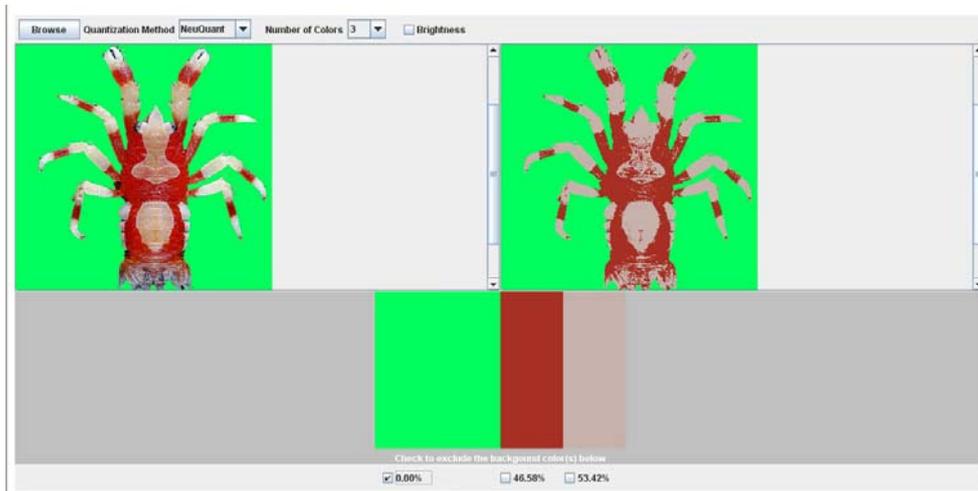


Figure 4. Squat Lobster, Ratio of 1:1.23

2.3 Ratio set 1.618:1

These two examples demonstrate the golden ratio which will be talked about in more detail in section 4.2. Figure 5 shows a sample of a Carolina Pygmy Rattlesnake and Figure 6 shows a sample of a Cape Zebra both having statistically identical ratios of 1.618:1 or 62% dark to 38% light.

