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Color for all Organisms: Landscapes Outside the Human Visible Spectrum

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Abstract

A more nuanced and empathetic understanding of the lives and intrinsic values of nonhuman species may be achieved by learning how to see the world through their eyes. Humans already use technology to sense “colours” outside those we can perceive and use them in scientific and commercial applications. We propose to use images created with these technologies to “see” and understand the world from the standpoint of nonhuman organisms. By transforming spectral wavelengths perceived by nonhuman visual systems into coordinate systems that we can see, we can create images that help us enter into the nonhuman world and develop empathy and compassion for its myriad inhabitants. The differing tonal values, contrast ranges, and objects revealed in our images support more complex narratives about nonhuman organisms and their interactions with one another and their environments. Seeing the world through their eyes also opens a window for us to use to see them for themselves, not just as resources for us to exploit. Finally, we expect that a detailed analysis of the aesthetic properties of images representing wavelengths and colours outside of the human visible spectrum will lead us to an expanded color theory and new directions in art and ecology.

Keywords: *Colour in Nature, Ecology, Perception*

Introduction

As humanity grapples with the Earth’s ongoing sixth “mass-extinction,” scientists, policymakers, and humanists alike continue to debate its proximate causes and consequences (e.g., Pievani 2013, Dirzo et al. 2014, Brondizio et al. 2019). Ecologists and environmental scientists have asserted that the sixth mass extinction is a result of complex interactions between anthropogenically-driven climatic change and Wilson’s (2002: 50) HIPPO: habitat fragmentation, invasive species, population growth and urbanization, pollution, and overexploitation of biological resources (Peviani 2013, but see Chew 2015 for an opposing point of view). In our view, an underlying cause of at least some of these drivers can be attributed to humans’ inability to see the world through the eyes of the other organisms who share the Earth with us but whom we treat only as “natural resources' ' to be commodified and exploited.

Wilson (2016; see also Dinerstein et al. 2020: 1) called for setting aside half of the Earth as a “global safety net” for the protection of biodiversity. Although setting aside 50% of the Earth’s surface in large conservation zones is technically feasible (Dinerstein et al. 2017, 2020), gaining broader support for conserving and protecting biodiversity requires that people see its value (Norton 1988). We already use utilitarian and aesthetic criteria in deciding, either consciously or subconsciously, which species to protect (e.g., Justus et al. 2008, Gunnthorsdottir 2015, Kress and Krupnick in press). But if we are serious about preserving a large amount of Earth’s biodiversity, we also need to recognize its intrinsic value and protect those species that we perceive as ugly, unattractive, or useless (Norton 1988). Finally, we need to do more than value diversity. We need to empathize with other species, too.

We suggest that a more nuanced and empathetic understanding of the lives of all nonhuman species would be achieved by learning how to see the world through their eyes (Zeigler and Ellison 2022). Even though it is conceptually and philosophically daunting to truly know what it is like to “be” another species (e.g., Nagel 1974, Haraway 2008), there are technical approximations. Using examples from our own work, we illustrate how photographing natural environments in spectra outside of the range of normal human colour vision and transforming these images into our colour spectrum allow us to envision how other species may perceive their world.

Methods for visualizing other spectra

We are interested in the spectrum ranging from ≈290 to 1100 nm. This spectrum extends beyond the range of human colour vision (≈380–750 nm) and includes spectra perceived by many other species. We first modified existing cameras so that they could record ultraviolet (< 380 nm) and infrared (750–1100 nm) spectra in addition to wavelengths in the spectrum visible to humans. We then photographed scenes from identical vantage points but in different wavelengths. Finally, we created comparison sets of images to reveal similarities and differences in perceptible details.

Specifically, we produced four images from each vantage point. Visible light images (both colour and a monochrome version of it that was subsequently “desaturated” in Photoshop) were made using a Nikon D800e camera with no modifications. Digital infrared and ultraviolet images were made using a self-modified Nikon D3000 camera that captures wavelengths from ≈325–1100 nm; ultraviolet images (340–380 nm) were made using this camera outfitted with a Kolari Vision ultraviolet bandpass transmission lens filter. Infrared images (850–1100 nm) were made using this same camera outfitted with an 850-nm infrared lens filter. We also made some ultraviolet images on Ilford HP5+ sheet film using a

Linhof 4 × 5 camera outfitted with a Kodak 18A Wratten ultraviolet-pass filter (allows wavelengths 290–400 nm).

