

## **Color Blindness and Visualizing Georeferenced Data in Mapped Products: We Can Do More.**

Author: Thogmartin, Wayne E.

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**Color blindness and visualizing georeferenced data in mapped products: We can do more.**—I suspect that it is not often that a book review in *The Auk* warrants a response, but the recent review of *Atlas of the Breeding Birds of Ontario, 2001–2005* prompted this letter because of a peculiar aside proffered by the author. In his review, Richard Brewer (2009:471, italics added) highlighted the difficulty that some people have in visualizing georeferenced data represented in mapped form:

A word about the colors of the maps: like nearly 10% of males in the United States (a similar prevalence in Canada, I suspect), I have red-green color blindness. Though it may seem unfair that maps and other color-coded graphics should be designed with 10% of one-half of the human population in mind, I suggest that *it is unwise to design materials that will be unintelligible or at best ambiguous for this segment of the population*. My wife, like 99% of the female population, has good color vision. She informs me that the breeding-evidence maps use the following colors: gold, orange, red, yellow, and dark gray (plus white). I can separate all these colors, whether I can identify them or not.

I have more trouble with the relative-abundance maps; they use white, yellow, gold, light orange, orange, and red. In areas where the abundance level marches in orderly progression from low to high, I can pretty much distinguish the six abundance classes. But an isolated blob might require considerable study in very good light.

At least these maps do not intermix red and green.

Maps and other color products are an increasingly common medium for communication among biologists, including ornithologists. In addition to atlas, areas of study such as regional conservation planning, niche or species-habitat modeling, and radar biology produce mapped patterns in bird occurrence and abundance (e.g., Thogmartin et al. 2004, 2006, 2007; Forcey et al. 2007, 2008; Ruth 2007; Twedt et al. 2007; Pearce et al. 2008). However,

for the color-vision impaired, as Brewer suggested, these mapped representations of bird biology often fall short in communication. This is unfortunate, because color blindness is not exactly rare.

Color blindness, in which certain colors cannot be accurately distinguished because of a lack of or mutation in wavelength-sensitive retinal cone cells, is typically an inherited, sex-linked trait (Wyszecki and Stiles 1982, Birch 1993). Color blindness takes many forms (Table 1), but because of its sex-linked characteristic, it is a condition that primarily afflicts males. As much as ~8% of the male populace, or 12.5 million men, are believed to be afflicted in the United States (Jenny and Kelso 2007). As such, the number of ornithologists and other biologists for whom this is an issue could very well number in the hundreds (8% of the 2009 male membership of the American Ornithologists' Union, for instance, is ~140 men).

Any failure to produce a color legend that is informative to the full spectrum of ornithologists is unfortunate, because there is a considerable amount of information available to prevent this from being an issue for mapmakers (I include myself among the guilty). Cynthia Brewer (no relation to the review author) has provided considerable guidance on how to accommodate those impaired by color-vision deficits (Brewer 1997, Olson and Brewer 1997, Harrower and Brewer 2003). She developed an online tool (ColorBrewer; [colorbrewer2.org](http://colorbrewer2.org)) for identifying color schema more easily read by the normally sighted and the vision-impaired alike. Once a map has been produced, a particularly useful tool is Color Oracle ([colororacle.cartography.ch/](http://colororacle.cartography.ch/)). Users of this tool can check their mapped output to identify how it may be perceived by those with a color-vision impairment (Jenny and Kelso 2007). The tool Vischeck ([www.vischeck.com/](http://www.vischeck.com/)) is yet another way to evaluate a mapped product (Fig. 1). With this online tool, the user simply uploads an image file, selects among three color-vision impairments (deuteranopy, protanopy, and tritanopy), and clicks run; VisCheck has a similar process for evaluating webpages and can

TABLE 1. Color-vision deficiencies ordered by the estimated proportion of the population afflicted with this condition.