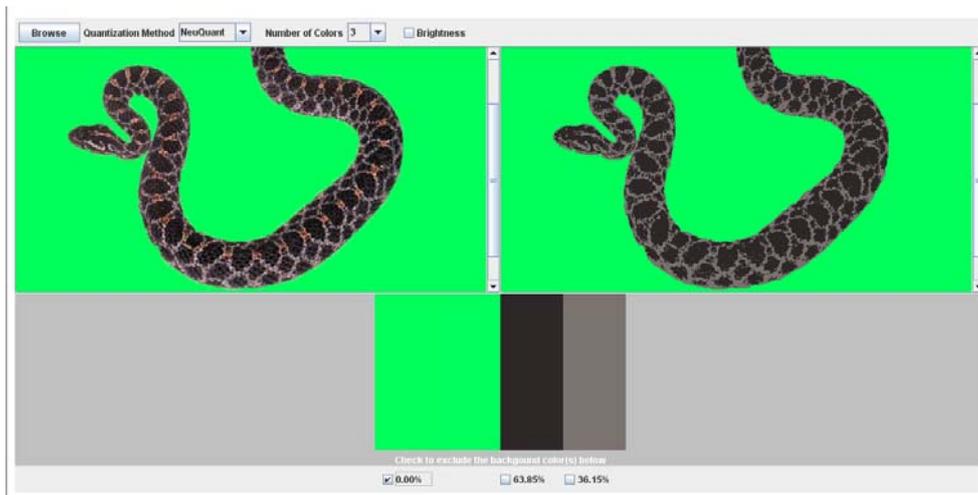


Figure 5. Carolina Pygmy Rattlesnake, Ratio of 1.618:1

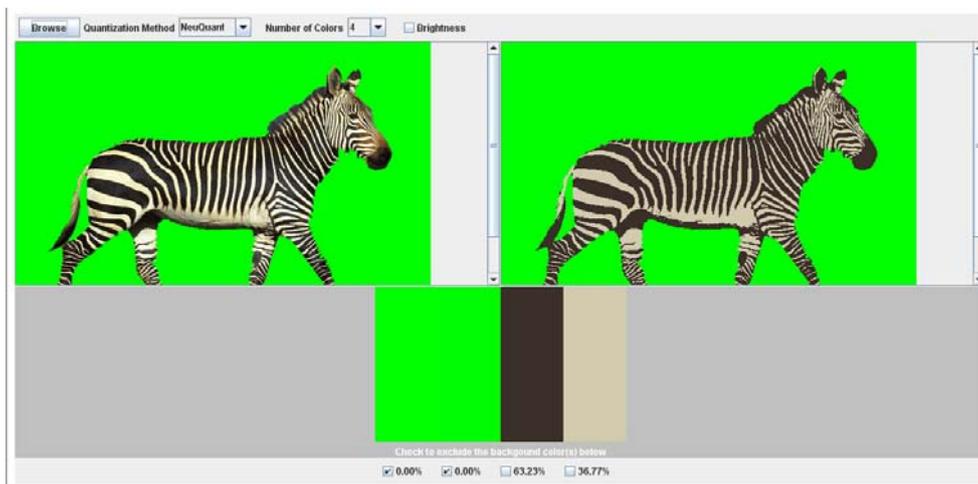


Figure 6. Cape Zebra, Ratio of 1.618:1

2.4 Ratio set 3:1

The fourth ratio set is 3:1 or 75% to 25%. This is a common method of dividing space familiar to most designers. Figure 7, a Reticulated Giraffe and Figure 8 a Zebra Longwing Butterfly demonstrating extreme difference in size, shape and pattern, both have statistical ratios of 3:1.