Each set of four images taken from a single vantage point is displayed below in a four-panel "multi-spectral grid," with the images consistently positioned. Starting in the upper left of each four-panel set and moving clockwise, the first image shows the scene in the familiar colours of the human visible spectrum. The second image (upper right) has had the visible wavelengths desaturated in Photoshop; the third (lower right) shows only the infrared wavelengths; and the fourth (lower left) shows only the ultraviolet wavelengths. By focusing on particular spectra, we see changes in the images, such as white skies in ultraviolet images and bright foliage contrasting with dark skies in infrared images.

We note that we cannot actually see reflected light in the ultraviolet (wavelengths below 380 nm) or the infrared (wavelengths beyond 780 nm). However, we can mathematically transform ultraviolet and infrared images into ones that reflect light into our own visual spectrum. Such transformed (or "mapped") images can be gray-scaled or artificially colored. We have chosen to work with the gray-scale images, which are superficially similar in appearance to the desaturated, monochrome versions of the colour visible-light photographs. We also note that the lack of colour in these images is a way to avoid the complexities of choosing how to map tones from different spectra into those that make sense to humans; how to make these choices will be a focus of our future work.

Examples

The images we have made so far are of forests, living and ancient, fire-scarred and heavily managed. These subjects also draw attention to plants, which many people ignore entirely (i.e., "plant blindness" sensu Allen 2003; more appropriately called "plant awareness disparity" by Parsley 2020) or think of only when they are edible, medicinal, or otherwise useful (e.g., Kress and Krupnick in press). In addition, the images challenge our sense of time. For example, the Great Basin Bristlecone Pine (*Pinus longaeva*) forests of Nevada and California in the United States also reveal ecological interactions on a time scale humans rarely consider, as the trees can live to 5,000 years of age. The images of fire-scarred and managed forests reveal the speed of transformation to human and non-human effects.

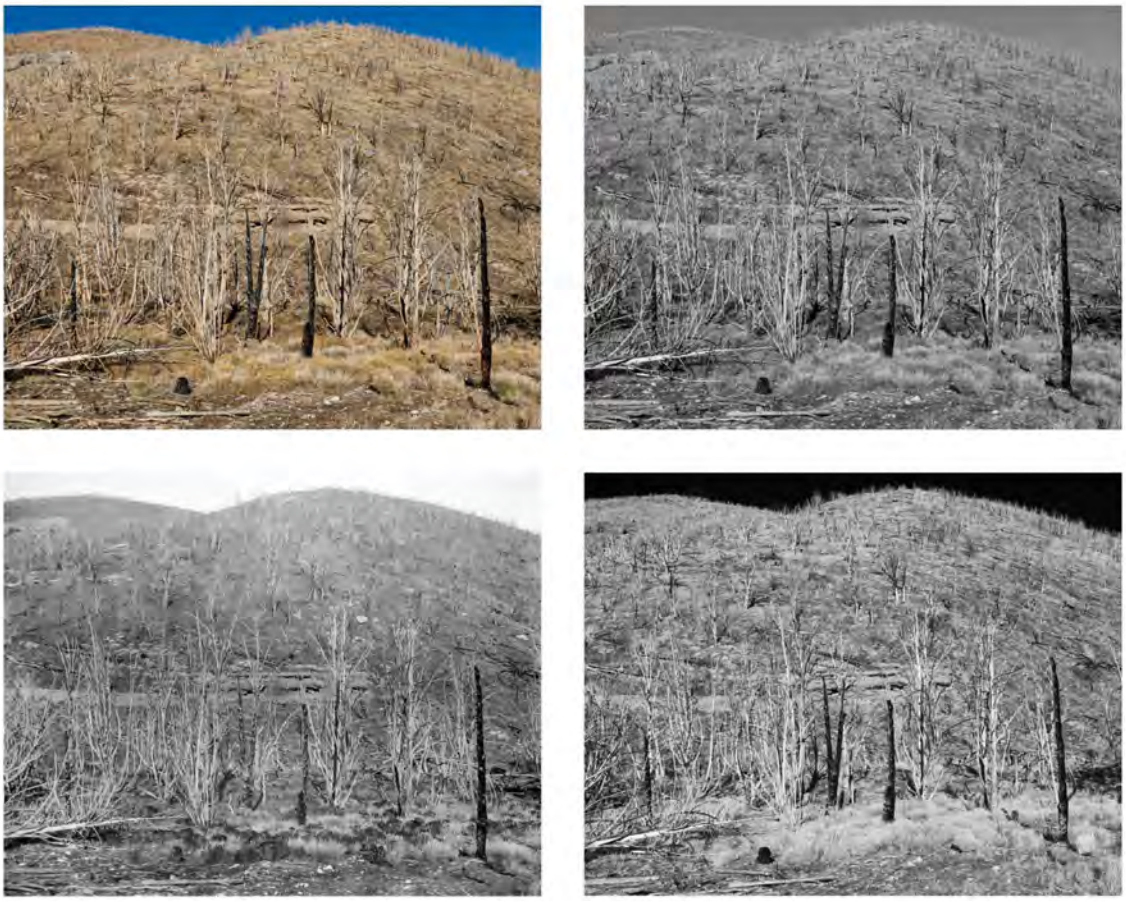

Figure 1. *Lexington Arch, Charcoal Snags on Hillside in Multiple Spectra* (2021), Original digital and film images © Eric Zeigler and Aaron M. Ellison.