Vision deficiency	Characteristic	Cause	Afflicted population
Deuteranomaly	Red-green color deficit	Mutated green cone shifted toward red	5% of males, 0.4% of females
Deuteranopy	Red-green color deficit	Lacking green-sensitive retinal cones	1% of males
Protanopy	Red-green color deficit	Lacking red-sensitive retinal cones	1% of males
Protanomaly	Red-green color deficit	Mutated red cone shifted toward green	1% of males
Full colorblindness/ monochromacy	Deficit across the full color spectrum	No cone cells or only single cone type	0.005% of the population
Tritanopy	Blue-yellow color deficit	Lacking blue-sensitive retinal cones	0.003% of the population
Tritanomaly	Blue-yellow color deficit	Mutated blue cone shifted toward green	"almost 0%"

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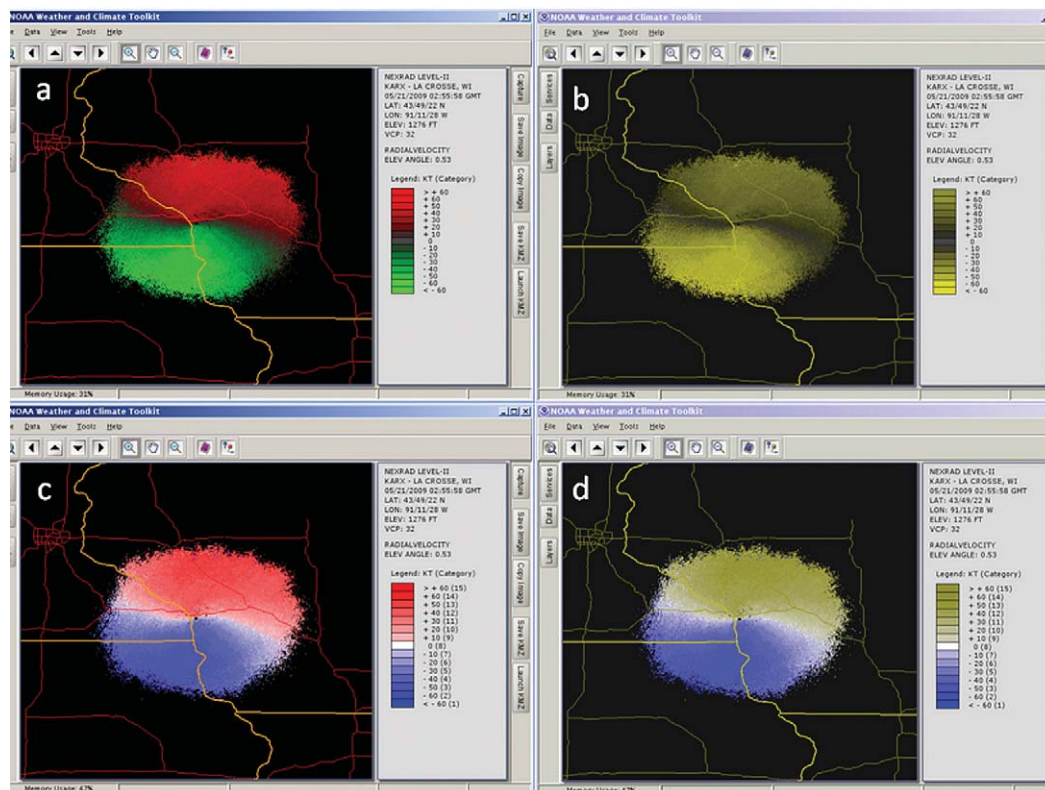


FIG. 1. (a) Doppler imagery used in studies of migration ecology is typically provided by the National Weather Service with a red–green color legend. (b) Deuteranopy makes this image largely impossible to understand. (c) Amending the color legend to scale from red to blue makes the image (d) much easier to read for a color-vision impaired individual. (Original images courtesy of M. Suárez.)

be downloaded to a computer for use off-line if, for instance, many images require processing. The output from these processes is a translation of the original map, image, or website as seen by the colorblind. For those producing full-color documents besides maps, Color Scheme Designer ([colorshemesigner.com/](http://colorshemesigner.com/)) is a tool useful for evaluating color schemes of page layouts. These tools are easy to use and, because they are freeware, largely without cost.

Because color-vision impairment is one of the most widespread physiological conditions that hamper map reading, there is an ethical consideration here for ornithologists who produce mapped and other colored products in their work. Yet I am not an ethicist and have not studied the full range of ethical implications associated with addressing color-vision impairment in our work. Rather than advance this argument on ethical grounds, what I can suggest is that color-vision impairment is easily addressed with the tools we have available to us—so why not do it?

*Acknowledgments.*—I extend my appreciation to R. Brewer for bringing this issue to light, and I hope my colleagues will join me in producing maps that are more useful to the full spectrum of map readers. I thank three colleagues that are engaged daily in geospatial analyses, T. J. Fox, D. A. Olsen, and M. Suárez, for informative discussions on this issue.—WAYNE E. THOGMARTIN, *U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, USA 54603; e-mail: wthogmartin@usgs.gov*

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