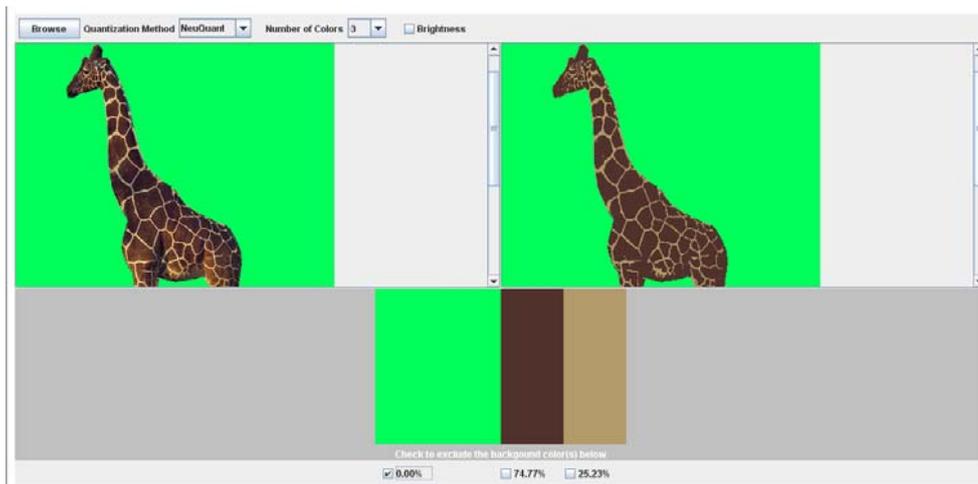


Figure 7. Reticulated Giraffe, Ratio of 3:1

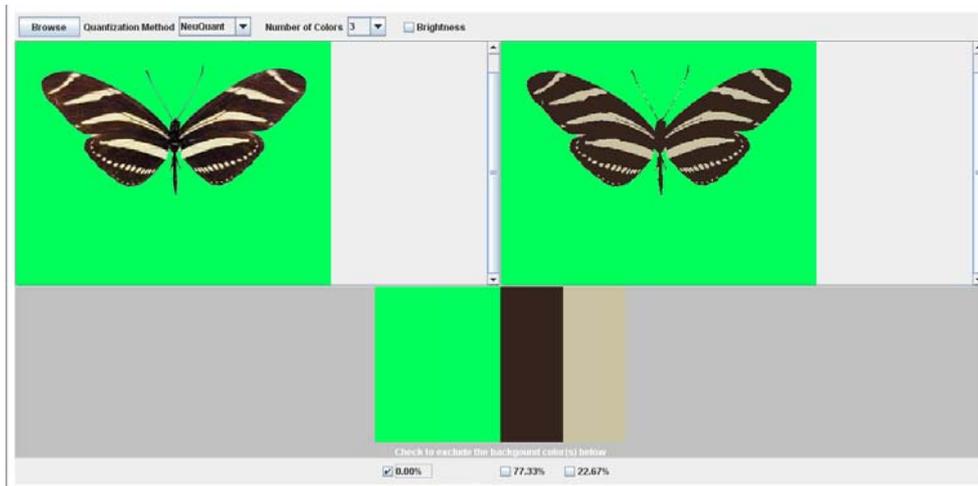


Figure 8. Zebra Longwing Butterfly, Ratio of 3:1

2.5 Ratio set 4.5:1

The fifth ratio set is 4.5:1 or 82% to 18%. Figure 9, a Pine White Butterfly and Figure 10 a Blue Morpho Butterfly though very different in hue and pattern both have statistical ratios of 4.5:1.