Figure 1 shows a Nevada hillside scarred by fire. The area photographed is within the section of the Great Basin National Park that was burned by the Black Fire in July 2013, a fire that was started by a lightning strike (Roberts 2013/2014). This comparison of the scene in different spectra reveals many of the differences commonly seen in ultraviolet, visible light, and infrared images. For example, the infrared image displays a dark sky, while the ultraviolet is rendered in near white, and living vegetation glows in the infrared, just like snow does in the visible spectrum. This same living vegetation is not reflective in the ultraviolet, so it shows up as dark tones in the image. These tonal differences can be useful to art photographers who may differentiate areas of an image with heightened or lowered contrast, but for nonhuman species, these different tones or reflected wavelengths may identify food, shelter, or predators (Zeigler and Ellison 2022).

Another difference among these images is the relative clarity of “information from a distance” or how we see through the atmosphere. In the ultraviolet, there is less contrast and differentiation between the foreground and the distant landscape. In contrast, tonal distinctions in the infrared image are clear at all distances. Because most other animals perceive ultraviolet wavelengths, their “vision” may be limited by an apparently “thick” atmosphere (e.g., Marshall 2010).

A more extreme vision of this phenomenon is illustrated with images of fire taken in different spectra (Figure 2). In the infrared spectrum, the flames are spectacular and far more dramatic than in the visible spectrum. However, the flame licks are not visible at all in the ultraviolet, whereas the smoke, not nearly as opaque to our eyes in the visible spectrum, clouds out any view of the distance. Consider an ultraviolet-seeing bird flying through a visually thick atmosphere. In the apparently dense smoke of even a small fire, the bird may be unable to orient and fly into another area as the fire danger increases. Such scenes are likely to be much more common as we move from the Anthropocene epoch into the so-called Pyrocene (Pyne 2022).

Figure 2. *Burning Orchard Prunings in Multiple Spectra* (2022), Original digital images © Eric Zeigler and Aaron M. Ellison.

Even in the Pyroxene, fire can have positive value; small, controlled fires can reduce the likelihood of large ones, and many species and even entire ecosystems are adapted to and thrive as a result of frequent, small fires (e.g., Bond and Midgley 1995, Odion et al. 2010, Scott et al. 2014). In our images of a forest stand managed with fire (Figure 3), different densities of plants in the regenerating forest understory are visible in different spectra; some species are clearly visible only in some spectra (e.g., bramble vine [*Rubus*] in the infrared).

Our sense of management, species diversity, and ecosystem structure in Figures 1–3 is conditioned by our relatively short lifespan. What would it mean to "see" the dynamics and changes of nonhuman species in natural systems through their lifespans (e.g., Bestelmeyer et al. 2011)? As an extreme example, Great Basin Bristlecone Pine trees can live for at least 5000 years on windy and cold mountains above 2900 m (9500 ft) above sea level (Figure 4; Schulman 1958, Ross 2020). The glistening foliage in the infrared, along with the dark, nonreflective foliage in the ultraviolet, shows us what light spectra are important for these plants. The ultraviolet is absorbed, and the infrared is scattered about in every direction; the plants make use of specific, narrow wavelengths across the entire spectrum from the ultraviolet through the near-infrared (Jones 2014). How might anthropogenic changes to the atmosphere affect what plants "see" and how they can use the light to eat?

Figure 3 (left) *Maumee State Forest Thinning and Prescribed Burn Test Plot* (2022), Original digital images © Eric Zeigler and Aaron M. Ellison. **Figure 4 (right)** *Great Basin Bristlecones #5* (2021), Original digital and film images © Eric Zeigler and Aaron M. Ellison.

Conclusion

The visions of the world in our photographs are helping us understand and tell the complex stories of how humans and nonhumans share and interact with one another and the environment. The "hidden stories" (sensu Chua et al. (2017) our images reveal by putting our colour vision into broader contexts may lead us toward a much richer discussion and understanding of our place on Earth.

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