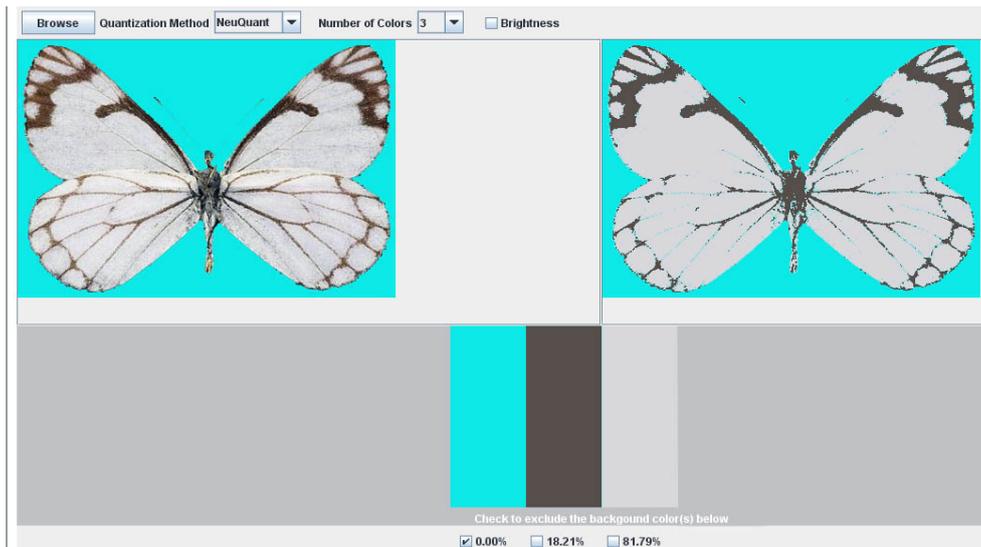


Figure 9. Pine White Butterfly, Ratio of 4.5:1

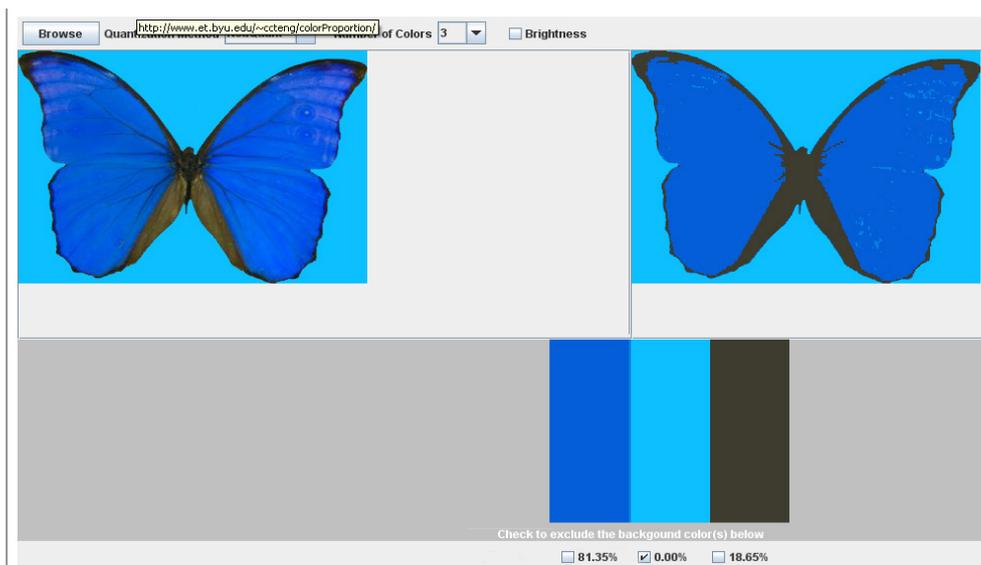


Figure 10. Blue Morpho Butterfly, Ratio of 4.5:1

2.6 Ratio set 9:1

The sixth ratio set is 9:1 or 90% to 10%. Figure 11, a White Daisy flower and Figure 12 a Yellow Tail Damsel fish both have statistical ratios of 9:1. At the higher ratios, the tool begins to have difficulty producing the desired readings. For example, The Yellow Tail Damsel fish number of colors had to be increased to 8 before the tail would show in the tool as yellow. This is because the dominant color (blue) mathematically overwhelms the secondary color (yellow) in the averaging calculations. Consequently, in this sample, all of the variations of blue colors have been added together to create the single 90% part of the ratio.

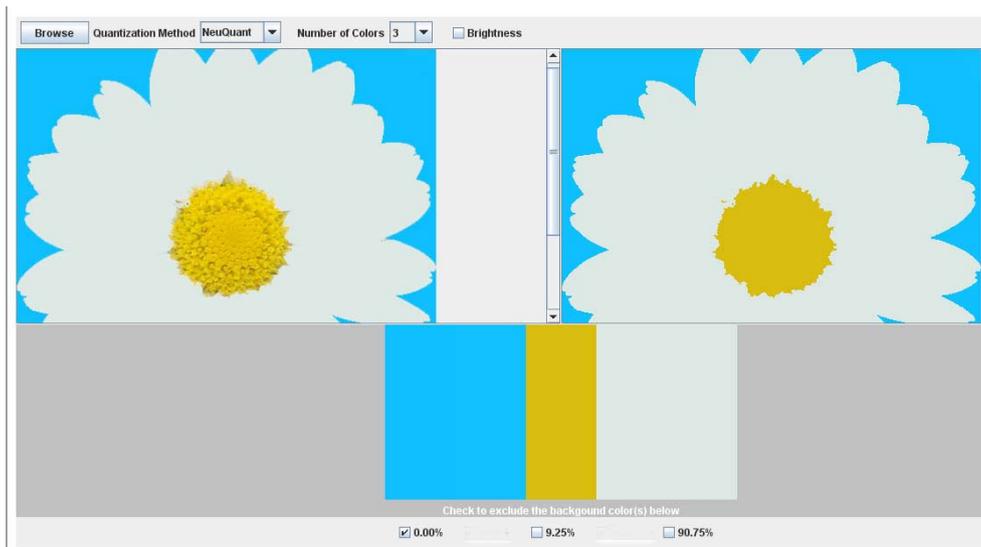


Figure 11. Daisy Flower, Ratio of 9:1

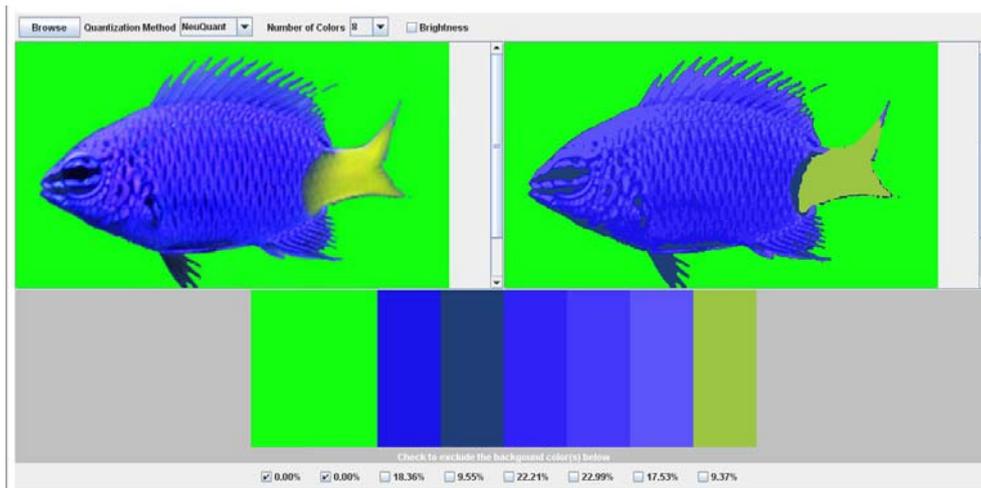


Figure 12. Yellow Tail Damsel Fish, Ratio of 9:1

3.0 The Zebra Question

While considering color proportion within animal families the team questioned whether or not, for example, all zebras had the same color proportion. In nature, there are a total of 11 types of zebras. Of these 11 zebras, the team was able to obtain measurable images of 8 of them including one that is now extinct.

The results showed that all but two zebras have a 1.23:1 ratio or 55% dark and 45% light colors. An example of this ratio is shown in Figure 13 which is a Burchelli Zebra from the Plains family. The Cape Mountain Zebra, Figure 14, has a ratio of 1.618:1 or 62% dark and 38% light and the Grant's Zebra from the Plains family, Figure 15, measured a 1:1 ratio (other images of Grant's zebras should be tested to see if this sample has a false reading, if so, we suspect the Grant's will join the 1.23:1 ratio with the other zebras). The team realized that this data provides another answer to the age old, school boy question of whether a zebra is black with

white stripes or white with black stripes. Proportionally speaking, all Zebras are predominantly black.

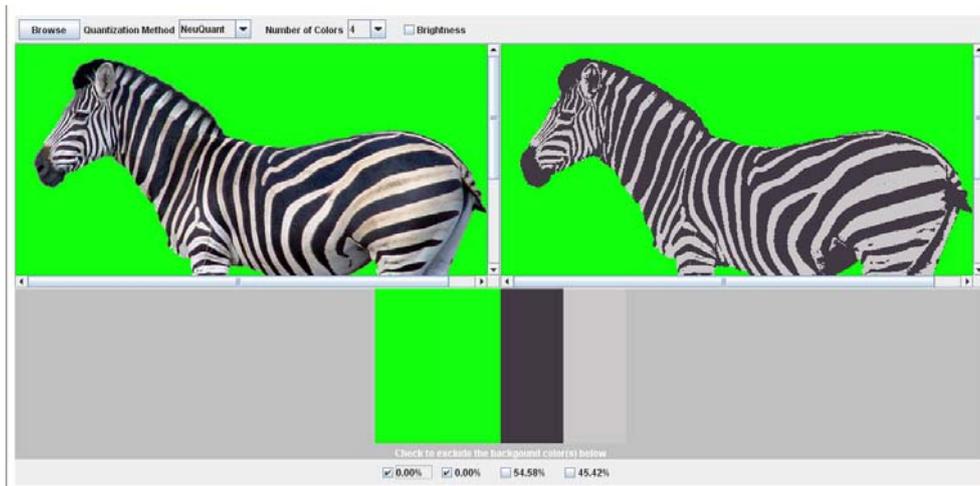


Figure 13. Burchelli Zebra, ratio 1.23:1

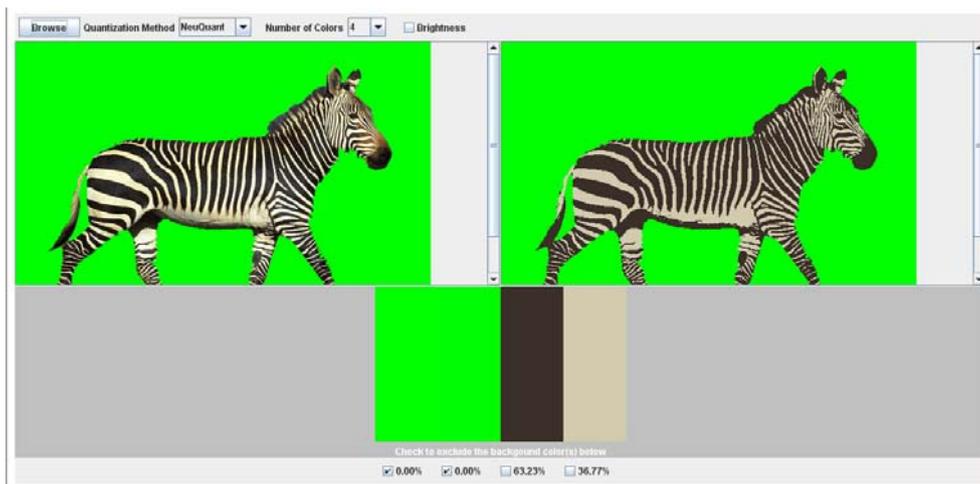


Figure 14. Cape Mountain Zebra, ratio 1.618: 1

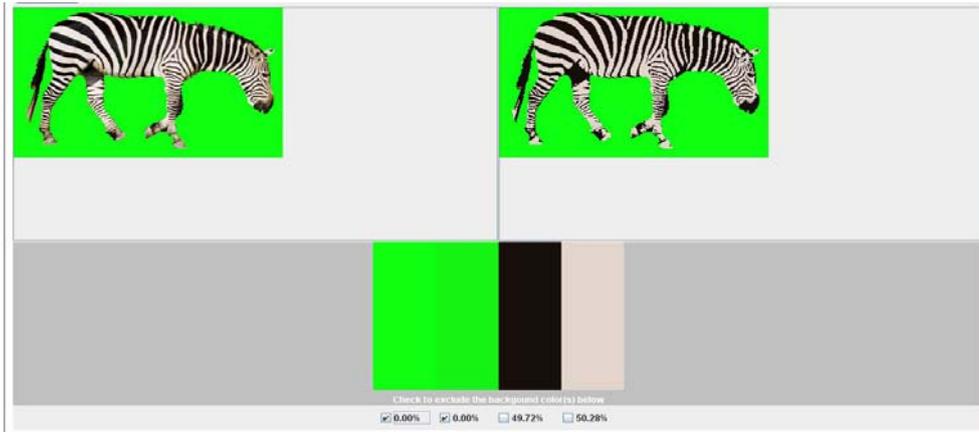


Figure 15. Grant's Zebra, ratio 1:1

4. Methodology

To create this list of ratio sets, the team relied heavily on digital technologies. First a web based tool was developed which simplifies the thousands of colors in a digital image into a few colors by counting, grouping and averaging pixels. The web tool calculates a percentage for each color in the image and displays the results numerically. The numerical percentages for each of the many samples are uploaded into the Statistical Analysis Software program (SAS) which calculates and generates a statistical cluster chart mapping the hierarchical and spatial relationships of the data provided by each sample. The SAS program was useful because it mathematically defined the initial list of Color Proportion Ratios.

Figure 16 shows a cluster chart of 29 two-color samples generated by SAS. The numbers 1, 13, 11, and so on, at the base of the chart each represent a particular two-color sample i.e. a bird, zebra, or snake, assigned to that number. The vertically oriented numbers on the left side of the chart are determined by the software and represent a statistical average distance between the clusters.

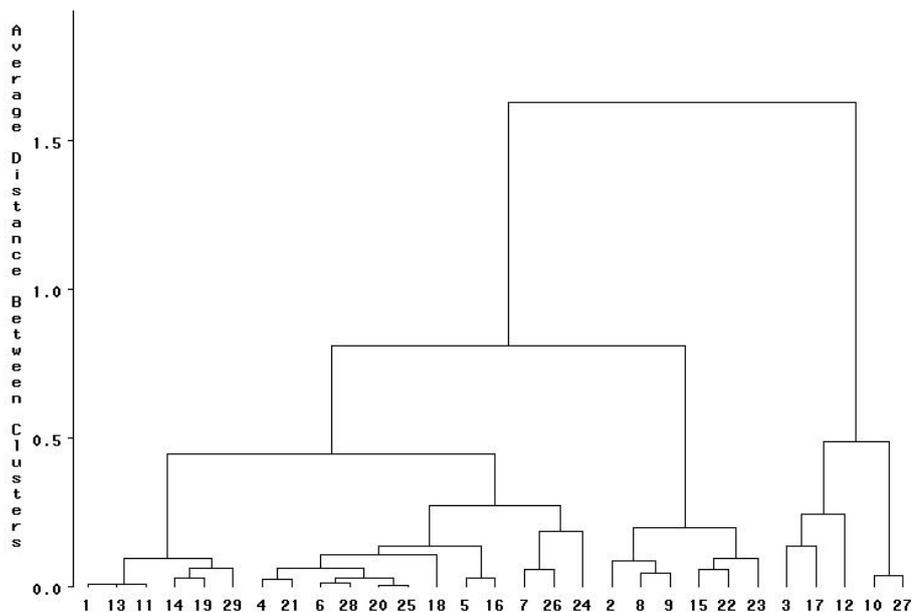


Figure 16. SAS computed Two-Color Cluster Chart

Successfully interpreting a cluster chart is primarily determined by the statistician who searches for naturally grouped families of data. He/She draws a horizontal line across the chart thus defining where family relationships stop and then circles the meaningful family groups. Figure 17 below shows how the two-color chart from Figure 16 was marked up.

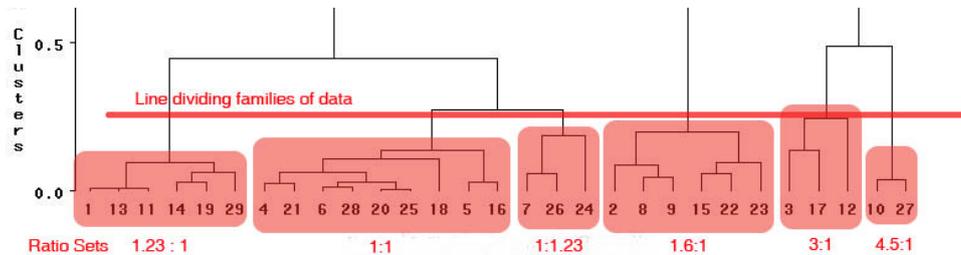


Figure 17. Marked up Two-Color Cluster Chart showing Family Groups

Now that the samples have been grouped into statistically meaningful families, it is a simple math calculation to average the numerical data of that family and determine its color proportion ratio. These ratios are shown in red numbers at the bottom of Figure 17.

The ratios of this particular chart contain some unique elements that require clarifying explanations and generate question forming observations.

4.1 Combining ratio 1.23:1 and ratio 1:1.23

Notice that the ratios 1.23:1 and 1:1.23 are separate families, made of the same ratio. SAS built two families out of the same ratio because it distinguished and separated the samples based on whether the dominant color was lighter or darker. All the samples analyzed in the chart above (except those found in ratio 1:1.23) exhibit darker dominant colors. However, when the team tested a new set of samples (not shown); they found many to have lighter dominant colors. Thus research on dominant color in color proportion will require further testing before any direction is established. For this paper, it is important to understand that these two proportionally identical ratio families were combined into one ratio family and the dominate color issue was set aside for the time being.

4.2 Ratio 1:1.618

It seems natural that the ratio 1:1.618, famously known as the golden ratio, golden section, golden mean or referred to as the divine proportion, would show up in this study of color proportion. It is also noteworthy that this ratio appropriately charts its six samples spatially symmetrical within its family group. While the sample charts in the other families are spatially asymmetrical.

The ratio 1:1.618 is famous because it is a ratio commonly used in nature to proportionally build many plants and animals. Figure 18 demonstrates how this ratio is used in nature as a guiding principle to proportionally build and align the curves, height and length of this duck. At the moment, this ratio does not play a leading role in color proportion like it does in the three dimensional construction of objects in nature. However, there is much work yet to be done and this ratio might yet emerge in a leading role in this study.



Figure 18. The white overlaid lines are golden ratio rectangles and spirals demonstrating how nature uses the ratio of 1:1.618 to proportionally build objects.

4.3 Patterns of “use”

The method SAS used to cluster the data also revealed that a ratio “use” pattern in nature might also be feasible. This “use” pattern refers to how often a particular ratio is used in nature. For example, is a ratio of 1:1 or the ratio 1:1.618 or some other ratio the most dominant ratio used in nature? The question could also be asked between classes of animals. For example, do fish follow one ratio “use” pattern and mammals another? The answer is unknown at the moment; however, the two-color chart shown in Figure 16 was used to provide the following example of a “use” pattern.

<u>Ratio</u>	<u>Percentage of samples found in the ratio set</u>
1:1	30%
1:1.23 / 1.23:1	10% and 20% which combine to create 30%
1.618:1	20%
3:1	10%
4.5:1	10%

This shows that of all the samples tested: 30% of them showed a ratio of 1:1 and another 30% showed at 1:1.23 / 1.23:1. Visually, the difference between the 1:1 sample objects and the 1:1.23 / 1.23:1 sample objects are difficult to distinguish; however, statistically they are defined into separate families. Either way, it is notable that 60% of all the samples tested in this data collection placed in these closely related ratios. Though this idea of “use” is interesting to note and speculate about, it will require further research to determine if there is a clear direction of study worth pursuing.

4.4 Ratio 1:9

The ratio 1:9 is listed in the introduction but not found in the SAS calculations shown in Figure 17. Following the completion of the first round of sample testing, multiple new samples were run through the web tool to verify whether or not the established ratios continued to be comprehensive and accurate. It was during this verification process that the new ratio 1:9 was discovered and added to the list.

5. The Tool

The success of this research is based around the strength of the digital web tool that is used to analyze the images. Currently the tool is in early beta form, it has issues, but with patience, it works. The tool can currently be found at:

<http://www.et.byu.edu/~ccteng/colorProportion/>

It will automatically pull up a Java logo that indicates the applet is loading which is followed by a security verification window which has two buttons, "run" and "cancel". Push the "run" button and the tool will open.

Finding and preparing appropriate images for measuring is currently cumbersome. The best images have flat lighting as strong highlights and shadows distort the color reading. For example, on the bottom portion of the belly of the zebra in figure 19 you can see that shadow produces a large black area. This will be calculated along with the black stripes which will distort the accuracy of the results. The background of the object that is to be analyzed must be removed and replaced with a distinct color that has no color relationship to the object being measured. An example of this can be seen in Figure 19 where the natural background has been removed in Photoshop and replaced with the bright blue background.

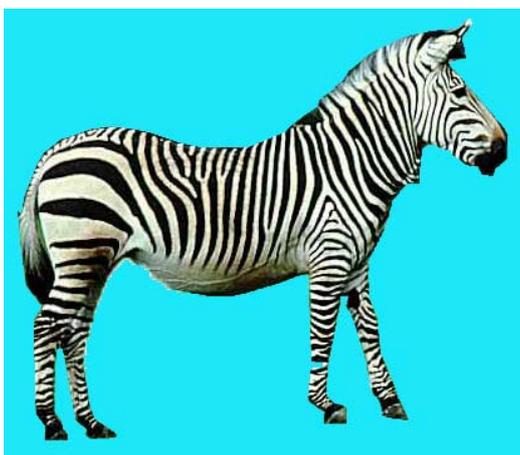


Figure 19. Sample image masked with a distinct color background.

To obtain an accurate representation of the object only full side views of the object are used. Perspective views can hide critical aspects of an objects color story.

Once the image is prepared, use the browse button on the web tool to find your saved image. Currently, it can only browse by file name, so use distinct names on the saved images. Once the image is found click the "open" button at the bottom of the window and it will load the image into the tool.

At the top of the tool there are three choices of quantization algorithms to choose from. This is the mathematical equation that averages and converts the thousands of unique colors in the image to a smaller number. For this study "NeuQuant" was the only algorithm used.

Next to the quantization button is a "number of colors" button. This tells the program how many colors the original image will become after analysis. At this point remember to include an extra number for the background color of the image. This background color is measured and proportioned with the other objects colors.

However, the tool provides a way to turn off measuring any color once it has been identified and then it recalculates the remaining colors.

The final button or box on the tool is the "brightness" box. This is how you turn on the color percentage number boxes at the bottom of the screen. Click this box and it will turn your colors into black and white values. A feature that provides data that is not showing much pattern yet and is thus ignored in this paper. "Uncheck" or click the box "off" on the top of the page and it leaves the percentages of the objects colors at the bottom of the page.

Next to the percentage numbers is a check box that corresponds to the color above it. Check any of these boxes and it turns off the calculation of the color above it and then recalculates the remaining colors. If you check the background color it will turn that color calculation off. This is how the background color is eliminated from the calculation.

6. Conclusion

To date, all of the two-color samples that have been run through the web tool have found a home in one of the six established ratios. This does not guarantee that the list of two-color ratios is complete, but, as of this writing, there are no anomalies unaccounted for. Thus, we believe that we are on a path to understanding and ordering color proportion in nature.

As a side note, questions have arisen regarding the testing of three, four and five-color objects in nature. The team has been working on this, but has seen limited success because the web tool is not yet sophisticated enough to capture and count the small amounts of typically bright highlight colors found on multi-colored birds, fish and flowers. As the accuracy of the web tool increases, the pursuit of multi-color objects will continue in earnest.

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